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THE COMPARATIVE ADVANTAGES AND DISADVANTAGES OF ROOT TRAINERS, DIBBLE TUBES, PLASTIC BAGS AND BARE-ROOTING

TECHNICAL SERIES #4

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INFORMATION MEMORANDUM

SUBJECT: Comparative Advantages and Disadvantages of the Use of Root Trainers, Dibble Tubes, Plastic Bags, and Bare-Rooting of Seedlings*

Traditionally, nurseries in the lesser developed countries (LDCs) use either plastic bags for growing tree seedlings or bare-root seedlings grown in seed beds. Often, the nurseries are centrally located and seedlings have to be transported over long distances.

In the bare-root process, seedlings are often injured when they are removed from the seedbeds. Many of the roots are broken, root hairs (essential for nutrient uptake) are torn off and roots dry out easily. Such transplant shock results in a high incidence of mortality. Walters reported that Eucalyptus seedlings in Hawaii, when planted by the bare-root method, suffered as much as 85-95 percent die-back. Because of transplant shock, initial growth is slow, die-back may occur (it may take some more than 3 or more months to recover), and the seedlings are poor competitors with other vegetation.

With seedlings in plastic bags, the weight of the soil (as much as 1-2 kg.) limits the number of seedlings that can be transported (by vehicle and by hand). Frequently, adequate transport is difficult to obtain and planting sites are hard to get to, thus it is difficult and expensive to move large numbers of the seedlings in heavy and cumbersome plastic bags. This increases project costs and reduces the number of seedlings that can be planted during critical planting periods. Also, seedlings are commonly planted in the plastic bag after the bottom has been cut off, which can retard plant growth, cause die-back or increase mortality incidence because the seedlings are restricted from maximum access to available water and nutrients. This is most likely to be a constraint in semi-arid areas or during periods of minimal rainfall. Often, poorly supervised workers will even fail to remove the bottom of the bag which is usually disasterous.

Seedlings grown in plastic bags have poorly developed lateral roots, which are essential and needed to enhance initial establishment and to maximize nutrient uptake. However, excessive growth of lateral roots can cause strangulation of and injure the tap root. When seedlings are grown too long in bags, root-curl occurs, spiraling the root at the bottom of the bags.

When tubes are too small or seedlings are left too long in tubes, the roots at the bottom are deflected emerging from the tube. However, root deformation can occur in any container, especially if seedlings are held too long. Therefore good nursery management is of upmost importance regardless of what system or condition is used.

*A portion of the information used in this memo was taken from the enclosed papers.

Once the root configuration is formed in the seedling stage, the root system continues to grow in the same pattern the rest of the life of the tree. Cannon reports that "The deleterious effects of abnormal root growth are seldom noticed in the first months or even after years of growth." "Rather, it is at more advanced ages and under adverse weather conditions when a deformed tree root system is most likely to fail to provide enough water or nutrients, or to anchor trees against strong winds." "Results indicate that although young seedlings suffer little from container-induced root deformities, several years after plantation establishment a significant proportion of these have grown poorly, fallen over, or died."

An alternative method to growing seedlings in plastic bags and in seed beds (bare-rooting) is a more modern method of containerization. Most of the widely used containers (i.e., root trainers and tubes) incorporate features such as vertical internal ribs designed to minimize root disturbance, to reduce root spiraling in the container and possible future strangulation problems, to maximize lateral root development and shape the roots into a form advantageous to the tree. Basically, the theory behind use of these types of containers is that, "If a tree seedling can be planted with a minimum of root exposure and disturbance, there will be less transplant shock, and survival and growth rates will be higher." [Kingham 1974 as cited by Tinus and McDonald].

Walters reports that for almost 20 years, little forestation was done with Koa (Acacia koa), Hawaii's most valuable native tree, because survival of bare root seeddlings was too poor to be worth the effort. However, several plantings of Koa seedlings (totalling about 75,000) grown in "Hawaii Dibble Tubes" (HDT) have survived at rates of about 85 percent. He goes on to say that survival of bare root Eucalyptus saligna plantings is unpredictable; one planting may result in 90 percent survival, the next in 10 percent. Survival of containerized (HDT) saligna plantings is predictably good; 91.2 percent with a standard deviation of 4.4.

Root trainers and tubes seem expensive when compared to the cost of plastic bags and seedbeds, however the use of them can result in considerable savings by reducing replanting and by increased growth. This often will more than off-set the cost of importing these containers. An additional cost is usually incurred because peat moss or a similar organic mix (which can be developed locally) is almost a necessity if maximum results are to be obtained from using these containers.

However, the costs of root trainers or tubes and buying or developing the planting medium are easily outweighed by the savings obtained by the (1) reduction of seedling mortality, (2) avoiding time lost in growing replacements, (3) avoiding the loss of growth time of replaced seedlings, (4) the advantages of reduced transportation requirements. Further savings are made from the increased growth rates and stability of trees which have good established root systems. If the root trainers are carefully handled, a high proportion can be reused several times. Tubes last even longer. (If plastic bags cost one cent each, and each tube or cell of a root trainer costs eight cents but can be used eight times, the cost per unit is the same.) Some problems have been reported in the use of styrofoam block containers; such as poor durability and roots growing into the block, making the seedlings difficult to remove thus damaging the roots upon removal.

A seedling (along with the growing medium) grown in an average size root trainer will weigh much less than one-fourth the weight of one in a plastic bag and take up much less than one-fourth of the space. Therefore, there is a large savings in the transportation of these seedlings as well as a more efficient use of space and water in the nursery. The root trainers are more easily stacked in tiers when transported in trucks.

Also, it may be possible to increase seedling survivability and growth rates by impregnating the rootmass of the containerized seedlings with starch graft polymers (ref. Technical Series #2, The Potential of Starch Graft Polymers, "Super Slurpers" for Forestry and Agriculture). This could be a very valuable technology, especially for semi-arid and intermittent rainfall areas.

Some notes of caution--The medium used in root trainers and tubes will hold substantially less water than soil in plastic bags and similar containers. Therefore, these containers and seedlings may need more frequent watering in the nursery and especially during transportation over long distances. A way to deal with this problem is by removing seedlings from the containers and placing them in wax lined cardboard boxes which reduces water evaporation (see Walter's paper). This problem is much more critical with bare-rooting than with containerized seedlings.

Johnson and Menge state that "Most media components--such as pine bark, vermiculite, perlite, builder's sand and peat mosses--are devoid of mycorrhizal fungi." "In addition many nurserymen steam, pasturize or chemically treat media to eradicate harmful pathogens; this also eliminates beneficial organisms, such as mycorrhizal fungi." Also, composts and other locally developed organic mixes generally generate enough internal heat to kill off mycorrhizal fungi and other organisms.

Mycorrhizal fungi facilitate the uptake of nutrients, thus increasing plant growth, and "... have been reported to improve water transport." (Safin, Boyer and Gerdemann, 1971, as cited by Johnson and Menge) Mycorrhizae fungi are capable of transforming unavailable phosphorous into available forms for plant uptake. This is extremely important, especially in phosphorous deficient tropical soils.

Johnson and Menge report that in relation to chemical fertilizer applications required in commercial nursery operations, "phosphorous levels could be reduced by approximately 70% and N, K and micronutrients by 30 to 40% using VA (vesiclar-arbuscular) mycorrhizal fungi."

Ectomycorrhizae are associated with numerous conifers, such as pines, and with other trees, such as casuarina, eucalyptus, oak, beech, birch, willow and poplar. It is an established fact that in the absence of mycorrhizal fungi, the growth of Caribbean pine, casuarina, citrus and other trees will be retarded and in some cases, without inoculation, it may be impossible to establish these trees on some sites. Ectomycorrhizal fungi are associated with Basidiomycetes (mushrooms and puffballs) and Ascomycetes (cup fungi truffles). [Johnson and Menge, 1982].

I am enclosing selected papers relevant to the subject matter and have included some sketches that I have made showing various devices that can be constructed of locally available materials used in conjunction with root trainers. If further information or other Technical Series Papers are desired, please contact me. I would be interested to learn of your results if you do use root trainers or dibble tubes.

Mike

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CONTENTS

Section I

THE USE OF CONTAINERS IN THE NURSERY

investigación forestal

RESPONSE OF TREES IN PLANTATIONS TO THE USE OF CONTAINERS IN THE NURSERY

By Phil Cannon

Research Report No. 74 December, 1981

SUMMARY

Eleven separate surveys were conducted to evaluate the effect of containerization of planting stock on the growth and development of plantation trees. Seedlings with one month growth in containers were the youngest trees examined while trees in a 6-year-old pine plantation were the oldest trees examined. Surveys included the documentation of the frequency and degree of container induced root deformations and tests to determine if correlations existed between the degree of root deformation and the growth and health of trees. Results indicate that although young seedlings suffer little from container-induced root deformities, several years after plantation establishment a significant proportion of these have grown poorly, fallen over, or died. When seedlings are grown too long in bags, roots tend to spiral in the bottom of the bag. When grown too long in tubes, the roots at the bottom are deflected emerging from the tube. Regardless of the type of container, excessive growth of lateral roots led to the initiation of strangling roots between the interface of the container and the potting media. If root lignification occurs the root systems continue to grow in the same pattern the rest of the life of the tree. Another problem was the lack of formation of lateral roots, especially in eucalypts, when seedlings were grown in tubes.

The deleterious effects of abnormal root growth are seldom noticed in the first months or even after years of growth. Rather, it is at more advanced ages and under adverse weather conditions when a deformed tree root system is most likely to fail to provide enough water or nutrients, or to anchor trees against strong winds.

Six solutions are proposed: 1) use larger containers; 2) move seedlings more frequently in the nursery; 3) plant stock before it grows too large; 4) remove the tubes before planting; 5) if oversized seedlings must be planted, remove the seedling from the container, shake the soil from the root system, and plant bare root and 6) plant correctly grown bare root stock where climate permits.

RESUMEN

Once investigaciones separadas fueron conducidas para evaluar el efecto de la producción de plántulas en envases sobre el desarrollo y crecimiento de árboles. Plántulas de apenas un mes de edad fueron los árboles más jóvenes que se examinaron mientras que los pinos en plantaciones de 6 años fueron los árboles más viejos examinados. Los objetivos de las investigaciones fueron documentar la frecuencia y el grado de deformación que había ocurrido como resultado del uso de los envases y determinar si existían correlaciones entre el grado de deformación de la raíz y el crecimiento y la salud de los árboles. Los resultados indican que, aunque los árboles pequeños sufren muy poco por las deformaciones inducidas por el envase, una proporción significativa de plántulas envasadas ha crecido mal, vulcada o ha muerto. Cuando se dejan las plántulas en bolsas de plástico demasiado tiempo en el vivero, las raíces tienden a espiralarse en el fondo de la bolsa. Cuando se dejan las plántulas en tubos demasiado tiempo las raíces que emergen del fondo se desvian al salir del fondo del tubo. Para cualquier tipo de envase, un exceso de crecimiento de las raíces laterales inició la formación de raíces estranguladoras en la zona entre el envase y la tierra. Entonces, si hay lignificación de las raíces en tal posición, éstas crecen en el mismo patrón el resto de la vida del arbol. Otro problema encontrado, especialmente en eucaliptos fué la falta de formación de raíces laterales, en plántulas cultivadas en tubos.

Los efectos perjudiciales debido a las raíces anormales raramente son obvios en los primeros meses o años. Más bien, los efectos adversos son visibles con la edad más avanzada y bajo condiciones adversas del clima cuando el arbol necesita más un sistema radicular vigoroso para obtener agua y nutrientes del suelo o suministrar fuerza estructural contra los vientos fuertes.

Se proponen seis soluciones a los problemas: 1) Usar envases de mayor tamaño; 2) Mover las plántulas más frecuentemente en el vivero; 3) Plantar las plántulas oportunamente 4) Quitar el tubo antes de plantar el arbolito; 5) Si es necesario usar árboles pasados quitar la bolsa

y la tierra y plantar a raíz desnuda, y 6) Plantar arboles a raíz desnuda en forma correcta donde el clima lo permita.

INTRODUCTION

Root systems of all trees have three important functions: 1) anchorage or structural support; 2) absorption of water and minerals from the soil; and 3) storage of reserve foods (Kramer and Kozlowski; 1979) If a root system is inadequate with respect to one or more of these functions, the tree suffers.

As a tree develops from seed the primary root branches and elongates to produce a ramified root system. The lateral roots which form do not develop from the surface of the root, but rather from deep within the root from a layer of tissue known as pericycle. Therefore, in order for a lateral root to form it must first either chemically dissolve or mechanically burst through the enclosing layers of corticle cells.

Root systems of both Pinus and Eucalyptus species, when developing naturally from seed in loose, adequately-watered soil, consist of a framework of relatively large perennial roots and many smaller, short-lived branch roots. The form of a trees root system can be modified by the soil and water regime in which it is growing. For instance, eucalypts form a deep root system on dry sites and a shallower, more fibrous root system on wet sites (Kramer and Kozlowski, 1979).

Despite the variations in root system morphology, various systems of root nomenclature have evolved. The system of nomenclature which will be used in this report is explained in Figure 1. The root system depicted represents development in a soil which offers no physical impediments to root expansion, and will be referred to as a normal root system.

The use of containers for the growth and transportation of seedlings of Eucalyptus and Pinus species has given greater establishment success than other planting techniques tried to date by the Company due primarily to minimal transplanting shock, especially from moisture stress. The common containers used in nurseries by Cartón de Colombia have traditionally been polyethelene bags 4 cm. wide by 12 cm. deep or plastic-lined paper tubes, having diameters of 4 cm. and depths of 10 cm.

Polyethelene bags are always removed at planting time, and care is taken to keep the earth mass holding the root system intact throughout the planting procedure. Tube seedlings have been planted with and without their containers. A minimum of 90% survival is usually achieved using containerized planting stock.

Excavation of trees in various plantations, which had been planted with containerized stock, led to the discovery that many trees had root systems substantially different morphologically from the normal root system depicted in Figure 1. The types of deviations from the normal root system most commonly found, and their probable causes, are listed in Table 1 and schematically represented in Figure 2. All of the abnormalities listed began at some stage, or over a period of time containerization process. Previously, the precise effect on growth due to these abnormalities was unknown, but now there are several indications that some container-induced abnormalities could be quite serious. At the Aguaclara Farm, Department of Valle, many trees in some portions of the plantation had dull red foliage, characteristic of trees which die rapidly from drought. On excavation, these trees were almost invariably found to have strangling roots. Healthier neighboring trees which were excavated did not have strangling roots. Another example is the patula pine plantation encountered on entering the La Paz farm near Popayan. Here, numerous trees have fallen as a result of stangling roots. These are two examples which spurred the initiation of this study.

The objectives of this study are to determine the frequency of the various root abnormalities caused by the containerization of planting stock in Carton de Colombia's plantations and to assess their effect on tree growth and health. These objectives are met by 11 separate surveys reported herein, ranging from seedlings in the nursery to trees in six-year-old plantations. Objectives, methods and results of each of these studies will be reported in succession:

Survey I	Influence of "J" Roots on Seedling Growth Rate
Survey II	Rate of Root System Development of Eucalyptus camaldulensis and Pinus sp. Raised in Containers
Survey III	Excessive Tap Root Growth of Pinus oocarpa
Survey IV	Effect of Tubes on the Root Morphology and Growth of Eucalyptus grandis.
Survey V	Consequences of Planting Eucalyptus grandis with their Tubes Intact Two and One-half Years After Planting.
Survey VI	Development of Root Systems of Eucalyptus Planted with Tubes on in a Fertilizer Study
Survey VII	Root Binding: An Accomplice in the Cause of Pine Mortality in Dry Areas
Survey VIII	Effects of Tubes on Eucalyptus camaldulensis Twenty-Eight Months After Planting.
Survey IX	Root System Development in Response to Different Methods of Dealing with Containers
Survey X	Effect of Planting Oversized Pine Stock in High Rainfall Areas
Survey XI	Proportion of Trees With Inadequate Lateral Root Systems in Plantations Which Have Been Planted with and Without Their Tube Containers.

SURVEY I INFLUENCE OF "J" ROOTS ON SEEDLING GROWTH RATE

Objective

To determine if the frequency and degree of bending of roots during transplanting from the seed bed to the container has an effect on subsequent seedling growth in the nursery.

Methods

One hundred 3-month-old containerized Eucalyptus camaldulensis seedlings from the Restrepo nursery were measured for their height in centimeters. After measurement, each seedling was removed from their container and the degree to which their tap root was bent as a result of transplanting was measured in degrees. A regression was run to see if there was a correlation between seedling height and the degree of root bending. A similar procedure was conducted for 100 Eucalyptus camaldulensis seedlings from the nursery in Yumbo.

Results

Only 2% of the seedlings examined had principle roots which had been bent more than 45%. Low R^2 values obtained for the regression equations (R^2=0.05 for the eucalypts from Restrepo and 0.11 for the eucalypts from Yumbo) indicate that root bending as a result of transplanting from the seed bed to the container has a negligible effect on the growth of Eucalyptus camaldulensis seedlings while they are in the nursery.

SURVEY II RATE OF ROOT SYSTEM DEVELOPMENT OF EUCALYPTUS CAMALDULENSIS AND PINUS SPP. RAISED IN CONTAINERS

Objective

To determine when containers begin to exert a deforming influence on the developing root system of three species.

Methods

Root systems of Eucalyptus camaldulensis, Pinus patula and Pinus oocarpa seedlings which had been 1, 2, 3, 4 and 5 months in containers in the Restrepo nursery were removed from the paper tube or polyethelene bag in which they had been planted. The diameters of both types of containers inspected were 4.0 cm. when filled with soil; the height of the tubes was 10 cm, whereas the mean bag height was 12 cm.

Root systems of 20 seedlings of each species in each of the five different age classes were examined to determine how completely the root system was occupying the soil medium and whether or not deformation of the root system had occurred as a result of contact with the container walls. Note was also made if such deformations had become lignified.

Results

Pine seedlings of both species were found to have root systems penetrating to the extremities of their containers one month after transplanting to the container. After two months abnormal root morphologies had become apparent, and after 3 months the deformed parts of root systems were becoming lignified.

Roots of Eucalyptus camaldulensis seedlings were found to have reached the limits of their containers between 1 and 2 months after transplanting. After 3 months many lateral roots had become lignified into the spiral root position. Development of lateral roots of eucalypt was much sparser than in pines.

SURVEY III EXCESSIVE TAP ROOT GROWTH OF PINUS OOCARPA

objective

To determine how much excess roots had formed in Pinus oocarpa four months after transplanting to polyethelene bags.

Methods

Sixty-one vigorously growing four-month-old Pinus oocarpa seedlings were removed from their 4 cm. wide by 12 m deep polyethelene bags and the root systems were shaken free of soil. In this manner the root systems could hang loosely. Seedling height and legnth of the longest root were then measured from the root collar for each seedling in centimeters. Twelve centimeters, which was the bag depth, was then subtracted from the legnth of the longest root. The difference, if positive, was considered to represent the amount that the root system had overgrown its container.

Results

The average height of the 61 four-month-old seedling was 14.7 cm. The average length of root overgrowth which had occurred in these seedlings was 13.2 cm. with a range of from 5 to 35 cm. There was no correlation between the height of the seedling and the amount of root overgrowth.

SURVEY IV EFFECT OF TUBES ON ROOT MORPHOLOGY AND GROWTH OF EUCALYPTUS GRANDIS

Objective

To determine how planting tube-raised eucalyptus seedlings with their tubes on affects the morphological development of Eucalyptus grandis root systems.

Methods

In November of 1980 a quarter hectare of land at the farm La Estancia was planted with 10-week-old tube-raised Eucalyptus grandis seedlings still in their tubes. On the same day an adjacent block was planted with the same planting stock but the tubes were removed at the time of planting. Six months later, 10 trees were selected at random in each block, measured for their heights, and were excavated. Root sytems of all excavated trees were then carefully examined and compared to determine if there were any differences in the amount of root deformation which had occured as a result of the seedlings being planted with their tubes on.

This procedure was repeated 10 months after planting as well; at this time 14 trees in tubes and 14 trees without tubes were measured for height, and excavated. For each excavated root system, the circumference of the primary root was arbitrarily divided into 4 quadrants and each quadrant was evaluated as to whether good lateral roots had developed in that quadrant in the top 10 cm. of the root system. Then tree height was regressed on the number of quadrants in the root system which had good lateral root development.

Results

After six months the seedlings which had been planted in tubes had grown 80 cm., the same as seedlings which had been planted without tubes. The tubes still had not decomposed and these trees were developing notably fewer lateral roots; the majority of lateral roots simply were not forming or were being deflected by the tube to grow straight downward.

"J" shaped principle roots, a result of poor transplanting technique, had occurred in 5 of the 20 trees excavated. Trees with "J" shaped roots averaged 66 cm. in height, whereas trees free of this defect averaged 84 cm. in height.

After 10 months of growth the seedlings which had been planted with tubes intact had the following characteristics: 1) Average height of 244 cm.; 2) Seven of the trees still had their tubes completely intact; 3) Ten of the trees had developed no lateral roots in the zone of the tube; 4) Seven of the trees were clorotic and puny and appeared to be dying; 4) Spiral roots were present in 4 trees; 5) Average height of trees without lateral roots in tube zone was 178 cm. and 6) Average height of trees with lateral roots in this zone was 364 cm. By comparison, trees planted without tubes had the following characteristics: 1) Average height of 261 cm.; 2) Five of the trees had developed no lateral roots in the zone of the bag; 3) Six of the trees had the unhealthy symptoms already described; 4) Spiral roots were present in 4 trees; 5) Average height of trees without lateral roots in the tube zone was 148 cm.; 6) With lateral roots in the zone of the tube was 292 cm.

Poor tree growth was very closely related to inadequate development of a lateral root system. Overall, trees which had developed good lateral roots had grown 1.9 times taller and were invariably healthier in appearance. Linear regression techniques indicate that the number of cuadrants in the top 10 cm. of the root crown with good lateral roots accounted for 86% (R^2= 0.86) of the differences in height growth. In two cases, although trees had no lateral roots in the zone of the tube, the seedling had been planted suficiently deep such that good lateral roots had formed above the zone of the tube. These trees had an average height of 275 cm.

SURVEY V CONSEQUENCES OF PLANTING EUCALYPTUS GRANDIS SEEDLINGS WITH THEIR TUBES ON TWO AND ONE-HALF YEARS AFTER PLANTING.

Objective

To determine how the planting with tubes on affected the growth of *Eucalyptus grandis* two and one-half years after planting.

Methods

Twenty six different provenances of *Eucalyptus spp.* had been planted with tubes intact in a provenance test at the La Arcadia Farm, near Popayan. At two and one-half years after planting the study was converted to a seed stand by eliminating trees which had inferior growth. Stumps from cut trees were excavated which facilitated a study of the root morphology of in-tube planted *Eucalyptus spp.* Stumps were measured for their collar diameters and the following observations were made for each root system.

1) The circumference of the primary root in the region of the tube was divided into 4 quadrants. Then each quadrant was assessed as to whether it had confined roots or not. Regressions were then run for root confinement against stump diameter.

2) The number of spiral roots in each root system was noted.

3) The presence of bent roots as a result of the principle root being bent in the nursery was noted.

4) The presence of root bending as a result of poor transplanting from the germination bed to the tubes was noted.

Results

1) Root systems which were confined by the tube over at least 180 degrees of their circumference in the region of the tube were found in 56% of the trees. When the degree of confinement of the root system was regressed against stump diameter the following equation resulted:

$$D = 14.1 - 1.31\ (C)$$

Where: D = stump diameter in centimeters

and C = degree of confinement of the root system where:

0 = no confinement
1 = confinement in one quadrant
2 = " two quadrants
3 = " three quadrants
4 = " all four quadrants

This equation explains 43% of the differences in stump diameters (R^2 = 0.43).

2) Strangling roots were evident in the tube zone in 54% of the trees. Two such affected trees had butt resinosis which appeared to be caused by the inability of the cambium to grow completely over convex portions

of deformed roots.

3) The principle root of 32% of the trees had been bent as a result of overgrowing the legnth of the tube while the seedling was in the nursery

4) Bent principle roots as a result of transplanting were found in 2% of the root systems.

SURVEY VI DEVELOPMENT OF ROOT SYSTEMS OF EUCALYPTS PLANTED WITH TUBES INTACT IN A FERTILIZER STUDY

Objective

To evaluate the growth and development of Eucalyptus grandis stock planted in tubes under different fertilizer treatments.

Methods

Eucalyptus grandis seedlings which had been raised in plastic-lined paper tubes, were transplanted to the Chupillauta farm for a fertilizer test with their tubes intact. Fifteen months later root systems of 6 trees from each of 4 fertilizer treatments in each of 4 blocks were excavated from the soil. A total of 96 trees were excavated. The fertilizer treatments from which trees were excavated are 1) 50 gm. calfos, 2) 50 gm. calfos + 10 gm. urea, 3) 100 gm. calfos + 10 gm. urea, 4) 200 gm. calfos + 25 gm urea. Root systems of 24 trees were examined within each fertilizer treatment for the presence of any of the deformations listed in Table I. Heights and collar diameters of excavated trees were also measured.

For each test plot the average height growth of tube-confined seedlings was compared to the height growth of seedlings which were free of the containerization influence; ie lateral roots had emerged from the tube.

Results

Eucalyptus grandis which were still confined by their tubes had only 36% of the height of their container-free counterparts within the same fertilizer test plot. E. grandis saplings which had bent primary roots as a result of contact with the nursery floor overall had 48% less height than those without this defect. Only 8% of the 96 saplings excavated in this survey did not have a root deformation of some type. Heavy fertilization appeared to help facilitate root systems breaking through the confining tube walls.

SURVEY VII ROOT BINDING: AN ACCOMPLICE IN THE CAUSE OF PINE MORTALITY IN DRY AREAS

Objective

To determine the cause of the red death of pines planted in dry areas of the Western Andes.

Methods

Foliage of the entire crown of many Pinus occarpa and Pinus kesiya trees in 2 to 4-year-old plantations in dry areas of the Western Andes has often been seen to turn to yellow and then red in one dry season. After the foliage turns red the tree dies. Trees suffering from this problem are located at random in plantations although the problem is more frequent in some areas and in some plantations than in others.

In one phase towards ascertaining the cause of this "red death" 30 trees with foliage which had just turned red, 4 trees which were in the yellow (chlorotic) condition and 3 trees which were perfectly healthy were excavated from the soil and autopsied to see if there was any potentially harmful biotic or abiotic agents. Comparisons in root system morphologies were also made. The study was conducted on the lower elevations in plantations in the Rancho Grande and Aguaclara farms which have altitudes of approximately 1300 m.a.s.l. and annual rainfalls of 1200 mm.

Results

The factor that almost all red trees had in common was that their root systems had been deformed as a result of remaining in the container too long in the nursery before outplanting. Yellow chlorotic trees often showed some root deformation as well, but this was not as pronounced as in red trees in the same plantation. Deformities were not found in the root systems of healthy trees in these dry areas. Besides the red foliage, conspicuous butt resinosis and above average sprout development were also associated with root strangulation of Pinus oocarpa. There was no consistant evidence of biotic pathogens associated with trees with red foliage.

SURVEY VIII EFFECTS OF TUBES ON EUCALYPTUS CAMALDULENSIS TWENTY-EIGHT MONTHS AFTER PLANTING.

Objective

To determine what effect, if any, planting Eucalyptus camaldulensis seedlings in tubes had on root morphology and diameter growth.

Methods

In 1977 Eucalyptus camaldulensis seedlings in the tube were machine planted on the Guachicona tract (elev. 1000 m.a.s.l., 1000 mm of rainfall year). Twenty-eight months later a road was built through the plantation facilitating the excavation of 60 E. camaldulensis stumps. Measurements of stump diameters at the root collar were made and the degree to which lateral roots had been confined or rerouted due to the paper tube was estimated using the quadrant method, explained in Survey V.

Results

The emergence of lateral roots in the region of the tube was extremely poor (Table II). The correlation between the diameter of the tree and the degree to which lateral roots had developed was not very strong ($R^2 = 0.26$)

SURVEY IX ROOT SYSTEM DEVELOPMENT IN RESPONSE TO DIFFERENT METHODS OF DEALING WITH CONTAINERS

Objective

To determine which of several different methods of dealing with the container at the time of outplanting would result in the best growth of *Pinus oocarpa* and *Cupressus* , *lusitanica*.

Methods

In 1975 seedlings of *Pinus oocarpa* or *Cupressus lusitanica* which had been raised in tubes or bags were outplanted in one of the following ways: 1) Seedling planted with the tube intact; 2) seedling planted with the tube removed; 3) seedling planted with the bag removed; 4) seedling planted with the bag intact, but cutting off the bottom of the bag; 5) seedling planted without the bag and cutting the bottom roots and the spiralling lateral roots; and 6) pulling the seedling from the bag, shaking off the soil and planting it bare-root. The experiment was installed in Andept soils on the Los Guaduales farm, near Popayan. One year later the degree to which the container had been removed had had no significant effect on the amont which seedlings had grown (Ladrach, 1977).

In May, 1980 trees in two blocks of the experiment were measured for height and root collar diameter and were excavated to assess the morphology of the root system. Any evidence of any of the forms of root deformation listed in Table I was noted for each root system.

Results

Among the treatments applied to cypress, results indicate that planting with either the tube or the polyethylene bag in place led to a deformation of the root system, but that no exceptional reduction of growth has resulted as a result of these deformities even after 5 years (Table III).

With one exception, no conlusions can be reached with respect to the pine portion of the experiment since it is evident from the high proportions of deformed roots in all treatments that seedlings were overgrown in their containers before this experiment was installed. The exception is that converting passed containerized stock to bare-root stock (treatment 6) apparently diminishes the proportion of root-bound root systems.

SURVEY X EFFECT OF PLANTING OVERSIZED PINE STOCK IN HIGH RAINFALL AREAS

Objective

To document the performance of seedlings which were too large for their containers in the nursery six years after they had been planted.

Methods

The two plantations examined during this survey are both located at the La Paz farm near Popayan. The farm is at 1750 meters elevation and normally receives about 1900 mm of rainfall annually.

In 1974 pines in two lots were planted with seedlings which were oversized in the nursery, which means that their lateral roots were growing in spirals around the inside of the bag. In the first plantation *Pinus patula* had been planted. Seedlings used in the second plantation were a mixture of *Pinus oocarpa* and *Pinus patula*. Six years later a noticeable number of trees in both plantations had fallen over due to wind throw; additionally many trees were leaning. On closer examination all such leaning or windthrown trees were found to have strangling roots. Severe strangulation had made the root systems of these trees ineffective as support structures. Many upright trees were found to have strangling roots as well, but it appeared that the degree of strangulation was not as severe.

In the pure *Pinus patula* stand, degree of leaning was used as an index of strangulation to enable a study to be conducted to determine whether degree of strangulation had had an influence on tree diameter. The diameters at DBH or 1.5 meters distance from the base were measured for 29 fallen trees, 30 trees leaning over at least 15° from the verticle, and 44 erect trees. All trees examined in this portion of the study were alive at the time the study was conducted.

In the mixed *Pinus patula* and *Pinus oocarpa* plantation each of 515 trees in one block were simply tallied as to whether they were erect, leaning over 15°, fallen over, or dead.

Results

In the pure *Pinus patula* plantation, trees which had fallen over; indicating severe root strangulation, had an average diameter of 9.4 cm. Trees which were leaning, indicating a moderate amount of root strangulation, had an average diameter of 12.0 cm. and trees which were upright, indicating that they had sufferred from the least amount of root strangulation, had an average diameter of 15.0 cm.

In the block of the mixed *Pinus oocarpa Pinus patula* plantation, 26% of the trees were erect, 53% were inclined, 8% were lying down and 13% were dead. In total, therefore, over 70% of the trees in the plantation had been windthrown over 15°. Windthrown trees were located at random in the plantation and all windthrown trees examined showed evidence of strangling roots. Windthrown *P. oocarpa* were further characterized by much higher than average sprouting.

SURVEY XI PROPORTION OF TREES WITH INADEQUATE LATERAL ROOT SYSTEMS IN PLANTATIONS OF EUCALYPTUS GRANDIS WITH AND WITHOUT TUBE CONTAINERS

Objective

To see if the proportion of trees which develop without adequate lateral root systems is different for seedlings of *Eucalyptus grandis* planted in their tubes versus seedlings planted after the tubes have been removed.

Methods

Two neighboring lots in the same plantation were planted during the same week with the same *Eucalyptus grandis* planting stock in October of 1980. The seedlings in one lot were planted by hand with their tubes on; in the other lot the tubes were removed before being planted by hand. The lot where the tubes were not removed has generally proven somewhat more satisfactory than the lot where the tubes were removed. All trees received 75 gms. of NPK 10-30-10 and 10 grams of borax at the time of planting.

Eleven months after planting a survey was run to see if the proportion of trees which had developed inadequate lateral root systems varied between the two lots. Since over 250 trees in each lot were to be examined a non-destructive sampling procedure was desirable. Results of Survey IV indicated that trees which were smaller, with chlorotic diminutive foliage, inclined or dying had inadequate development of their lateral root systems. These symptoms were therefore used as a guide to the development of lateral roots.

The survey was conducted by walking down random rows of trees in both lots and tallying the number of healthy (green straight and vigorous) and unhealthy trees (small leaning, chlorotic, dying at the terminals).

Results

Of the 288 trees examined in the lot where the tubes had been removed, 13% had the unhealthy and diminutive symptoms indicating poor lateral root development, of the 255 trees examined in the lot when tubes had not been removed, 30% of the trees had these symptoms indicating poor lateral root development. Trees not suffering from this problem were growing excellently in both lots.

DISCUSSION

Deformation of the root system as a result of the containerization process appears to have three causes: poor transplanting technique, inadequate lateral root development and excessive root growth while in the container. Bending the principle root when the seedling is transplanted incorrectly into the container, from the seed bed causes the principle root to remain in the J shape. Results of Survey I indicated that having a "J" shaped principle root does not significantly influence the growth rate of the seedling in the nursery. However, results of Survey IV showed that young trees with J shaped principle roots were smaller than trees planted as their contemporaries which did not have the problem. The frequency of J shaped root systems was found to vary with batch of seedlings, nurseries, and species; the eucalypts are more prone to have the problem than the pines probably due to the difference in flexibility of the different types of seedlings when they are transplanted.

Lateral root development in the zone of the tube is extremely important for *Eucalyptus grandis*; in Survey IV the variation in tree height of this species was found to be very highly correlated to the number of quadrants in a root system which had developed good lateral roots ($R^2 = 0.82$).

Leaving a pine seedling in a polyethylene bag in the nursery for such a legnth of time that its root system becomes deformed or shaped by the walls of the container was found to promote two different kinds of adverse effects on the health and growth of the resulting tree (Surveys VII y X). On relatively dry sites with 1200 mm. of rainfall per annum, the foliage of pine trees with strangling roots is likely to undergo a rapid color transformation over a period of a few months (from green to clorotic to red) as a result of inadequate quantities of water being translocated past the root binding to the crown during the dry season. When the foliage is red the tree is effectively dead. The age at which a tree is affected is roughly inverse to the degree to which the root system was deformed in the container. These symptoms have been most commonly observed in plantations of 2 to 5 years of age.

Although evidence was not collected in plantations in dry sites, it is also logical that sub-lethal strangling or constricting of root systems, may allow the tree to grow only at a rate beneath its genetic potential. Lindgren and Orlander (1978) found that, as compared with a natural root system, containerized root systems had only one third the cross sectional root area leaving the imaginary zone of the container seven years after planting.

On wetter sites with 1900 mm. of rainfall per year foliage of trees was never found to have turned red as a result of root-strangling, confined root systems. Rather, the most obvious evidence of strangled root systems is windthrown trees. In this case lateral roots, which, if they had they not been deformed by the container, would have contributed to the support of the tree, actually interfere with their intended function. The place of structural failure of windthrown trees with strangling roots is frequently just above the point of strangle. Ironically, the point where strangulation prevents the principle root from growing in diameter is the natural fulcrum for a tree; the one place where tree diameter should be the thickest.

Windthrow problems from strangulation of the containerized root system are not uncommon elsewhere (Bell, 1978; Tinus 1978). According to Lindgren and Orlander (1978), *Pinus sylvestris* trees with 35 cm. diameters which resulted from containerized stock were able to resist less than one-half the force against their trunks as similarly sized trees which had developed naturally from seed. Interestingly *Pinus sylvestris* trees which had developed from bare root stock could sustain 90% as much force as the trees which had developed naturally from seed.

Experience gained from the surveys reported here and available literature indicate that windthrow problems typically increase with age (Bergman and Haggstrom 1976; Bell, 1978; Lindgren and Orlander 1978). However, there is also evidence that in some species the strangling and entangled roots resulting from the containerized seedlings may eventually coelesce under the overgrowth of a continuous cambial layer. If this point is reached the root can apparently function quite normally from a structural standpoint (Hagner, 1978; Hay and Woods, 1978). In Colombia the initial coelescing of the bound root mass has been seen in *Eucalyptus camaldulensis* in as little as 3 years but has not been observed in *Pinus oocarpa* up to 8 years of age. Most roots are not likely to coelesce within a pulpwood rotation.

Evidence from Survey X also shows that *Pinus patula* diameter growth on 1900 mm rainfall sites is severly stunted by root deformities caused by excess time in containers; trees with the most severely deformed root systems on the average, grew only 63% as large in diameter as trees with the least deformed root systems.

Results of Survey VII suggest that strangling roots cannot translocate as much water as unaffected root systems. In studies conducted by Hay and Woods (1978) the translocation of carbohydrates in the phloem was also found to be impeded by the presence of strangling roots. The inability of root-strangled trees to translocate sugars past the point of strangulation could be part of the reason for the abnormally heavy basal sprouting observed in strangled *Pinus oocarpa*.

Butt resinosis is another adverse effect of planting stock with deformed root configurations which occurs in eucalypts but is more frequent in pines. Besides being symptomatic of ill-health and causing growth loss, the presence of resin lowers the value of the wood for many wood products.

The effect of planting trees with tubes in place is still not totally resolved. Results of the surveys IV, V, VI, VIII and IX indicate that the morphology of seedlings planted with their tubes on is different than that of a seedling developing in an unconfined soil media, but the impact on volume growth is not clear. The initial survival rate is not affected by planting with tubes intact, but tubes often have not degenerated 18 months after planting. Lateral roots of tube-planted seedlings were seldom seen to break through the walls of their tube, such roots either do not form, or, on contact with the wall, are usually deflected downward.

Results of Survey IX indicate that cypress grew better if removed from the tube before planting. Removing the tube at planting time had essentially eliminated problems with deformed roots. On the other hand pine growth apparently dropped as a result of removing the tube. Perhaps untubed seedlings had to recover from more transplanting shock. The test with pines, however, is considered unfair since all seedlings were planted after their root systems were already set in container-deformed growth patterns.

Survey IV and V indicate that the number of cuadrants with good lateral root development is highly correlated with the growth of *Eucalyptus grandis*. The reason for the somewhat lower coefficient of determination in Survey V ($R^2 = 0.43$) as compared to Survey IV ($R^2 = 0.86$) is probably due to having several different provenances in Survey V and only one in Survey IV.

The reason why good growth of *E. camaldulensis* is not as dependent as *E. grandis* on the formation of lateral roots may in part be explained by genetic differences between species. According to Cremer *et al* (1978) eucalyptus species native to dry areas of Australia, including *E. camaldulensis* tend to develope more prominent tap roots than eucalypts from moister areas
As such, *E. camaldulensis* would naturally be less dependent on having lateral roots than *E. grandis*.

In Surveys IV and XI it also appears that poor development of lateral roots of *E. grandis* raised in tubes dates back to even before planting since a significant proportion of these seedlings failed to develope lateral roots even though their tubes were removed at the time of planting. This is of interest because the seedlings had been held in the nursery the minimum amount of time necessary to have grown to an adequate size for outplanting. Apparently the lateral root development in tubes was inadequate in many *E. grandis* seedlings and leaving the tube on at the time of planting simply increased the proportion of trees which developed without adequate lateral roots.
A good lateral root system leaving from the top 15 cm. of the root crown is vital to tree health. Results of Surveys IV, V and VI demonstrate this point. Results of Surveys IV, V and VI demonstrate this point. These thoughts have also been reflected by Ben Salem (1978) working with tubed *Pinus pinea* seedlings in Tunesia. Nonetheless, Ladrach (1970) reports a case where, seedlings of *Pinus taeda* grew the same regardless of whether they had been planted with or without their tubes.

Also even where tubes do impair root system development of a small proportion of trees, the efficiency of planting seedlings with tubes intact in mechanical operations many be a more important factor. Furthermore, if seedlings are planted so that the top of the tube is slightly below the soil level, lateral roots often develop from adventitious buds which form at the top of the root crown; such trees had as good of growth as healthy trees in Survey IV.

Results of studies reported indicate that trees are likely to grow better if they have good lateral root development, but do not have spiral lateral roots or excessive principle roots at the time of planting. To ensure the formation of this kind of root system one or more of the following practices could be helpful:

1) Use containers 15 cm. deep by 6 cm. in diameter. Root systems of pine and eucalyptus seedlings fill 12 cm. deep by 4 cm. wide containers within one month and six weeks respectively from the time of transplanting (results of Survey II). There will be 2.6 times more soil in these larger containers.

2) Move seedlings around in the nursery. Up to 5 moves are commonly conducted in Brazilian nurseries for nursery stock in polyethelene bags. The first move is conducted about 40 days after transplanting from the germination bed at a time when, according to results of Survey II, the principle roots should just have grown into the bottom of the container. The moving apparently restricts the growth of these long roots and thereby prevents their piling up in coils. in the bottom of the bag. It also stimulates the growth of lateral roots which is especially important for the eucalypts. All moves can be timed to correspond to selection processes when faster growing seedlings are segretated from their slower growing contemporaries. The principal root should be pinched off at each move.

3) Nursery stock should be outplanted before root systems of seedlings overgrow the dimensions of their containers. This is basically a problem of timing; if the nursery manager knows exactly how many seedlings are needed of each species he can lay out a schedule of work activities which, if followed, will result in the production of the desired number of seedlings of proper size for planting.

4) With the possible exception of mechanically planted tube seedlings, the tubes should always be removed at the time of planting. The lined paper tubes presently being used in Carton de Colombia nurseries dont decompose rapidly when they are planted along with the seedling, and the morphology of the enclosed root system is often poorer as a result of the confinement.

5) Another technique for dealing with oversized seedlings is to remove them from their container medium just before outplanting and plant them bare root. Results of Survey IX show that this is an effective way for reducing the amount of root deformity in containerized seedlings. Meskimen (1974) even recommends growing oversized stock and then removing all soil with streams of water prior to planting to ensure sturdy eucalyptus planting stock. This technique has not worked well in Brazil; however, it is logical to assume that normal methods of raising bare-root stock would result in more robust and more easily plantable seedlings.

6) Conventional bare-root stock could also be use in some circumstances. Many species commercially planted above 1800 meters in Colombia can be planted easily and with good establishment success, and trees from bare-root stock are generally more wind firm than trees from containerized stock (Lindgren and Orlander, 1978).

CONCLUSIONS

Basically there are three types of problems which develope as a result of using containers in the nursery: 1) "J" roots 2) overgrowth of the container by the seedling root system; and 3) lack of development of lateral roots in the zone of the container.

"J" roots result when the tip of the primary root is doubled over as it is being transplanted from the germination bed to the container. In the surveys conducted only 2% of the seedlings were affected with this problem. Trees with severe J roots grow more slowly than their non-affected contemporaries.

Overgrowth of the container by the seedling root system was found to be a much more common defect. Normally large planting stock is preferred because the survival on outplanting will be high. However, if containerized seedlings are so large that their primary roots are bunched or bent at the bottom of the container, and their lateral roots are spiralling around the inside of the container, root binding problems will develop years later.

On dry sites strangling roots, which develop from spiral roots, cut off the flow of water nutrients and carbohydrates between the root system and the tree crown.

The problem becomes aggravated as the affected tree ages. On dry sites root-bound trees commonly die showing typical drought symptoms. Pine folliage turns red.

On sites with more favorable moisture balances, root bound trees are not so obvious. Although the strangling of root bound trees also occurs on such sites, the more regular rainfall helps prevent affected trees from passing over the drought threshold. In such areas root-strangled trees are more likely to suffer a loss of growth increment or to be windthrown due to structural failure of the root system.

Poor development of lateral roots in the zone of the container was more common among eucalypts than pines. Eucs with this problem have slow growth and occasionally die.

RECOMMENDATIONS

To reduce the incidence of root binding in eucalypts and pines the following is recommended:

1) Use containers 6 cm. in diameter by 15 cm. deep as a minimum size.

2) Move containerized seedlings periodically in the nursery pruning roots that emerge from the container each time.

3) Mantain good scheduling between seedling production in the nursery and the field outplanting to minimize the number of oversized seedlings.

4) For oversized seedlings with root binding in the nursery, remove the container and the soil, prune the spiraled roots and plant the tree bare root; this where the climate permits.

5) For trees in tubes of paper lined with plastic, remove the tube before hand planting; for machine planting it is necessary to leave the tube intact. In the case of plastic bags, these are removed as always.

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TABLA I. TIPOS DE DEFORMACIONES DE LA RAIZ ASOCIADOS CON EL CRECIMIENTO DE PLANTULAS EN ENVASES

TIPO DE DEFORMACION	CAUSA
A) Raiz principal en forma de "J" en los primeros 8 cms. del sistema de las raíces	El punto de la raíz principal se queda a un lado del hueco mientras se está haciendo el repique causando el doblamiento de la raiz. Este problema existe con tubos y con bolsas.
B) Las raíces principales están dobladas a 90° a una profundidad correspondiente a la profundidad del envase.	Despues de crecer por el largo del envase, las raíces principales encuentran el piso duro del vivero. Como no pueden penetrar en éste piso se doblan y crecen por encima del piso del vivero. Especialmente se encuentra en plántulas de tubo.
C) Las raíces principales están enrolladas a una profundidad que corresponde a la profundidad del envase	Las raíces principales pueden crecer hasta 3 veces en largo en altura de la plántula. Cuando el largo de la raíz principal está creciendo en exceso en la profundidad del tubo, comienza a enrollarse en el fondo del envase. Sucede con más frecuencia en bolsas.
D) Raíces Espirales	Las raíces espirales se forman cuando las raíces laterales han crecido demasiado largo por el radio del envase y empiezan a crecer alrededor de la raíz principal entre las paredes del envase y el suelo del envase. El problema existe con plántulas en bolsas y en tubos.
E) Falta de Raices Laterales	La causa no es conocida con seguridad. Una posible causa puede ser por el suelo compactado en el envase que no permite la formación inicial de raíces laterales. Una practica que se emplea para conservar la masa de tierra mientras se quita la bolsa, también puede perjudicar la formación de raíces laterales.
F) Raices Laterales Redirigidas	Las raíces laterales, si no crecen en espirales, pueden crecer directamente por debajo entre las paredes el envase. Es común especialmente cuando se plánta las plántulas en tubos.

TABLA II FRECUENCIA DE DISTRIBUCION DE SISTEMAS DE RAICES POR NUMERO DE CUADRANTES CON RAICES LATERALES

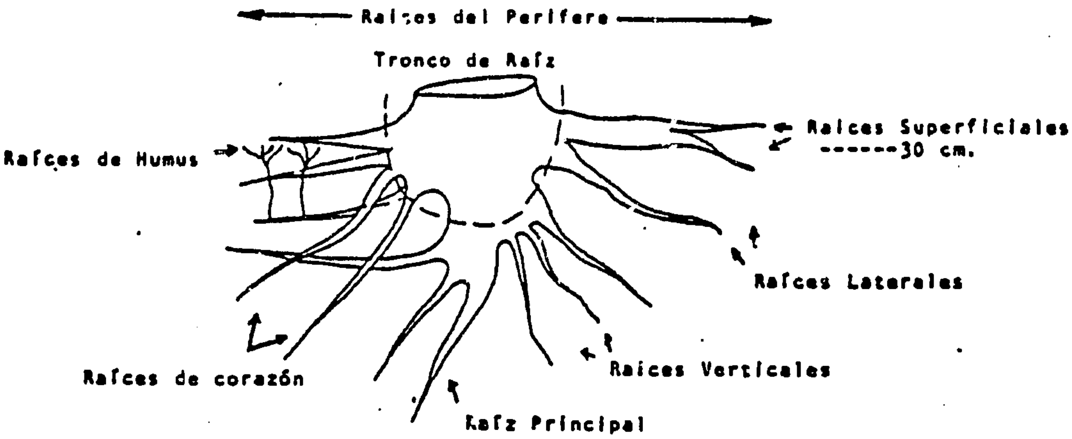
Número de Cuadrantes Con Raices Laterales	% del Sistema de Raices en esa Categoría	Promedio de Diametro (cms.)
0	66	8.7
1	27	10.4
2	5	14.0
3	2	13.0
4	0	-

TABLA III. PROMEDIOS DE ALTURA Y PORCENTAJE DE SISTEMAS DE RAICES DEFORMADAS EN RESPUESTA A SEIS DIFERENTES METODOS DE TRATAR ENVASES AL MOMENTO DE PLANTAR CINCO AÑOS A PARTIR DE LA PLANTACION [1]

Número de Tratamiento	Tratamiento	Cupressus lusitanica: % de árboles con sistema de raíces deformadas	Cupressus lusitanica: Promedio de altura en (cms.)	Pinus oocarpa: % de Arboles con sistema de raices deformadas	Pinus oocarpa: Promedio de altura en (cms)
1	Plantado en tubo	64	647	77	753
2	Plantado sin tubo	8	705	85	698
3	Plantado sin bolsa	38	722	92	745
4	Plantado con bolsa sin fondo	64	738	92	806
5	Plantado sin bolsa cortando raíces espirales	0	709	100	719
6	Plantado sin bolsa y sin suelo	0	637	50	713

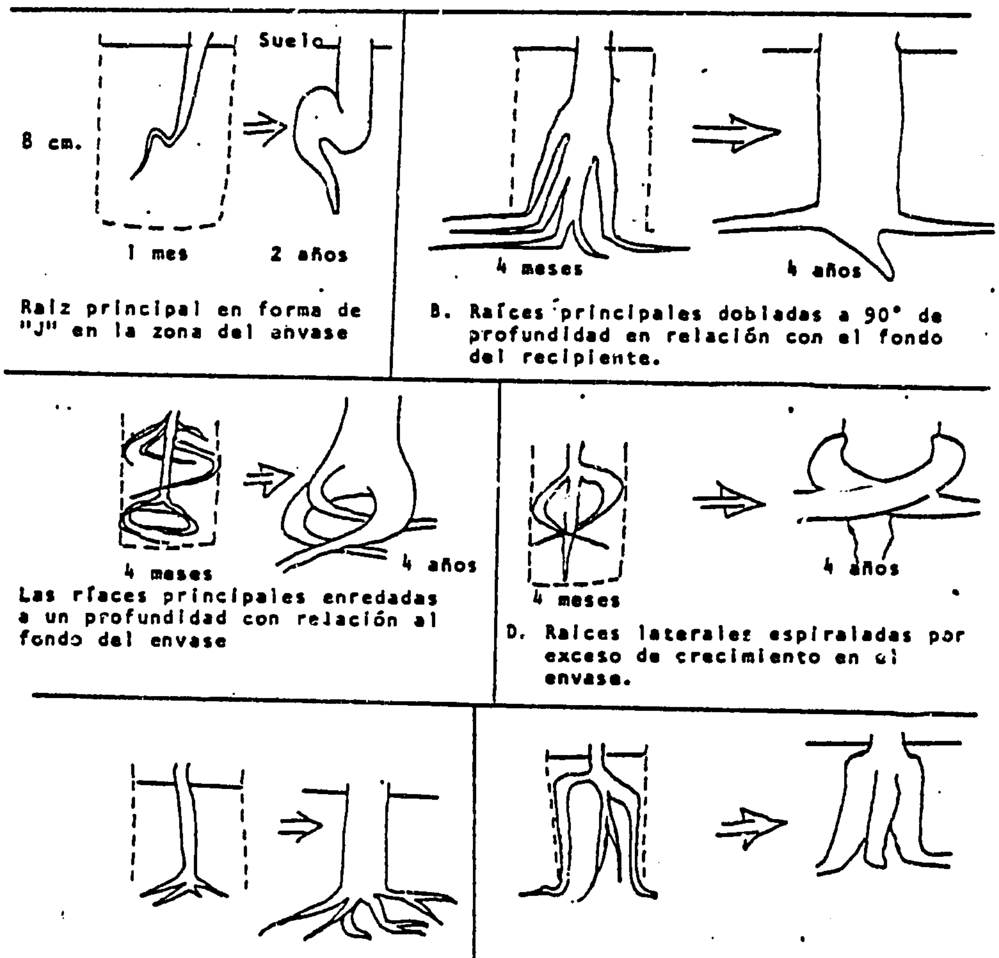
1) Cada tratamiento para las dos especies fué representado de 12 a 14 árboles. Las plántulas para los tratamientos 1 y 2 fueron crecidas en tubos de papel con una película de polietileno en el vivero. Las demás fueron crecidas en bolsas de polietileno.

FIGURA 1. REPRESENTACION ESQUEMATICA DE UN SISTEMA DE RAICES DE AKBOLES NORMALES*



*/ Tomado de Lyr y Hoffman (1967)

FIGURA 2. REPRESENTACION ESQUEMATICA DE LOS TIPOS DE DEFORMACIONES DE LAS RAICES ASOCIADAS CON LOS RECIPIENTES DE LAS PLANTULAS*



A. Raiz principal en forma de "J" en la zona del anvase

B. Raíces principales dobladas a 90° de profundidad en relación con el fondo del recipiente.

C. Las rfaces principales enredadas a un profundidad con relación al fondo del envase

D. Raices laterales espiraladas por exceso de crecimiento en el envase.

E. Falta de raícos laterales

F. Raíces laterales redirigidas por abajo.

* La localización del envase se indica por las líneas interrumpidas. Las causas de las deformidades se explican en la Tabla I.

Section II

MYCORRHIZAE MAY SAVE FERTILIZER DOLLARS

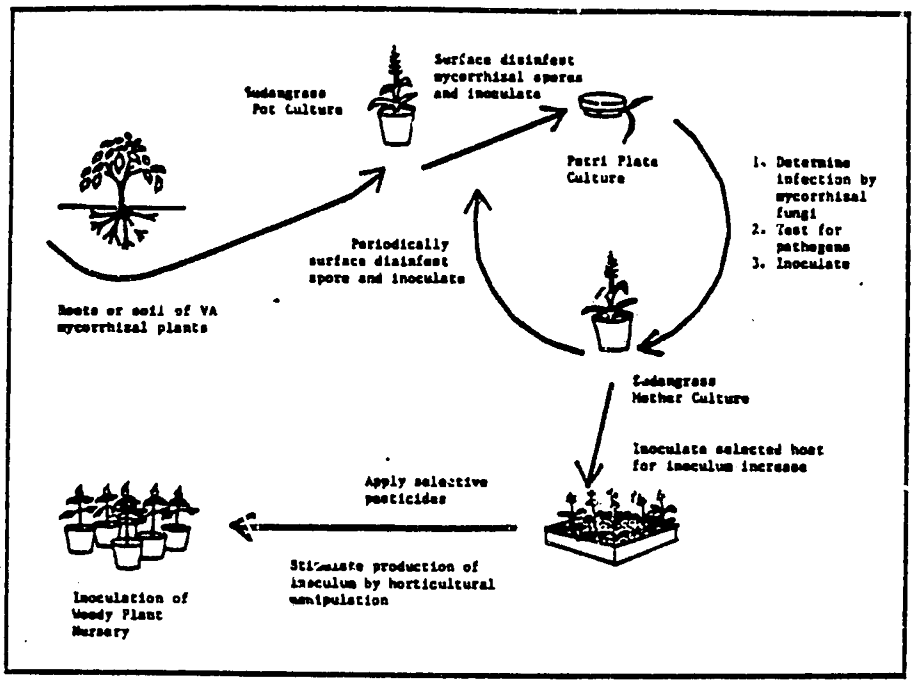


Fig. 1. Proposed scheme for commercial production of mycorrhizal inoculum.

Mycorrhizae may save fertilizer dollars

By Dr. Charles R. Johnson and Dr. John A. Menge

MYCORRHIZAL FUNGI are associated with the roots of nearly all plants. They form a symbiotic association termed mycorrhizae. Because of their importance to plant growth and their widespread distribution, mycorrhizae must be considered in all aspects of plant science and agriculture.

Mycorrhizal fungi are frequently categorized into four major groupings: ectomycorrhizae, vesicular-arbuscular (VA) mycorrhizae, ericaceous mycorrhizae and orchidaceous mycorrhizae. Ericaceous and orchidaceous mycorrhizae are associated with ericaceous and orchidaceous plants, respectively. Little information is available on these two types of mycorrhizae, and their economic importance is limited, so they

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Mycorrhizal inoculum costs

Item	Cost per pot
Cash Costs	
Management salary	7¢
Other wages & salaries	
Potting & inoculation	5
Moving pots	2
Pruning	1
Spraying	1
Watering (drip)	2
Harvesting	3
Grinding & packaging	2
Quality control	2
Maintenance mother culture	5
Plants & seeds	.2
Pots—4-inch	7
Media	2
Fertilizer	.3
Pesticides & other chemicals	1
Other production supplies	1
Repairs & maintenance	1
Insurance	2
Telephone	.5
Electricity & fuel	9
Taxes, licenses & bonds	1.1
Advertising	.3
Rent (land and/or buildings)	.8
Other cash expenses	13
Total Cash Costs	**69.2¢**
Noncash Costs	
Depreciation on machinery & equipment	2.2
Depreciation on buildings	.9
Interest on capital @ 12%	12
Total noncash costs	**15.1¢**
Total cost per 4-inch container	**84.3¢**

Fig. 2. Estimated costs for producing vesicular-arbuscular mycorrhizal inoculum on Sudan grass in four-inch pots.

Fertilizer cost comparison

Fertilizer: Material	Fertilizer: Rate[2,3]	Annual fertilization cost for 1,000 gallon containers[1]: Without VA mycorrhizae	With VA mycorrhizae	Potential savings
Micronutrients	2.5 lb/cubic yd	$22.14	$13.28	$ 8.86
Double superphosphate	5 lb/cubic yd	3.06	.91	2.15
Ammonium nitrate	Avg. 130 ppm N	37.81	26.47	11.34
Potassium chloride	Avg. 80 ppm K_2O	9.58	6.71	2.87
Other nutrients (Ca, Mg)		7.25	5.80	1.45
Totals		**$79.84**	**$53.17**	**$26.67**

[1]Based on January, 1981, price estimates.
[2]Fertilization rates based on commercial woody nursery operations using overhead fertigation system.
[3]Phosphorus levels could be reduced by approximately 70% and N, K and micronutrients by 30 to 40% using VA mycorrhizal fungi.

Fig. 3. Estimated fertilizer costs for woody landscape plants grown in gallon containers with and without VA mycorrhizae.

pp. 80, 81, 82, 83 & 84

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will not be discussed further.

Ectomycorrhizae are associated with numerous conifers and other trees, such as oak, beech, birch, eucalyptus, willow and poplar. Ectomycorrhizal fungi are Basidiomycetes (mushrooms and puffballs) and Ascomycetes (cup fungi and truffles). They are characterized by a thick fungal layer, known as a fungal mantle, which covers the host feeder roots.

VA mycorrhizae are found on a majority of the angiosperms of the world. They do not visually alter the structure of roots and often cannot be detected without a microscope. VA mycorrhizal fungi are found in almost any field soil from arctic to tropical regions (17).

Both of these mycorrhizal types penetrate the outer regions of roots (cortical cells), but only VA mycorrhizae penetrate individual cells. Inside host plant cells, VA mycorrhizal fungi form branched structures known as arbuscules and ballon-like structures termed vesicles.

Arbuscules are thought to be the site of nutrient transfer between the symbiotic partners. Vesicles are likely storage organs that the fungus produces to store nutrient materials inside the plant host. Because a great majority of woody landscape species are infected by beneficial VA mycorrhizal fungi, this will be the only group of mycorrhizae discussed below.

What They Do

VA mycorrhizae are capable of improving growth of many woody landscape plants (10, 11, 12, 21). VA mycorrhizal fungi stimulate plant absorption of phosphorus and may be involved in uptake of other ions (4, 15, 16). Mycorrhizal fungi have been reported to improve water transport (19), although this may simply reflect improved nutritional status of mycorrhizal plants.

There is also evidence that mycorrhizae provide resistance to plant disease (20). Many scientists feel that VA mycorrhizal effects on disease are a result of improved phosphorus nutrition caused by the increased absorbing surface conferred by mycorrhizal hyphae.

Container production of ornamentals eliminates or significantly reduces populations of VA mycorrhizal fungi. Most media components—such as pine bark, vermiculite, perlite, builder's sand and peat mosses—are devoid of mycorrhizal fungi. In addition, many nurserymen steam, pasteurize or chemically treat media to eradicate harmful pathogens; this also eliminates beneficial organisms, such as mycorrhizal fungi.

Nurserymen have compensated for the absence of mycorrhizal fungi by applying luxury amounts of fertilizer and water to achieve desired growth. But high levels of nutrition and irrigation will not always be feasible, because of limited petroleum available for making inorganic fertilizer, high costs of fertilizer and rigid restrictions on water use. In addition, high nutrition and subsequent required pesticide applications are being more carefeully monitored by environmental regulatory groups.

Inoculating container-grown plants with VA mycorrhizal fungi may reduce the need for current high levels of fertilizer, water and pesticides. This can be done, and it has some economic advantages.

Inoculum Production

Commercial production of VA mycorrhizal inoculum is being attempted at only a few places in the country. Currently, the only way to produce suitable quantities of inoculum is on roots of susceptible host plants. With the proper safeguards, mycorrhizal inoculum that is free of plant pathogens can be produced in commercial greenhouses.

Menge et al (13) proposed a scheme for producing inoculum as shown in Fig. 1. The inoculum is produced in pot cultures of selected hosts that have no root diseases in common with the host plant for which the inoculum is intended. For example, inoculum for citrus could be produced on Sudan grass but never on citrus.

Precautions must be taken to ensure the inoculum is free of nematodes, insects and harmful pathogens. Nemec (18) tested a number of fungicides that are compatible with producing mycorrhizal fungi.

Cost estimates of inoculum production can be generated using current greenhouse business analyses. A reasonably accurate cost estimate of mycorrhizal production, including technical labor and quality control, is approximately 84.3¢ for a four-inch container of VA mycorrhizal inoculum (Fig. 2). This would be enough to inoculate approximately 50 to 60 gallon containers.

A method similar to the one outlined above is being developed in England for large-scale commercial use (7). In this method, plants are grown in peat blocks that are standing in a shallow nutrient-flow culture. After VA mycorrhizal spores are produced in the peat blocks, the blocks are ground up for inoculation.

Inoculating Woody Landscape Plants

A number of methods have been used to inoculate plants with VA mycorrhizal fungi in greenhouse and nursery trials. Inoculation can be done when potting rooted cuttings into liner or gallon containers by placing five to eight grams of soil inoculum directly beneath roots of the cuttings. Phosphorus levels must be kept low (less than 34 parts per million for citrus) during all phases of plant growth, and other nutrients should be kept low for the first six to nine weeks of mycorrhizal infection.

Infection has also been accomplished by inoculating plants during propagation, shortly after root initiation, using mycorrhizal spores or soil inoculum. The greatest success with infection and subsequent growth response has been realized from early spring to summer.

Various methods have been used successfully to inoculate field-grown plants, including layering the inoculum under seed and banding the inoculum along plant rows (8). Commercial applications of mycorrhizal inoculum using fertilizer banding machinery were successfully carried out in a California citrus nursery (2). Some success has been achieved by pelleting seeds with inoculum (6) and by inoculating seeds (3).

Growth and Economic Benefits

Because VA mycorrhizal fungi occur on a wide variety of woody plant species and improve growth of these plants, the potential of these fungi as commercial "biotic fertilizers" is enormous.

Researchers have shown that woody landscape plants in containers grow about as well with low to moderate nitrogen and potassium fertilization plus mycorrhizal inoculation as they do with luxury fertilization (10).

Benefits of these fungi on important tree fruits, such as citrus (13), avocado (14) and peaches (11), has prompted inquiries and demand for inoculum to improve plant growth.

Fertilization currently constitutes two to four percent of the cash nursery production expenses (5). This will continue to rapidly escalate.

With inoculation, the expense of phosphorus fertilization could be reduced by approximately 70 percent. Current levels of nitrogen, potassium and micronutrients could be reduced by 30 to 40 percent.

This potentially could reduce fertilizer expenditures by 33.4 percent, for savings of approximately $26.67 per 1,000 gallon containers annually for woody plants under a typical fertilization program (Fig. 3).

Preliminary research has indicated that an additional benefit is improved establishment and survival of mycorrhizal plants in landscape soils (9). Reduced costs for better water and fertilizer uptake and improved plant survival should create consumer demand for such plants in the landscape.

Summary and Conclusions

Mycorrhizal fungi benefit growth of several woody landscape plants under controlled experimental conditions. Cost benefit figures indicate an economic advantage to using them. Container studies are being established at nursery sites to test the feasibility of using mycorrhizal fungi under commercial cultural programs.

With successful results from such tests and growing interest, more commercial sources of inoculum should develop. Current methods of watering and fertilizing will be radically changed in the next decade because of shortages. Using alternatives like VA mycorrhizae will become common.

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Section III

FAO--A HANDBOOK OF NURSERY PRACTICE

FO:SF/MAL 12
Working Paper No. 19

PILOT PLANTATIONS OF QUICK-GROWING INDUSTRIAL TREE SPECIES
MALAYSIA

A HANDBOOK OF NURSERY PRACTICES -- FAO FOR PINUS CARIBAEA VAR. HONDURENSIS AND OTHER CONIFERS IN WEST MALAYSIA

by

D. K. Paul
F.A.O. Forestry Officer (Nurseries)

[redacted]

UNITED NATIONS DEVELOPMENT PROGRAMME

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

KUALA LUMPUR, 1972

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The Food and Agriculture Organization is greatly indebted to the many people who provided the expert with information, advice and facilities and especially to the Forestry Department of Malaysia in allowing Mr. Isaac Ho Sai-Yuen, the Photographer, to publish his work in this Handbook.

TABLE OF CONTENTS

LIST OF MAPS AND FIGURES

PHOTOGRAPHIC SUPPLEMENT

(Inserted between pages 62 and 63)

Section IV

BARE-ROOT SEEDLING SURVIVAL

Root growth capacity: One key to bare-root seedling survival

Edward C. Stone ☐ Edward A. Norberg

More often than is generally recognized bare-root coniferous seedlings are planted that cannot possibly survive. For example, most of the true-fir (*Abies concolor* and *A. magnifica*) seedlings planted in the Sierra in 1978 never had a chance. In several plantations there are no survivors, and a preliminary survey has indicated that, overall, survival may be as low as 30 percent. On the other hand, the white fir seedlings planted during 1976 and 1977, at the height of the drought, came through with flying colors. Certainly not because of the drought, but because following transplanting, these seedlings had the capacity to develop extensive root systems—the key to bare-root seedling survival in California.

Why was the capacity high in 1976 and 1977 and low in 1978? We now believe that variation in the nursery climate was responsible and that most bare-root seedlings raised in California can be expected to respond similarly.

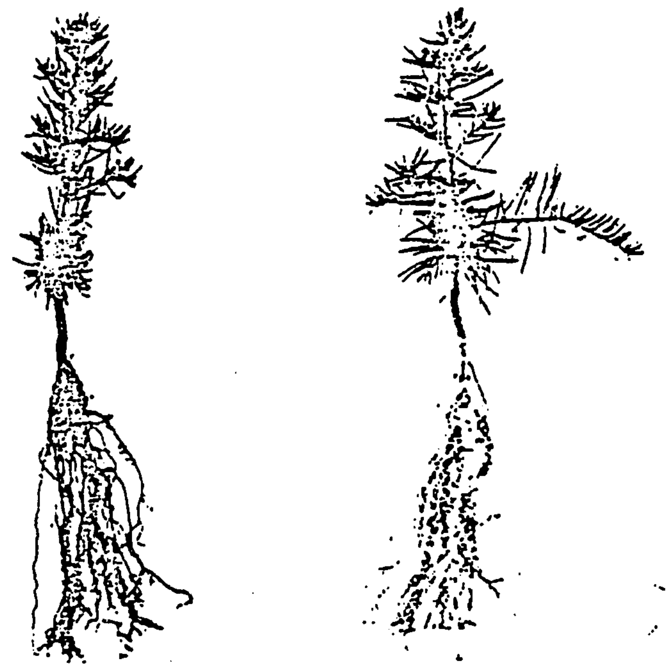
Since the early 1950's the University of California Department of Forestry has joined the California State Division of Forestry and the U.S. Forest Service in determining why some seedlings develop extensive root systems following transplanting and others do not. As a quantitative measure of this root growth capacity (RGC) we have used the root growth of a representative sample of seedlings in a standard test environment.

The seedlings are transplanted into watertight containers filled with a forest soil in which the soil water potential has been adjusted to -0.3 bars. The containers are then immersed in a 20°C water bath located in a room maintained at 25°C during a 12-hour day and at 20°C during the night. Light closely resembling sunlight is supplied by Xenon lamps. Water is added periodically to the containers to maintain the water potential between -0.3 and -0.5 bars. Twenty-eight days later, the seedlings are removed from the containers and all new root growth greater than 3 centimeters in length is recorded. Average elongation per seedling serves as a measure of the RGC the seedlings had when placed in the test environment.

We were handicapped in our early studies of the relationship among RGC, nursery climate, and cold storage by a lack of controlled environment facilities. Efforts to establish firm correlations were repeatedly complicated by variation in the nursery climate, the importance of which could not be assessed. But following the completion of four temperature-controlled greenhouses in 1972 and five controlled environment chambers shortly thereafter, the effect of climatic variation on RGC could be evaluated.

Early findings

Before these controlled environment facilities became available, however, we found that the RGC was low before the onset of cold autumn nights and increased steadily until a peak was reached two to three months later. Often the RGC then abruptly decreased. Sometimes, it remained at the peak level for a month or more and then decreased. In most cases it increased to a second, but lower, peak in the late spring. When RGC was plotted against time, the shape of the curve as well as the magnitude of points along the curve varied from one nursery to the next, and at any one nursery often varied from one year to the next.



Unseasonally warm early winter temperatures can reduce root growth capacity. Seen here are typical root elongations—one month after removal from cold storage—of seedlings grown with a two-week warm interruption in December, left, and without an interruption, right.

Later, we found that when cold storage was employed, the highest RGC that could be obtained subsequent to storage required that the seedlings be placed in storage when the RGC could, according to our estimate, be expected to reach its first peak. Initially, this estimate was based on the number of hours the seedlings had been exposed to temperatures lower than 10°C; later it was based on the number of nights the seedlings had encountered during which the temperature dropped to 5°C.

Once in a while, the RGC of seedlings removed from storage was too low to assure seedling survival following planting in the field, even though the seedlings had been place in storage when the RGC, according to our estimate, could be expected to reach its first peak. Still later, we found that seedlings can survive over a wide range of RGC's because the minimum acceptable RGC—the RGC at which field survival is not further increased when seedlings with a higher RGC are planted—varies with the species, the time of planting, and the environments encountered on the planting site.

Controlled environment findings

Only after controlled environment facilities became available, enabling us to follow the RGC of seedlings grown in various nursery climates under our control, was a hypothesis for the variability encountered in the RGC in our previous studies forthcoming. Unseasonally warm temperatures during late autumn or early winter appear responsible. Although this is still only a hypothesis, it is strongly supported by the RGC patterns obtained when seedlings are grown in controlled nursery climates, with and without warm interruptions.

When seedlings are not subject to a warm interruption (which in our studies means that once a 5°C temperature is initiated it is maintained throughout the study) the RGC steadily increases to a peak over one, two, or three months. How long it takes to reach the peak depends on the time that has elapsed after shoot elongation has ceased before cold temperatures are initiated. Once the peak is reached, the RGC generally decreases abruptly. Sometimes, depending on the species and seed source, it remains near the peak for a month or more and then decreases. Later, a second peak is reached, one that is generally lower than the first although in a few seed sources it is higher.

In our studies, when seedlings are subject to a warm interruption, the temperature is raised to 20°C for two weeks, six weeks after a 5°C temperature is initiated, and then the temperature is returned to 5°C. The result: the RGC decreases abruptly by 50 percent or more.

The RGC is always reduced when seedlings are placed in cold storage. When they have not been subject to a warm interruption the magnitude of the reduction is not uniform and depends on the length of the time the seedlings are exposed to a 5°C temperature before being placed in cold storage. Invariably the minimum reduction in the RGC occurs when the RGC reaches its first peak or shortly thereafter. Consequently, since the RGC is high to begin with during this period, a minimum reduction leaves these seedlings with the highest RGC. This means there is a better chance that seedlings placed in storage during this period will come out of storage with a RGC above the minimum acceptable level than if they were placed in storage either at an earlier or a later date.

On the other hand, when seedlings are subject to a warm interruption before being placed in cold storage, the RGC, already reduced by the warm night interruption, is further reduced by storage. In all cases the effect is sufficient to reduce the RGC of 70 to 80 percent of the seedlings coming out of storage to below the minimum acceptable level characterized by field survival.

Before we can characterize a climate as one with warm interruptions that can affect RGC, we must determine the minimum temperature and duration required for a warm interruption to be deleterious. Should warm interruptions prove to be anywhere near as effective in reducing RGC as our studies suggest, and should they prove to be as widespread as temperature records indicate, a strong case can be developed for moving nurseries subject to warm interruptions to locations where such interruptions rarely occur, or for identifying those species that can be grown without the danger that their RGC's will be reduced below a minimum acceptable level by warm interruptions.

In favorable years at some nurseries ponderosa pine seedlings, for example, are produced with an RGC considerably above the minimum acceptable level. At such nurseries, warm interruptions that reduce the RGC of these seedlings by 100 cm or more can be tolerated, because after such a reduction the RGC is still above the minimum acceptable level. But when true-fir seedlings are produced, we do not have this kind of latitude. The maximum RGC is much lower and any significant reduction because of warm interruptions in the nursery can be expected to be directly reflected in lower field survival.

Summary

It now appears that if bare-root, cold-stored, true-fir seedlings, with a consistent minimum acceptable RGC are to be available for planting in the Sierra, new nursery locations may be required. Additional studies will be needed to determine whether this is so, and if so, where new nurseries should be located.

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Section V

USDA/FS--HOW TO GROW TREE SEEDLINGS IN CONTAINERS

General Technical Report RM-60 May 1979

How to Grow Tree Seedlings in Containers in Greenhouses

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USDA Forest Service

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[1]Central headquarters is maintained in Fort Collins, in cooperation with Colorado State University. Tir _ is assigned to the Station's Research Work Unit at Bottineau, North Dakota, in cooperation with North Dakota State University.

Forword and Acknowledgments

A comprehensiv manual on containerized tree seedling nurseries and the methods of growing trees in containers has been needed for some time. This manual, begun in June 1975, is presented for use in the field with the understanding that its immediate need will outweigh its flaws. We have consulted with administrators and nurserymen many times in the last few years. This manual attempts to answer the questions that have been asked most often. It is intended to be most useful to beginners, but we hope experienced practitioners will also find it useful.

Many people have contributed to this manual. We have relied heavily on publications and our personal interactions with authorities on the subject. We especially thank the following reviewers for their suggestions and constructive criticisms:

James Arnott	Peyton Owston
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Phillip Hahn	Robert Smith
James Hanover	Robert Stevens
Thomas Landis	Ronald Stewart
James Lott	Frank Ter Bush

Cover drawing is by Arline Tinus.

We plan to revise the manual in a few years. We hope the readers will advise us of inconsistencies or of new findings in their investigations or experience by contacting us at the Rocky Mountain Forest and Range Experiment Station (USDA Forest Service, Bottineau, N. Dak. 58318) or State and Private Forestry, Rocky Mountain Region, USDA Forest Service, Box 25127, Lakewood, Colo. 80225).

CONTENTS

Page

Page

Page

Page

How to Grow Tree Seedlings in Containers in Greenhouses

Richard W. Tinus and Stephen E. McDonald

SECTION 1.—INTRODUCTION

1.1 Orientation of the Manual

This manual is designed to provide the user with two types of information:

1. A general reference for greenhouse nursery development (sections 2 through 9) with advice on greenhouse development, economics, hardware, and containers. The general advice in the earlier sections should be helpful in making decisions about greenhouse nursery development.
2. A specific reference for growing containerized forest tree seedlings (sections 10 through 21). Explicit directions are provided concerning environmental conditions for optimum growth, nutrition, mechanics, pest control, and trouble-shooting. These sections should be most useful to nurserymen.

The manual focuses on greenhouse development and tree growing in the western United States, particularly the interior West, where many new greenhouse nurseries are being started and a great variety of problems are encountered. Much of the information also applies to greenhouse nursery systems anywhere.

This manual is intended to answer most of the questions asked by novices and to help them avoid blunders. It is not an operating manual for any particular nursery, but, by using the principles and guidelines included, a nurseryman can assemble his own (Goodwin 1975, Matthews 1971).

The suggestions and directions in this manual should be used with judgment and discretion. Nothing is as valuable as a nurseryman's personal observation and deduction based on his own experience in his own location.

Throughout this manual, trade names are used only for specificity, brevity, and the convenience of the reader. No endorsement to the exclusion of equally suitable products is implied or intended.

Parts of this manual discuss the use of pesticides. Because of rapid changes in registration and labeling, the reader should check to be sure his proposed use is legal. Remember that pesticides can be harmful to humans, domestic animals, desirable plants, and fish or other wildlife if they are not handled or applied properly. Use all pesticides selectively and carefully, following the directions on the container. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.

1.2 Information Confidence Levels

This manual is intended to provide the nurseryman with as much information as possible, but the quality of information about seedling biology varies considerably. The following grading system is used throughout to help the reader decide how much confidence to place in the information:

Level A—This information has been developed in controlled experiments of adequate size and thoroughly tested in production greenhouse situations. It is thought to be complete and accurate.

Level B—This information has been developed in small scale experiments or results from accumulated experience in production greenhouses. It is believed to be valid, but is subject to further testing.

Level C—This information is based on observation, and frequently from isolated cases. It is offered in the view that some knowledge is better than none.

SECTION 2.—DETERMINING PLANTING STOCK NEEDS

There are logical, sequential steps that should be taken before making a final decision to build a tree nursery. Several important facts should be determined at the outset:

1. What species and sizes of trees are wanted?
2. When and where will such trees be planted?
3. How many trees of each species and size will be needed?
4. How long will these needs persist, and how will they change over time?

With these facts determined, the potential nursery developer can analyze the planting stock alternatives available. (Note: Throughout this manual, the acronym "CTS" is used to abbreviate the term "containerized tree seedling.")

SECTION 3.—ALTERNATIVE PLANTING STOCK SOURCES

SECTION 3.—ALTERNATIVE PLANTING STOCK SOURCES

3.1 Should You Grow Your Own Trees?

Growing your own trees, either in a bare-root (conventional) or CTS facility requires a concerted effort. Much time must be devoted to the project, especially at the outset. Capital investment will be required. In return, there will be good control over the operation and source of planting stock.

There are a number of advantages to not growing your own trees. Some of these are the converse of the advantages noted above. Time and capital would be freed for other opportunities. Also, buying planting stock from others passes many of the worries of producing seedlings to the producer.

There are some advantages to procuring some trees from outside sources and growing the rest. Growing only part of the program planting needs affords some security of supply and provides the technical capability needed to produce full program needs, if outside sources are cut off. Growing part of a program's tree needs will also allow good control of production of critical species, or plant materials of unusual value or for special purposes.

3.2 Is a Bare-Root or Container Nursery Wanted?

When a decision is made to start a nursery, should it be a bare-root or container facility? Both types have advantages and disadvantages. In bare-root nurseries, seedlings are grown in exposed seedbeds under specialized farming practices, removed from the soil, and shipped to the planting site with roots bare (fig. 3-1). The principal characteristics of bare-root nurseries are:

1. The trees are grown in soil. Consequently the soil must be suitable for tree-growing (Wilde 1958). Such soil is often difficult to find in a convenient location, and is often expensive.
2. Large amounts of high-quality irrigation water are required (Stoeckler and Jones 1957).
3. Seedlings are exposed to the adverse weather.
4. Much high-quality land is involved along with farm equipment, special nursery implements, an extensive irrigation system, and expensive support buildings.
5. The operation is sensitive to the economies of scale. Once the operation is begun, it is important to function at near capacity levels to keep unit production costs to a minimum.
6. Rate of seedling growth and time of dormancy break are largely controlled by the climate.
7. Little energy is required, compared to greenhouse operations.
8. Seedlings can be compactly packaged and shipped. However, they are perishable and must be kept moist and cool.
9. Natural buffering in the outdoor environment allows seedlings to tolerate mistakes in culture and timing better than in greenhouse nurseries.

The term "containerized tree seedling nursery" refers to those nurseries where the tree seedlings are grown in a medium placed in a container (fig. 3-2). The containers usually are specially designed for this purpose. They can be placed in the open, where the climate is mild, but in more rigorous climates are placed in a greenhouse or under shade fabric where the growing environment is controlled. In this manual, the term "container nursery" usually means "a controlled-environment greenhouse nursery where tree seedlings are cultured in specialized containers" (Tinus 1974a). Container nurseries have a number of common characteristics:

1. They can be constructed on land with low agricultural value (i.e., in many places unsuited to bare root seedling production).
2. While high water quality is an asset in CTS nurseries, it is not as crucial as for a bare-root nursery. Relatively small quantities are required, and quality can be upgraded by filtration and/or addition of chemicals.
3. Greenhouse-grown trees are not exposed to adverse weather, so, production is more reliable.
4. A container facility is less sensitive to the economies of scale than a bare-root nursery. Each greenhouse unit tends to support its own costs, and the nursery is a multiple of such units tailored to demand. No large workforce of diversified skills is required, and most equipment necessary for operation is used all of the time.
5. Container nurseries can use large amounts of energy. This energy is consumed in increasing the speed and reliability of production.

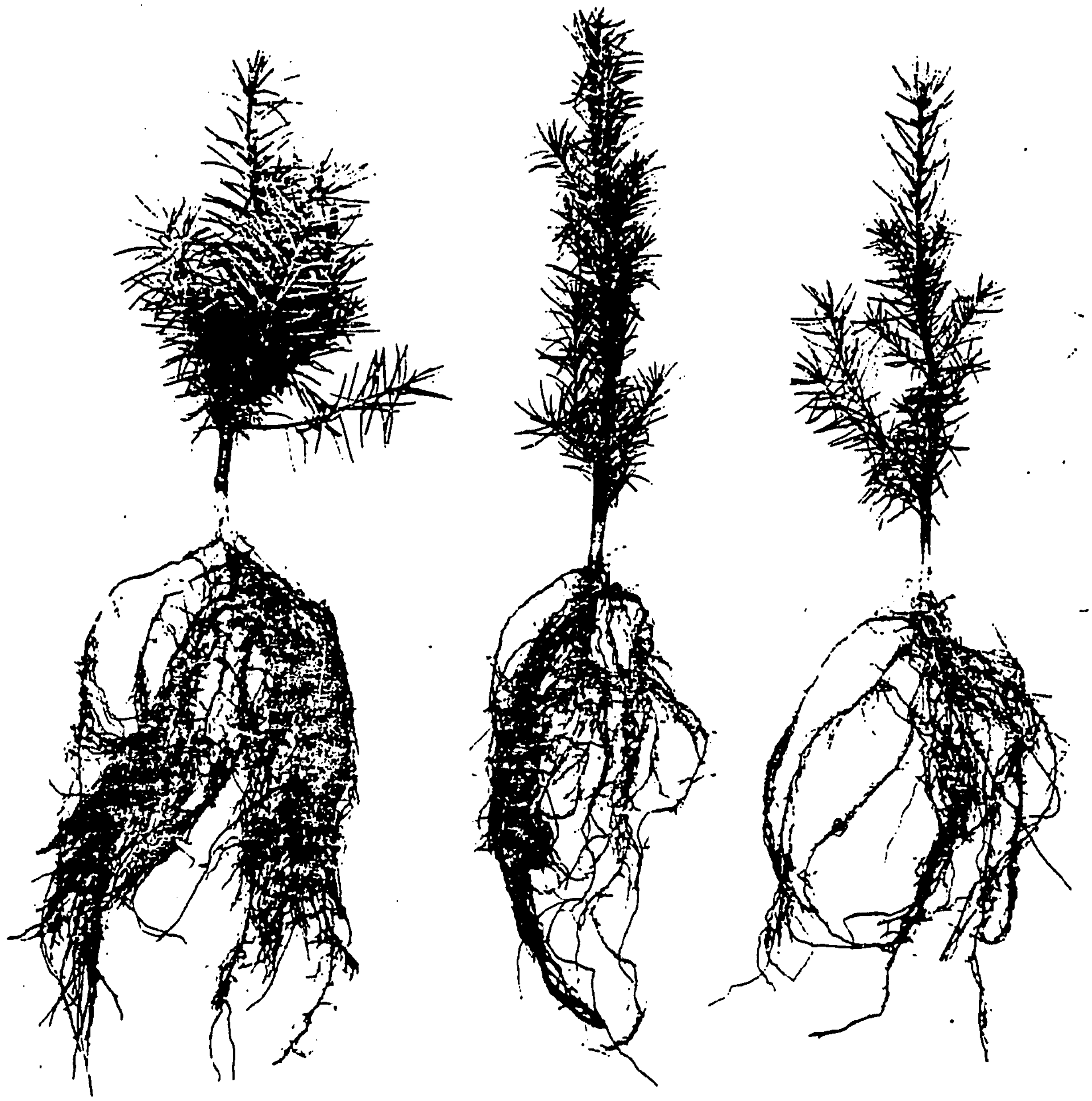

Figure 3-1.—Typical bare root conifer seedlings.

- Containerized seedlings are bulky to package and ship. However, they are usually less perishable than bare-root seedlings.
- The controlled environment in a greenhouse increases ability to control diseases and insects, but incidence and rate of spread may be much higher.
- Container trees can be produced faster than bare-root trees (Stein 1974).

Under some circumstances, a facility combining bare-root and container nursery features might be appropriate. An example might be a nursery site suitable for growing broad-leaved, but not conifer, seedlings. In another case, where the amount of arable land at nursery is insufficient to meet increasing demands by bare-root production, a container facility can be added to supplement production. Perhaps trees from high-value, genetically superior

Figure 3-2.—Typical container-grown conifer seedlings.

seed would be raised in a greenhouse where they are protected from the weather, while lesser value stock is reared in outdoor seedbeds. Another case for a combined facility could relate to planting site requirements. Some sites may require containerized seedlings for adequate survival, while on others, bare-root seedlings are most cost effective. Some argument for a combined operation can be made simply on the basis of providing a flexible response to varying production demands, such as rearing container trees to quickly replace a stand destroyed by wildfire.

There are many circumstances where a combination of bare-root and container facilities can be highly complementary, especially where a bare-root facility already exists. Generally, bare-root facilities are most practical for large-scale operations, where providing many seedlings will result in low unit production costs. However, a bare-root nursery must also be on a favorable site, with a reasonably long growing season, to be economical. Container nurseries, however, can produce trees at about the same cost as in small and medium scale bare-root facilities.

3.3 Choosing Between Alternatives

First, is container stock needed for adequate field survival in plantations? If so, the decision is to use a container facility. However, if costs per surviving tree are similar using bare-root or containerized trees, the decision is still open.

Second, is there a suitable bare-root nursery site in the vicinity? Both biological and economic factors (land costs) should be considered. If no such site exists, the decision against a bare-root facility is made.

If both options are still open, the next step is to determine whether the desired production capability can be generated with the available capital. If one option was dropped earlier and insufficient capital is available to develop the desired production level in the other option, the option can be modified to a simpler version (which may be biologically riskier), the level of production reduced, or more capital sought.

Fixed-cost/variable-cost interactions between container and bare-root operations differ as volume of production increases. Projection of production levels, coupled with capital investment and production costs of each option, should indicate the optimum type of operation at different production volumes. A combined container/bare-root operation may be indicated.

Energy source is a key factor in greenhouse operations and should significantly influence the choice between a container or bare-root facility. Fossil fuels are dwindling, becoming more expensive, and in some cases, are interruptable (Besemer 1977, Pimentel 1975, McDonald 1977a). Alternative energy sources, such as waste heat from electrical generating facilities, may be readily available and are adequate for greenhouse heating (Jensen 1977a). Warmer climates cut heating needs. Cheap and reliable energy for greenhouse heating could radically revise an economic analysis of container production. Sole reliance on expensive sources of energy (electricity, propane, oil) reduces the attractiveness of the greenhouse option option.

Finally, consider availability of the technical expertise required. No formal training programs for tree nurserymen are available. However, horticultural departments of various universities train people in greenhouse and ornamental nursery management. As a result, expertise for container nursery operations may be more readily available than corresponding expertise in bare-root nursery operations.

The authors have deliberately kept these discussions of nursery alternatives brief; before a final decision between CTS and bare-root facilities is made, the reader should consult sections 4 and 5.

SECTION 9.—CONTAINERS AND GROWING MEDIUM

SECTION 9.—CONTAINERS AND GROWING MEDIUM

9.1 Function of Containers

Biologically, the function of containers is to:

1. Provide a medium for support and nutrition of the roots.
2. Protect the roots from mechanical damage and desiccation.
3. Shape the roots into a form advantageous to the tree.
4. Maximize field survival and early growth, because the root system is not disturbed but remains in intimate contact with the growing medium.

Operationally, the function of containers is to package the seedling into a standard size and shape for ease of handling throughout the nursery, shipping, and planting phases.

Recently, a great deal of concern has been expressed about the root form of planted trees (van Eerden and Kinghorn 1979). There is no question that planted trees, bare-root or container, have a different root configuration than trees grown from seed in place. In some instances, windthrow of plantations has been traced to poor root development. Pines of all species seem to be particularly susceptible. Two problems seem to be most important. When the tree is planted, roots must not be allowed to remain in a circle around the central axis. As they grow in size, they will eventually restrict diameter growth of the tap root. Even if the circling roots graft and fuse with the tap root, a weak spot is created as the stem diameter above continues to enlarge. The tree may suddenly break at the root collar in a high wind. The other problem is lack of an adequate number or distribution of lateral roots near the surface. The container must be designed to overcome these two problems.

In horticulture, the term "container" signifies what most forest tree nurserymen would call a "pot," meaning a cylindrical or rectangular plant container, slightly smaller in diameter at the bottom than the top, with a depth not much greater than the diameter, and having a flat bottom. Containers of this type are referred to by the volume they displace. They are made of fired clay, metal, plastic, compressed wood pulp, or peat.

When forest tree nurserymen refer to "containers" they mean "a container designed specially for the growth and culture of tree seedlings."

The shape of these small containers is very much different from the usual nursery pot. CTS containers are usually much deeper than their top diameter (as much as 10 times). This is because, in many instances, forest tree seedlings produce taproot systems rather than fibrous root systems, and a narrow, deep container is more compatible with this growth habit. Second, in wildland plantings, it is desirable to place the roots as deeply as possible into the soil where moisture will be available the longest. Third, planting holes of necessary depth are easier to punch or auger if the hole has a small diameter, because less earth must be moved and there is less compaction.

9.2 Container Concepts and Types

Basically, the theory of containerized tree seedlings is that, if a tree seedling can be planted with a minimum of root exposure and disturbance, there will be less transplanting shock, and survival and growth rates will be higher (Kinghorn 1974). The design of all containers is intended to minimize this root disturbance.

9.21 The Basic Types of Containers

There are two approaches to container design:

1. The container is planted with the tree. Provision is made for root egress from the container by its biodegradability, or through holes, slots, and expandable seams built into the container.
2. The tree and its plug of rooting medium held together and in shape by the tree's roots are removed from the container and then planted. The container is not planted, but may be either discarded after a single crop, or reused, depending on the type.

Each of these approaches has inherent advantages and disadvantages. In North America, most of the container seedlings are grown in rigid-wall containers that are removed from the tree when it is planted. The advantages of this concept are:

1. In the nursery, it is fairly easy to prevent tree roots from growing from one cavity to the next. When it occurs, this results in root breakage, disruption of contact between growing medium and roots, and greater physical effort to extract the plug from the container.
2. The container can be reusable, which lowers its unit cost per tree.
3. The shape of the container can greatly affect future growth of the seedling in the field (section 9.22). Most rigid wall containers incorporate vertical ribs or grooves, rounded horizontal corners, and a bottom hole for root egress, which successfully prevents lateral roots from circling around the central axis, provided the tree is outplanted on schedule. (Trees can become rootbound in even the best container, if they are held too long).
4. When planting, removal of the container instantly eliminates any barrier to root egress caused by the container. (There may still be a barrier caused by difference in properties between the growing medium and soil, however).

The disadvantages are:

1. The root ball must be removed from the impermeable walled container. This operation is not necessary when the container is planted with the tree.
2. To be reused, the container must be returned to the nursery, cleaned, and sterilized. This is a nuisance, and many damaged containers will not be reusable.

There are several types of containers designed to be planted with the tree. The new Walters' square bullet (fig. 9-1) and ITW One-way® (fig. 9-2) are not degradable, have impenetrable walls, and have the root control features mentioned above, but the walls do not interfere with root egress. This is because the walls of the bullet are intended to come apart into four pieces as the tree grows, and the One-way® has a removable sleeve.

Most containers designed to be planted with the tree are degradable. These are particularly desirable in concept, because they involve less handling and have the potential to produce a more natural form of root system than current, impermeable walled, containers (fig. 9-3). However, the currently available types have three major disadvantages:

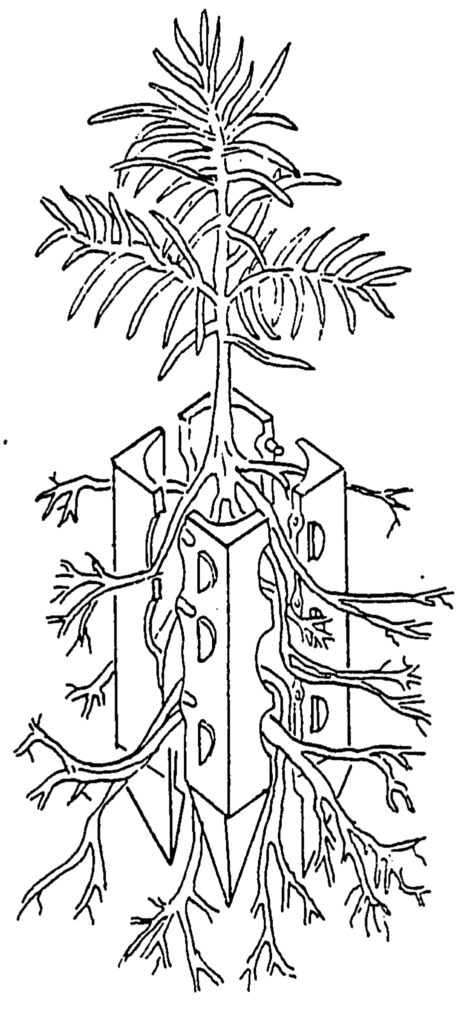

Figure 9-1.—Walters' square bullet showing radial separation of bullet sections caused by force of root growth (Walters 1974).

1. When the container wall remains impermeable to roots through the nursery phase, it will usually continue to restrict root growth after outplanting. If free root egress after outplanting is possible, the container has probably disintegrated to the point that it is difficult to handle in shipping and planting.
2. If root egress from one container to the next has occurred in the nursery, roots will be broken and lost when the containers are separated. Small seedlings, with weak or unlignified roots, will separate cleanly, but large ones will not without considerable effort and root damage.
3. Degradation rate and root penetration is critically dependent on adequate moisture. This type of container cannot be recommended for dry sites.

9.22 Container Characteristics

There are numerous other characteristics of containers that affect their use. Many of these characteristics affect the way they interact with the tree seedlings grown in them.

Volume.—The volume of rooting medium the containers will hold varies. The largest CTS containers are in the 45-cubic-inch (700-cm^3) range, while the smallest are approximately 2 cubic inches (30 cm^3). Container volume is directly related to the size of seedling desired.

Shape.—Containers may be round, hexagonal, rectangular, or square in horizontal cross-section. The ratio of depth of container to surface area at the top of the container also varies, as does the structural rigidity of the unit.

Taper.—Some containers are tapered (become progressively smaller in cross-section from the top to the bottom), and some are not. Some are tapered only over a portion of their length, often near the bottom of the container.

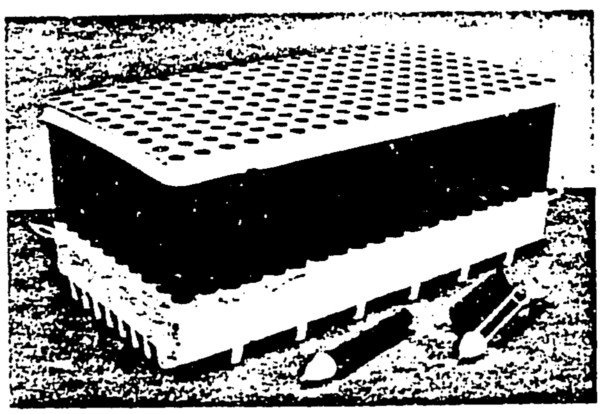

Figure 9-2.—ITW One-way[5] as the block comes ready to fill and seed. In the foreground, individual containers intact, and with the outer sleeve removed.

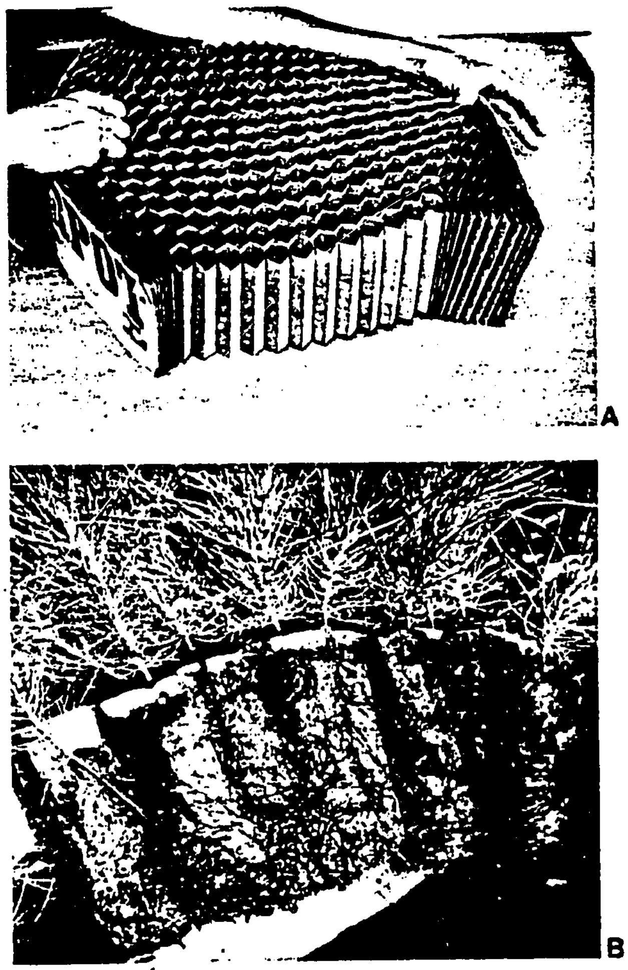

Figure 9-3.—Paperpot as it comes from the manufacturer before filling (A) and after the seedlings are grown (B).

Root control.—As mentioned in 9.21, containers can produce malformed root systems that cause windthrow and breakage later in the life of the tree (Donald 1968, Ben Salem 1971). In general, container shape controls root system configuration (Hiatt and Tinus 1974). Most of the widely used containers designed for CTS growing now incorporate features such as vertical internal ribs to reduce root spiralling in the container and possible future strangulation problems. These ribs, ridges, or grooves direct the roots to the bottom of the container where they are air pruned. Use of a properly shaped container for root control for a proper length of time should result in few root spiralling problems. Kinked roots and container compression of roots can be expected in some containers (Carlson and Nairn 1977).

Root egress opening.—All CTS containers currently in use provide an opening at the bottom for root egress to prevent root balling in the bottom of the container and allow excess water to drain out. This opening can be as large as the cross-section of the container or somewhat smaller. Because the vertical ribs and rounded horizontal corners direct growing root tips to the bottom of the container, the egress hole must be large enough to accumulate a large number of roots without plugging and causing the growing medium to waterlog. The hole should be as large as possible, but still prevent loss of the growing medium.

Construction material.—The container is usually made of plastic or paper. The strength, thickness, durability, and other structural features vary considerably, depending on the intended function and use of the container. All share one characteristic: they must be impermeable to the seedling's roots while the containers are at the nursery. Otherwise, the seedling will lose part of its root system when removed from the container or when the containers are separated (Tinus 1974d).

Unitization.—Some containers are freestanding units that can be used alone, some require a supporting rack system to keep them upright and properly spaced, and others are simply a cavity formed in a larger unit or block and cannot be separated from the larger unit. Each approach has certain advantages and disadvantages.

System design.—The nature of the container unit selected can have profound effects on the design of the greenhouse container handling system and the benches used. Where a variety of containers are to be used, the handling methods and bench system must be flexible. The container unit used also will affect seedling packaging, shipment, storage, and planting methods. In some cases, the container is part of a larger growing, handling, and planting system design.

Density.—Depending on container configuration and size, there will be a certain number of containers on a given area of bench space. This establishes the number of containers that can be placed on the benches of a greenhouse. This is illustrated in section 5.3. In general, as containers become progressively larger, the trees that will be grown in them will be of larger shippable size. These larger trees will have larger tops, and the containers must be spaced further apart, otherwise, the seedlings will compete for light, resulting in slower growth and spindly tops.

9.23 Containers Planted with the Tree

This type of container can be divided into two categories:

Those filled with rooting medium.—These include tar paper pot, the Conwed® open mesh plastic tube, the Alberta peat sausage, the Walters square bullet, and various paper pot systems. In these systems, the container is filled with medium, the tree is grown in the container, and the container is then planted with the tree. The container is either degradable or has openings that allow for root egress as the tree develops after planting. Degradable pots are advantageous, because the roots are not disturbed during shipment and planting (section 9.1.) Operationally, the use of the same unit all the way through the growing and shipping process is efficient. The container protects the root system from mechanical damage and from exposure to drying and temperature extremes. Theoretically, the root-soil interface is never disturbed. Ideally, the walls of the container restrain root penetration and remain structurally sound up to the time of planting, then degrade rapidly after planting to allow free root egress and free exchange of water and nutrients between the root plug and the native soil. However, because of variations in the degradation rate of the container, roots often penetrate the walls of the container before they should, or the structural integrity of the container breaks down too late or too soon. If either occurs, the advantage of using degradable containers is quickly lost. Considerable effort has been expended by manufacturers of degradable containers to control the degradation rate (Clendinning et al. 1974). Some paper pots have components incorporated in the paper that provide differing rates of degradation.

Containers planted with the tree that depend less on biodegradability than mechanical expansion or openings for root growth and egress are available in several forms. With pines especially, the major problems with these types of containers are (1) roots intertwine between containers during culture in the greenhouse, and (2) root development is restricted after outplanting in the field (section 9.1). Advantages of the other plantable containers also apply to these types.

Plantable containers not filled with rooting medium.—In some cases, the container is a molded block of growing medium without a wall. Some examples of this type of container are Polyloam®, Tree Start®, and BR-8 Blocks® (fig. 9-4). The biggest potential advantage of these containers is that there is no need to mix and load a separate rooting medium into a container shell. The other advantages of containers planted with the tree also apply. There is no chance for root binding in the container, because there is no wall. However, roots can readily pass from one container to the next, unless impenetrable dividers are used. The containers then may be hard to separate without damage to the root system. The premise is that such containers will be planted just as roots emerge from the container, so, timing becomes critical as it does with the walled degradable units.

The container is made of various materials including peat, wood pulp, and plastic foam and fiber. The chemical and physical properties of the material can be regulated in the manufacturing process to produce a substrate suitable for plant growth. Control of the growing medium formulation is left to the container manufacturer. This may result in a loss of flexibility. These manufactured substances normally harbor no diseases, insects or weed seeds.

9.24 Containers Not Planted with the Tree

In 1979, it is most common to remove the tree seedling with its cohesive plug of roots and growing medium from the container before outplanting. Removal can take place at the nursery before the seedling is shipped or in the field just before planting. In such systems, it is essential that the roots of the tree hold the rooting medium together so that the plug retains its structural integrity and shape. This is essential not only to minimize root disturbance and exposure between removal of the root plug from the container and planting, but also so that the plug will conform to, and fit snugly in, the hole prepared for it in the soil. As a consequence, the degree of root development at planting time is critical. The seedlings must be removed and planted when the roots are ready for rapid egress to avoid potbinding (Kinghorn 1974). The plug-like appearance of the roots plus growing medium of seedlings properly grown in these containers, combined with the fact this matrix is "plugged into" a dibbled planting hole, is the reason these containers are called "plug containers" or "plug systems."

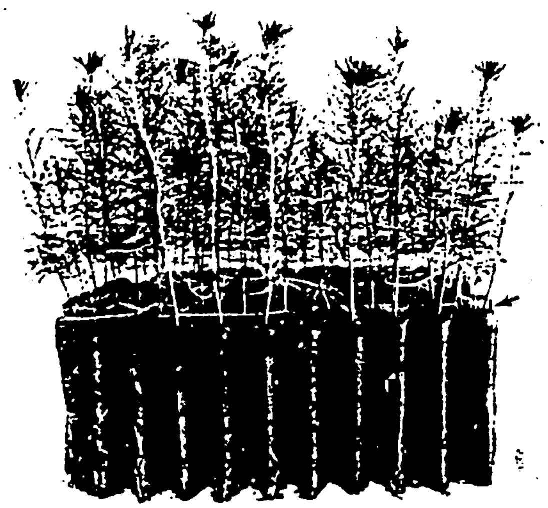

Figure 9-4.—Tree Start® is a molded block of growing medium, mainly peat. Polyethylene strips prevent roots from crossing from one row to the next. (Photo courtesy of Keyes Fibre Co.).

Common characteristics of plug containers.—Good plug containers have the following characteristics:

1. The seedling must be easily removable from the container.
2. The container walls are impenetrable by the seedling roots. In properly designed containers, there is no possibility of intertree entanglement.
3. The containers are lightweight to facilitate handling and transport.
4. The containers are constructed of sterile, essentially inert material.
5. Because of the impenetrable container walls, there should be some feature, such as vertical internal ribs, to prevent root spiralling and possible future root strangulation. Such ribs or grooves conduct the roots toward the drainage hole at the bottom of the container.
6. Containers that taper from the top to bottom produce a root plug that is pointed or somewhat bullet-shaped. The plug then fits tightly into a hole created with a pointed planting dibble of similar shape; a desirable feature.
7. When the plug is removed from the container and planted, there is no container barrier at the plug-soil interface.

Container systems or any other new reforestation technique must yield biologically acceptable results as well as be suitable for mechanization (Kinghorn 1970). All systems typically are a compromise between operational or mechanical and biological goals. For simplicity, three general approaches, called "cell," "block," and "book" designs, are explained below.

Cell designs.—A cell is an individual container unit. Although it may be unitized in trays or racks for handling, each seedling is in a container that can be separated from the others (Allison 1974). The most prominent example is the Leach Cone-tainer® (fig. 9-5). Cell containers are usually made of polyethylene.

For nursery operations, the individual cells are usually placed in special racks or trays to hold them upright and in place. The holder or rack for the cells determines spacing between cells and the resultant density of cells per unit area.

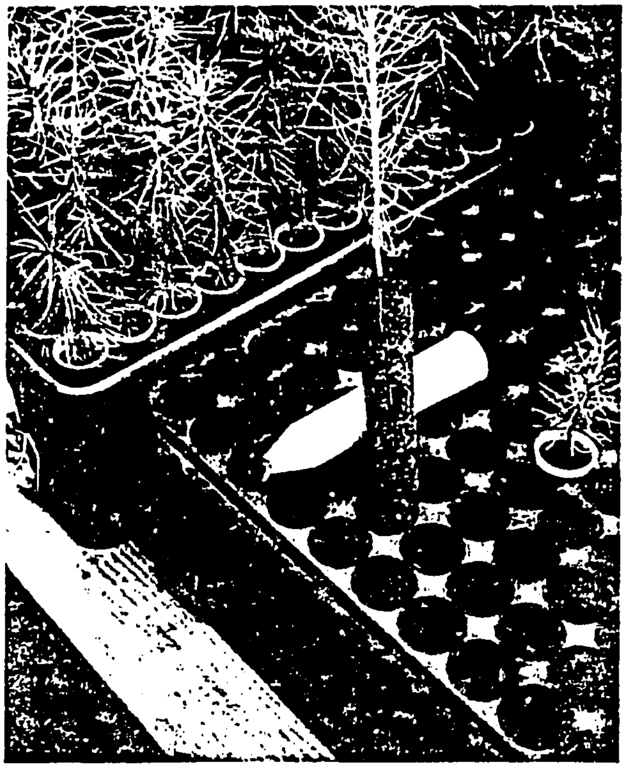

Figure 9-5.—The single cell system consists of separate containers and a rack to hold them.

An advantage of single cell plug container design is that the cells can be handled either singly or as a unit of 100 or more. If, in the growing process, a certain number of cells do not develop actively growing seedlings, the empty cells may be removed and replaced with cells with a tree. This way only good trees are kept in the holder, and maximum bench space can be utilized. Also, if more growing space is desired per tree, the spacing between the cells can be increased rather easily by removing every other cell. This strategy works well in operations where greenhouse space is at a premium. It is not a big advantage in extensive operations where low labor intensity is paramount. This is offset to a degree by the fact that each cell must be handled individually when loading racks or cleaning recycled cells.

It is possible to remove the seedlings from the cells at the nursery and ship only the plugs to the field. The advantage is that the container is not shipped with the tree. Since nearly all cell and block container units are designed to be used for more than one crop, this prevents losses and damage to the containers in shipping and in the field. However, since all mechanical protection for the seedlings is removed and its container-plug interface is disrupted, a different packaging method must be substituted for the cell or block to protect the trees and keep the plug from drying out before planting. The trees must be handled carefully at all stages of this process to preserve plug integrity.

With cell systems, it is common for the seedlings to be sent to the field in the containers. Usually, but not always, the cells are removed from the holders or racks, culled, bundled, and packaged in cardboard boxes for shipment to the field. This reduces the space needed to ship a given number of seedlings (fig. 9-6). Seedlings are extracted from the container in the field just before planting. The cells are saved and returned to the nursery for cleaning and reuse.

With both cell and block systems (discussed below), extracting the seedlings from the cavity is a nuisance. Under the best of conditions, it is time consuming. In the field, it cuts tree planter's production by requiring extra motions in the planting process. The proper development of the root system and the proper moisture content of the plug are important to easy plug extraction. The nature of the container walls and the number and height of root control ridges in the cavity also play a part. Some kneading of cells made of pliable plastic or knocking the container gently against the hand or other object usually facilitates extraction.

Block design.—Blocks are a group of individual cavities or cells that are permanently attached to each

Figure 9-6.—Ponderosa pine grown in single cells and bundled for packing. A rubber band holds the cells together.

other. Examples are the Styroblock® and the Multipot® among others (Sjoberg 1974 and Wood 1974). Styroblocks (fig. 9-7) are formed from expanded bead polystyrene with various sized cavities for different species and sizes of trees. The Multipot® (fig. 9-8) is similar, except it is molded of high density polyethylene. The advantages of these units are:

1. Cavities and block are all one rigid, lightweight unit about the right size to handle.
2. The cavities are always in the same position in the block and cannot come loose or fall out. There are no cells to have to handle individually.
3. The material in polystyrene bead formed blocks provides insulation from temperature extremes for the root systems of the trees.

The disadvantages are:

1. The trees must be extracted without kneading or jarring the container. However there have been few extraction problems with this type of container.
2. The containers must be sent back to the nursery, if they are sent to the field—a problem in common with all recycled containers.
3. Cavities where no tree develops must have seedlings transplanted into them or remain blank. Sowing more than one seed per cavity and then thinning excess trees tends to offset this problem.
4. Damage to the block, beyond a certain degree, results in loss of the whole block, even if most of the cavities are still intact.

Trees are sometimes removed from the blocks at the nursery, packaged, and then sent to the field. The blocks then remain at the nursery, which helps preserve the containers and returns them quickly to production, but the seedling plugs are more susceptible to damage. Removal of plugs from the blocks has some advantages:

1. It allows grading of stock and elimination of blank cavities.

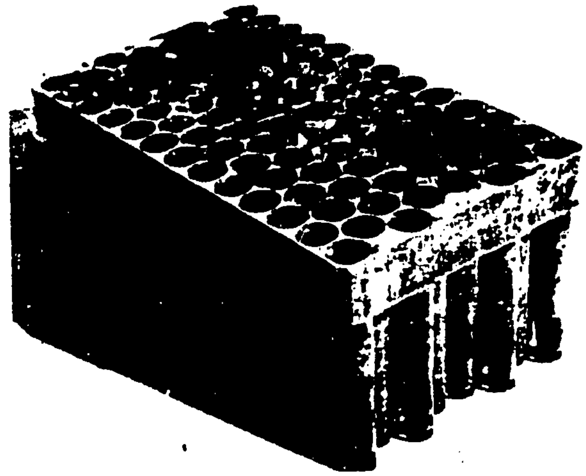

Figure 9-8.—The Crown Zellerbach Multipot.

2. It reduces shipping volume, usually by more than half.
3. It obviates the need for recycling the container from the field and eliminates damage to containers in shipment and field use.

The procedure used in British Columbia (Sjoberg 1974) has been to extract seedlings by hand and wrap in bundles of 25 in stretchable PVC film commonly used for produce and meat packaging. The bundles are placed in waxed cartons in an upright position for truck transport (fig. 9-9).

Nearly all block container designs incorporate root control ridges in the inside of the cavity. Some of the blocks are specially sized and adapted to nursery benches and conveyors to facilitate handling—a reflection of the fact that the modular block design lends itself well to machine handling and mechanization.

At least one block system (the Hahn Quarterblock System) allows for the block to be broken down into smaller unit blocks to facilitate field handling of the trees. Four of these "quarterblocks" are then reas-

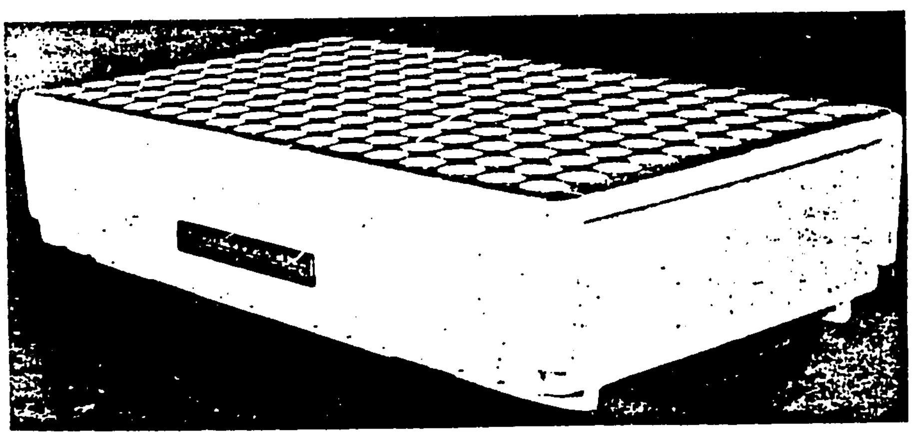

Figure 9-7.—BC/CFS styroblock.

Figure 9-9.—Seedlings are extracted from the container, wrapped in bundles of 25 (A), and placed upright in waxed cartons for shipment (B).

sembled with tape into a larger "nursery" block to facilitate nursery production (Hahn 1976).

Book designs.—The term "book" denotes those containers thermoformed from thin polystyrene sheet plastic to produce a row of cavities when each portion is assembled. These may have a plastic hinge at the bottom, as do the Spencer-Lemaire Rootrainers® (fig. 9-10A) so that one piece of formed plastic is folded like a book to form the cavities (Spencer 1974). The Tubepak® is another book system, but two pieces of formed plastic snap together. When assembled, book planters form three to six cavities, more or less rectangular in cross-section, which taper at the lower end to a root egress hole, and have numerous internal ridges to control root orientation and prevent root spiralling.

Book planters must be held together in specially designed trays or with tape, glue, or straps to form units that are multiples of individual books (fig. 9-10B). When such units are assembled, the books are filled with rooting medium and seeded. The thin

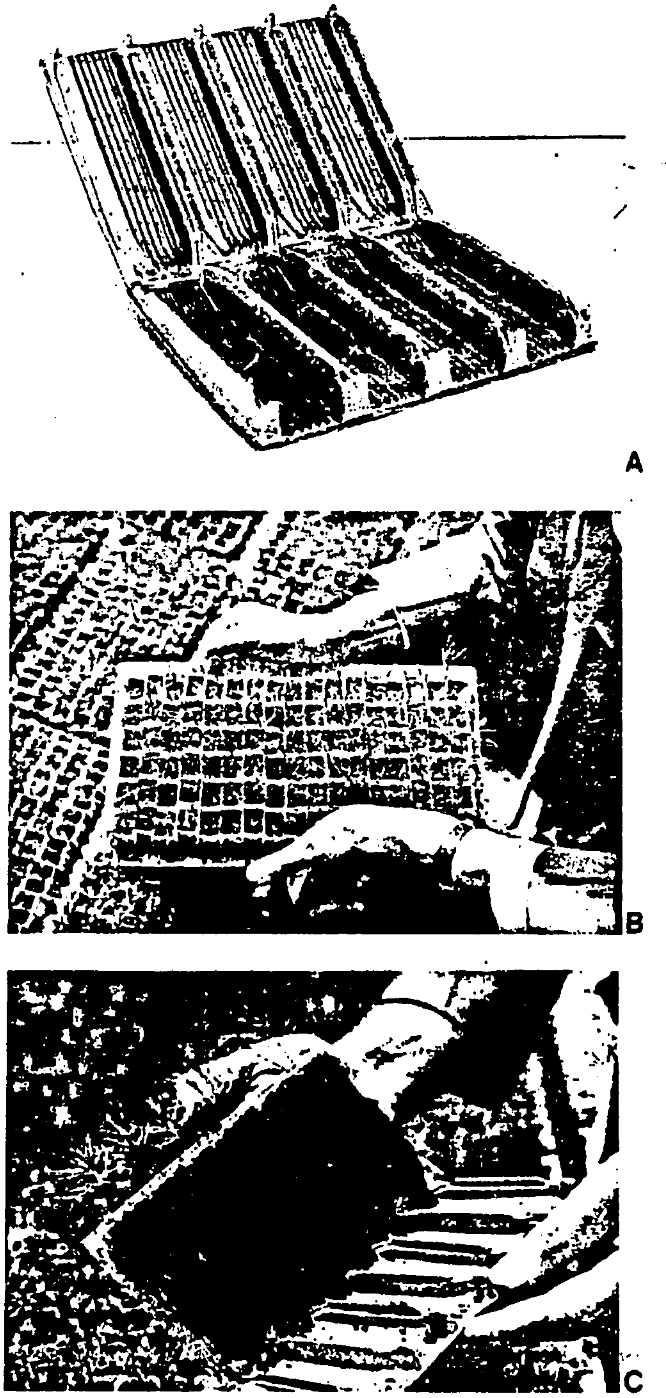

Figure 9-10.—Spencer-Lemaire Rootrainer unit (A), assembled into a block (B), and opened for inspection or to remove seedlings (C).

plastic shells of these containers are generally intended for one crop use. The material usually begins to become brittle near the end of a long growth period (9 months). In the South, where crops are reared 10-12 weeks, the books may be used one or two more times, however.[1] In the field, the book is opened by removing or folding back one side, and the plugs lifted out (fig. 9-10C).

Some advantages of book designs are:

1. The tree is sent to the field in the container.
2. If the container is discarded when the trees are planted; no return to the nursery is necessary.
3. When new containers are always used at the nursery there are no recycled containers to handle or clean for the next crop.
4. Plugs are quickly and easily extracted.

Some disadvantages of the book containers are:

1. The containers must be assembled before loading.
2. The container units require a frame, tray, gluing, or taping to form a unit for handling and shipment.
3. The container is generally used only once, which tends to make it expensive per crop.
4. Blank cavities must be reseeded or have germinated seed transplanted into them to avoid blanks.

9.25 Types of Containers Available by Manufacturer

During the past several years, the numbers and types of containers specially engineered and produced for tree seedling culture have grown considerably. At present, the types and designs appear to be stabilizing, but continuing development work is apparent. Thus, any compilation of container types and manufacturers tends to become obsolete rapidly. The latest, and most complete compilation, by Venator (1975), with some additions by the authors is reproduced in table 9-1.

9.26 Summary and Discussion

Each type of container has advantages and disadvantages in actual use. The selection of the particular size and type of container to use is determined by a number of factors. In the early stages of CTS program development, it is often best not to select any one size or type of container, unless considerable evidence indicates it is the size and type necessary for planting success. Such information is usually not available early in a program, so, container selection is based largely on experience and the developer's knowledge of the market or local field planting requirements.

The developer should test a number of container sizes and types, if possible. In this way, the container best fitting the situation from operational and biological standpoint can be determined. Considerable field testing with different containers may be necessary before sufficient reliable data on planting productivity, nursery production costs, and cost per surviving seedling, is available to permit decision. In general:

1. The best container type and size combination is that which will produce an established, rapidly growing seedling at the minimum cost per tree. In severe climates or very brushy areas, this may mean a very large tree. In ideal situations, a small tree may do equally well. The smaller the container and tree necessary, the cheaper it will be produced at the nursery. This is because more trees can be produced per unit area of greenhouse space, and each crop will be in the house a shorter time.
2. Until the best container system and tree size is determined, it is generally unwise to purchase sophisticated loading and seeding equipment which can handle only one or two types of containers. The equipment options should remain flexible until a definite type of container and container size is selected. Some loading and seeding equipment allows for such flexibility; other types do not.
3. There is no ideal container, but there is usually a best one for a given production and planting situation. This best size and type can be determined by operational cost collection and planting survival and growth results. Where a variety of planting conditions are expected, along with different packaging and transport problems, several container sizes and types may offer the optimum solution.
4. Most of the containers on the market today are good, but container development is continuing and even better ones can be expected in the future. For instance, when a plug seedling is outplanted, most of the new roots develop from the accumulated growing points at the bottom of the plug. Many species, especially pines, produce few roots close to the surface. A possible improvement over currently available rigid wall containers would be to provide holes or slits in the side of the containers and space the containers apart sufficiently to air prune the roots at these openings. A tree grown in such a container should produce lateral roots close to the surface from the growing points developed at the slits. It should develop a balanced, more

[1] *Personal communication with O. C. Goodwin, North Carolina Division of Forest Resources, Raleigh, N.C., May 1978.*

Table 9-1.—Manufacturers or distributors of containers suitable for growing forest tree seedlings.

Supplier	Common name of container	Container material	Container volume (cm^3)	Biodegradable properties	Root egress
Agritec Co. Inc. 4939 D Milwee Houston, Tex. 77018	Polyloam Tree Container	Nutrient enriched synthetic base material	20-37	Slowly	Yes
Beaver Plastics, Ltd. 12806-63 Street Edmonton, Alberta Canada	Styroblock	Polystyrene foam	35-120	No (reusable 2-3 times)	No
Better Plastics, Inc. 2206 N. Main Street Kissimmee, Fla. 32741	Test Tube	Polyethylene	Variable	No (reusable)	No
Brighton By-Products P. O. Box 23 New Brighton, Pa. 15006	Kys-Kube	Organic-inorganic mixture	20-25	Yes	Yes
Brighton By-Products P. O. Box 23 New Brighton, Pa. 15006	0-903	Phenol formaldehyde with residual phosphates, nitrates, and soda ash	20-30	Slowly	Yes
Colorado State Nursery Foothills Campus Colorado State Univ. Fort Collins, Colo. 80521	Tar Paper Pot (Containers are not commercially available; however, blueprints for production systems are available upon request)	15 pound tar paper	Variable	Slowly	Yes
Columbia Plastics, Ltd. 2155 West 10th Ave. Vancouver, British Columbia, Canada	Modified Walter's Bullet	High impact polystyrene	15-10	No	Yes
Conwed Corporation 742 29th Ave. SE Minneapolis, Minn. 55414	Conwed Open-mesh plastic tubing	Plastic webs	Variable	No (products under development)	Yes
Edmonton Nurseries, Ltd., 13332-13th Ave. Edmonton, Alberta Canada	Peat Sausage or Easy Root Container	Low density polyethylene filled with peat	Variable	Slowly	No
Famco, Inc. 300 Lake Road Medina, Ohio 44256	BR-8	Modified cellulose fiber	20-30	Yes	Yes
GASPRO, Inc. 2305 Kamehameha Hwy. Honolulu, Hawaii 96819	Hawaii Dibbling Tube	Polyethylene	30	No (reusable)	No
Green Thumb Products Corp., Drawer 760 Apopka, Fla. 32703	Rack Substratum System 73	Natural and synthetic fibers	Variable	Yes	Yes
Illinois Tool Works Hi-Cone Division 1140 Bryn Mawr Ave. Itaska, Ill. 60143	One-Way	Molded polystyrene and polystyrene sheet	60	No	Yes
Jiffy Products of America, P.O. Box 338 West Chicago, Ill. 60185	Jiffy-7 peat pellets, strips, and pots	Peat	20-40	Yes	Yes
Keyes Fibre Co. Horticultural Div. Department X New Iberia, La. 70560	Kys-Kube	Organic-inorganic mixture	20-25	Yes	Yes
Lannen Tehtaat Oy Paperpot Department SF-27820 ISO-VIMMA Finland	Paperpot Method, Special Paper for the Paperpot Method, consulting service in nursery planning (European distributor)		10-650 (approx. 20 different sizes 3 different qualities)	Yes	Yes

Table 9-1.—Continued.

Supplier	Common name of container	Container material	Container volume (cm^3)	Biodegradable properties	Root egress
Lannen Tehtaat Oy Paperpot Department SF-27820 ISO-VIMMA Finland	NISULA Roll Plant Method Transplanting machines (European distributor) (For above 2, see also Reid, Collins and United Asia)	Polyethylene film	Variable	No	No
J. M. McConkey Co., Inc. P. O. Box 309 Sumner, Wash. 98390	Plug Tray	High density polyethylene	140	No	No
J. M. McConkey Co., Inc. P. O. Box 309 Sumner, Wash. 98390	DEEPOT	High density polyethylene	656	No	No
Micro-Plastics Co., Ltd. P. O. Box 844 Guelph, Ontario, N1H 6M6, Canada	Ontario Tube	High impact polystyrene	Variable	No	No
Poly-cast Plastics Route 2, Box 706 Beaverton, Oreg. 97005	Cone-tainer	High density polyethylene	Variable	No (reusable)	No
Reid, Collins and Associates, Inc. Reforestation Division 550 Burrar Street Vancouver, Canada V6C 2K6	Paperpot Method Equipment for the Paper Method, consulting service in nursery planning (Canadian distributor)	Special paper	10-650 (approx. 20 different sizes, 3 different qualities)	Yes	Yes
Rex Packaging, Inc. P. O. Box 18257 Jacksonville, Fla. 32229	Polypot	Polyethylene coated paper	200 (square dimensions)	Slowly	No
Silvaseed Company P. O. Box 118 Roy, Wash. 98580	Styroblock (USA distributor)	Polystyrene foam	35-120	No (reusable 2-3 times)	No
Spencer-Lemaire Industries, Ltd. 9160 Jasper Ave. Edmonton, Alberta Canada	Rootrainers (Equipment for Rootrainers Method also available)	Polystyrene	30-340	No (perhaps reusable)	No
Tree Tech. Inc. P. O. Box 86 Mason, Mich. 48854	Plant Bands	Paper, polyethylene coated or not	Any size	Yes	Yes
Tri-State Mill Supply Co. P. O. Box 220 Crossett, Ark. 71635	Styroblock	Polystyrene foam	35-120	No (reusable 2-3 times)	No
Tubepak 402 East 900 South Suite 2 Salt Lake City, Utah 84111	Tubepak	Polystyrene	280	No (perhaps reusable)	No
Union Carbide Corp. Chemicals and Plastics Div., River Road Bound Brook, N.J. 08805	—	Polycaprolactone	Variable	Yes (currently in experimental stages)	Yes

Table 9-1.—Continued.

Supplier	Common name of container	Container material	Container volume (cm^3)	Biodegradable properties	Root egress
United Asia Trading Co. 3840 Crenshaw Blvd. Los Angeles, Calif. 90008	NISULA Roll Plant Method Transplanting Machine (USA distributor)	Polyethylene film	Variable	Yes	No
United Asia Trading Co. 3840 Crenshaw Blvd. Los Angeles, Calif. 90008	Paperpot Method, Equipment for the Paperpot Method, consulting service in nursery planning (USA distributor)	Special paper	10-650 (approx. 20 different sizes, 3 different qualities)	Yes	Yes
Western Pulp Products Co., Box 968 Corvallis, Oreg. 97330	Fiber pot	Wood pulp	Variable	Yes	No (but roots penetrate pot)

windfirm root system more like that of a natural seedling and devoid of detrimental root configurations. In addition, fewer growing points should accumulate at the bottom, which would permit using a smaller bottom hole in the container.

9.3 Growing Media

9.31 General Discussion

"Growing medium" is by no means as standard a term as "container." Other terms used synonymously are "rooting mix," "pot mix," "growth medium," "soil mix," and "potting mix." It is the material that fills the containers and performs the same function for the seedling as soil does in the field. The term "mix" is used in a number of the terms synonymously with medium, because it describes the medium to be a mixture of substances. This is usually, but not always, the case. The term "growing medium" will be used here because it is probably the most general term and least likely to cause confusion.

Many materials can be used as a growing medium, such as sand, compost, peat, sphagnum moss, vermiculite, topsoil, and some synthetic materials, but for functional and economic reasons, peat-vermiculite mixtures predominate (Phipps 1974). Natural soil is not used as a CTS growing medium, because other media have more desirable physical characteristics (i.e., water holding capacity, aeration, and bulk density). Also, natural soil and sand are too heavy for CTS products that often have to be carried over precipitous terrain to the planting sites. Ground bark is used as a medium by a few growers, especially where it is readily available.

For CTS operations, peat-vermiculite mixes are most widely used for several good reasons. When properly prepared:

1. They are lightweight—a consideration of some importance in forest planting, as well as nursery operations.
2. They are uniform in composition, relatively inexpensive, and readily available.
3. They are relatively free of insects and diseases.
4. They have a high cation exchange capacity per unit dry weight compared to ground bark or sandy loam soil.
5. They have a high water holding capacity, so, the frequency of irrigation and fertilization is reduced compared to sandy soil.
6. In most instances, they provide an acid growing medium, conducive to conifer growth.
7. When the peat and vermiculite are in proper proportions, they yield a medium that is well aerated and drained while still holding substantial quantities of water that is readily available to the plant.

In some cases, a spongy volcanic material called "perlite" is used in place of the vermiculite. This is also acceptable. Both materials are used to increase the aeration and drainage capability of the peat.

9.32 Growing Medium Components

A good growing medium should have the following characteristics (Richards et al. 1964):

1. The medium must be sufficiently firm and dense to hold the cuttings or seeds in place during rooting or germination. Its volume must be fairly constant when either wet or dry. Excessive shrinkage upon drying is undesirable.

2. It must sufficiently retain moisture so that watering does not have to be too frequent.
3. It must be sufficiently porous that excess water drains away, permitting adequate aeration. This is crucial in conifer tree culture.
4. It must be free, or nearly so, of weed seeds, nematodes, and various noxious organisms.
5. It must not have a high salinity level.
6. It should be capable of being sterilized with steam without harm.
7. There should be adequate cation exchange capacity to maintain nutrient availability.

In addition, the most outstanding characteristic for containerized seedling tree culture is that it be lightweight. Since sand and soil are excluded primarily because of weight, what have been termed "soil less" media are discussed.

Peat.—The most common component of CTS growing media, and the most highly recommended, is sphagnum peat. Peat consists of the remains of aquatic, marsh, bog, or swamp vegetation which has been preserved underwater in a partially decomposed state (Hartmann and Kester 1959). The composition of this material varies. The differences depend on the plants from which it originated, degree of decomposition, chemical content, and acidity. There are three basic types of peat: moss peat, sedge, and peat humus (Hartmann and Kester 1959).

Moss peat or "peat moss" is composed of sphagnum, hypnum, or other mosses. While hypnum moss is used in many ornamental container growing media and a few coniferous container media, sphagnum moss peat is most highly recommended for CTS media (Armson and Sadrieka 1974, Brix and van den Driessche 1974, and Hellum 1975).

Sphagnum moss is the dehydrated young residue or living portions of acid plants in the genus *Sphagnum*. This material, as opposed to sphagnum moss peat, is not decomposed to any degree. Sphagnum moss peat, not sphagnum moss is needed for CTS growing medium formulation. According to Hellum (1975):

"Peat sold commercially varies in character, causes problems in nurseries where seedlings are to be grown consistently to specific dimensions in a certain length of time. Only sphagnum peat, among organic materials, has the many desirable characteristics for a good CTS potting medium. There are many reasons—high water holding capacity, fibrosity, acidity (which means it is relatively free of fungi and bacteria), its breakdown makes nutrients available, and it has high cation exchange capacity compared to most mineral soils.

"Available commercial sphagnum peat varies by species composition, organic deposit which is mined, vendor, year of mining, and handling and use. Avoid peat composed of mosses other than *Sphagnum* because of desirable sphagnum water holding capacities and fibril strength. *S. fuscum* is the best species. Peat should be from as acid minerotrophic fens as can be found, and peat from fens with pH above 6.5 should be avoided.

"Peat should not be exposed to air for more than a few months before use, because this hastens humification (nitrogen release) and may cause top-heavy seedlings. Therefore:

1. Only sphagnum peat should be used that has a minimum of grass and other moss species.
2. Choose peat from fens where small leaved species of *Sphagnum* are dominant; *S. fuscum* is best.
3. Look for peat that has been hydraulically mined. It will be more consistent than surface mined peat.
4. Avoid force dried commercial peat, which generally gives less consistent results than bulk mined *Sphagnum* peat that has not been force dried."

Armson and Sadreika (1974) note, "Peat should be fibrous and free of woody fragments and mineral soil inclusions. With peat moss it is usually necessary to put it through a hammermill; all peats have to undergo screening in order to produce a uniform homogeneous material for the containers. Physical condition of peat is critical in relation to the filling of containers. If the peat is too dry, it will not flow evenly and great difficulty may be experienced in wetting it. The result will be uneven levels in the containers and large air spaces, both of which will result in uneven seedling development. On the other hand, a peat which is too wet will also not fill or settle uniformly into containers.

"The main chemical property of concern is that of pH; preferably the range should be 4.5 to 6.0. Other properties, such as nitrogen, phosphorus, potassium levels and also those of other nutrient elements are of less concern, because a program of fertilization is necessary if satisfactory growth is to be maintained. Peats with excessively high levels of nutrients which might be toxic should not be used. Table 9-2 gives results of analyses for a range of peats used in container production in Ontario."

Vermiculite.—Hartmann and Kester (1950) explain that vermiculite "is a micaceous mineral which expands markedly when heated. Extensive deposits are found in Montana and in North Carolina. Chemically, it is a hydrated magnesium-aluminum-iron silicate. When expanded it is very light in weight (6 to 10 pounds per cubic foot) (100-140 kg/m^3) neutral in reaction with good buffering properties, and insoluble in water; it is able to absorb large quantities of water—3-4 gallons per cubic foot (400-450 l/m^3).

Table 9-2.—Chemical analyses of unfertilized peats used in Ontario container stock production (all elements % o.d. weight) (Armson and Sadreika 1974).

Origin	pH	Cation exchange capacity meq/100 g	N[1]	P	K	Ca	Mg	Cu	Fe	Mn	Zn
Thessalon	4.8	76	1.61	0.05	0.03	1.00	0.002	0.002	0.775	0.018	0.003
Swastika	6.0	87	1.31	0.05	0.02	1.75	0.002	0.001	0.340	0.012	0.002
Fort Frances	5.9	124	1.91	0.01	0.03	2.60	0.401	0.001	1.300	0.005	0.003
White River	5.8	78	0.81	0.03	0.03	0.14	0.003	0.002	0.330	0.008	0.002
Hearst	6.8	172	0.91	0.04	0.04	4.21	0.407	0.002	0.210	0.024	0.003
Cochrane	4.8	99	1.11	0.17	0.20	2.02	0.311	0.481	0.330	0.102	0.014

[1]*N determined by micro-kjeldahl procedure, all other elements in solution after ashing of peat.*

Vermiculite has a relatively high cation exchange capacity and thus can hold nutrients in reserve and later release them. It contains enough magnesium and potassium to supply most plants. In the crude vermiculite ore, the particles consist of a great many very thin, separate layers which have microscopic quantities of water trapped between them. When run through furnaces at temperatures near 2,000°F (1,100°C) the water turns to steam, popping the layers apart, forming small porous, sponge-like kernels. Heating to this temperature gives complete sterilization. Horticultural vermiculite is graded into four sizes: No. 1 has particles from 5 to 8 mm in diameter; No. 2, the regular horticultural grade, from 2 to 3 mm; No. 3, from 1 to 2 mm; and No. 4, which is most useful as a seed-germinating medium, from 0.75 to 1 mm. Expanded vermiculite should not be pressed or compacted when wet, as this will destroy its desirable porous structure."

In most cases, vermiculite is an important ingredient in growing medium mixtures for CTS production. There is much less agreement about the size of vermiculite to be used. Indeed, there seems to be considerable confusion regarding the terminology surrounding the material. Some writers refer simply to "vermiculite" with no further definition. A number refer to "attic fill" vermiculite. Generally, this means a coarse grade of vermiculite equivalent to horticultural grade No. 1 to 1½. Some users simply refer to using "horticultural grade" vermiculite, which usually means No. 2 (from 2 to 3 mm). Probably horticultural vermiculite grade No. 2 or 3 is the most commonly used if readily available, but the grade of vermiculite used is not as important as how well it works as a mix component. The purpose of incorporating vermiculite or perlite in a growing medium with peat or ground bark is to keep the growing medium from settling and compacting to the point where good root aeration and water drainage is lost.

Horticultural grade No. 1 is recommended for any container of 10 cubic inches (160 cm^3) or more, and No. 2 for smaller containers. Finer vermiculite will not function well as a bulking agent to prevent settling and should be used only for very short-term crops or ones that can tolerate poor aeration. Vermiculite bought as a "poultry litter" or "attic fill" insulation is usually cheaper than the same thing bought for horticultural use. Do not buy "block fill" that has been treated to make it water repellent.

Perlite.—Perlite is used in CTS growing media instead of vermiculite. It is also often used as a seed covering medium (section 16.33). Hartmann and Kester (1959) describe perlite as a "grey-white siliceous material of volcanic origin mined from lava flows. The crude ore is crushed and screened, then heated in furnaces to about 1,400° F (760° C), at which temperature the small amount of moisture in the particles changes to steam, expanding the particles to small, sponge-like kernels which are very light, weighing only 5 to 8 pounds per cubic foot (70-120 kg/m^3). The high processing temperature gives a sterile product. A particle size of 1-3 mm in diameter is usually used in horticultural operations. Perlite will hold three to four times its weight in water. It is essentially neutral, with a pH of 6.0 to 8.0, but with no buffering capacity; unlike vermiculite, it has no cation exchange capacity and contains no mineral nutrients. It is most useful for increasing the aeration in a mixture."

The main advantage of perlite for use in CTS growing media is that it does not compress. However, it sometimes will make root plugs harder to extract, but this is important only in plug container types. Vermiculite is used much more often in CTS media than perlite.

Ground bark.—In some instances, ground bark has been used instead of sphagnum peat (Wood 1974). Some types of fresh bark contain materials toxic to plants (Hartmann and Kester 1959). When finely ground bark is used as a substitute for peat moss, supplemental nitrogen is usually needed to prevent the tree seedlings from becoming chlorotic (Barnett 1974) because the bark begins to break down and uses the nitrogen. Also, van den Driessche (1974) reports that a 1:1 mixture of Douglas-fir bark and vermiculite only has about 70% of the cation exchange capacity (CEC) (72 versus 103 milliequivalents per 100 g of dry weight) of a 1:1 mixture of sphagnum peat-vermiculite.

Unless there is an overwhelming reason to use ground bark, sphagnum peat is probably preferable. The reasons include higher CEC, better C:N balance, less likelihood of less organisms and toxic substances, and greater weight. However, there is work going on regarding the use of sawdust and wood residues (Montano et al. 1977 and Lumis 1976).

Other components are used in some cases, but peat, vermiculite, perlite, and ground bark are the major ones.

9.33 Media Mixes and Mechanics of Aeration and Drainage

There is considerable variation in the proportions of growing medium constituents from one successful CTS operation to another. The most commonly used mix is a 1:1 mix of shredded sphagnum peat and vermiculite. Other ratios are used, most commonly a 3:2 or 3:1 mixture of these same components. Owston (1972) indicates a 1:1 or 3:2 mixture is best for Pacific Northwest species. In Wisconsin, Phipps (1974) found that the medium components and their relative proportions significantly influenced seedling growth, with the largest red pine seedlings produced on a 1:1 peat-vermiculite medium.

After trying numerous mixtures, Tinus (1974b) settled on a 1:1 peat vermiculite mixture. In Louisiana, Barnett (1974) is also using a 1:1 peat vermiculite mix. Some nurseries have successfully used straight peat without any vermiculite or perlite (Routledge 1974).

To determine the best growing medium for a given situation one must consider the degree of aeration and drainage required when using a given container in a given greenhouse, growing certain species. In general:

1. There is some degree of latitude in formulating growing media that the trees will tolerate (Phipps 1974 and Owston 1972). Usually trees will perform best in a certain mix. This can be discovered through simple experimentation.
2. As more and more vermiculite or perlite is added to the peat, the aeration and drainage of the medium in the container increase. Too much vermiculite may allow the mix to fall out of the root egress hole and prevent the root plug from being cohesive upon removal from the container.
3. Larger and deeper containers require greater drainage, because water must percolate through a greater length of medium.
4. The higher the humidity maintained in the greenhouse, the better drained the medium should be.
5. The less evenly the water is distributed in the CTS greenhouse, the better drained the medium must be, because some containers must be overwatered in order to thoroughly soak others.
6. Some tree species require good root aeration; others will tolerate less aeration.
7. Drainage should not be so rapid as to necessitate overly frequent watering.
8. Drainage should not be so slow as to waterlog the container and starve the roots for air.

The proper aeration and drainage can be measured as a percentage of macropore space in the growing medium. Hellum (1975) states that for a straight peat medium, about 25% macropore space is needed for good seedling root development. For peat-vermiculite mixes good macropore space can vary between 10% and 50% depending on the depth of the container, with very deep containers being nearer 50%. Nelson (1973) describes how to measure the macropore space of the various media mixes in figure 9-11A through F.

If the trees grown in the medium do not perform well and the grower suspects poor aeration and drainage may be part of the problem, the proportions of components can be altered. The percentage of macropore space, which is related to how trees grow, can be found for the new mixture. By continued comparisons of the tree condition to the medium mixture, the best macropore space percentage for that container, species, and greenhouse situation can be found over several crops of seedlings.

Symptoms of problems with the mix are:

1. Too coarse (too well drained, aerated): medium falls out of root egress holes, root plug not cohesive, plug easily falls apart, very frequent watering needed to keep the medium damp, trees stunted.
2. Too fine (not well drained, aerated): medium appears waterlogged, dries out slowly, fungal diseases prevalent, infrequent irrigation necessary, high EC reading on leachate, trees stunted, chlorotic, algal development on growing medium surface prevalent, and there may be root rot.

9.34 Preparation of growing medium

Preparation of the growing medium for loading into containers is relatively simple. Essentially, it is the blending of the components to provide a medium of uniform texture and proper moisture content that is free of weed seeds and pathological organisms.

Mixing the growing medium components can be done in a number of ways. Equipment is discussed in

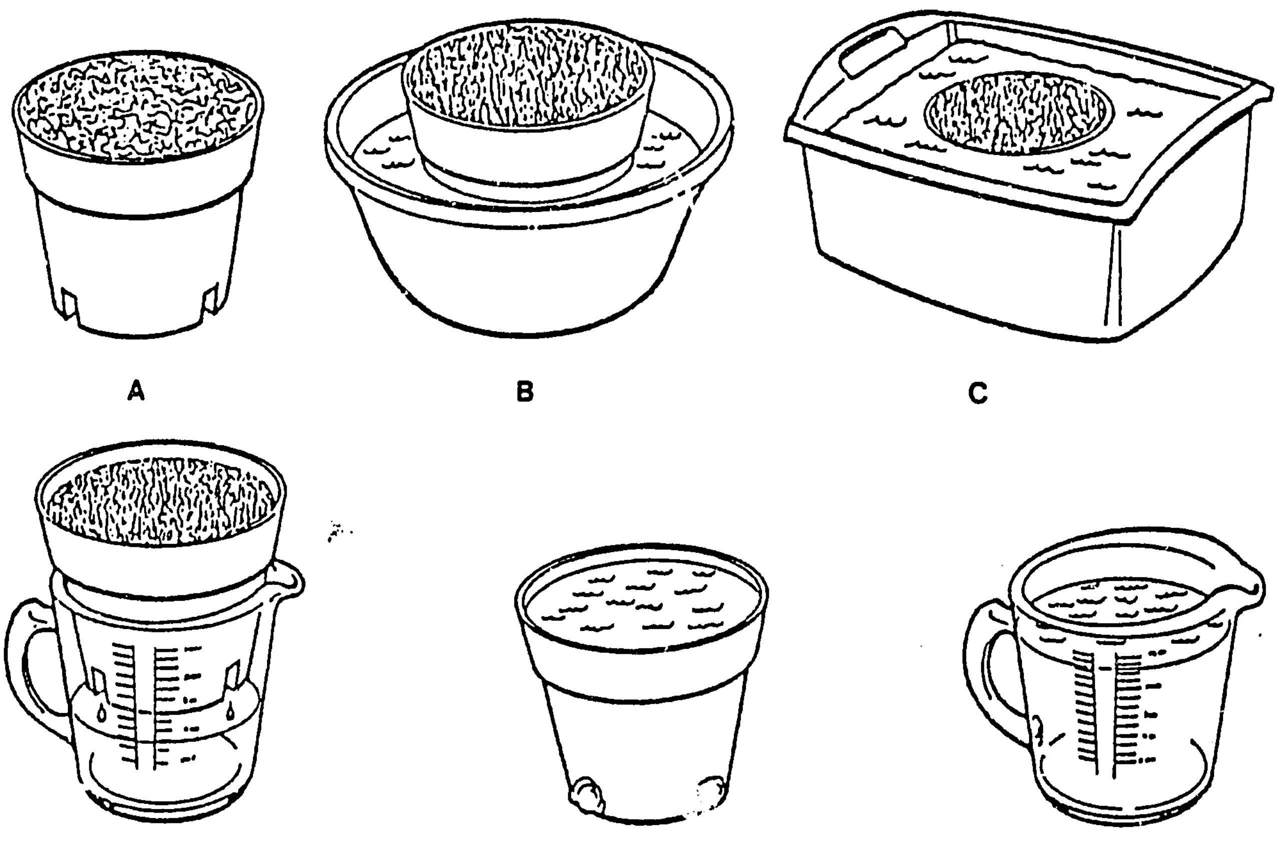

Figure 9-11.—(From Nelson 1973). Water drainage test for greenhouse soils. By means of this test, each grower can analyze his soils before planting and determine if the water drainage meets the standards of other soils he has used successfully. First make the test on a soil (either potting or bench soil) which drains well and is favorable for plant growth. Then make the test on the new soil mix before planting, compare results, and make the necessary adjustments to the soil mixture.

(A) Fill a plastic, 6-inch azalea pot with the soil mixture. Do not pack the soil in the pot, but from about a 3-inch height tap the pot on the counter top three times to settle the soil in the pot. The soil should be level with the top of the pot. (B) Subirrigate the pot of soil by placing it in a bowl with water about 3 inches above the pot bottom. Do not disturb for 24 hours. (C) transfer the pot of soil to a deeper pan and bring the water level in the pan to the top edge of the pot. Keep the pot in this pan until water is visible at the soil surface. (D) Transfer the pot of saturated soil to the measuring glass (a one-quart measuring glass should accommodate the plastic pot about as sketched). Let the pot drain for four hours, record the amount of water that drained, and mark the level of the soil in the pot after draining. Discard the soil and wash the pot. (E) Plug the pot holes with florist clay and fill the pot with water to the soil level after draining. (F) Measure and record the volume of water in the pot. The pot probably will contain more water than the one-quart measure will hold, but fill the measure to the quart level, dump, and measure the balance of the water in the pot.

To find the percentage of the pore volume that drained, as compared to the total volume of the soil, divide the amount of water that drained out of the pot by the total amount of water measured in the pot.

section 7.2. Some other important operational points should be noted.

The area and equipment to be used in the mixing process must be kept as clean as possible, not only free of refuse, but also free of weed seeds, fungi, and bacteria. Equipment should be thoroughly washed with mild disinfectants before and after use. Goodwin (1975) recommends a solution of commercial bleach (5% sodium hypochlorite) diluted 10:1 with water. Two percent formaldehyde, rubbing alcohol, boiling water, or live steam can also be used (Hartmann and Kester 1959). These methods can also be applied to flats, greenhouse floors, walls, and benches, as well as tools.

All growing media for CTS operations should have some water added to it during the mixing process. This is because peat or ground bark absorbs moisture very slowly. Addition of coarse organic materials, such as peat moss, to mixtures can cause a decrease in wettability. No good method for preventing nonwettability (hydrophobicity) is known. Use of commercial wetting agents may improve water penetration, but there are questions about their safety. Owston[2] reports decreased germination in pine resulting from the use of wetting agents. The water repellent quality of dry mixes containing peat is well known to CTS nurserymen who have filled containers with growing medium in a dry condition. In such cases, unlimited irrigation of the containers often will not wet the lower portions of the medium in the containers.

A slightly damp mix will not fall out of root egress holes while the container units are being handled, and will hold its shape after being compressed. The mix must not be wet or sticky, just damp. When it is properly moistened excess moisture can just be squeezed from the mix. Goodwin (1975) has provided some relative weights of dry and wet media shown in table 9-3.

Once moistened, the medium should not be allowed to dry out before or after the containers are filled and seeded. To help avoid this, seeded containers can be kept in cold storage for a period of time prior to loading the greenhouse.

9.35 Commercially Prepared Growing Media

A number of commercially prepared growing media, such as Jiffy-mix®, Micapeat®, Redi Earth®, and Pro-mix® have definite advantages for the CTS grower:

1. The grower does not have to mix his own except to moisten the product prior to filling the container. Large quantities may be ordered custom-mixed.
2. Most of the commercial mixes have nutrients added to them, which may provide needed nutrients to the crop.
3. The commercial mixes are usually claimed to be sterile. The nurseryman should not have to worry about sterilization.
4. They may be more evenly mixed than homemade mixes.

In other words, using commercially prepared mixes for CTS operations is very convenient. But there are disadvantages:

1. The grower gives up control of quality and type of component used in the mixture. This can vary with changes in company management and sources for components of the mix. A number of CTS growers have been surprised by plant responses to changes in growing medium. This is much less likely to happen with homemade mixtures.
2. Fertilizers or wetting agents added to the commercial mix may or may not be beneficial to tree seedling growth. Even if they are beneficial, their solubility in the container cannot be controlled by the nurseryman. In some cases, the fertilizers added are expressed only as N, P, and K, and the chemical source is not specified. Wetting agents are added to some of these mixtures and their possible phytotoxic effects have been mentioned earlier (section 9.34).
3. It may be necessary to alter the proportions of the components of the mix to achieve proper aeration and drainage. This is not possible with commercially prepared growing media, once purchased.

Because the source and preparation of the components of the growing medium is important, use of commercially prepared growing media for tree seedling culture is not recommended unless component specification and quality can be guaranteed. Commercially prepared growing media are used by a number of CTS growers, but a few growers have tried and abandoned them for one reason or another.

9.36 Addition of Fertilizer and Mycorrhizal Fungi to Medium

The addition of fertilizers to the growing medium before filling containers is discussed in section 13.21. For CTS operations it is not recommended. In CTS culture, growth and final dimensions of the trees produced are controlled by adjusting fertilizer regimes and other environmental factors. Soluble fertilizers, placed in the mix, will be leached-out right away and do little good. Persistent fertilizers only complicate later cultural procedures.

Considerable work has been done on the addition of various species of mycorrhizal fungi to the growing medium (section 14.1). Many tree species require fungal symbionts. Although some may not require them, they usually promote growth and make the seedlings less susceptible to root disease.

[2]*Personal communication with Dr. Peyton W. Owston, Pac. Northwest For. and Range Exp. Stn., Corvallis, Oreg., June 1978.*

Table 9-3.—Weight (pounds) of 1 cubic foot of medium (Goodwin 1975).

Soil Mix	Dry	Moist	Saturated	Water gain
1 peat: 1 sand	54.00	64.5	84.0	30.0
1 peat: 1 vermiculite	6.25	27.8	46.8	40.5
3 peat: 1 vermiculite	6.90	28.5	47.5	40.6

Research in progress is directed toward addition of pure cultures of specific fungi to the growing media (Marx and Barnett 1974, Zak 1977). CTS nurserymen should expect some useful research results and, perhaps, commercially available cultures, by the end of the decade. Some CTS producers are adding forest duff, assumed to contain mycorrhizal fungi, to growing media. In most cases, this procedure has resulted in excellent mycorrhizal development. However, there is an element of risk involved, because the duff can contain inoculum of phytopathological fungi, nematodes, insects, weed seeds, and other pests. Consequently, the practice of adding duff to growing media cannot be recommended without reservations. The individual grower must make this decision. To follow the practice in research investigations is one thing; to expose millions of trees to such risks in production operations is another.

9.37 Growing Medium Sterilization

The controlled environment of the greenhouse is conducive to the development of insects, disease pathogens, and weeds, as well as crop plants. Every available means should be used to eliminate the source of these problems before they get started. In horticultural potting mixtures, soil is almost always a component. Soil must be sterilized before use to avoid serious disease problems. In CTS greenhouse operations, the growing medium is generally not sterilized, because the medium components are often nearly sterile to begin with (section 9.32). Some bark contains compounds that are biotoxic. Also, the character of bark texture and the way it is usually handled at mills, tends to allow weed seeds, spores, etc., to be incorporated in it. Consequently, CTS growing media mixes containing peat, vermiculite, or perlite usually don't require sterilization, but ground bark components may need to be. In research, it is probably prudent always to sterilize the growing medium. In operational CTS projects, it is recommended only where there is demonstrated need.

There are several ways to sterilize soil or growing media. The best and most widely used is heating the soil with steam to about 180° F (82° C) for 30 minutes. This procedure will kill most harmful bacteria, fungi, nematodes, insects, and weed seeds (fig. 9-12) (Hartmann and Kester 1959). Detailed steam sterilization procedures are available in a number of horticultural texts such as Nelson (1973).

Chemicals are also useful for growing media sterilization, if steam is not available. However, chemical sterilization of mixes with vermiculite in them may be risky because the chemicals become bound within the expanded vermiculite. This can result in toxicity to seedlings even after prolonged aeration.[3] CTS nurserymen, therefore, are advised to use chemical sterilization with this possibility in mind. The more common chemical sterilants and how they are used in horticultural practice are provided in the following excerpt from Hartmann and Kester (1959):

"Chemical fumigation will kill organisms in the propagating mixes without disrupting their physical and chemical characteristics to the extent to which may occur with heat treatments. Ammonia production may increase following chemical fumigation, however, owing to the removal of organisms antag-

[3] *Personal communication with James P. Barnett, Southern For. Exp. Stn., Pineville, La., May 1978.*

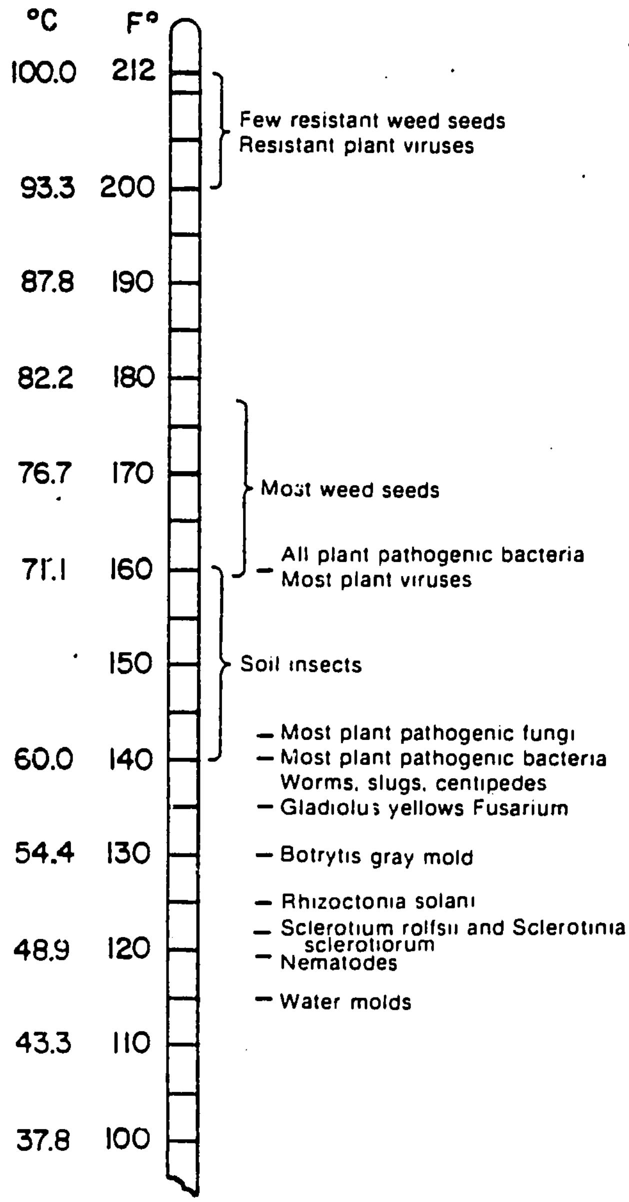

Figure 9-12.—Soil temperatures required to kill weed seeds, insects, and various plant pathogens. Temperatures given are for 30 minutes under moist conditions (Hartmann and Kester 1959).

onistic to the ammonifying bacteria. The mixes should be moist (between 40% and 80% of field capacity) and at temperatures of 65° to 75° F (18° to 24° C) for satisfactory results. After chemical fumigation, a waiting period for dissipation of the fumes of 2 days to 2 weeks, depending upon the material, is required for use.

"**Formaldehyde.**—This is a good fungicide with strong penetrating powers. It will kill some weed seeds, but is not reliable for killing nematodes or insects. Commercial formalin (40% strength) is mixed 1:50 with water and applied to the soil at the rate of 2 to 4 quarts per square foot (20-40 l/m²) or 1 volume of 0.8% formaldehyde to 9 parts soil). The treated area should be covered immediately with an airtight material and left for 24 hours or more. Following this treatment, about 2 weeks should be allowed for drying and airing, but the soil should not be planted until all odor of formaldehyde has disappeared.

"For small-scale treatments, commercial formalin can be applied at a rate of 2½ tablespoons per bushel (1 ml/l) of a light soil mixture or 1 tablespoon (14 ml) per standard size flat. Dilute with five to six parts of water, apply to soil and mix thoroughly. Let stand 24 hours, plant seeds, and water thoroughly.

"**Chloropicrin (Tear Gas).**—This is a liquid ordinarily applied with an injector, which should put 2 to 4 ml into holes 3 to 6 inches (7-15 cm) deep, spaced 9 to 12 inches (23-30 cm) apart. It may also be applied at the rate of 175 ml/m³ of soil. The gas should be confined by sprinkling the soil surface with water and then covering it with an airtight material, which is then left for 3 days. Seven to ten days is required for thorough aeration of the soil before it can be planted. Chloropicrin is effective against nematodes, insects, some weed seed, *Verticillium*, and most other resistant fungi. Chloropicrin fumes are very toxic to living plant tissue.

"Chloropicrin and methyl bromide are hazardous materials to use, especially in confined areas. They should be applied only by persons trained in their use and who will take the necessary precautions as stated in the instructions on the containers or in the accompanying literature.

"**Methyl bromide.**—This odorless material is very volatile and very toxic to humans. It should be used mixed with other materials and applied only by those trained in its use. Most nematodes, insects, weed seeds, and some fungi are killed by methyl bromide, but it will not kill *Verticillium*. It is often used by injecting the material at 1 to 4 pounds per 100 square feet (50-200 ml/m²) from pressurized containers into an open vessel under a plastic cover placed over the soil to be treated. The cover is sealed around the edges with soil, and should be kept in place for 48 hours. Penetration is very good, and the sterilization effect will extend to a depth of 12 inches (30 cm). For treating bulk soil, methyl bromide at 4 pounds per 100 cubic feet (6 kg/m³) can be used.

"**Methyl bromide-chloropicrin mixtures.**—Proprietary materials are available containing both methyl bromide and chloropicrin. Such combinations are more effective than either material alone in controlling weeds, insects, nematodes, and soil-borne disease organisms. Aeration for 10 to 14 days is required following applications of methyl bromide-chloropicrin mixtures.

"**Vapam® (sodium N-methyl dithiocarbamate dihydrate).**—This is a water-soluble soil fumigant which will kill weeds, germinating weed seeds, most soil fungi, and, under the proper conditions, nematodes. It undergoes rapid decomposition to produce a very penetrating gas. Vapam® is applied by sprinkling it on the soil surface, through irrigation systems, or with standard injection equipment. For seed-bed fumigation, 1 quart of the liquid formulation of Vapam® in 2 to 3 gallons water is used, sprinkled uniformly over 100 square feet of area (1:1 diluted with about 10 parts water covers 9 m²). After application, the Vapam® is sealed with additional water or with a roller. The soil can be planted two weeks after application. Although Vapam® has a relatively low toxicity to man, care should be taken to avoid inhaling fumes or splashing the solution on the skin."

Section VI

HAWAII DIBBLE-TUBE SYSTEM

from OTsel
Sent to Dart

Why Hawaii Is Changing To the Dibble-Tube System of Forestation

FILE COPY

Gerald A. Walters

ABSTRACT—The dibble-tube system was developed to meet the constraints of Hawaii's diverse species and planting sites, restrictive planting weather, generally inexperienced tree planters, and high costs. This system, which is based on the Hawaii dibble tube and rack, includes the nursery, transport, and field phases of forestation with container-grown stock. It is more reliable and less costly than the bare-root system in Hawaii.

The forestation program of the Hawaii Division of Forestry and Wildlife calls for planting 2 to 2.5 million seedlings on about 2,500 acres annually. About 2,000 acres will be planted for timber, pulp, and fuel. The other acreage will be planted to extend or improve native forests and windbreaks, and to cover erosion scars.

For several decades the division has used the bare-root system of forestation. The system has not worked well within the local constraints of diverse species and planting sites, restrictive planting weather, generally inexperienced tree planters, and high costs. During any one forestation project, one or more of the constraints negatively—and usually unpredictably—affect seedling survival and growth.

Several studies were made to determine if survival and growth rates could be improved. Transpiration retardants, root stimulants, pesticides, alternative packing methods (Walters 1971, 1972a, b, c), and careful nursery handling and field planting failed to better field performance. An alternate system was needed.

In 1972, the Institute of Pacific Islands Forestry, Pacific Southwest Forest and Range Experiment Station, in cooperation with the Hawaii Division of Forestry and Wildlife, began a program to develop a system that would be economical for seedling production, transport, and field planting, and would result in high survival and rapid growth after planting. The result is the dibble-tube forestation system.

The Hawaii dibble tube is a specially designed plant container (*fig. 1*) made of high-density polyethylene. Its size, about 5 inches deep and 1⅛ inches inside top diameter, represents a trade-off between biologic and economic considerations. It is large enough for adequate seedling development, but small enough for economical handling. Four ridges extend from top to bottom on the inside and prevent the lateral roots from spiraling within the container.

One hundred tubes fit into a styrofoam rack at a spacing of about 40 per square foot. The dimensional uniformity of the tube and rack provides the same rooting and aerial volume for each seedling, and also allows mechanization of each of the nursery operations. Tubes and racks are reusable. With a team of six to eight people, the tubes can be washed, filled with rooting medium, sown with seeds, topped off with gravel, and moved to the seedling culture area at a rate of 75,000 to 100,000 per day. A combination of manual and mechanized equipment is used (Walters and Horiuchi 1980). Tubes cost about $0.05 each; the racks about $3.50 each.

Seedlings are grown in the tubes until the stems are about 14 inches tall. They are then removed from the tubes, packed in wax-lined boxes, and shipped to the planting site. Seedlings are planted by hand or machine. Hand planting is done with a dibble that makes a hole the same size and shape as the seedling root system. The steel dibble part, with a step-on grubbing bar welded to it, is attached to a wooden handle.

The dibble-tube system has worked well under all of the local constraints.

Tree Species

More than 20 different tree species are grown at the Central Tree Nursery of the Hawaii Division of Forestry and Wildlife and planted throughout the state on public and private lands. Koa (*Acacia koa*), mamane (*Sophora chrysophylla*), casuarina (*Casuarina equisetifolia*), saligna (*Eucalyptus saligna*), loblolly pine (*Pinus taeda*), and slash pine (*Pinus elliottii*) are the principal species.

Seedlings of these principal species do not undergo dormancy and hence cannot be stored. They are succulent during transport and planting. Planting success of bare-root seedlings in terms of survival and growth depends largely on conditioning in the nursery. The

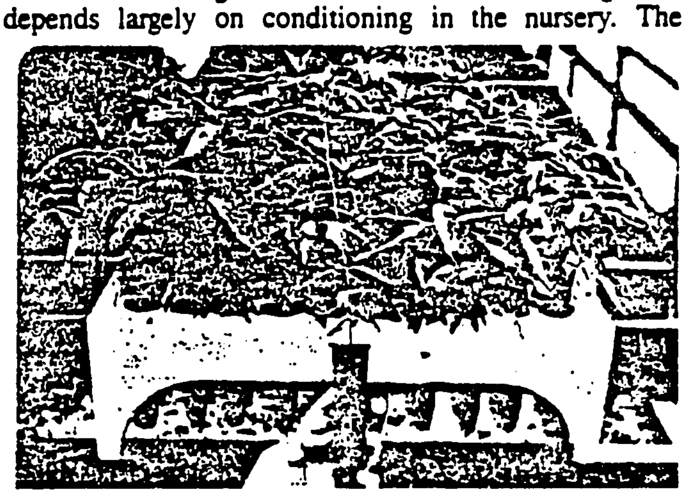

Figure 1. Eucalyptus saligna *seedlings growing in dibble tubes. The rack holds 100 seedlings.*

potential for conditioning varies with species. Southern pine and eucalyptus seedlings can be conditioned to have woody stems, "leathery" foliage, and abundant roots by controlling water and nitrogen applications, by undercutting, and by lateral root pruning. Koa, mamane, and casuarina are nitrogen fixers and therefore cannot be conditioned by nitrogen stressing.

Consistent bare-root planting success in Hawaii is relatively easy to attain with southern pine seedlings, difficult with eucalyptus, and almost impossible with koa, mamane, and casuarina. Bare-root pine, eucalyptus, and casuarina seedlings must be planted within three days after lifting because of the rapid loss of survival ability and growth potential. Casuarina is generally planted bare-root only if irrigation is possible. Koa and mamane are not planted bare-root. With the dibble-tube-system, success is regularly attained with all six of the principal species.

Saligna is currently the most widely planted species. Mean survival rate of 10 plantings of dibble-tube seedlings was 91.2 percent with a standard deviation of 4.4. Survival of containerized saligna plantings is predictably high. Survival of bare-root saligna plantings is unpredictable: it may be 90 percent in one planting and 10 percent in the next. Records from 20 bare-root saligna plantings, mostly for research (Walters 1970, 1971, 1972a, b, c), showed an average survival of 56.2 percent with a standard deviation of 31.5. About 70 percent of the survivors suffered stem dieback.

Koa is Hawaii's most valuable native tree, having wood properties similar to those of black walnut (*Juglans nigra*). For almost 20 years, little koa was planted, because survival of bare-root seedlings was too poor. However, several plantings totaling about 75,000 dibble-tube seedlings have survived at rates of about 85 percent.

In planning and conducting a forestation project, one must be able to predict planting success. If seedling survival is predictable, the proper number of seedlings can be grown and planted to attain the desired stocking. If survival is unpredictable, too many or too few seedlings may be grown or planted. If stocking is too low, replanting is necessary; if too high, a precommercial thinning may be required.

Satisfactory initial survival is essential for all plantations, but is especially important for saligna. With this species, coppicing is depended upon to establish the second, third, and fourth crops. If initial stocking is poor, yield will be reduced not only for the first, but also for all subsequent crops.

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Planting Sites

Planting sites for all species are diverse, with elevations ranging from near sea level to 9,500 feet, rainfall ranging from 20 to 250 inches annually, and soils varying from deep to shallow and from fine-textured to undifferentiated volcanic cinders and rocks. Accordingly, much of the knowledge required for planting success is site-specific by species. Little information is available, however, for developing seedlings that have the optimum physiological and morphological characteristics to survive under a wide range of field conditions. But with the dibble-tube method, survival has been consistently high for all the species on their respective sites.

Soil characteristics significantly affect tree planting rates and planting quality. In clay and in lava rockland, planting holes are more difficult to make with a mattock than with a dibble.

Planting Seasons

In Hawaii, planting seasons are not so clearly defined as they are in specific areas of the mainland United States, where seedlings can be planted almost anytime between certain dates. The winter months in Hawaii are generally the wettest, but may have several days or weeks that are just as dry, hot, bright, and windy as during the dry season. Weather forecasts are considered when final planting plans are made. However, because the weather is often different from the forecast, a decision must be made about what to do with the planting crew and with the thousands of seedlings when conditions become too hot, windy, or dry. Unlike lifted bare-root stock, dibble-tube seedlings, if kept in the tubes, can be held until conditions become favorable. Comparison plantings indicate that containerized seedlings can be successfully planted under a wider range of site conditions—soil moisture, wind, temperature, and light intensity—than bare-root seedlings (Walters 1970, 1972b, and unpublished data on file at the Institute of Pacific Islands Forestry).

Planting Rate

Dibble planting of containerized seedlings is faster than mattock planting of bare-root seedlings because it is physically easier to do, and requires less skill. Workers can keep up a steady rate all day, planting 750 to 1,000 seedlings. With mattocks, workers become tired, and planting rate and quality soon decrease.

About 90 percent of tree planters, public and private, are inexperienced in seedling handling, planting, and postplanting care. Those in federal or state employment are usually on temporary programs. About the time they become proficient, their employment program ends and a new group must be trained. Because dibble planting is simpler than the mattock planting, it requires less training and supervision.

Costs per Acre for Field Establishment

Dibble-tube seedlings are more expensive to grow and transport than bare-root seedlings (*table 1*). In Hawaii, they cost about $75 per thousand, as against $40 for bare-root seedlings. Transport adds about $4 per thousand, twice as much as for bare-root seedlings. These higher outlays, however, are more than offset by the lower costs of planting and maintaining a stand. The high survival of dibble-tube seedlings makes replanting

Table 1. Costs per acre (680 seedlings planted per acre) for establishing bare-root and dibble-tube saligna eucalyptus seedlings in Hawaii.

Item	Bare-root stock	Dibble-tube stock
	---- *Dollars* ----	
Nursery production		
Initial	27.20	51.00
Replanting:		
Equivalent stocking[1]	6.00	—
Minimum stocking[2]	1.92	—
Seedling transport		
Initial	1.36	2.72
Replanting:		
Equivalent stocking	.30	—
Mimimum stocking	.10	—
Field establishment		
Site preparation (initial)	200.00	200.00
Second site preparation:		
Equivalent stocking	25.00	—
Minimum stocking	8.00	—
Planting (initial)	77.71	38.86
Replanting:		
Equivalent stocking	20.00	—
Minimum stocking	6.40	—
Maintenance:		
Equivalent stocking	125.94	8.92
Minimum stocking	106.16	
Total cost per acre		
Equivalent stocking	483.51	301.50
Minimum stocking	428.85	

[1]*Stocking is the percent of planted trees alive after three to six months. The costs tabulated are those to attain stocking equivalent to the 95-percent achieved with dibble-tube seedlings.*
[2]*Costs to attain minimum acceptable stocking of 80 percent.*

unnecessary, while two to three replantings are sometimes needed with bare-root seedlings. Dibble-tube seedlings begin growing sooner after planting than bare-root seedlings and are better competitors with weeds. Consequently, fewer and less extensive weedings are required. Total establishment costs for dibble-tube seedlings are about $302 per acre. This is 58 percent of the establishment costs of bare-root seedlings figured on the basis of 80-percent stocking, and 40 percent when figured on the basis of stocking equal to that obtained with dibble-tube seedlings. If 2,000 acres are planted annually at a spacing of 8 by 8 feet, the total establishment cost for dibble-tube seedlings would be about $603,000. To achieve minimum stocking on these 2,000 acres with bare-root seedlings, total cost would be about $857,700. For stocking equivalent to that attained with dibble-tube seedlings, total cost with bare-root seedlings on 2,000 acres would be about $967,020. Use of dibble-tube seedlings, therefore, results in substantial savings. ■

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WALTERS, G.A. 1971. Survival and growth of saligna eucalyptus seedlings treated with a transpiration retardant in Hawaii. Tree Plant. Notes 22(1):2–4.

WALTERS, G.A. 1972a. Pesticide treatments on saligna eucalyptus, Australian toon seedlings affect dieback, but not survival. Tree Plant. Notes 23(3):16–18.

WALTERS, G.A. 1972b. Chemical treatment of bare-root saligna eucalyptus seedlings offers no advantages. Tree Plant. Notes 23(4):4–7.

WALTERS, G.A. 1972c. Packing methods studied for Australian toon and slash pine plantings. Tree Plant. Notes 23(4):7–9.

WALTERS, G.A., and H. HORIUCHI. 1980. Containerized seedlings: key to forestation in Hawaii. P. 87–92 *in* Proc. Intermountain Nurseryman's Association meeting, Aug. 14–16, 1979, Snowmass Village, Colorado.

Evaluating Scaling Systems

Thomas D. Fahey, Thomas A. Snellgrove, James M. Cahill, and Timothy A. Max

ABSTRACT — A proposed method of analyzing scaling systems consists of two parts. Part I applies only to sound logs and compares the precision of scaling systems using the relationship between lumber recovery and scaled volume. Part II uses only defective logs to compare the abilities of scaling systems to adjust volume for defect.

There are many systems for scaling logs. Freese (1973) described over 95 different log rules, bearing 185 names, in the United States and Canada. No objective methods exist for selecting among systems. This article first gives some of our ideas of what constitutes a good measurement system. Second, it presents a technique for objectively evaluating performance of various systems.

Characteristics of a Good Measurement System

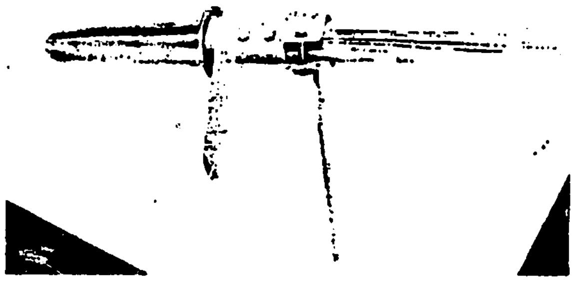
Certain characteristics are necessary for a good measurement system. Rapraeger (1950) and Bruce and Cowlin (1968) discussed a number of these. For example, a scaling system should be applicable at a reasonable cost under a variety of conditions. Scale estimates made by different people under varying conditions should be consistent and expressed in practical units.

The primary reason for measuring trees is to predict product volume. To that end, what constitutes a good measurement system? Ideally, one unit of scaled log volume should equal a constant number of units of product volume regardless of log diameter, length, or defect. If we use Scribner scale as an example, a log with a gross scale of 400 board feet and a deduction of 100 board feet for defect has an estimated net scale of 300 board feet. This log should yield the same volume of products as a 300-board-foot sound log, since a buyer will pay for the same volume. We realize that perfect comparability is not attainable in practice, but the system that most nearly approaches it would be best.

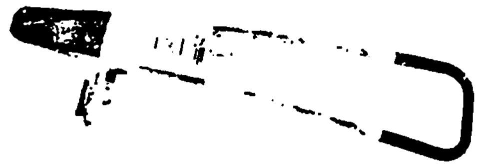
Many sources of variation affect how well a scaling system relates to product yield. For example, how is diameter measured and how is it rounded? How is length measured and rounded? What formula is used to calculate gross volume? Variation associated with deduction for defect is one of the most important sources of error. What is considered to be a defect, how is it measured, and what method is used to estimate the volume to be deducted? These sources of variation are inherent in all scaling systems and will affect product estimates made by any scaling system.

Terms useful in categorizing and evaluating this variation (Freese 1962) are:

Accuracy refers to the success of estimating the true value.



Dibble with attached scalper.



The Nordplanter.

Specifications

Adze hoes:

Blade width 6 to 12 in (15 to 30 cm)
Handle length 36 in (91 cm)
Weight 4.5 lb (2 kg)

Planting hoes:
Blade length 13 to 17 in (33 to 43 cm)
Blade width 3 to 4 in (7.6 to 10.2 cm)
Handle length 36 in (91 cm)
Weight 7.3 lb (3.4 kg)

The Nordplanter:
Blade length 6 in (15 cm)
Blade width 3.5 in (8.9 cm)
Overall length 38 in (97 cm)
Weight 5 lb (2.3 kg)

Planting bars:
Blade length 10 to 12 in (25 to 30 cm)
Blade width 3 to 4 in (7.6 to 10.2 cm)
Overall length 37 to 42 in (94 to 107 cm)
Weight 8 to 12 lb (3.6 to 5.4 kg)

Hand planting augers:
Core diameter 1.5 to 3 in (3.8 to 7.6 cm)
Length 23.5 to 37.5 (60 to 95 cm)
Weight 3.5 to 5 lb (1.6 to 2.3 kg)

Dibbles:
Length 26 to 52 in (66 to 132 cm)
Weight 4.5 to 7.8 lb (2 to 3.5 kg)

Planting tubes:
Diameter 1.5 to 2.8 in (3.8 to 7.1 cm)
Length 36.5 in (93 cm)
Weight 5.5 to 6.6 lb (2.5 to 3 kg)

Availability

Handtools for bareroot seedlings:

A&M Steel Craft
8250 124th St.
Surrey, B.C., Canada V3W 3X9

Ames Co.
Division of McDonough Co.
Box 1774
Parkersburg, W.Va. 26101
(304) 424-3000

Ben Meadows Co.
3589 Broad St.
Atlanta, Ga. 30366
(404) 455-0907

Forestec, Ltd.
6393 Bayne St.
Halifax, Nova Scotia, Canada B3K 2V6
(902) 455-4062

Forestry Suppliers, Inc.
Box 8397
Jackson, Miss. 39204
(601) 354-3565

International Reforestation Suppliers
Box 5547
Eugene, Oreg. 97405
(503) 345-0597

A. M. Leonard, Inc.
6665 Spiker Rd.
Piqua, Ohio 45356
(513) 773-2694

Oregon Reforestation Equipment and Supply
Box 2597
Eugene, Oreg. 97402
(503) 746-2529

TSI Co.
Box 151
Flanders, N.J. 07836
(201) 584-3417

Western Fire Equipment Co.
440 Valley Dr.
Brisbane, Calif. 94005
(415) 467-5650

Handtools for containerized seedlings:

A&M Steel Craft
8250 124th St.
Surrey, B.C., Canada V3W 3X9
(604) 594-0615

Columbia Plastics, Ltd.
2155 West 10th Ave.
Vancouver, B.C., Canada V6K 3H7
(604) 736-9261

Forestec, Ltd.
6393 Bayne St.
Halifax, Nova Scotia, Canada B3K 2V6
(902) 455-4062

Hakmet, Ltd.
179 Place Frontenac
Pointe Claire, Quebec, Canada H9R 4Z7
(514) 694-4791

International Reforestation Suppliers
Box 5547
Eugene, Oreg. 97405
(503) 345-0597

Oregon Reforestation Equipment
Box 2597
Eugene, Oreg. 97402
(503) 746-2529

Plant-A-Plug Systems
Division of RCB Corp.
Box 386
Crossett, Ark. 71635
(501) 364-6010

Reid, Collins, and Assoc., Ltd.
Reforestation Div.
550 Burrard St.
Vancouver, B.C., Canada V6C 2K6
(604) 669-3134

Dibbles and planting tubes are specialized planting tools for containerized stock. Dibbles punch holes in the soil the size of the seedling tubes. Planting tubes displace the soil with a foot lever and place the seedling through the hollow handle.

Techniques

Adze hoes remove the litter and plant competition from the area surrounding the planting site. Planting hoes dig holes 10 to 12 in (25 to 30 cm) deep and up to 5 in (13 cm) wide. The seedling is placed in the hole and the soil is packed around it. Planting hoes can also scalp the site prior to planting.

The Nordplanter and planting bars are thrust into the soil and rocked back and forth to create a suitable planting hole. When the seedling is placed the tool is again thrust into the soil and pulled back, packing the soil against the seedling roots.

Planting augers are twisted into the soil and pulled out removing a soil core. The seedling is planted in the remaining hole.

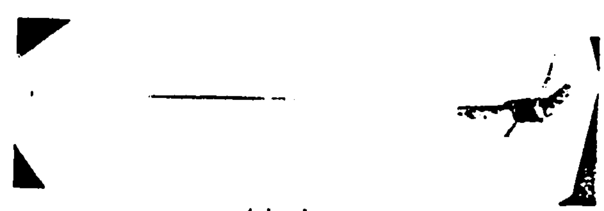
Dibbles and planting tubes are driven into the soil, displacing a hole the same size as the type of container used.

Capabilities

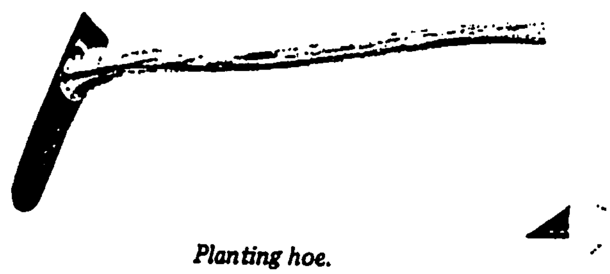
Most seedling planting is with handtools. Planting hoes and planting bars are the most common planting tools. Hoes may prepare the sites as well as plant. Planting bars are often used on rockier sites. Shovels are used for large stock. Handtools are easily packed to remote areas.

Limitations

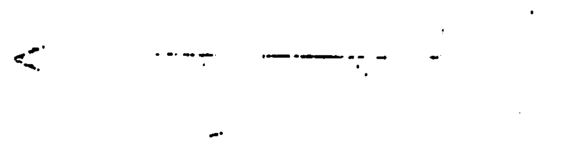
Hand planting tools are not well suited to areas with many rocks or extensive brush and debris. They usually require site preparation. Planting bars, dibbles, and planting tubes may cause excessive soil compaction around the seedling, especially in heavy or clay soils. Hand planting is labor intensive and may prove rather costly.



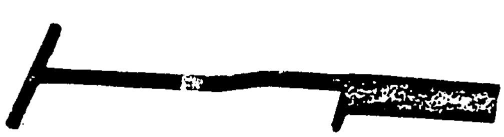
Adze hoe.



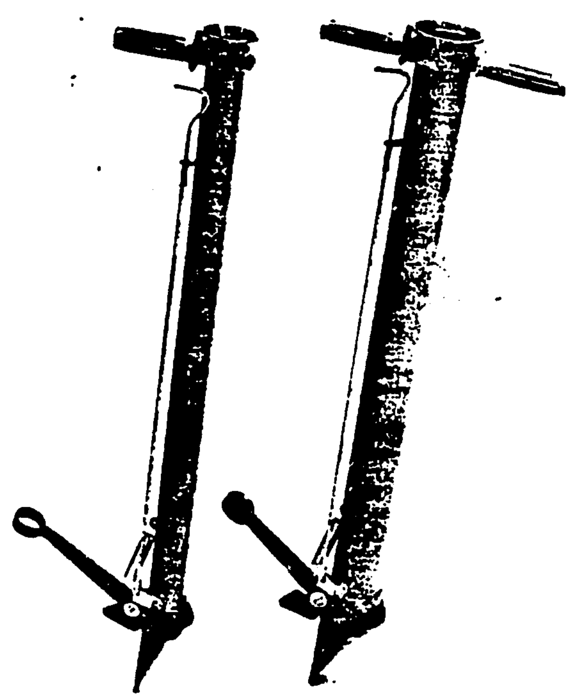
Planting hoe.



KBC planting bar.



OST planting bar.



Planting tubes.

Large portable auger operated by two people.

Specifications

Diameter 1.5 to 18 in (3.8 to 45.7 cm)
Depth 2 ft to 3 ft 6 in (.6 to 10.7 m) single bit to 12 ft (3.7 m) with extensions
Weight 30 to 86 lb (14 to 39 kg)
Power ratings 3 to 8 hp (2.2 to 6 kW)

Availability

Ardisam, Inc.
Box 666
Cumberland, Wis. 54829
(715) 822-2415

Fred A. Lewis Co.
40 Belknap Rd.
Medford, Oreg. 97501
(503) 772-9646

General Equipment Co.
Box 334
Owatonna, Minn. 55060
(507) 451-5510

Ground Hog, Inc.
Box 290
San Bernardino, Calif. 92404
(714) 888-2818

Hoffco, Inc.
358 Northwest F St.
Richmond, Ind. 47374
(317) 966-8161

Little Beaver, Inc.
Box 840
Livingston, Tex. 77351
(713) 327-3121

Stihl, Inc.
Box 5514
Virginia Beach, Va. 23455
(804) 460-3333

Hand Planting Tools

Function

Hand planting tools prepare microsites and plant bare-root seedlings. Specialized tools are also available for various sizes of containerized stock.

Description

Hand planting tools include adze hoses, planting hoes, the Nordplanter, planting bars, and hand planting augers. Dibbles and planting tubes are designed for containerized seedlings.

The adze hoe has a heavy, wide blade for scalping. The planting hoe, sometimes called a hoedad or Rindt hoe, has a long, tapered blade. The blade is flattened or curved inward with a beveled edge for easy penetration. The opposite square end may be used for scalping.

The Nordplanter is a specialized shovel designed for planting. Planting bars are similar to planting shovels except for a wide T-bar handle and a wide, sturdy crossbar for foot placement. The blades are usually flat with sharply beveled edges.

Hand planting augers are simple boring devices that remove soil plugs.

Planting Augers

Function

Planting augers are portable, powered augers to dig holes for planting containerized or bare root seedlings. Larger augers can also dig holes for fence posts.

Description

A typical planting auger consists of a power unit, a gear box, and the auger bit. The power units may be lightweight chainsaw engines, backpack engines with flexible drive, or separate engines with either flexible or hydraulic drive. The gear box links the power source with the auger bit. Many are adaptable to the chain drive from chainsaw engines. The auger bits have hardened steel base plates. Some bits have rows of brazed carbide along the leading edge for greater durability. Some bits also feature replaceable nose cones.

Techniques

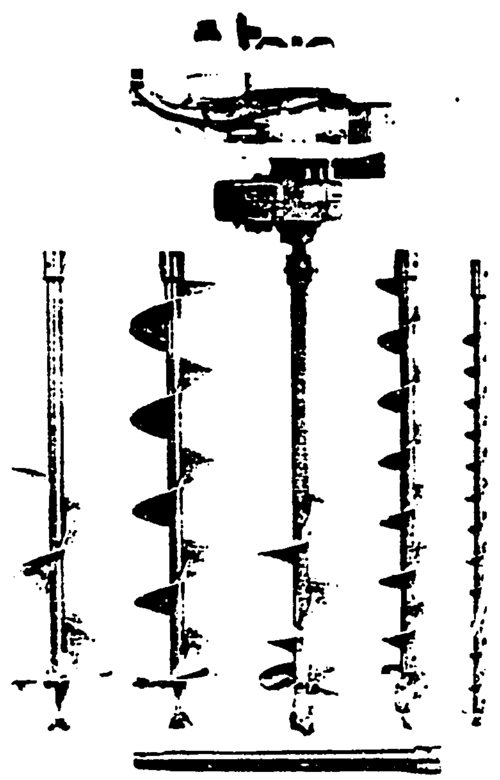
The engine is started and the gear box is engaged. The auger bit cuts into the ground and removes the soil. The hole is drilled vertically to the desired depth. The seedling or fence post is placed in the hole and the loose soil is packed tightly around it, filling in any spaces. One person can easily operate most planting augers, however, some of the larger ones require two people.

Capabilities

Planting augers enable operators to dig holes quickly and consistently. Large, deep holes can hold larger seedlings. Because the soil surrounding the roots is not compressed, better growth and higher survival is usually obtained. Auger bits are very durable and may be replaced with specialized bits for ice or wood boring.

Limitations

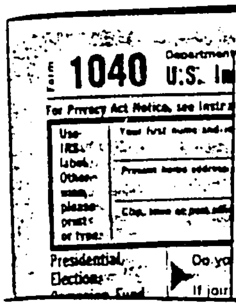
Planting augers are not well suited to areas with many large roots or rocks. They become difficult to operate on areas with extensive surface debris or in clay soils. Fine textured soils tend to settle in the holes leaving the seedling roots exposed underneath.



Small powered earth auger.

Backpack powered earth auger.

TREE PLANTERS!



A TAX BREAK FOR TREE PLANTERS

A new law (PL 96-451) includes a tax break on your federal income tax for all tree planting done after Dec. 31, 1979.

Briefly, here's how it works. You can subtract 10% (up to $1,000) of your tree planting costs (including cost of tree planting tools) from the amount of federal income tax you owe. Also, for the next 7 years you can subtract from your yearly gross income a proportional amount of the total planting costs. The total tree planting costs eligible for this new tax break cannot exceed $10,000 per year.

For a detailed guide on the new law, write to Forestry Suppliers, Inc., P. O. Box 8397, Jackson, MS 39204. Ask for the brochure ***The New Reforestation Tax Incentives.***

Tree Planting Bars

KBC Bar

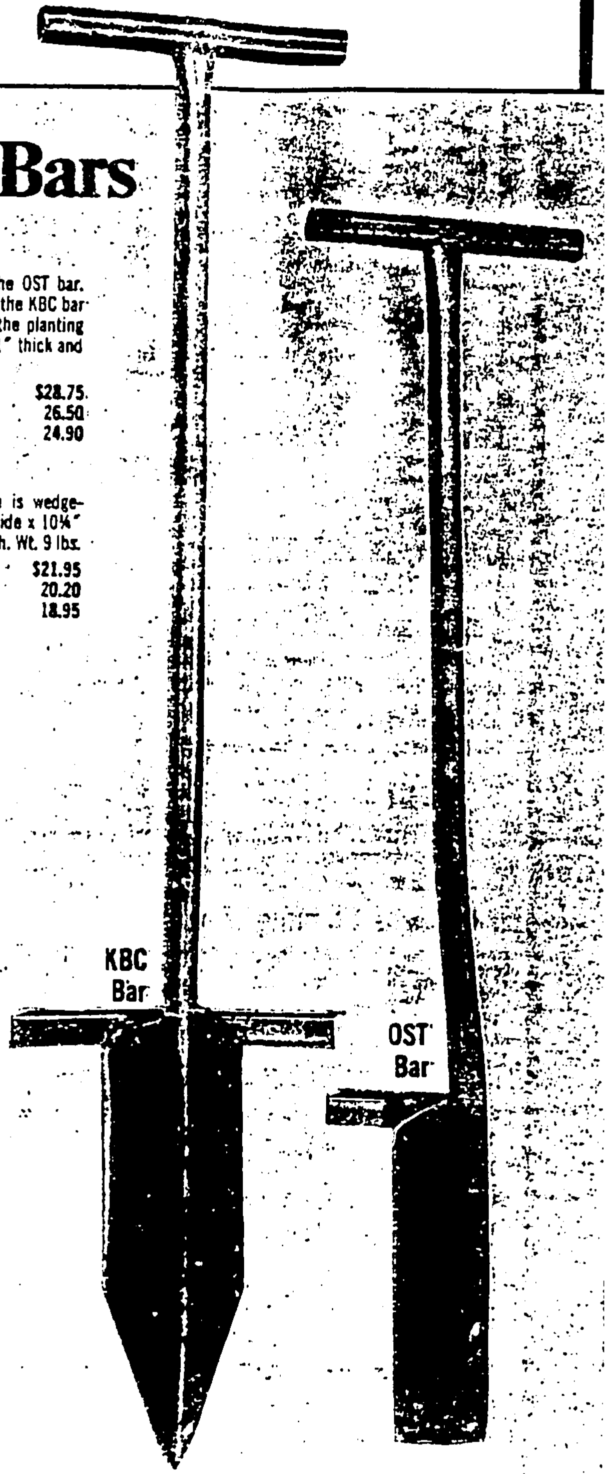
Works better in rocky or hard-to-penetrate soils than the OST bar. Blade is triangular in cross section. The pointed shape of the KBC bar penetrates the soil cleanly and easily. Less dirt falls in the planting hole. Overall length: 39". Blade is 4" wide x 12" long x 1" thick and tapers to a point. Sh. Wt. 11 lbs.

69041	1 to 5	ea.	$28.75
	6 to 11	ea.	26.50
	12 or more	ea.	24.90

OST Bar (Dibble Bar)

Works best in non-rocky, easy-to-penetrate soils. Blade is wedge-shaped in cross section. Overall length: 38". Blade: 3" wide x 10¼" long; blade thickness: ¼" at top tapering to thin wedge. Sh. Wt. 9 lbs.

69042	1 to 5	ea.	$21.95
	6 to 11	ea.	20.20
	12 or more	ea.	18.95



Tree Planting Hoe and Handle

Flame-hardened blade - 3½" x 10". Hickory handle, 3' long. **HOE only, without handle.** Sh. Wt. 4 lbs.

69060	1 to 11	ea.	$24.95
	12 or more	ea.	22.95

HICKORY HANDLE only. Sh. Wt. 2 lbs.

69089	1 to 11	ea.	$ 7.30
	12 or more	ea.	6.55

Hazel Hoe and Handle

Meets State Forestry specs in Oregon and Washington. Adze-eye with 6" wide blade. Hickory handle. 3' long. **HOE only, without handle.** Sh. Wt. 3 lbs.

69057	1 to 11	ea.	$27.25
	12 or more	ea.	25.10

HICKORY HANDLE only. Sh. Wt. 2 lbs.

69089	1 to 11	ea.	$ 7.30
	12 or more	ea.	6.55

Dibble (for Leach Pine Cell)

NEW

Excellent for planting container stock. Features low alloy steel point, convenient foot plate, and 52" ash handle. Dibble head size is 1" top dia. x 5.3" long (4 cu. in.). Other sizes available on request.

69140 Sh. Wt. 5 lbs. $37.05

Tree Planting Gloves

NEW

70% nylon, 30% polyester blend with non-slip rubber "beads" on outside. Sh. Wt. ¼ lb./pair.

69136	Small. Per pair.	$2.65
69137	Medium. Per pair.	2.65
69138	Large. Per pair.	2.65

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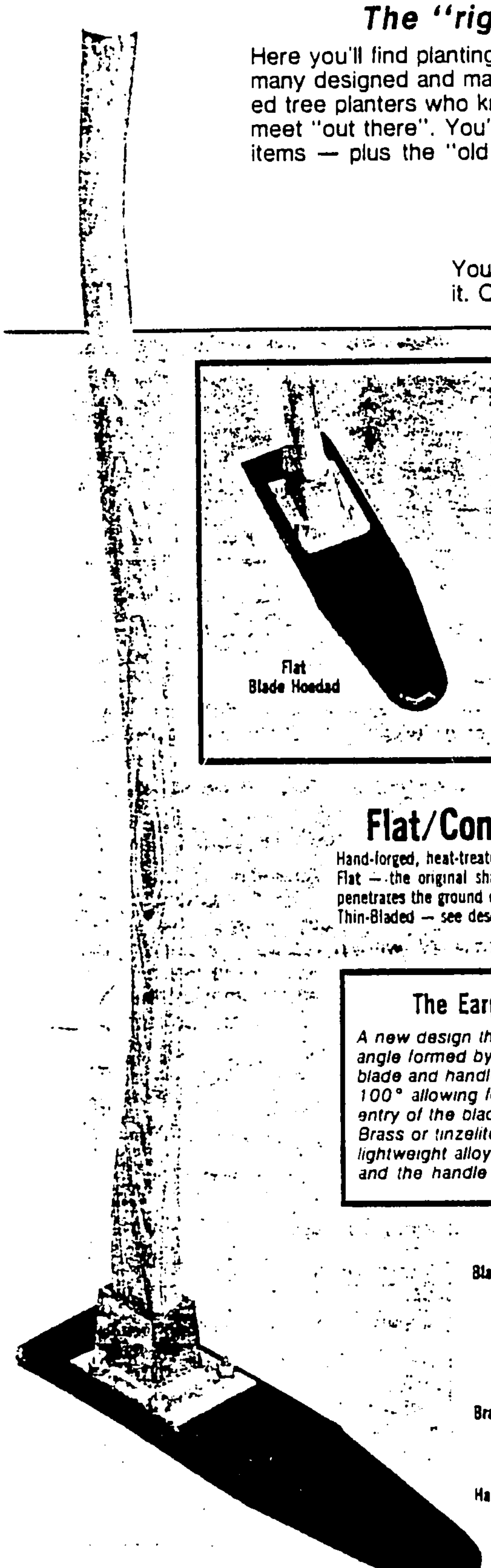
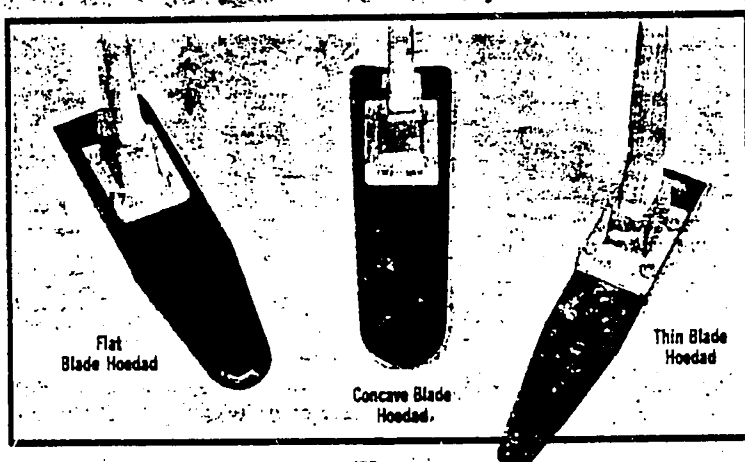




Hoedads

(also called Rindt Planting Hoe)

Originally designed and used for tree planting in the Northwest, the hoedad is becoming increasingly popular with professional planters throughout all of the U.S. — especially the Southeast.

Flat/Concave Blade Hoedads

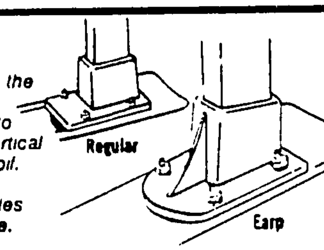
Hand-forged, heat-treated, carbon alloy blades come in three shapes: (1) Flat — the original shape; (2) Concave (and sharpened all sides) — it penetrates the ground easier, and removes/holds the dirt in the hole. (3) Thin-Bladed — see description at right.

Thin Blade Hoedad

(Also called plug hoe). A modified version of the traditional hoedad. It's a much thinner blade - 3" at top tapering to 1" - allowing it to slide between the rocks. Now-used to plant bare-root loblolly and slash pine in the South. Originally designed for planting containerized seedlings in the West.

The Earp Bracket

A new design that increases the angle formed by the hoedad blade and handle from 90° to 100° allowing for a more vertical entry of the blade into the soil. Brass or tinzelite—a strong, lightweight alloy. Fits all blades and the handle on this page.



Replacement Parts for Hoedads

Blades - fit any bracket.		
69087	17" Flat Blade. Sh. Wt. 4½ lbs.	$17.15
69088	15" Flat Blade. Sh. Wt. 4 lbs.	15.40
69098	17" Concave Blade. Sh. Wt. 4 lbs.	20.70
69095	15" Concave Blade. Sh. Wt. 3½ lbs.	19.00
69080	15" Thin Blade. Sh. Wt. 3 lbs.	15.30
69081	13" Thin Blade. Sh. Wt. 2½ lbs.	14.70
Brackets - fit any blade.		
69077	Regular bracket; brass. Sh. Wt. 2 lbs.	$5.80
69078	Earp bracket; brass. Sh. Wt. 1¾ lb.	6.50
69079	Earp bracket; tinzelite. Sh. Wt. ½ lb.	4.80
Handle - fits all brackets.		
69089	Hickory handle - 3' long. 1-11	$7.30
	Sh. Wt. 2 lbs. 12 or more	6.55

Ordering Information

Flat blade, Regular bracket - Brass, 36" hickory handle:		
69085	17" blade. Sh. Wt. 7½ lbs.	$29.25
69086	15" blade. Sh. Wt. 7 lbs.	27.70
Flat blade, Earp bracket - Brass, 36" hickory handle:		
69109	17" blade. Sh. Wt. 7¼ lbs.	29.85
69110	15" blade. Sh. Wt. 7¼ lbs.	28.30
Flat blade, Earp bracket - Tinzelite, 36" hickory handle:		
69111	17" blade. Sh. Wt. 5¾ lbs.	28.35
69112	15" blade. Sh. Wt. 6¼ lbs.	26.80
Concave blade, Regular bracket - Brass, 36" hickory handle.		
69097	17" blade. Sh.Wt. 7 lbs.	32.45
69064	15" blade. Sh. Wt. 6 lbs.	30.90
Concave blade, Earp bracket - Brass, 36" hickory handle.		
69113	17" blade. Sh. Wt. 7¼ lbs.	33.05
69114	15" blade. Sh. Wt. 6¼ lbs.	31.50
Concave blade, Earp bracket - Tinzelite, 36" hickory handle.		
69115	17" blade. Sh. Wt. 6¼ lbs.	31.55
69116	15" blade. Sh. Wt. 5¼ lbs.	30.00
Thin blade, Regular bracket - Brass, 36" hickory handle.		
69107	15" blade. Sh. Wt. 6 lbs.	27.60
69108	13" blade. Sh. Wt. 5¾ lbs.	27.00
Thin blade, Earp bracket - Brass, 36" hickory handle.		
69117	15" blade. Sh. Wt. 6¼ lbs.	28.20
69118	13" blade. Sh. Wt. 6 lbs.	27.60
Thin blade, Earp bracket - Tinzelite, 36" hickory handle.		
69119	15" blade. Sh. Wt. 5¼ lbs.	26.70
69120	13" blade. Sh. Wt. 4¾ lbs.	26.10

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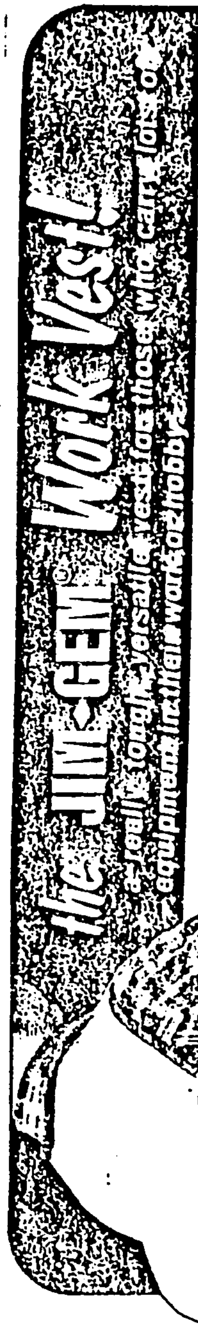

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See page 41 for complete details.

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REGULAR (not pictured)
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CONTAINERIZED SEEDLINGS: KEY TO FORESTATION IN HAWAII[1]

Gerald A. Walters[2] and Howard Horiuchi[3]

Abstract.—A forestation system based on the Hawaii Dibbling Tube containers has been developed in Hawaii. Plantings of containerized seedlings of both native and introduced species have had consistently higher survival and growth rates than those of bare-root seedlings. Although the technology of the system has been developed, more research is needed to ensure optimum seedling quality.

About one-half of the 4 million acres that make up the State of Hawaii is forest land. This land forms the base for water, timber, wildlife habitat, recreation habitat, and forage resources. Forest resources must be managed intensively to meet current demands and future needs. Hawaii has the potentials to produce more timber volume than the 150 million board-feet that we now import each year. It also has the potential to extend or improve windbreaks, revegetate erosion scars, and rehabilitate or expand both native and introduced forests. To begin to realize these goals, however, we must successfully accomplish forestation: sites must be prepared and seedlings must be reared in a nursery, transported to the field, planted, and maintained until they are established.

The forestation program in Hawaii calls for planting 3.5 to 4 million seedlings on about 6000 acres annually. About 5000 acres will be for timber production. The remaining acreage will be planted to rehabilitate or extend native forests, to heal erosion scars, and to extend or improve windbreaks.

In the past, the Hawaii Division of Forestry relied on cans, bags, and flats as rooting media containers for tree seedlings. These containers and the methods employed required much labor for seedling production, transport, and planting. Although field survival was generally high and little transplant shock occurred, the system became prohibitively expensive.

In 1962, the Division changed to bare-root production and planting, an approach not as expensive as producing and planting of balled-root seedlings. Survival of field plantings, however, is often unacceptably low. Low survival is especially true for several hardwood species. Also, because of transplant shock, initial growth of all species is generally slow. If this shock is great, the stem may die back. The extent of such dieback may range from only the terminal to the entire stem. Sometimes as many as 85 to 95 percent of the eucalyptus seedlings in a planting die back (Walters 1971). Generally, eucalyptus seedlings that suffer severe dieback require 3 or more months to reach their original height.

Seedlings that do not start to grow soon after planting are often poor competitors for the aggressive tropical vegetation. Overtopped seedlings must be released. The Division of Forestry estimates that each maintenance of seedlings planted at a 10- by 10-foot spacing requires about 3 man-days per acre. Maintenance number and frequency vary with the speed of seedling establishment.

Studies have been done to determine if bare-root seedling survival and growth rates can be improved. Transpiration retardants (Walters 1971, 1972), root stimulants (Walters 1972), pesticides (Walters 1972), and alternative packing methods (Walters 1972) have failed to significantly affect field performance of bare-root seedlings.

Because of the high cost of balled-root seedlings and the low survival and initial growth rates of bare-root seedlings, an alternative approach to forestation was sought. In 1972, developmental work was started on a system that would provide efficient seedling

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[1]Paper presented at the Intermountain Nurseryman's Association Meeting, Snowmass Village, Colorado, Aug. 14-16, 1979.

[2]Research Forester, Institute Pacific Islands Forestry, Pacific Southwest Forest and Range Experiment Station, Forest Service, U. S. Department of Agriculture, Honolulu, Hawaii.

[3]Assistant Forester, Hawaii Division of Forestry, Hilo, Hawaii.

production, transport, planting, and high survival and growth rates after field planting. Because specialized containers for tree seedlings were being developed elsewhere, it seemed to us that our new system should focus on a specialized container.

Originally, we planned to adapt one of these existing container systems to Hawaii. After growing seedlings in different containers and evaluating the potential systems, however, the Hawaii Dibbling Tube (HDT) and the HDT forestation system was designed. Just as the containers and container systems used elsewhere are designed for their species, soils, climates, and people, the HDT system was designed to meet Hawaii's requirements.

Hawaii Dibbling Tubes are individual containers that fit into a rack, 100 per rack. Density is 40 tubes per square foot. The tube itself is made of high density polyethylene, and measures 5 inches deep and 1 1/8 inches inside top diameter. The volume is about 3.4 cubic inches. The cavity has four ridges that extend from top to bottom. These ridges prevent lateral roots from spiraling within the container, and thus prevent pot binding.

More than 20 different tree species, mostly broadleaf, are now being planted in Hawaii's forests (table 1). The many species are needed because of the variable site conditions and planting objectives in Hawaii: annual rainfall on different sites can range from 20 to 250 inches; soils vary from deep to shallow and from fine-textured to undifferentiated volcanic clinkers; plantable elevations extend from near sea level to more than 9500 feet.

The forestation system developed for Hawaii includes the nursery, transport, and field phases (fig. 1). Each phase is an integral part of the whole, like links in a chain. Each link can be divided into the technological and biological aspects. Most of the technology has been developed to allow efficient progress from seed in the nursery to established seedlings in the forest.

Table 1.--Tree species presently used for reforestation in Hawaii

Scientific name	Common name
Acacia koa	Koa
A. melanoxylon	Blackwood acacia
Araucaria heterophylla	Norfolk-Island-Pine
Casuarina cunninghamiana	Short leaf Ironwood
C. equisetifolia	Long leaf Ironwood
Cupressus lusitanica	Mexican cypress
C. macrocarpa	Monterey cypress
Eucalyptus citriodora	Lemon-Gum eucalyptus
E. deglupta	Bagras eucalyptus
E. robusta	Robusta eucalyptus
E. saligna	Saligna eucalyptus
Flindersia brayleyana	Queensland-Maple
Melaleuca quinquenervia	Cajeput-Tree (Paper-bark)
Olea europaea	Olive
Pinus elliottii	Slash pine
P. radiata	Monterey pine
P. taeda	Loblolly pine
Sequoia sempervirens	Redwood
Sophora chrysophylla	Mamane
Toona australis	Australian toon
Tristania conferta	Brushbox

NURSERY PHASE

Headhouse Operation

The headhouse is divided into storage and work areas. Sufficient tubes, racks, rooting medium, and gravel (seed cover) are stored to produce about 500,000 seedlings. The work area is designed so that one process flows smoothly into the next. Tubes are put into racks, cleaned, filled, sown, covered and transported to the seedling culture area in one continuous flow (fig. 2).

Rooting Medium

A 1:1 mix by volume of sphagnum peat and vermiculite is used. A 1-cubic yard soil mixer (modified Bouldin & Lawson[4]) is used to prepare the medium. Bales of peat and vermiculite are placed in the mixer; the covers are slit and removed. This method of loading the mixer reduces the dust problem. The solid lid on the mixer has spray nozzles. The lid is closed and a recycling timer is activated, allowing a

[4]Mention of trade name is solely for information purposes. No endorsement is implied.

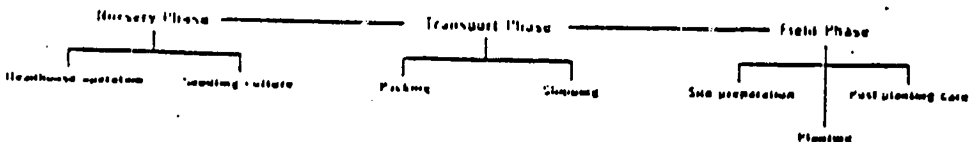

Figure 1.--Forestation phases involved in going from seed in the nursery to established tree in the forest.

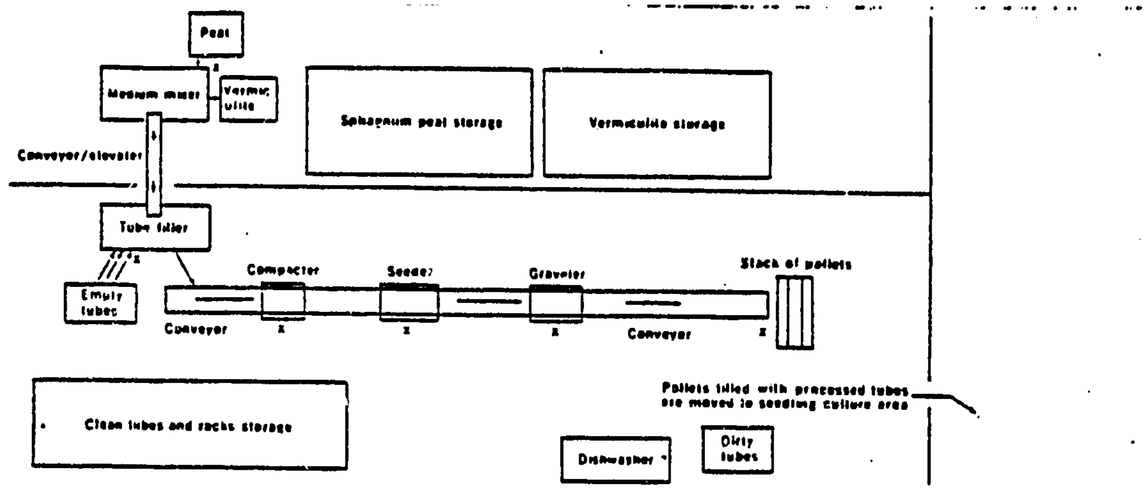

Figure 2.—Layout of headhouse showing storage of materials and processing equipment for tubes and racks.

known amount of water to spray into the mixer. This ensures that each batch of rooting medium has the same moisture content. Once the rooting medium is mixed, the batch of this self-cleaning mixer is opened and the rooting medium falls onto a conveyor-elevator. The rooting medium is carried to a hopper over a tube-filling machine.

Tube and Rack Cleaning

Tubes and racks are cleaned in a commercial dishwasher at a rate of about 8000 tubes per hour. The rate can be increased by using more automated types of dishwashers. The unit used by the Division of Forestry has a water-saving system and provides a chlorine rinse.

Tube Filling

Three racks or 300 hundred tubes are placed in an impact loader. A hydraulic system moves plates out of the way, allowing rooting medium to fall into the tubes. The machine is turned on and the racks are raised, then dropped; the sudden stop at the bottom forces the medium into the tubes. After about 30 seconds, the machine automatically shuts off. The hydraulic system moves the plates back to prevent any further downward movement of the mix. The filled tubes are removed from the machine and placed on a dead-roller conveyor.

Rooting Medium Compaction

When the tubes come from the tube-filling machine they are filled to the top; consequently, there is no room for seeds. A simple press device, consisting of a plate with 100 dowels fixed in the same arrangement as the tubes in the rack, is used to compress the rooting medium. An easy adjustment permits compaction to different depths, depending on the size of the seeds to be sown.

Seed Sowing

Two different devices are used to sow seed. A vacuum seeder is used for sowing flat seeds. Its principles and technique are the same as those of vacuum seeders used elsewhere, except it places seeds at a spacing appropriate for the Hawaii Dibbling Tubes. The second device is a manual seeder and is used for round seeds.[5] It consists of three plates held by a frame. Holes in all three plates have the same arrangement as the tubes in the rack; however, holes in the top and bottom plates do not line up and the middle plate slides between the top and bottom plates. Seeds are put on the top plate. When the middle plate is slid so that the holes in it line up with the holes in the top plate, seeds fall into the holes in the middle plate. And then when the middle plate is slid so that holes in it line up with the holes in the bottom plate, the seeds fall through into the tubes (fig. 3). Multiple sowings can be made by moving the middle plate back and forth as many times as the desired number of seeds per tube. The number of seeds sown per tube is based on germination tests.

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[5]Walters, Gerald A. and Donovan Goo. A new manual seeder for round seeds. (To be published in Tree Planters' Notes)

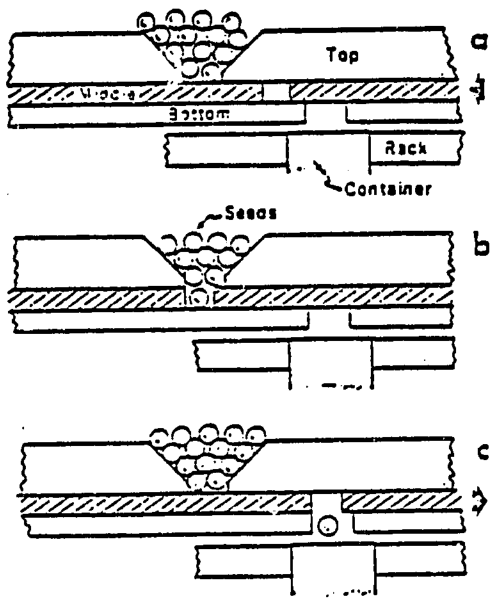

Figure 3.—Schematic of part of the Manual Seeder illustrating its operation: (a) a hole in the top plate is filled with seeds. (b) the middle plate is moved so that hole in it lines up with the hole in the top plate, a seed drops into the hole. (c) then as the middle plate is moved so that the hole in it lines up with the hole in the bottom plate, a seed falls into the container.

Seed Covering

Seeds are covered with crushed basalt rock (2 mm in size). A device similar to the manual seeder is used to apply the gravel.

Transfer of Tubes and Racks to the Seedling Culture Area

A stack of specially designed pallets is placed at the end of the conveyor. When a rack of tubes is complete, it is placed on the pallet. When the pallet is filled with 12 racks or 1200 tubes, a forklift picks up the load and moves it to the plant shelter. The next pallet in the stack is there to receive more racks. In the plant shelter, the pallet is set on four cement blocks so that it forms the bench top.

Headhouse Productivity

By using the mechanical and manual equipment described, six people can process about 100,000 tubes per day, including transferring the pallets with tubes to the growing area.

Seedling Culture

Racks are kept in the plant shelter for about 6 weeks, or until the seedlings are several inches tall. Light intensity is kept at about 50 percent. Water is applied daily through an overhead irrigation system. Nutrients are injected into the irrigation system using a Smith liquid fertilizer injector[4] at a rate of 75 to 100 ppm N basis of 12.5-25-25. All formulations are commercially prepared. Pesticides are applied as necessary. When ready, pallets of seedlings are moved outside with a forklift.

When the seedlings are outside, the only environmental factors that are controllable are water and nutrients. Water is applied daily through impact irrigation heads. The system provides about 120 percent overlap which is necessary because of the frequent 20-plus mile-per-hour winds. Nutrients are injected through the irrigation system. The nutrient solution initially is about 75 ppm N basis of 20-20-20. After several weeks, the concentration is increased to 250 ppm N basis. When the seedlings are about 10 inches tall, the formulation and rate are changed to 75 ppm N basis of 12.5-25-25. When the seedlings are from 12 to 14 inches tall, they are shipped to the field for planting. Most of our species are tropical and semitropical so there is often no dormant period. We can generally only slow growth by limiting water and nitrogen.

TRANSPORT PHASE

Seedling Packing

A forklift carries a pallet of seedlings to the packing area where they are removed from the tubes and packed horizontally in wax-lined cardboard boxes so that the roots face toward the box ends and the tops overlap. These boxes, which hold 200 seedlings, provide protection even when they are stacked. Palletizing a load of seedlings is, therefore, possible. Also, sealing the seedlings in boxes fulfills State Department of Agriculture regulations for shipping plant material between islands.

Seedling Transport

Pallets of seedlings are loaded onto trucks and transported to the planting site. Seedlings destined for other islands are shipped via air freight.

FIELD PHASE

Site Preparation

Sites are prepared by using bulldozers, herbicides, or both. Preparation of sites with soil is relatively routine; that is, brush and debris are crushed or windrowed by a bulldozer. Preparation of sites of lava rockland, however, can be challenging. Throughout lava rockland areas are lava tubes—natural caves with roofs that may vary from several inches to several hundred feet thick. A bulldozer may break through and drop into a lava tube, sometimes 10 to 20 feet deep. Herbicides, especially dalapon and Roundup[6], are used for site preparation on steep slopes.

Planting

Packing boxes containing the seedlings are quickly converted to seedling carrying boxes by making several cuts and folding the box (fig. 4) (Walters 1978). Packing seedlings fully in one end of the box before packing the other end allows the tops to separate easily when the box is cut and folded. When the box is empty, it is flattened and shipped back to the nursery and reused. The cut section is taped for reuse.

A dibble is used to make the planting holes. The dibble is specially designed for seedlings grown in the Hawaii Dibbling Tubes. Our dibbles are made from readily available materials: the dibble portion is made from a broken axle, the foot and grubbing bar from a broken truck spring, and the wooden handle receptacle from a 1-inch galvanized pipe fitting. The dibble used for making holes in clay soils has burrs on it to scarify the inside of the planting hole. The burrs are made by striking the rod of an arc-welder against the dibble. Dibble planting works well in lava rockland as the dibble acts as a probe to find cracks into which to plant the seedlings.

A single worker, using this system, can plant from 750 to 1000 seedlings per 8-hour field day. Dibble planting is about twice as fast as the pick method used for bare-root seedlings. Besides being fast, dibble planting helps ensure planting quality. The dibble consistently makes a hole that is the right size and shape for the seedling's root system. The tree planter does not have to decide how deep and wide to dig the planting hole. Planters' bias, therefore, is significantly reduced. Dibble planting also helps maintain consistency of planting quality between planters. All the tree planter has to do is to make the planting hole, insert the seedling root system, press it down to ensure maximum contact between the roots and soil, and then cover the top of the plug.

In the past, machine planting has been used for bare-root pine seedlings. Although it has not been tried with containerized seedlings, with slight modification, it should work. Machine planting has the greatest potential for establishing eucalyptus stands on abandoned agricultural land and for establishing eucalyptus windbreaks in rangeland.

Postplanting Care

More and more, newly planted seedlings in Hawaii are being fertilized. Generally, about 2 ounces of 10-30-10 fertilizer are placed in a hole made about 4 inches from the seedling. This practice is based on preliminary research.

[6]Mention of herbicides does not imply recommendations for their use, nor does it imply that the uses noted here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

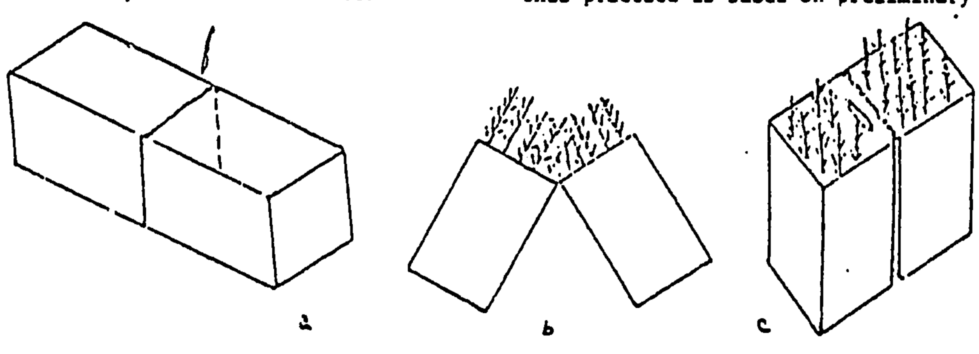

Figure 4.—Seedling packing box is easily converted to seedling carrying box by a) cutting along premarked lines on three sides, and b) folding the box ends together. A precut hand-hold c) makes the box easy to carry.

Seedlings are maintained free of weed competition by chemical and manual methods.

RESEARCH REQUIREMENTS

Now that the technology has been developed, we need to determine the biological requirements for the nursery, transport, and field phases. Containerized seedlings to date have been grown using the "green-thumb" approach. More research is required to develop seedlings with optimum physiological and morphological characteristics in the shortest reasonable time (3 to 4 months) and in large quantities. At present we do not know which seedling characteristics—stem height and diameter, leaf area and number, shoot/root ratio, and stem hardness—are important for high survival and growth rates in the field. Nor do we know how these seedling characteristics are influenced by fertilizer, water, light, temperature, rooting medium, seed cover, mycorrhizae, and nodulation. Further research needs to assess the ranges of site conditions at which 80 percent or more of the planted seedlings will survive and rapidly initiate new growth. Site conditions include light, temperature, wind, and soil moisture. We can potentially modify each site factor by controlling surrounding vegetation. This can be done by windbreaks, seedling maintenance, or by using different harvesting systems. Irrigation systems can also be used to modify soil moisture. Seedling characteristics may be manipulated in the nursery to obtain seedlings that are best adapted to the prevailing site conditions. Although the green-thumb approach has been used throughout the nursery, transport, and field phases of the HDT system, results in terms of survival and growth of field plantings of HDT seedlings have generally been better than those obtained for bare-root seedlings.

The following examples will illustrate why we have concluded that containerized seedlings are the key to successful, reliable forestation in Hawaii.

. Koa (Acacia koa) is a native tree that has wood properties similar to those of black walnut (Juglans nigra). One reason that it is a declining species at present is because koa seedlings cannot be established using the bare-root system. For more than 20 years, little koa planting has been done because survival was too poor to be worth the effort. However, several plantings totaling about 70,000 Hawaii Dibbling Tube-grown seedlings have survived at a rate of about 85 percent. The success of these plantings has generated renewed interest in koa forest management.

. Saligna (Eucalyptus saligna) is an extremely fast-growing species; some trees grow more than 100 feet tall in just 5 years. The wood is valued for pulp and fuel. Survival and growth of field-planted bare-root seedlings are unpredictable. This unpredictability has resulted in a loss of interest in reforesting with this species as well as with other eucalypts. Recent plantings of HDT-grown seedlings have had survival rates of about 90 percent with minimal stem dieback. Plans are currently being developed to establish large-scale saligna plantings for pulp and fuel.

Containerized seedlings are the key to successful forestation in Hawaii; the key to realizing the potential of Hawaii's forest resources in terms of timber supply, wildlife habitat, recreation habitat, extending or improving windbreaks, rehabilitating or expanding native forests, and revegetating erosion scars.

LITERATURE CITED

Walters, Gerald A. 1971. Survival and growth of saligna eucalyptus seedlings treated with a transpiration retardant in Hawaii. Tree Planters' Notes 22(1):2-4.

Walters, Gerald A. 1972. Packing methods studied for Australian toon and slash pine plantings. Tree Planters' Notes 23(4):7-9.

Walters, Gerald A. 1972. Chemical treatment of bare-root saligna eucalyptus seedlings offers no advantages. Tree Planters' Notes 23(4):4-7.

Walters, Gerald A. 1972. Pesticide treatments on saligna eucalyptus, Australian toon seedlings affect dieback, but not survival. Tree Planters' Notes 23(3):16-18.

Walters, Gerald A. 1978. Seedling packing box easily converted into seedling carrying box. Tree Planters' Notes 29(1):27-29.

Section VII

DIRECTORY OF MANUFACTURES AND DISTRIBUTORS OF CONTAINERS

U. S. D. A. Forest Service

RESEARCH NOTE NO. ITF 15

INSTITUTE OF TROPICAL FORESTRY*

RIO PIEDRAS, PUERTO RICO

FOREST SERVICE – U.S DEPARTMENT OF AGRICULTURE

March, 1975

DIRECTORY OF MANUFACTURERS AND DISTRIBUTORS OF CONTAINERS SUITABLE FOR GROWING FOREST TREE SEEDLINGS

compiled

by

Charles R. Venator
Institute of Tropical Forestry
P. O. Box AQ
Río Piedras, Puerto Rico 00928

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*In cooperation with the University of Puerto Rico

The development of mechanized systems for the production of container-grown forest tree seedlings has received considerable attention by nursery researchers during the last 6 years. A variety of containers have been tested; however, few comprehensive containerized systems have evolved. An important consideration is the development of a nursery container which is compatible with mechanized field planting systems. The cost of the container is important, but it should not be the limiting factor in selecting a containerized planting system.

Currently many types of containers are being tested in experimental forest tree nurseries. These containers are manufactured from a variety of materials and range widely in design. Unfortunately, tropical and subtropical countries are isolated from the mainstream of temperate climate containerized seedling research. The paucity of advertisement in tropical nursery literature by container producers contributes to this isolation. Also, there appears to be little personal communication between tropical and temperate climate nurserymen. The compilation of this directory was undertaken to help bridge this information gap.

This directory was compiled by writing to all known manufacturers and/or distributors of containers for forest tree seedling production. Letters were also sent to many individuals working with containerized seedling systems. In almost all instances individuals and manufacturers have cooperated by sending addresses, samples and additional information about particular containers. The Institute of Tropical Forestry is making this information available as received in order that researchers will have a directory which can be used for product information orientation; however, we cannot guarantee its completeness or accuracy. We hope to republish the directory within 12 to 18 months in order to update the listings and to describe new containers as they become available. Any additions or corrections to this directory will be greatly appreciated.

La producción mecanizada de arbolitos forestales, utilizando envases en el vivero, ha recibido mucha atención de parte de los investigadores en los últimos seis años. Se ha experimentado con una variedad de envases; sin embargo, muy pocos sistemas de envase, amplios y comprensivos, han sido desarrollados. El desarrollo de un envase que también sea compatible con los sistemas mecanizados existentes de plantar el arbolito en el campo, es de mucha importancia. El costo del envase es importante, pero no debe ser el factor restrictivo para escoger un sistema de producción por envase.

Actualmente se están ensayando muchos tipos de envases en los viveros forestales experimentales. Estos envases son fabricados de una variedad de materiales y en diferentes diseños. La gran mayoría de los estudios y ensayos utilizando envases en el vivero forestal proviene de los países de la zona templada. La práctica de producir arbolitos en envases es vieja en los países tropicales y subtropicales; sin embargo las técnicas de mecanización del sistema de producción en masa recién utilizadas por los países de las zonas templadas no han sido empleadas en el trópico. El poco conocimiento de estos sistemas en el trópico es en parte una falta de comunicación entre investigadores de ambas partes del mundo. También ha habido muy poca propaganda comercial en los países tropicales sobre los nuevos adelantos y tipos de envases utilizados en la producción en masa de arbolitos. Se espera que este directorio logre cerrar esta brecha de información.

Este directorio fue preparado basado en la información suplida por los fabricantes de envases. Se espera que dicha información sea una repetición fiel de la información recibida por nosotros. De todos modos recomendamos que cada investigador escriba personalmente a cada fabricante para obtener muestras e información adicional sobre los envases descritos en este directorio. De esta manera el investigador podrá orientarse mejor sobre los productos disponibles para la producción en masa de arbolitos en envases. El Instituto de Dasonomía Tropical espera publicar de nuevo este directorio dentro de 12 a 18 meses con nuevas direcciones y más información sobre los envases.

Alphabetical list of manufacturers and/or distributors of containers suitable for growing forest tree seedlings

Lista alfabética de manufactureros y distribuidores de envases para arbolitos forestales

Address Dirección	Common Name Nombre Común	Container Material Material del Envase	Container Volume cm^3 Volumen del Envase	Biodegradable Properties Propiedades Biodegradables	Root Egress Penetración de Raíz
Agritec Co. Inc. 4939 D Milwee Houston, Texas 77018	Polyloam Tree Container	Nutrient enriched synthetic base material	20 - 37	slowly	Yes
Beaver Plastics, Ltd. 12806-63 Street Edmonton, Alberta Canada	Styroblock	Polystyrene foam	35 - 120	No (reusable 2-3 times)	No
Better Plastics, Inc. 2206 N. Main Street Kissimmee, Florida 32741	Test Tube	Polyethylene	variable	No (reusable)	No
Brighton By-Products P. O. Box 23 New Brighton, Pennsylvania 15006	Kys-Kube	Organic-Inorganic mixture	20 - 25	Yes	Yes
Brighton By-Products P. O. Box 23 New Brighton, Pennsylvania 15006	0-903	Phenol formaldehyde with residual phosphates, nitrates and soda ash	20 - 30	slowly	Yes

Address Dirección	Common Name Nombre Común	Container Material Material del Envase	Container Volume cm^3 Volumen del Envase	Biodegradable Properties Propiedades Biodegradables	Root Egress Penetración de Raíz
Colorado State Nursery Foothills Campus Colorado State Univ. Fort Collins, Colorado 80521	Tar Paper Pot (Containers are not commercially available, however, blue-prints for production systems are available upon request)	15 # Tar Paper	variable	slowly	slowly
Columbia Plastics, Ltd. 2155 West 10th Avenue Vancouver 9, British Columbia Canada	Modified Walter's Bullet	High impact polystyrene	15 - 25	No	Yes
Conwed Corporation 742, 29th Avenue S.E. Minneapolis, Minn. 55414	Conwed R Open-mesh plastic tubing	Plastic webs	variable	No (products under development)	Yes
Edmonton Nurseries, Ltd. 13332 - 137th Avenue Edmonton, Alberta Canada	Peat Sausage or Easy Root Container	Low density polyethylene filled with peat	variable	slowly	No
Famco, Inc. 300 Lake Road Medina, Ohio 44256	BR-8	Modified cellulose fiber	20 - 30	Yes	Yes

Address Dirección	Common Name Nombre Común	Container Material Material del Envase	Container Volume cm^3 Volumen del Envase	Biodegradable Properties Propiedades Biodegradables	Root Egress Penetración de Raíz
GASPRO, Inc. 2305 Kamehameha Highway Honolulu, Hawaii 96819	Hawaii Dibbling Tube	Polyethylene	30	No (reusable)	No
Green Thumb Products Corp. Drawer 760 Apopka, Florida 32703	Rack Substratum System 73	Natural and synthetic fibers	variable	Yes	Yes
Jiffy Products of America P. O. Box 338 West Chicago, Illinois 60185	Jiffy-7 peat pellets, strips and pots	Peat	20 - 40	Yes	Yes
Keyes Fibre Co. Horticultural Division Department X New Iberia, Louisiana 70560	Kys-Kube	Organic-Inorganic mixture	20 - 25	Yes	Yes

Address Dirección	Common Name Nombre Común	Container Material Material del Envase	Container Volume cm^3 Volumen del Envase	Biodegradable Properties Propiedades Biodegradables	Root Egress Penetración de Raíz
Lännen Tehtaat Oy Paperpot Department SF-27820 ISO-VIMMA Finland	Paperpot Method, Equipment for the Paperpot Method, consulting service in nursery planning (European distributor)	Special Paper	10 - 650 (approximately 20 different sizes, 3 different qualities)	Yes	Yes
Lännen Tehtaat Oy Paperpot Department SF-27820 ISO-VIMMA Finland	NISULA Roll Plant Method Transplanting machines (European Dist.)	Polyethylene film	variable	No	No
		(For above 2, see also Reid, Collins and United Asia)			
Micro-Plastics Co., Ltd. P. O. Box 844 Guelph, Ontario N1H 6M6	Ontario Tube	High impact polystyrene	variable	No	No
Poly-cast Plastics Route 2, Box 706 Beaverton, Oregon 97005	Cone-tainer	High density polyethylene	variable	No (reusable)	No
Reid, Collins and Associates, Inc. Reforestation Division 550 Burrar Street Vancouver, Canada V6C 2K6	Paperpot Method, Equipment for the Paperpot Method, consulting service in nursery planning (Canadian distributor)	Special paper	10 - 650 (approximately 20 different sizes, 3 different qualities)	Yes	Yes

Address Dirección	Common Name Nombre Común	Container Material Material del Envase	Container Volume cm^3 Volumen del Envase	Biodegradable Properties Propiedades Biodegradables	Root Egress Penetración de Raíz
Rex Packaging, Inc. P. O. Box 18257 Jacksonville, Florida 32229	Polypot	Polyethylene coated paper	200 (square dimensions)	slowly	No
Silvaseed Company P. O. Box 118 Roy, Washington 98580	Styroblock (U.S.A. distributor)	Polystyrene foam	35 - 120	No (reusable 2-3 times)	No
Spencer-Lemaire Industries, Ltd. 9160 Jasper Ave. Edmonton, Alberta Canada	Rootrainers (Equipment for Rootrainers Method also available)	Polystyrene cellulose acetate	30 - 340	No (perhaps reusable)	No
Tri-State Mill Supply Co. P. O. Box 220 Crossett, Arkansas 71635	Styroblock	Polystyrene foam	35 - 120	No (reusable 2-3 times)	No
Union Carbide Corp. Chemicals and Plastics Division River Road Bound Brook, N. J 08805	- - -	Polycaprolactone	variable	Yes (currently in experimental stages)	Yes

Address Dirección	Common Name Nombre Común	Container Material Material del Envase	Container Volume cm^3 Volumen del Envase	Biodegradable Properties Propiedades Biodegradables	Root Egress Penetración de Raíz
United Asia Trading Co., Inc. 3840 Crenshaw Blvd. Los Angeles 8, California	NISULA Roll Plant Method, Transplanting Machine (U.S.A. distributor)	Polyethylene film	variable	Yes	No
United Asia Trading Co., Inc. 3840 Crenshaw Blvd. Los Angeles 8, California	Paperpot Method, Equipment for the Paperpot Method, consulting service in nursery planning (U.S.A. distributor)	Special paper	10 - 650 (approximately 20 different sizes, 3 different qualities)	Yes	Yes
Wood Nursery Division of Crown Zellerbach Route 2, Box 285 Aurora, Oregon 97002	Multiple Pot	High density polyethylene	140	No	No

Section VIII

SELECTED EXAMPLES OF ROOT TRAINERS, MULTI-POT NURSERY TRAYS, STYRO-BLOCKS, JIFFY POTS, COATED CLAY CONTAINERS AND RELATED DRAWINGS

UNITED STATES INTERNATIONAL DEVELOPMENT COOPERATION AGENCY
AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON, D.C. 20523

July 8, 1980

FILE COPY

Wally Turnbull
Mountain Maid l'Artisane
Box 673
Port-au-Prince, Haiti

Dear Wally,

Just a note to ask you the name and address of the manufacturing company that makes the root trainers that you gave Ron Smith. Also, do you remember which of the trainers, the #4 or #5, give the best results?

Thanks, in advance.

Sincerely,

Mike

Michael D. Benge
DS/AGR, Agro-forestation
Rm. 420-B, SA-18

Depends on what you are growing and where. Up here in the mts we get by with #5's which take less mix. In the heat the #4's might be better—

Peace

Wally

UNITED STATES INTERNATIONAL DEVELOPMENT COOPERATION AGENCY
AGENCY FOR INTERNATIONAL DEVELOPMENT
WASHINGTON D C 20523

September 3, 1980

FILE COPY

Mr. Sidney Draper
World Bank
1818 8th St. N.W.
Room D-848
Washington, D.C. 20433

Dear Sid,

Sorry to have taken so long in responding to you. I have been awaiting a USDA paper which gives a complete listing of where root-trainers can be purchased, however, as to this date they have failed to respond.

In the meantime, I have received a letter from a friend of mine in Haiti who has experimented a lot with root-trainers. He has had good success with root-trainers manufactured by Spencer-Lemaire Industries in Canada (see enclosed). In cooler climates, he recommends #5s for less peat moss is required, thus costs are reduced. In the hotter, lower elevations, he recommends #4s.

I'll send you the USDA information when it arrives.

Sincerely,

Michael D. Benge
DS/AGR, Agro-forestation
Room 420-B, SA-18
Office of Agriculture
Bureau for Development Support

Enclosure: a/s

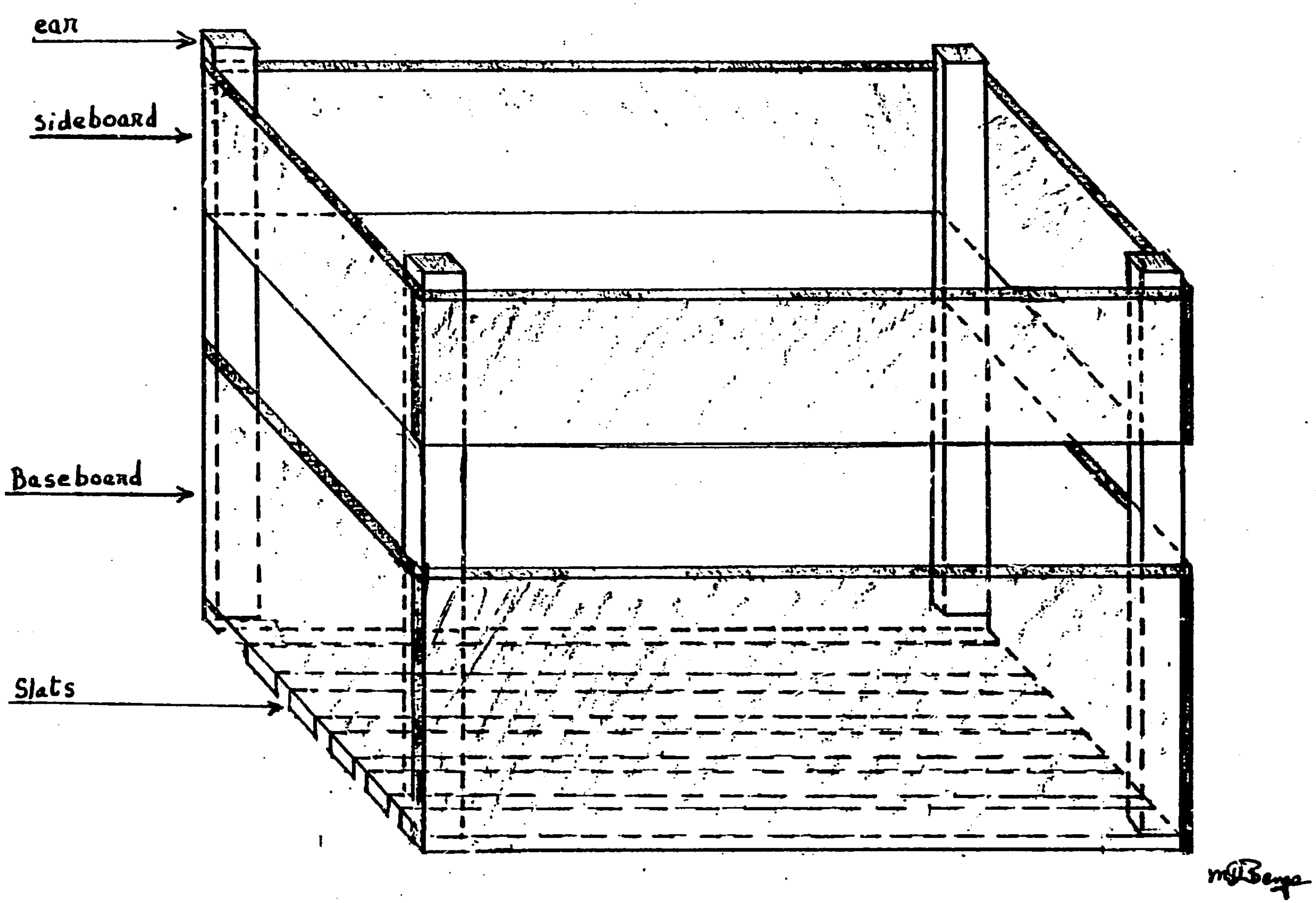


Fig. 1: PACKING CRATE FOR CONTAINERIZED SEEDLINGS

This packing crate is made from local wood. The length and width of the crate is determined by the number of books of root trainers you want to carry in each crate. The four support posts are approx. 4cm X 4cm, and an additional 2cm to 4cm is added for the ears on the top of the posts to facilitate stacking. The bottoms are recessed the same amount to receive the ears when stacking. The heigth of the baseboard should be a little more than ½ the heigth of the root trainer (approx. 10cm X 1.5cm). The sideboard at the top part of the crate is to strengthen the crate (approx. 5cm X 1.5cm). The bottom is slatted to allow drainage. If available, a plastic milk carton packing case works as well.

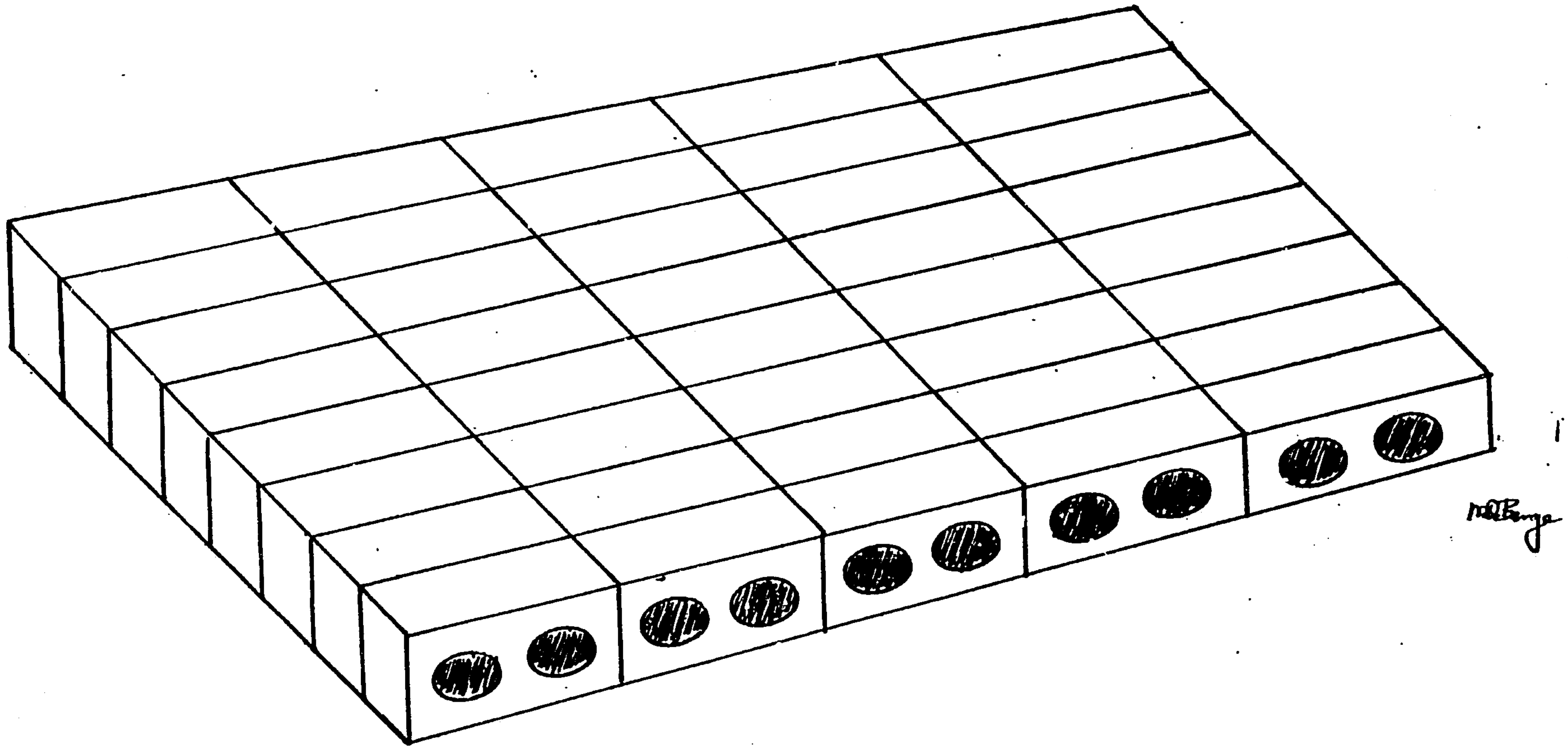


Fig. 2: CONCRETE BLOCK BASE FOR CONTAINERIZED NURSERY

Rather than build racks up off the ground to support containers in which seedlings are propagated in the nursery, a much cheaper and convenient means of support is to build a platform on the ground from concrete blocks. The concrete block base provides good drainage for the seedlings, reducing damping-off and other moisture related problems. The roots which emerge from the bottom of the containers will be adequately air pruned on the concrete block base. A design for a simple fr me to support root trainers is shown in Fig. 3.

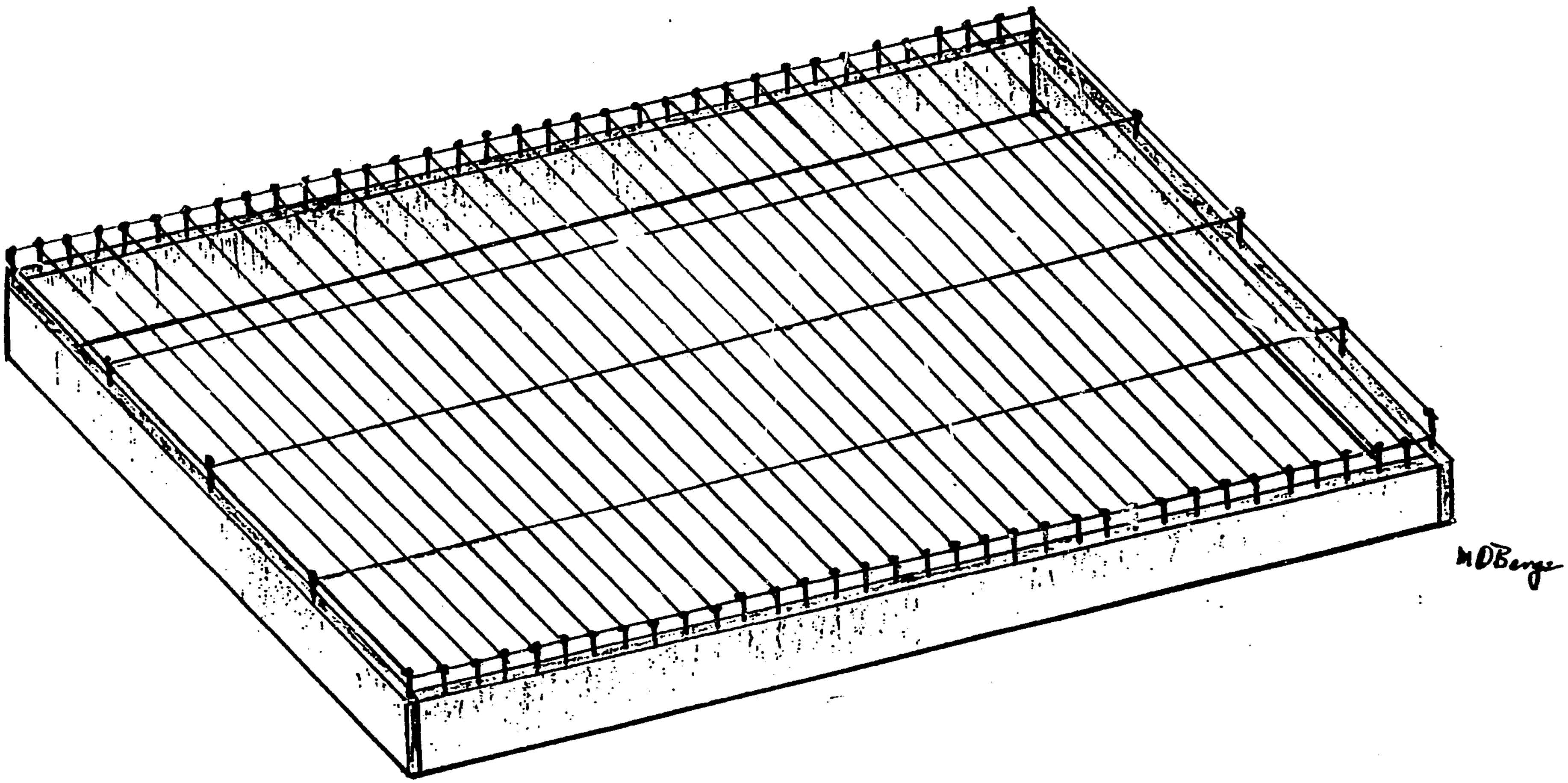


Fig. 3: SIMPLE FRAME TO SUPPORT ROOT TRAINER BOOKS

The frame is made from wood, the heigth should be more than 1/2 of the heigth of the root trainer book (approx. 9cm X 2.5cm). The length and width is determined by the number of root trainer books you want to accomodate in each frome. More often, the width is determined by the ease of watering of and caring for the seedlings in the nursery. Nails are driven in the top of the frame, spaced at intervals determined by the length and width of the root trainer book and allowing adequate space for accomodation. Wire or string is then strung from mail to opposite nail, forming the support for the individual root trainer book. The combined heigth of the frame and string (or wire) should be approx. 2/3 of the heigth of the root trainer book. The frame is placed on top of the concrete block base shown in Fig. 2.

ƽPENCER-LEMAIRE INDUSTRIES .IMITED
EDMONTON, ALBERTA
CANADA

1979 1979

10310 - 112 Street T5K 1N1 Tel. (403) 426-3203

SPECIFICATIONS AND PRICES FOR ROOTRAINERS AND TRAYS

ROOTRAINER "Books": The fold-up ganged cavities for 3 to 6 plants per books are available as follows:

Prices effective June 1, 1979.

BOOK STYLE	VOLUME	NOMINAL SIZE	BOOKS PER TRAY	CAVITIES PER BOOK	CAVITIES PER TRAY	CAVITIES PER CASE	TRAYS REQUIRED PER CASE
Ferdinand	2.5 cu."	3/4"x3/4"x4"	17	6	102	3000	30
Fives	3.8 cu."	1"x1"x4"	14	5	70	2500	36
Hillson	10.5 cu."	1½"x1½"x5"	8	4	32	2000	63
Tinus	21.5 cu."	1½"x2"x7¼"	10	4	40	1000	25
Super 45	45.0 cu."	2"x2½"x9"	9	3	27	300	11

*NOTE: For less than case lots add 2 cents per book for handling costs.

Ferdinands (500 bks./cs. @ 18.5#)

CASES	COST PER CASE	COST PER BOOK
1-49	$40.00	8.0¢
50-249	$38.00	7.6¢
250&Over	$36.00	7.2¢

Fives (500 bks./cs. @ 21.5#)

CASES	COST PER CASE	COST PER BOOK
1-49	$50.00	10.0¢
50-249	$47.50	9.5¢
250&Over	$45.00	9.0¢

Hillson (500 bks./cs. @ 33#)

CASES	COST PER CASE	COST PER BOOK
1-49	$85.00	17¢
50-249	$75.00	15¢
250&Over	$65.00	13¢

Tinus (250 bks./cs. @37#)

CASES	COST PER CASE	COST PER BOOK
1-49	$75.00	30¢
50-249	$70.00	28¢
250&Over	$65.00	26¢

Super 45's (100 bks./cs. @ 19#)

CASES	COST PER CASE	COST PER BOOK
1-19	$65.00	65¢
20-49	$60.00	60¢
50&Over	$55.00	55¢

Standard Folding Trays

Hold the three smaller sizes of Rootrainers: Ferdinands, Fives, and Hillsons. Overall dimensions: 8½"x 14½"x4" high; Metric: 22cm.x37cm.x 10cm. high. Packed 50 per case. Weight 22#.

Folding Tray Prices (50 per case)

CASES	COST PER CASE	COST PER TRAY
1-500	$45.00	90¢
501-2000	$41.00	82¢
2001-5000	$37.00	74¢
Over 5000	$33.00	66¢

Tinus Toters (For 5 Books)

1-100 $1.85 each 101-500 $1.70 each
Over 500 - $1.60 each

Standard Wire Trays

Hold the two larger sizes of Rootrainers: Tinus and Super 45's Overall dimensions: 11¼"x18½"x8" high Metric: 29cm. x 47cm. x 20cm. high. Wire Trays weigh 2# each. 20 per case of 40#.

Wire Tray Prices

1-100 $3.75 to 1M $3.50 Over 1M $3.25

TERMS: Net 30 days from date shown on Invoice on approval of credit.

Prices are F.O.B. SPENCER-LEMAIRE INDUSTRIES LIMITED.

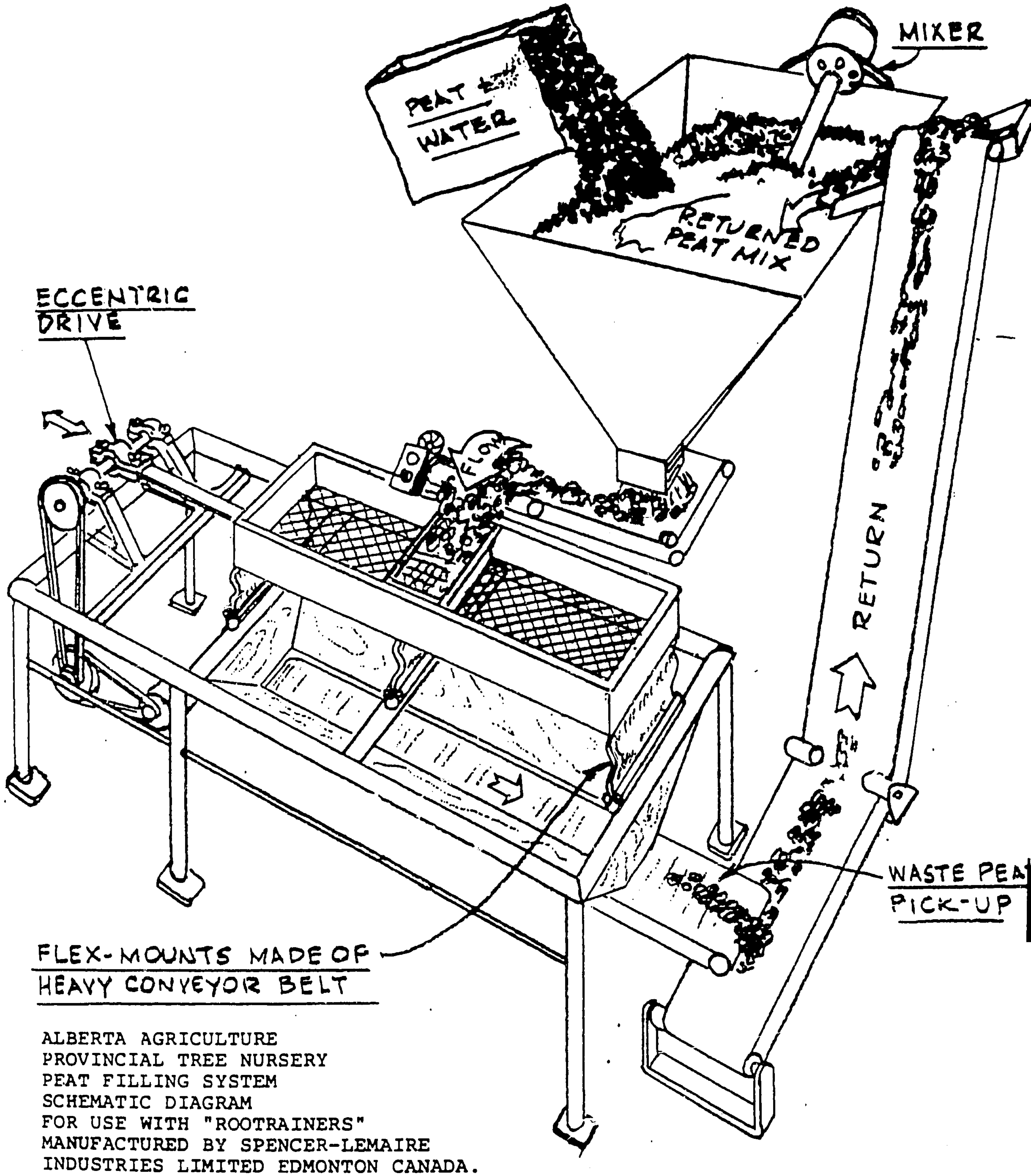
PHOTO PAGE

Single ROOTRAINER - Squeeze gently - and -

the seedling slides out of the Single ROOTRAINER.

ROOTRAINERS have new top lock design - Tinus Size.

Reinforced edges on Folding Tray.



ALBERTA AGRICULTURE
PROVINCIAL TREE NURSERY
PEAT FILLING SYSTEM
SCHEMATIC DIAGRAM
FOR USE WITH "ROOTRAINERS"
MANUFACTURED BY SPENCER-LEMAIRE
INDUSTRIES LIMITED EDMONTON CANADA.

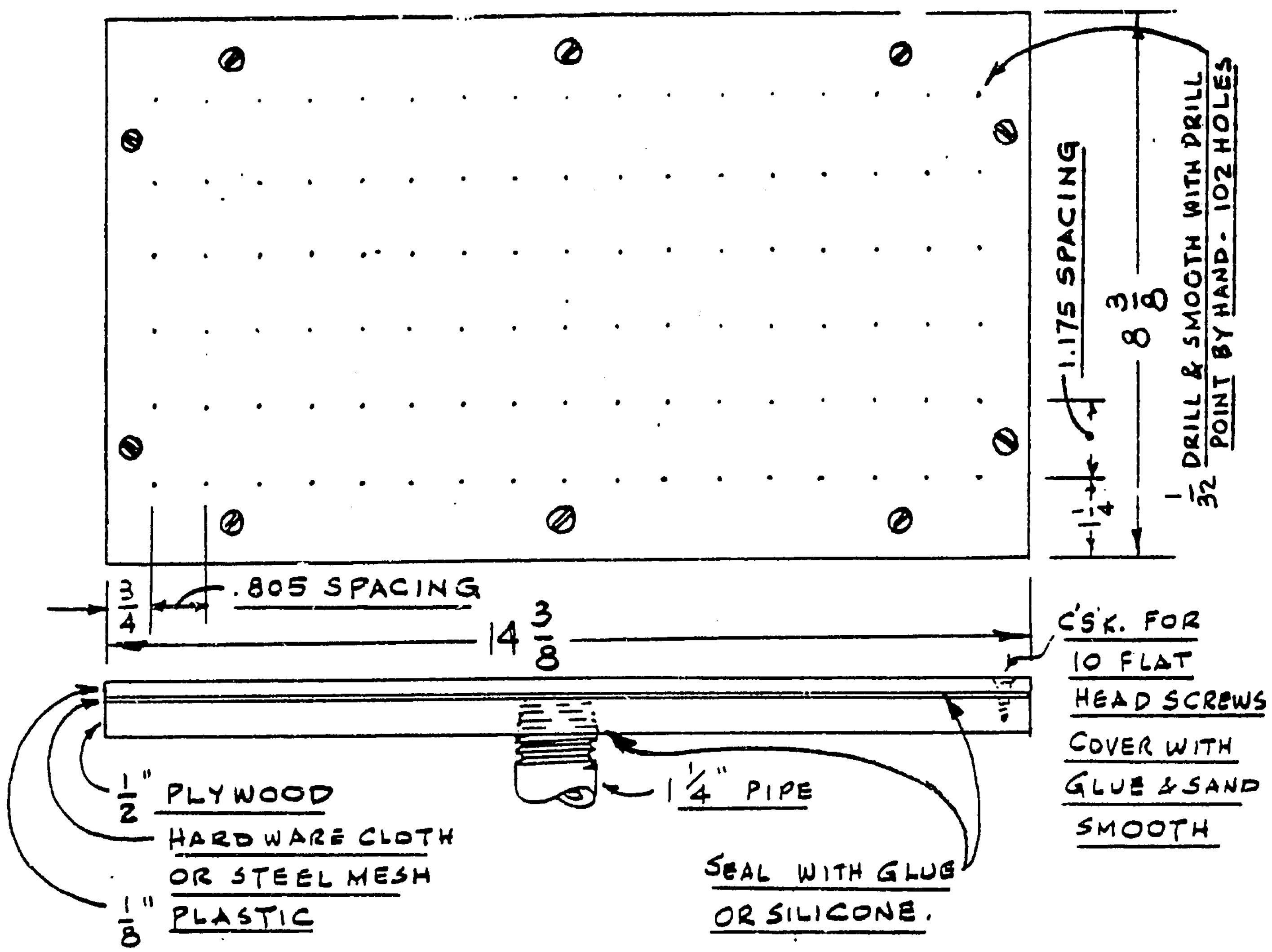


FIGURE 13 — PLAN OF VACUUM HEAD SEEDER

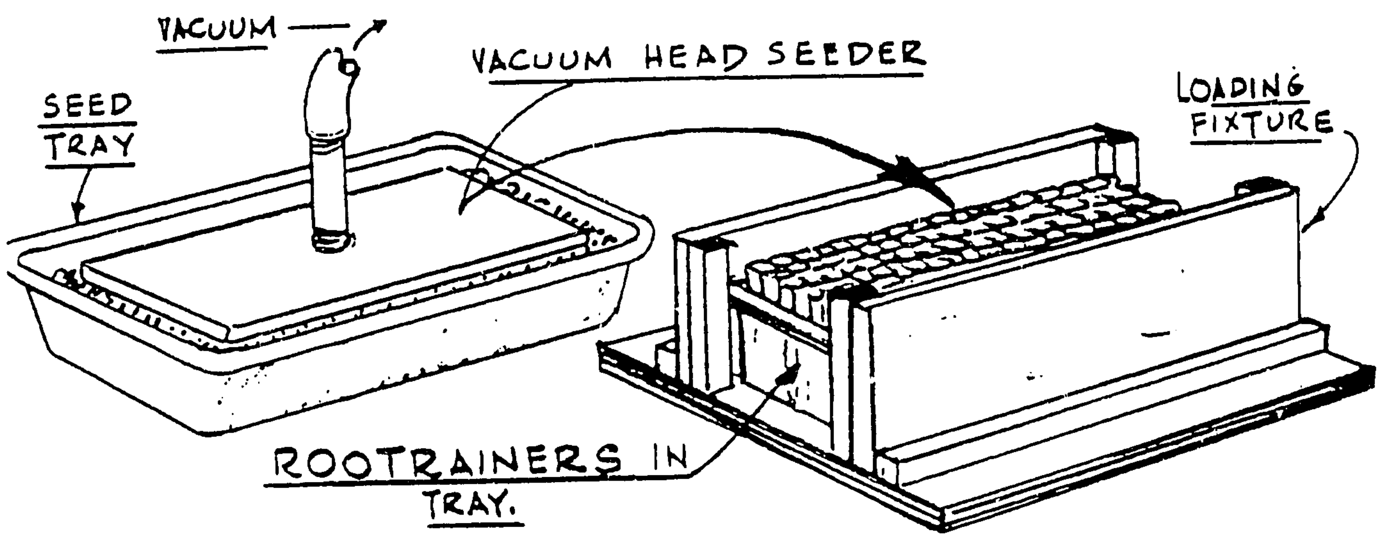
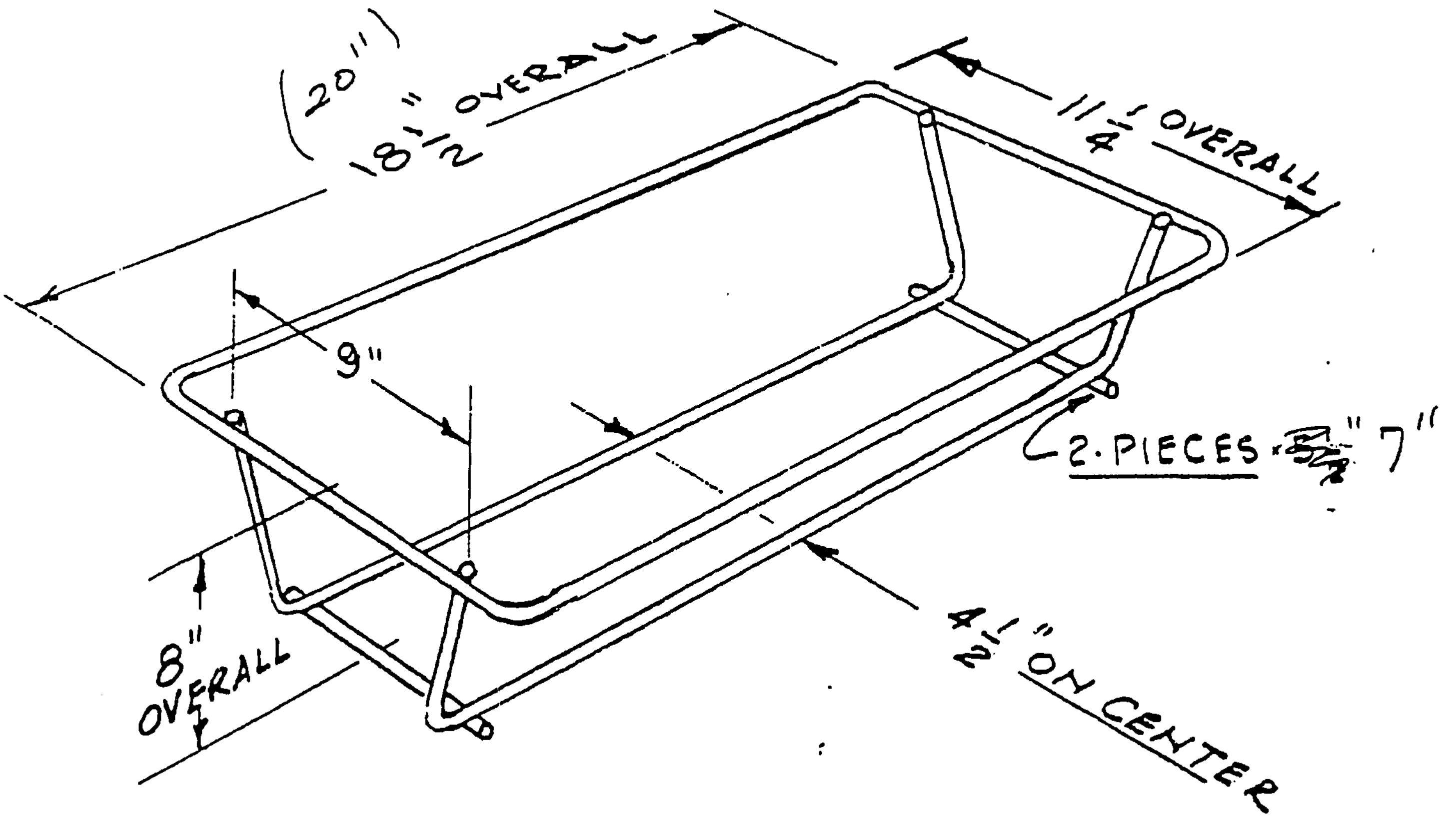


FIGURE 14 — OPERATION OF SEEDING ROOTRAINERS

MATERIAL: STEEL WIRE
DIAM. 1/4" OR 5/16"



SKETCH OF WIRE RACK FOR ROOTRAINERS
10 TINUS BOOKS OR 9 SUPER·45'S

Henry A. Spencer
Jan. 1/76

SPENCER-LEMAIRE IND. LTD. 9160 JASPER AVENUE EDMONTON, ALBERTA

SECTION VII - REVEGETATION, TUBELING PLANT AND NATIVE SEEDING

GENERAL

The general provisions of the contract including general conditions and special conditions apply to work specified in this section.

GENERAL INFORMATION

Materials shall meet the standards and requirements under this specification. The work to be performed under this division shall consist of furnishing all materials, labor, tubeling plants, equipment, seed, supplies and in performing all operations in connection with the installation of tubeling plants (in all species described) and proper native seed mixture in strict accordance with this section of the specifications and applicable drawings.

PLANT TERMINOLOGY AND PLANT QUALIFICATIONS

Plants or plant material having characteristics not conforming to terms as defined will not be accepted. Plant materials or plants refers to all plants, whether woody plants, forbs, herbaceous plants or seed.

Quality and quanity will be determined by the adaquated lead time per specific species and a sured account of its Genus, species and if shown its subspecies characteristics.

All seed is to be from a source on or near the work site or from an eco-type compatible to the work site.

PLANT MATERIALS - TUBELINGS

Plants

Tubeling plants shall be of the Genus, species, sizes and quantities as shown on the plans and matrix in this section. Any plant variations due to availability must be approved by Landscape Architect prior to any germination procedures.

Containers

Disposable, with corregate or ribbed sides, containers are to meet the minimum requirement of 1-1/2" x 1-1/2" x 7-1/2" with soil volume minimum of 14 cubic inches. Containers must be able to support shipping and handling.

Root System

The potting media shall be permeated and bonded by tubeling plant's root system. Plants are not to be root bound and are to be of size and quantity to meet lead time requirements or otherwise specified by Landscape Architect.

Hardening Off and Exposure

All tubeling plants shall undergo "hardening off" by exposure to the natural elements for a minimum peroid of 4 - 6 weeks prior to shipment.

Fertilizer

Fertilizer shall be Agriform Planting Tablets 20-10-5. 21 gram tablets. Sierra Chemical Company-1001 Yosemite Dr., Milplas, California 95035 or equivalent.

Application of Fertilizer

Application of fertilizer shall be inserted into the planting pit (one per plant) with a two inch (2") soil cover and moistened on non-irrigated areas prior to planting tubeling.

Soil Media

Plants are to be grown in an approved soil mix. Peat moss, vermiculite, perlite, bark, sand and natural minerals soils are considered acceptable for soil mixes. The soil must be able to support plant growth and good root development. Any soil variations must be approved by Landscape Architect.

Seed

Seed is to be from a source on or near the work site or from an eco-type compatible to the work site.

CONSTRUCTION REQUIREMENTS

The Contractor shall retain competent supervision on the project at all times when the work is in progress and shall notify The Land Group at least 48 hours in advance of beginning the work on the project.

Planting season may fluctuate depending upon soil moisture, temperature and any site conditions that would hinder the establishment of plant bed. Approximate early start would be September 15, 1979, date of completion is October 15, 1979 in accordance with the computer construction network of Somerset Hollow.

Tubeling plants and related items shall be obtained from sources approved by the Landscape Architect before initial delivery. The Landscape Architect reserves the right to withdraw its approval of sources of supply which do no consistently furnish uniform materials or which furnish materials which prove unacceptable at the time of delivery and the Contractor shall furnish approved materials from other approved sources.

The Department reserves the right to inspect and reject tubeling plants at any time and place. Inspection shall be made at the source of supply with subsequent inspections to be made on delivery immediately prior to planting and after planting is completed. Any unsatisfactory tubeling plants shall be replaced with approved tubeling plants at no additonal cost to the Owner.

Layout of area of seed and tubeling plant locations shall be staked or marked by Landscape Architect. The distribution and configuration of the plant varieties in each section will be reviewed on site with the Construction Foreman prior to any vegetation installation. Any alteration must be approved by Landscape Architect.

Tubeling plants shall be legibly labeled as to genus, species, size and quantity of shipment. A legible copy of the invoice shall be furnished to the Landscape Architect for each shipment.

Planting pits shall be of a size such that the plantable container or the consolidated root system will fit snugly when in place without damage to the root system.

Planting pits may be dug by any approved method.

Where planting pits are dug with an auger and the sides of the pits become plastered or glazed, the plastered or glazed surface shall be scarified.

Planting pits shall be at eleven inches (11") before fertilizer with two inches (2") cover if using same hole or eight and one quarter inch (8 1/4") approximately using example in detail section.

Planting procedure for tubeling plants shall be as follows:

> Tubeling plants shall be furnished at the planting site in a healthy condition.
>
> Fertilizer of the type, formulation and rate of application shown on the plants shall be applied to the bottoms of the planting pits in accordance with the method shown in the specifications.
>
> The tubeling plant shall be inserted into the planting pit such that the top of the potting media is level with the existing ground line. A depression of two inches (2") minimum will be formed around each plant for water retention.
>
> After the tubeling plant is in place in the planting pit, all air spaces shall be filled with approved soil.

SPECIFICATIONS

Tubeling Plants

Plants are to be of the types, classes, sizes, and quantities shown on plans. Tubeling plants are to be aclimated by exposure to the natural elements for a minimum period of 4-6 weeks prior to shipment.

Containers

Disposible, black in color with corregated or ribbed sides, containers are to meet the minimum requirement of 1-1/2" x 1-1/2" x 7-1/2" with soil volume minimum of 14 cubic inches. Containers must be able to support shipping and handling.

Soil Media

Plants are to be grown in an approved soil mix. Peat moss, vermiculite, perlite, bark, sand, and natural mineral soils are considered acceptable for soil mixes. The soil must be able to support plant growth and good root development.

Seed

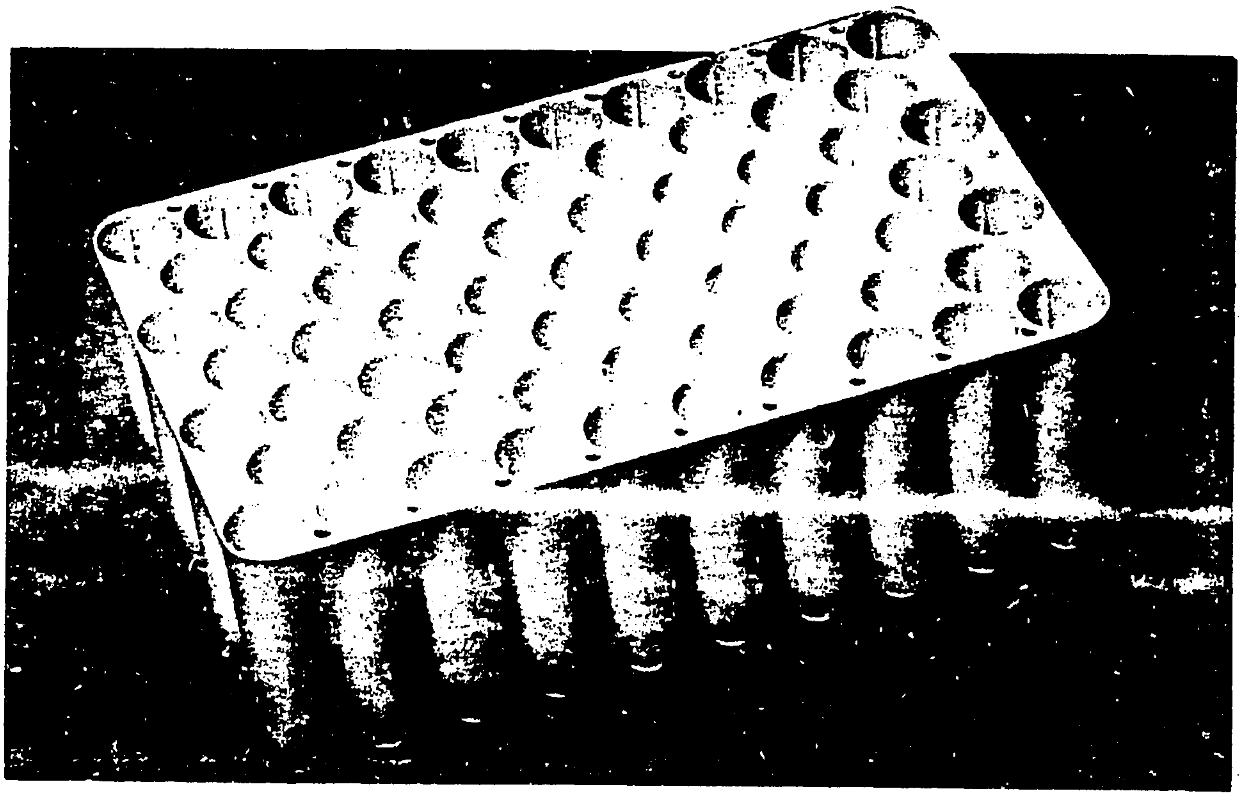
Seed is to be from a source on or near the work site or from an ecotype compatible to the work site.

Root System

Potting media shall be permeated and bonded by tubeling plants' root system. Plants are not to be root bound and are to be of size and quality to meet the architects requirements.

WESTERN MAINE Forest Nursery Co.
Phone 207-935-2161
FRYEBURG, MAINE 04037

MULTI POT NURSERY TRAY



This tray is a rugged reusable unit 8.75" X 14" containing 67 cavities, 1.3" in diameter at the top for seed or cuttings. It is available in two depths. The #1 Multi-Pot is 3.5" deep with a 3.4 cubic inch volume and has three vertical ribs to prevent root spiraling. The #2 Multi-Pot is 4.75" deep with 4.2 cubic inch volume and has six vertical ribs. Each pot is tapered at the bottom to a ½" hole for air pruning. These pots are produced from high density rigid polyethylene for strength and durability with treatment for maximum sunlight resistance. The Multi-Pot units nest for storage and, if protected from direct sunlight when not in use, can be expected to last several years.

Quantity	Prices	
	#1 Multi-Pot 3.5" deep	#2 Multi-Pot 4.75" deep
10-99	$ 2.16	$ 2.81
100-1000	2.11	2.75
1001-2500	2.08	2.71
2501-10,000	2.05	2.67
10,000-up	1.89	2.47

All prices F.O.B. Fryeburg, ME. Sales Tax extra if applicable. Prices subject to change without notice.

Shipping Instructions

To insure that your trees arrive in good condition they will be shipped "best method". For small shipments this is usually United Parcel Service. Shipments by UPS are limited to 50 lbs. per carton and 100 lbs. per day per customer.

UPS Delivery: Residential addresses: if not a street address give specific directions. Box numbers unacceptable for UPS delivery. Business addresses: Street or RR# acceptable. Please include phone number on order blank.

Please select your zone from the chart and forward the indicated amount for the first 100 trees and the same amount for each 100 thereafter. Example: 100 or less, 3 Yr. Red Pine transplants to the 3rd Zone send $1.80. 500, 3 Yr. Red Pine transplants $1.80 x 5 = $9.00.

Large Shipments: Large shipments (usually 500 or more transplants) will be sent Bus or Motor Freight if within 300 miles. Bus or Air Freight is recommended for intermediate distances and Air Freight for distances over 1,000 miles. Large shipments will be sent COLLECT for shipping charges, and your postage remittance refunded to you. Beyond the 3rd Zone bus shipments cost about 50% more than UPS. Air Freight is only slightly higher than bus.

Partial Shipments: It may be necessary to ship part of your order at different times because of the shipping method or digging conditions. Shipment of the balance will be made as soon as possible.

Shipping Seasons

Our **Spring** shipping season is from mid-April to mid-May, and the **Fall** season from mid-September to early November. With notification by October 15, stock can be Fall-dug and stored for shipment prior to April 1. To avoid possible sell-outs of the varieties you want, we urge you to order early. We will acknowledge your order and schedule it for shipment.

Terms

Cash in full with order or 25% cash with order, balance due before shipment. On orders scheduled for Spring shipment, balance is due by April 1. All prices are F.O.B. Fryeburg, Maine, net, no discount. Please give second choice on orders. Maine customers add 5% Sales Tax.

Prices quoted in this list are based on present market conditions and are subject to change without notice.

SHIPPING & HANDLING CHARGES

Add amount listed below for your zone for each 100 trees ordered.

Zone	1-2	3	4	5	6	7	8
Container-grown Seedlings	2.05	2.35	2.75	3.20	3.90	4.60	5.50
Bare-root Seedlings	1.35	1.50	1.60	1.75	1.90	2.20	2.50
3 Yr. Transplants	1.65	1.80	2.00	2.25	2.65	3.10	3.60
4 or 5 Yr. Transplants	3.30	3.85	4.70	5.75	6.90	8.00	9.60

This should be sufficient for UPS or Parcel Post charges; however, any additional shipping costs incurred will be billed.

Parcel Post and UPS Zone Chart

Please include UPS zone in box on order blank.
The chart below shows which parcel post or UPS zone you live in for shipping from Fryeburg, Maine. Simply put the zone number indicated opposite your state in the order blank.

ST	Z	ST	Z	ST	Z	ST	Z	ST	Z	ST	Z	ST	Z	ST	Z	ST	Z	ST	Z
AL	6	CO	7	GA	6	IA	6	MD	4	MO	6	NJ	4	OH	5	SC	5	VT	2
AK	8	CT	3	HI	8	KS	6	MA	2	MT	7	NM	8	OK	7	SD	7	VA	4
AZ	8	DE	4	ID	8	KY	5	MI	5	NE	6	NY	3	OR	8	TN	5	WA	8
AR	6	DC	4	IL	6	LA	7	MN	6	NV	8	NC	5	PA	4	TX	8	WV	5
CA	8	FL	6	IN	5	ME	1	MS	6	NH	1	ND	7	RI	2	UT	8	WI	5
																		WY	8

Please cut along dotted line.

WESTERN MAINE Forest Nursery Co. ORDER BLANK

36 Elm Street, Fryeburg, Maine 04037
Phone: (207) 935-2161

Date ____________

Name ______________________________
Please use peel-off label.

Address ______________________________

City ____________________ State ________ Zip ____________

Tel. No. ____________________ ☐ Please send FREE Copy of Christmas Tree Growers Guide

When calling ask for ______________________________

Use this space for Shipping Address if different from above.

Please type or print clearly. 50 is minimum order of any one size or variety.

Determine your UPS Zone from table and insert here. ☐

QUANTITY	AGE	SIZE	VARIETY	PRICE EACH	AMOUNT

SUBSTITUTION—If we are sold out of a variety may we substitute a similar variety, or size of equal or greater value. ☐ YES ☐ NO

SHIP BY: ☐ Best Way
☐ UPS ☐ Motor Freight
☐ Bus ☐ Air Freight

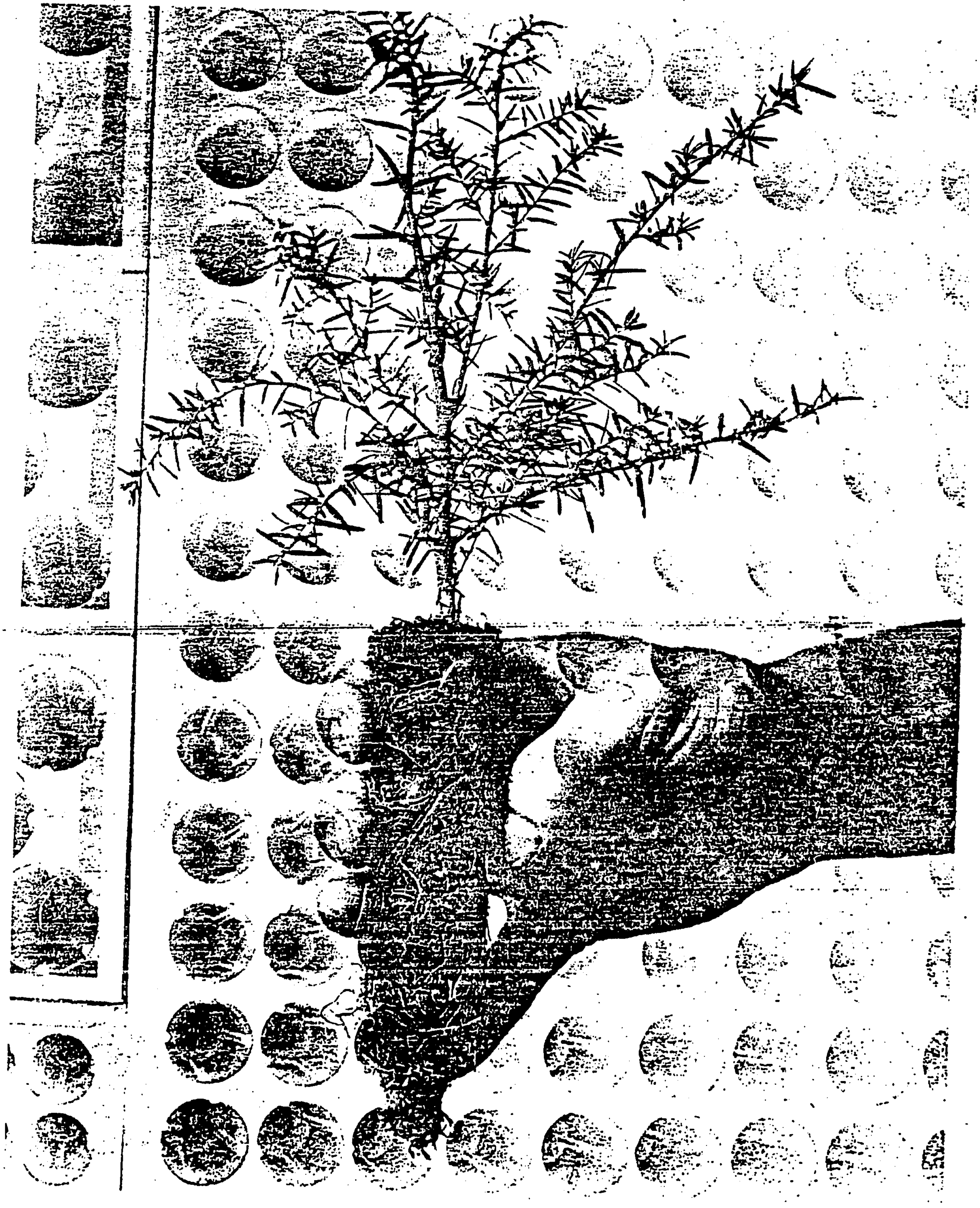
Have you ordered from us before?
☐ *Yes* ☐ *No*

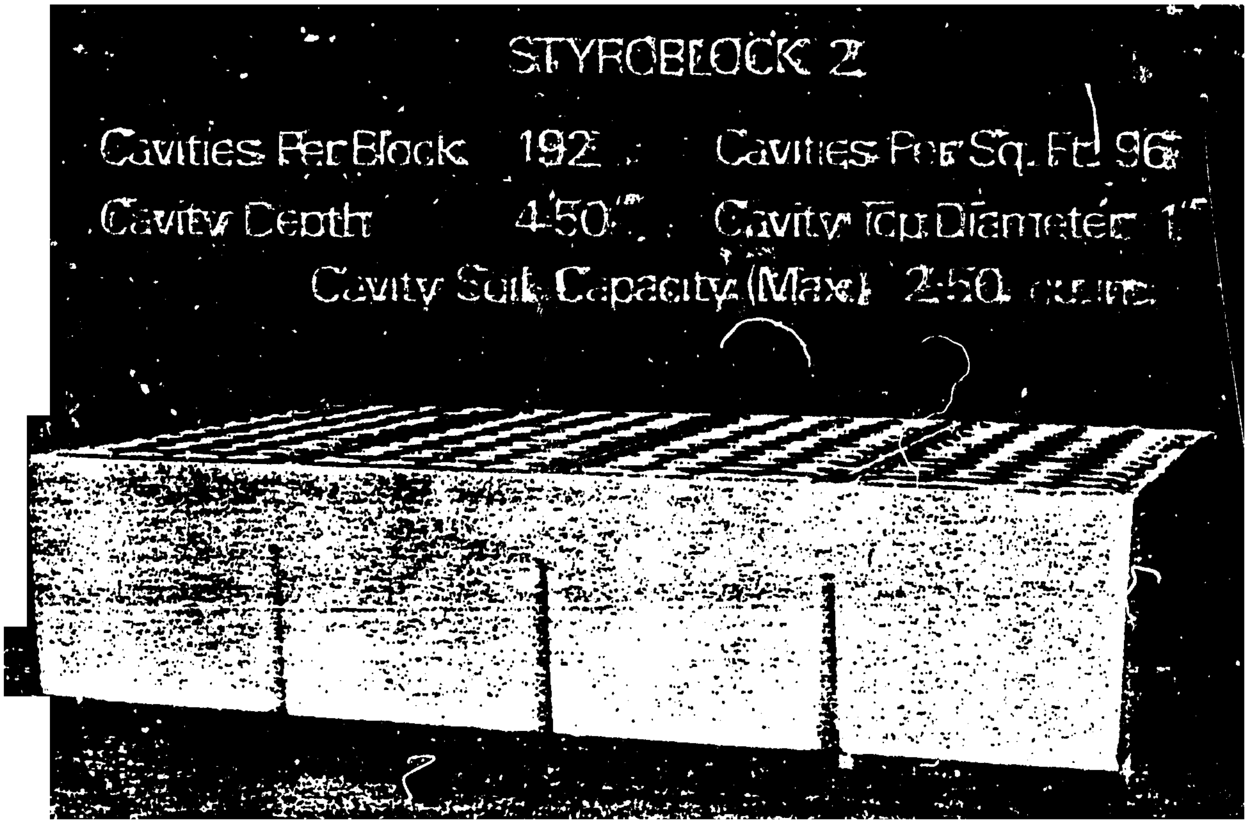
Total Amount of Order	
Me. Customers: add 5% Sales Tax	
Postage & Handling	
TOTAL	
Total Amount Enclosed	

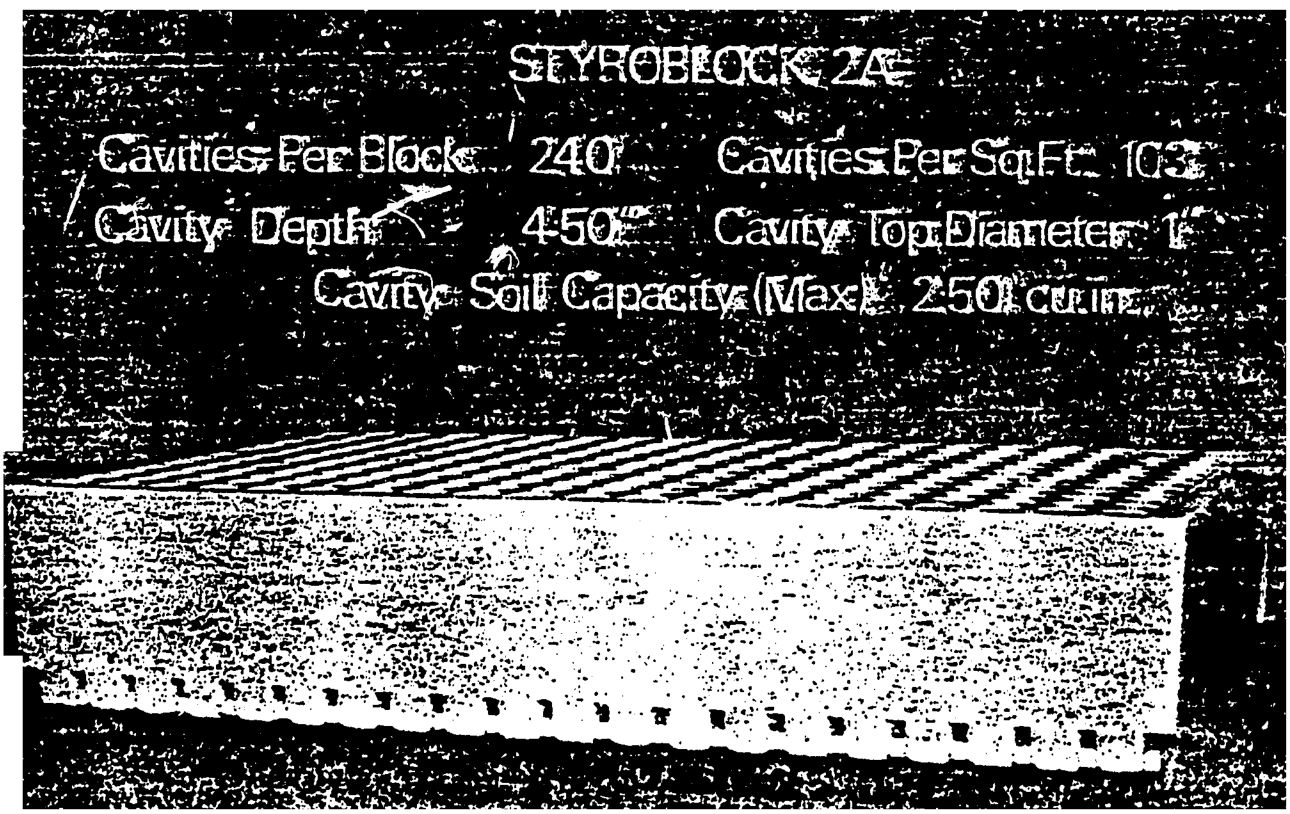
☐ Check ☐ Money Order ☐ VISA ☐ MasterCharge
Credit Card No. ____________
MasterCharge Interbank No. __ __ __ __
Expiration Date ____________

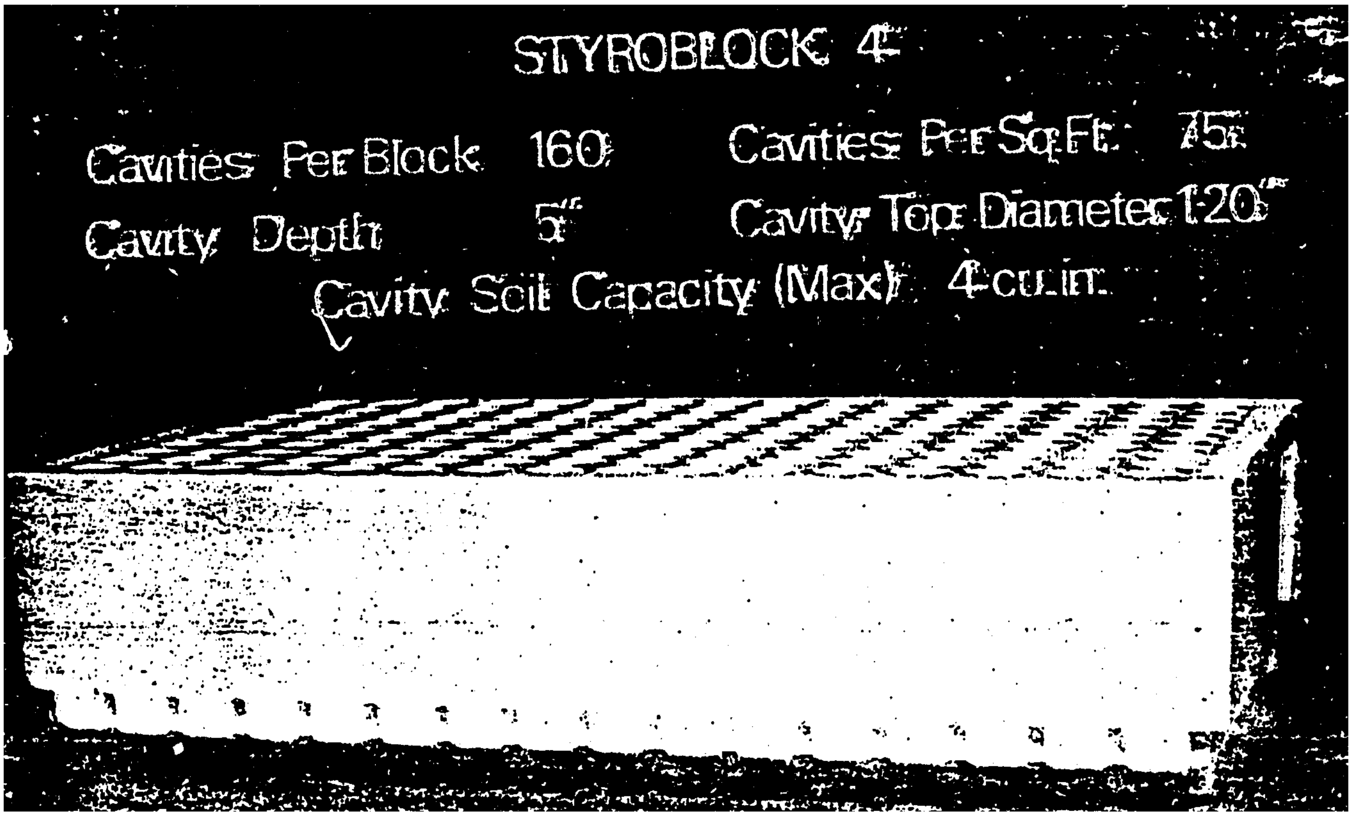
STYROBLOCKS

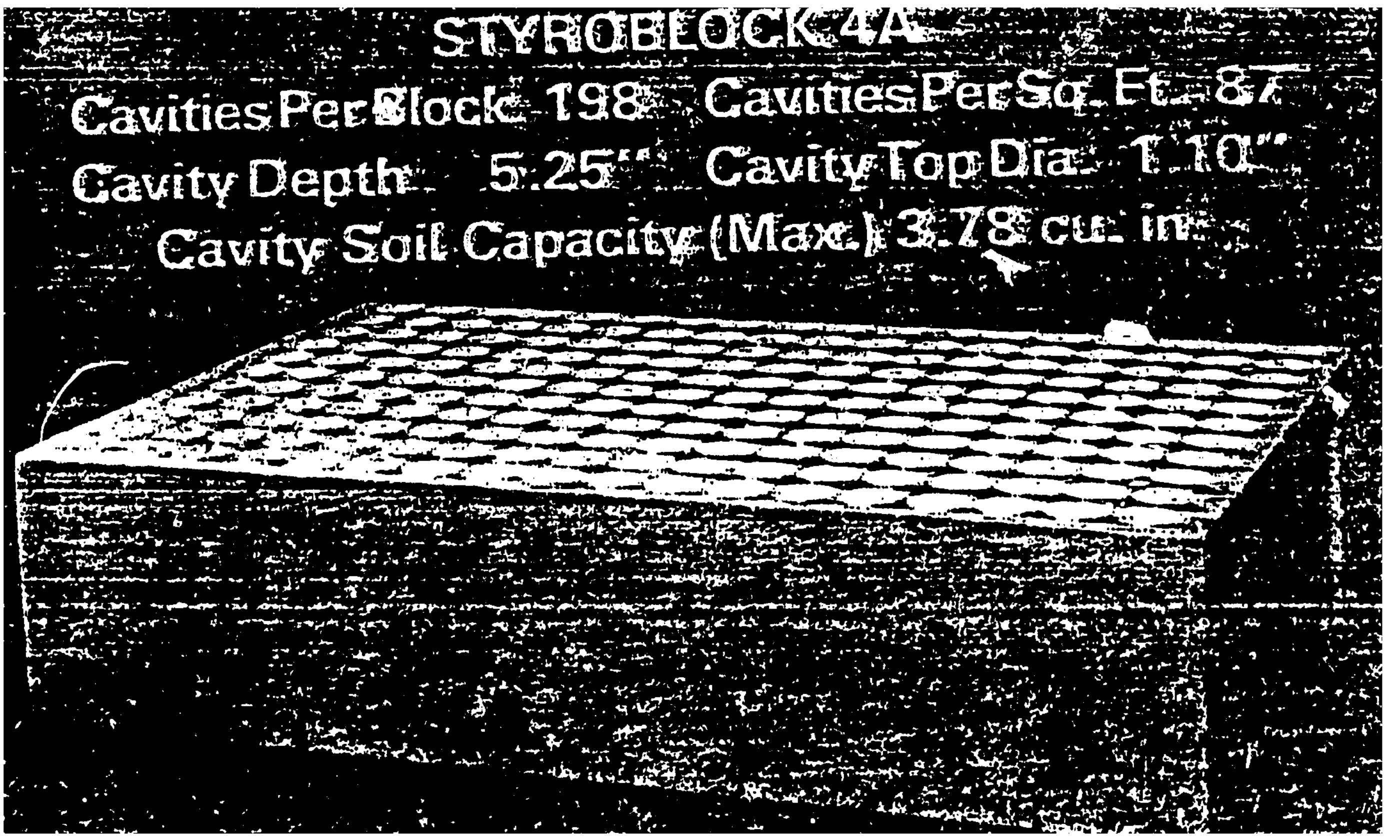
SILVASEED COMPANY
P. O. BOX 118
ROY, WASHINGTON 98580

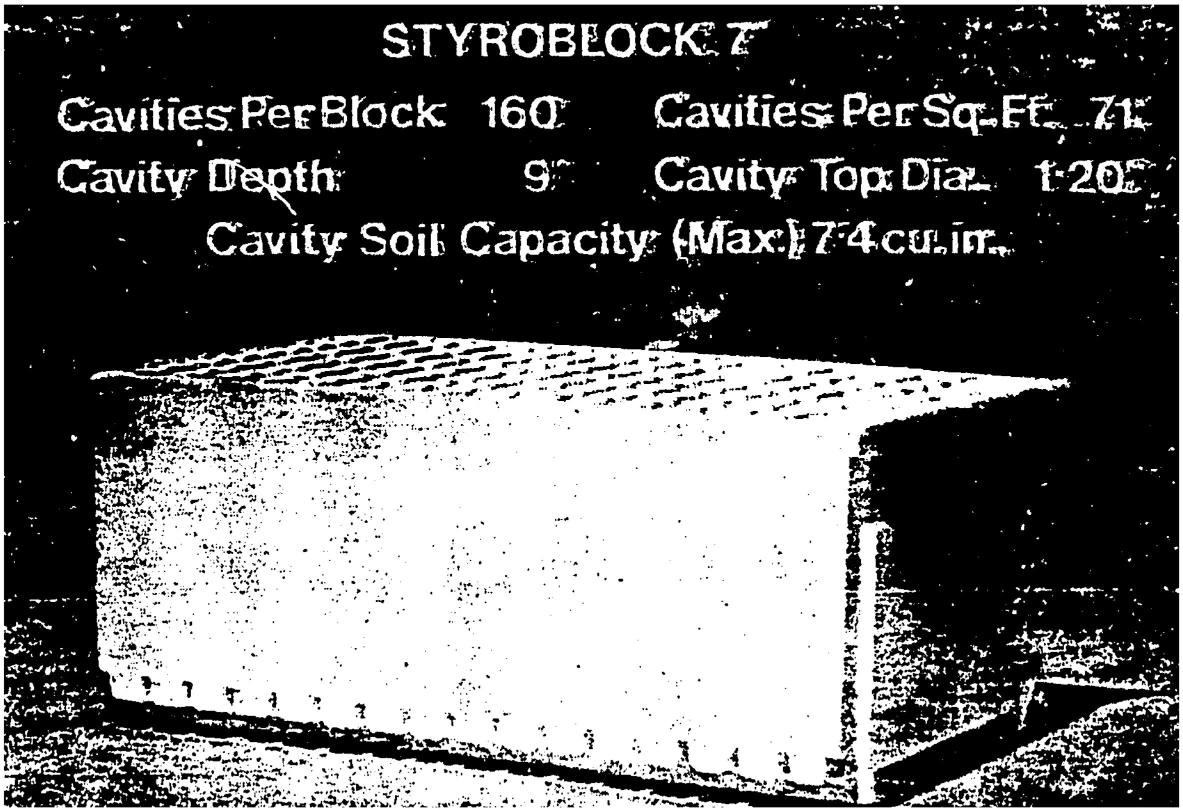


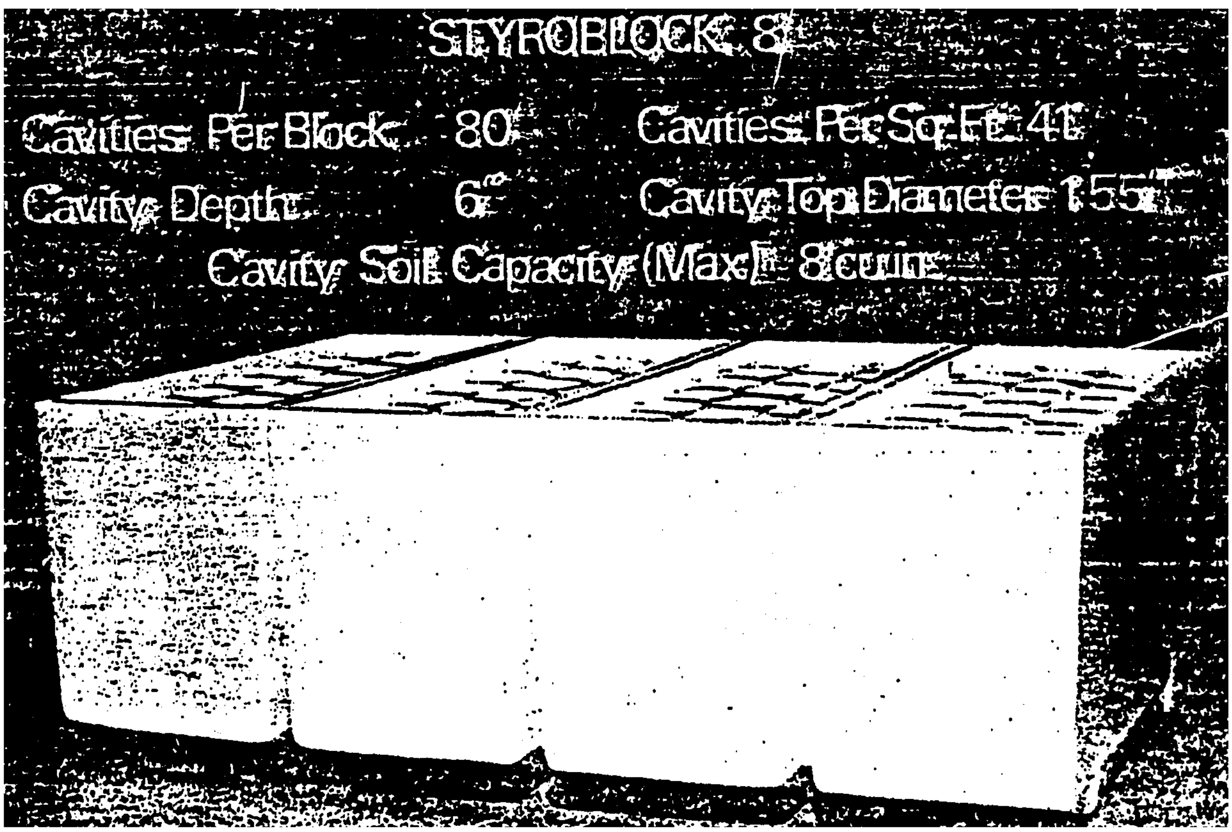

STYROBLOCK 2
Cavities Per Block 192
Cavities Per Sq. Ft. 96
Cavity Depth 4.50"
Cavity Top Diameter 1"
Cavity Soil Capacity (Max) 2.50 cu.in.

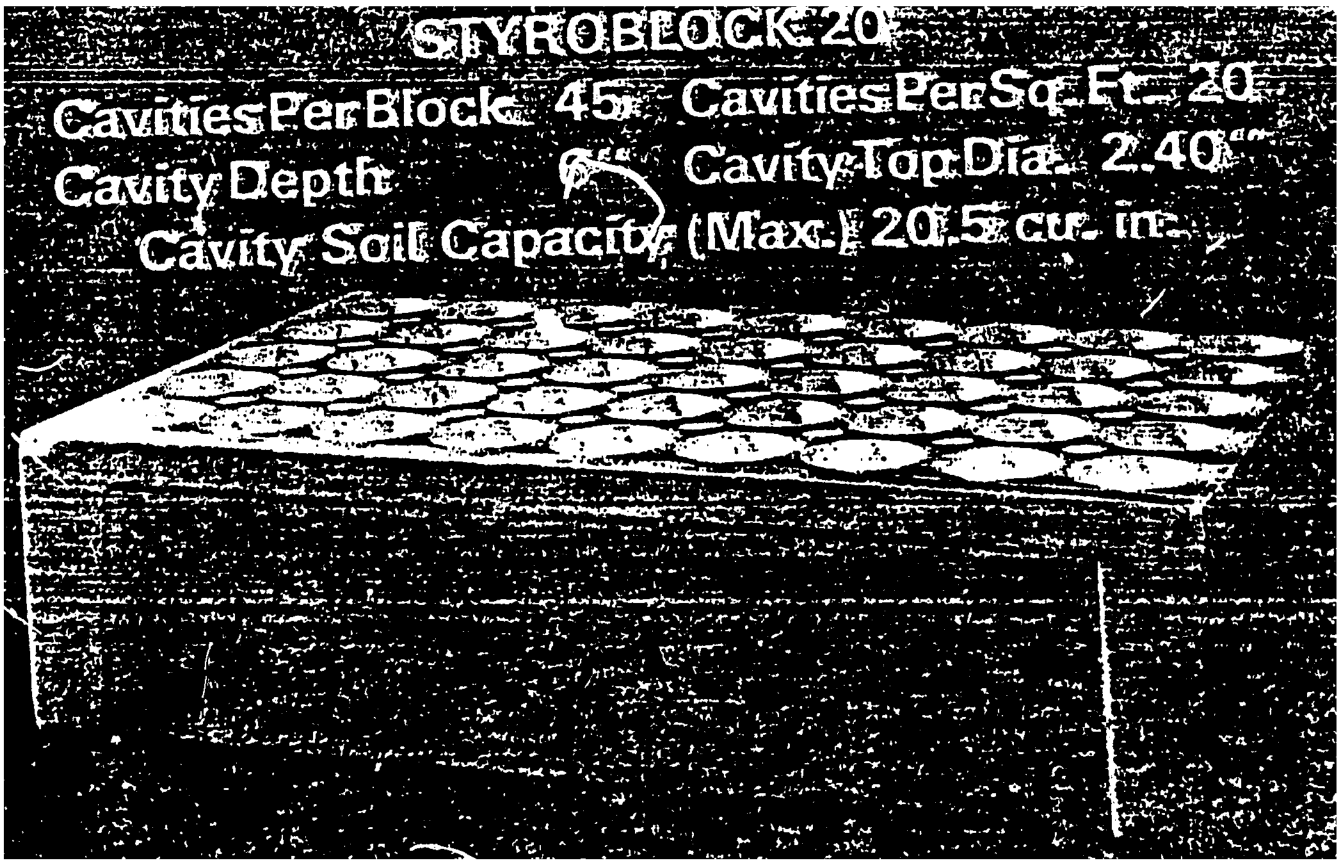

STYROBLOCK 2A
Cavities Per Block 240
Cavities Per Sq.Ft. 103
Cavity Depth 4.50"
Cavity Top Diameter 1"
Cavity Soil Capacity (Max) 2.50 cu.in.

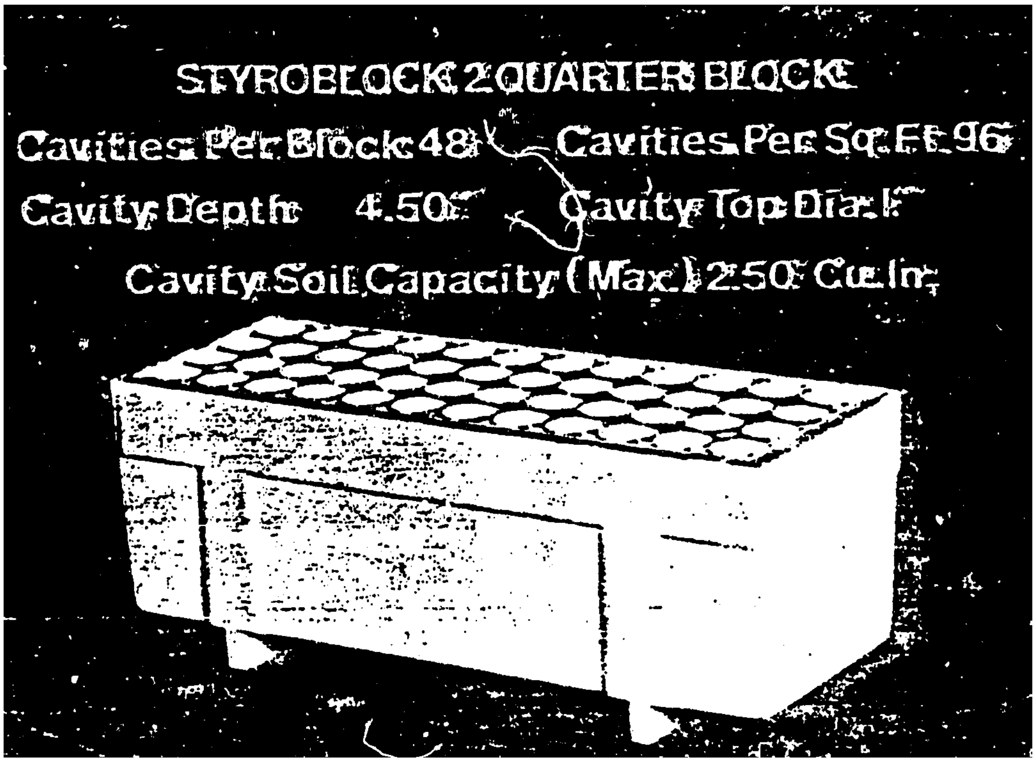

STYROBLOCK 4
Cavities Per Block 160
Cavities Per Sq.Ft. 75
Cavity Depth 5"
Cavity Top Diameter 1.20"
Cavity Soil Capacity (Max) 4 cu.in.

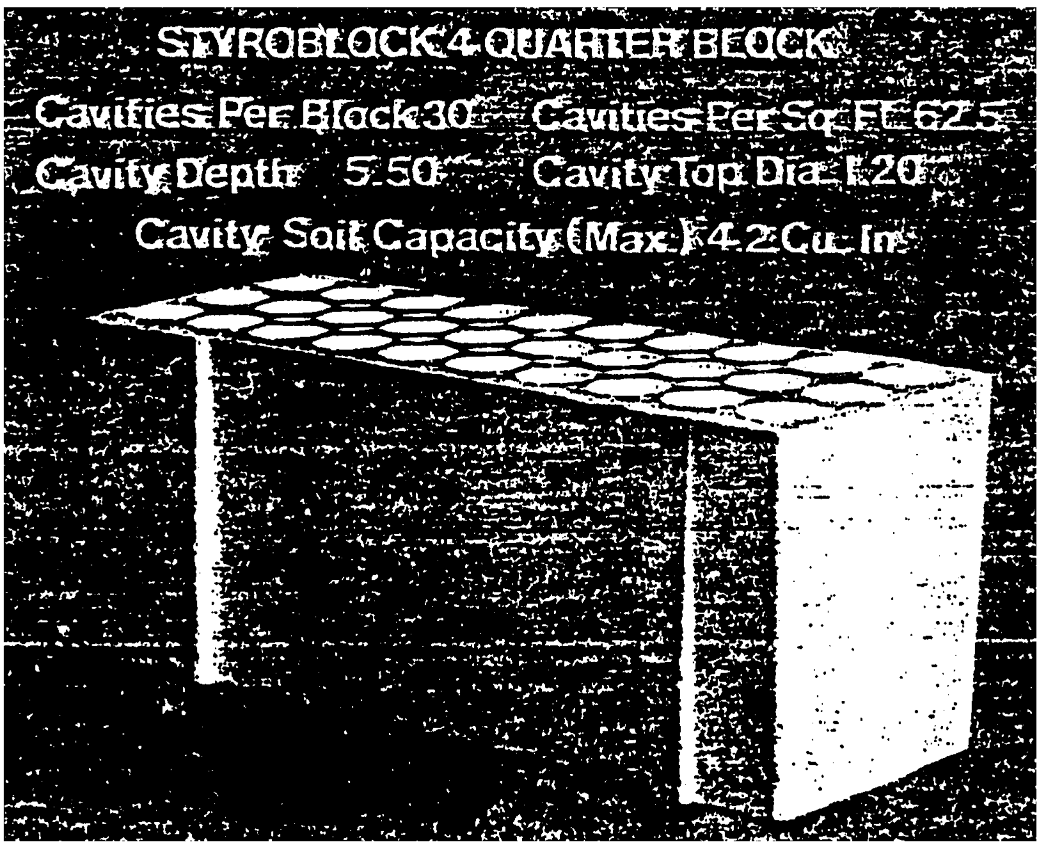

STYROBLOCK 4A
Cavities Per Block 198
Cavities Per Sq. Ft. 87
Cavity Depth 5.25"
Cavity Top Dia. 1.10"
Cavity Soil Capacity (Max.) 3.78 cu. in.


STYROBLOCK 7
Cavities Per Block 160
Cavities Per Sq. Ft. 71
Cavity Depth 9"
Cavity Top Dia. 1·20"
Cavity Soil Capacity (Max.) 7·4 cu. in.


STYROBLOCK 8
Cavities Per Block 80
Cavities Per Sq. Ft. 41
Cavity Depth 6"
Cavity Top Diameter 1·55"
Cavity Soil Capacity (Max.) 8 cu. in.


STYROBLOCK 20
Cavities Per Block 45
Cavities Per Sq. Ft. 20
Cavity Depth 6"
Cavity Top Dia. 2.40"
Cavity Soil Capacity (Max.) 20.5 cu. in.





MANUFACTURED BY BEAVER PLASTICS LTD.
EDMONTON, ALBERTA CANADA

PRINTED IN CANADA

SILVASEED COMPANY
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Roy, Washington 98580
Tel. (206) 843-2246

STYROBLOCKS

PRICE LISTING

AERIAL SEEDING
SEED TREATING
CONTAINER SEEDLINGS
STYROBLOCK CONTAINERS

STYROBLOCK PLANTING CONTAINERS — ALL PRICES F.O.B. ROY, WASHINGTON — PRICES SUBJECT TO CHANGE WITHOUT NOTICE — 2/79

TYPES OF BLOCKS	"2"	"2-A"	"4"	"4-A"	"7"	"8"	"20"	QUARTERBLOCK "2"	QUARTERBLOCK "4"
SINGLE BLOCK	$5.00 each	$5.00 each	$5.00 each	$[illegible].00 each	$6.00 each	$5.00 each	$6.00 each	$5.00 each	$5.00 each
MORE THAN 1 BLOCK BUT LESS THAN FULL BUNDLE	$4.00 each	$4.00 each	$4.30 each	$[illegible].50 each	$5.55 each	$4.50 each	$5.60 each	$1.50 each	$1.50 each
1 - 5 BUNDLES	$3.25 each	$3.60 each	$3.80 each	$[illegible].10 each	$5.25 each	$4.20 each	$5.30 each	$1.00 each	$1.10 each
5 BUNDLES OR MORE	$2.75 each	$3.30 each	$3.40 each	$[illegible].80 each	$4.95 each	$3.90 each	$5.00 each	$0.80 each	$0.90 each
TRUCKLOAD QUANTITY	2,464 approx	2,142 approx	2,000 approx	1,[illegible]32 approx	1,176 approx	1,848 approx	2,250 approx	10,080 approx	8,568 approx
BLOCKS PER BUNDLE (Order Full Bundles)	28	21	21	21	16	21	21	112	84
CAVITIES PER BLOCK	192	240	160	[illegible]98	160	80	45	48	30
CAVITIES PER SQ/FT	96	103	75	[illegible]7	71	41	20	96	62.5
CAVITY DEPTH	4½"	4½"	5"	5¼"	9"	6"	6"	4.5"	5.5"
CAVITY TOP DIAMETER	1"	1"	1.2"	1.1"	1.2"	1.55"	2.3"	1"	1.2"
CAVITY SOIL CAPACITY	2½ cu. In.	2½ cu. In.	4 cu. In.	3[illegible]8 cu. In.	7.4 cu. In.	8 cu. In.	20 cu. In.	2.5 cu. In.	4.214 cu. In.
OUTSIDE DIMENSIONS OF BLOCKS	20-3/8" X 13-7/8 x 5¼"	23-5/8" X 13-7/8 x 5¼"	23-3/8" X 13-7/8 x 5-3/4	2[illegible]-5/8" X 1[illegible]7/8 x 6"	23-3/8" X 13-7/8x9-3/4	20-1/4" X 13-3/4x6-5/8"	13-7/8" X 23-5/8x6-3/4"	13-7/8" X 5" X 5-1/4"	13-7/8" X 5" X 6-1/4"

NOTE: IN ORDERING, ORDER FULL BUNDLES IF AT ALL POSSIBLE.

GIVE YOUR PLANTS A BETTER START WITH JIFFY POTS AND JIFFY PEAT PELLETS

Jiffy Pots and Jiffy Peat Pellets provide you with 3 important advantages:

1. *Improved Quality of Growth.*
2. *Shock-Free Transplanting*
3. *Convenience and Ease of Handling*

⬅ JIFFY POT

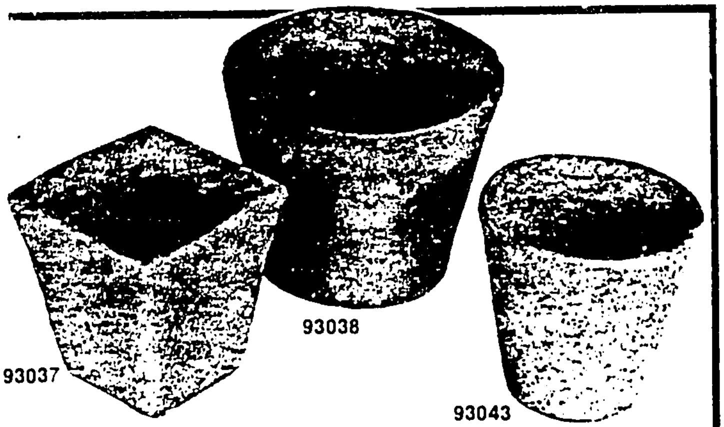
JIFFY PEAT PELLETS ➡

What are Jiffy-Pots?

They are pots made of peat moss whose walls allow roots to *grow right through*, permitting replanting without removing the pot. Jiffy-Pots are made of 70% sphagnum peat moss and 30% virgin wood fiber. They are treated with just enough nutrients to offset the loss of nitrogen from the soil, which results from the breakdown of the wood fiber in the pot walls during the growing period.

What are Jiffy Peat Pellets?

They are small discs of compressed peat which, when watered, expand to form "pellets." Each pellet serves as a growing medium and growing container - all in one. "Jiffy-7" Peat Pellets are encased in a thin net which helps to hold the expanded pellet together. "Jiffy-9's" are not encased in a net. Seeds, seedlings, or root cuttings may be started in Jiffy Peat Pellets.



93038

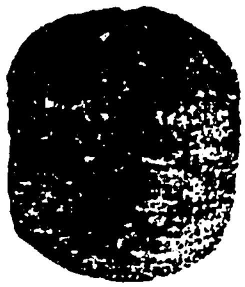
93037

93043

Special features of Jiffy-Pots:

Plant roots readily penetrate the walls.
Highly-porus walls permit plenty of aeration.
Pot walls absorb and hold water for uniform moisture supply.
Light-weight, easy to carry, easy to store.
Completely sterile, disease-free.
Inexpensive and expendable.

A dry Jiffy-7 Pellet.



Add water and the pellet expands. It's ready for planting.

Special features of Jiffy Peat Pellets:

High quality sphagnum peat growing medium.
Peat medium provides balanced aeration, moisture control.
Major and minor fertilizer elements plus lime present.
Eliminates soil preparation, sterilization.
Minimum storage space.
Roots easily grow through net on Jiffy-7.
Two pH levels available (5.5 - 6.0 or 6.0 - 6.3).

ORDERING INFORMATION

STOCK NUMBER	TOP DIMENSION/ SHAPE/ DEPTH	POTS/ CASE	SH. WT./ CASE	PRICE/ CASE
93041	2¼"/square/2¼"	2500	29 lbs.	$67.95
93037	3"/square/3"	1000	28 lbs.	54.95
93043	2¼"/round/2¼	3000	27 lbs.	69.95
93042	3"/round/3"	1500	27 lbs.	60.95
93038	4"/round/3½"	750	33 lbs.	62.95

ORDERING INFORMATION

All Jiffy Peat Pellets are packed 1000/case.

STOCK NUMBER	DESCRIPTION	SIZE DRY/WET	pH LEVEL	SH. WT./ CASE	PRICE/ CASE
93039	Jiffy-7 (w/net) For direct seeding and seedlings	¼" x 1¾"/1¾" x 2-1/8"	5.5-6 0	23 lbs	$56.95
93035	Jiffy-7 (w/net) Pre-drilled for unrooted cuttings.	¼" x 1¾"/1¾" x 2-1/8"	6.0-6.3	23 lbs.	56.95
93032	Jiffy-9 (w/o net) Pre-drilled for unrooted cuttings	¼" x 1¼"/1¼" x 1¼"	5.5-6 0	13 lbs.	34.95
93033	Jiffy-9 (w/o net) Pre-drilled for unrooted cuttings	¼" x 1½"/1½" x 2-1/8"	5.5-6.0	24 lbs	44.95

SEE IMPORTANT INFORMATION PAGES FOLLOWING THE INDEX.

Forestry Suppliers, Inc.

205 W. Rankin St. - P.O. Box 8397
Jackson, MS 39204 TELEX 585-330 FORSUP INC JKS.

MS 1-800-682-5397 24 hours
AK, HI CALL COLLECT 0-601-354-3565 8 am - 5 pm CT

BILL TO: Customer Number ______

TYPE OR PRINT

______

SHIP TO: UPS shipments must have street or highway address.

TYPE OR PRINT

______

Date ______ P.O. No. ______ Authorized Signature ______ Phone ______

PRICES in this catalog were current at press time. If the price of an item you order has increased by a reasonable amount, your order will be shipped and billed at the higher price. If the increase is substantial, we will call or write for your permission to ship at the higher price. If you want to be notified of any increase before your order is shipped, check here ☐.

PAGE NO.	STOCK NO.	QTY.	UNIT ea., etc.	DESCRIPTION	UNIT PRICE	TOTAL PRICE
NOT REQUIRED						

PAYMENT METHOD Minimum Charge Order is $10.00

☐ VISA ☐ MasterCard

If MasterCard, include numbers above your name.

Expiration Date ______ Signature ______

☐ PAYMENT ENCLOSED
☐ CHECK
☐ MONEY ORDER
☐ C.O.D.
☐ OPEN-ACCOUNT CHARGE. See back.

TOTAL	
SALES TAX of 5% on shipments to Mississippi addresses	
SHIPPING & INSURANCE CHARGES (See Back)	
TOTAL AMOUNT	
AMOUNT ENCLOSED, if any	

PLEASE ☒ THE APPROPRIATE BOX

In my opinion my work is best related to the following:
1. Forestry: ☐ Practicing ☐ Research ☐ Education
2. Wood Products Industry: ☐ Wood Production ☐ Wood Mfg
3. Agriculture: ☐ Production ☐ Research ☐ Education
3. Engineering Surveying ☐
5. Utilities: ☐ Electric ☐ Water ☐ Gas ☐ Phone ☐ Sanitation ☐ Oil
6. Mines Minerals Geology: ☐ Location ☐ Production ☐ Reclamation
7. Recreation: ☐ Parks ☐ Wilderness Areas ☐ Museums ☐ Libraries
8. Wildlife Biology: ☐ Practicing ☐ Research ☐ Education
9. Construction: ☐ (Not Eng. or Surv.) ☐ Real Estate
10. Education (Other than above) ______
11. Environmental Protection: ☐ Land ☐ Water ☐ Air ☐ Industry
12. Other: ______

My employer is
1. Government: ☐ Municipal ☐ County ☐ State ☐ Federal
2. ☐ Private Industry
3. ☐ Self
4. ☐ Other ______

Thank you for this order. Each of us at **Forestry Suppliers, Inc.** hopes this merchandise will make your day easier and more rewarding.

Send Catalog 32 (for 1982-83) to:

Name ______
Employer ______
Address ______
City, State, Zip ______

Tear along perforations and enclose attached Order Form in envelope.
THANK YOU FOR YOUR ORDER.

See page 41 for complete details.

SOME BIOLOGICAL AND ENGINEERING DESIGN

ASPECTS OF A COATED CLAY CONTAINER[1]

William W. Elam and Harold A. Koelling[2]

Abstract.--A wax coated clay container is being developed for machine planting tree seedlings. The rigid container is impervious to moisture in the greenhouse but is allowed to soften by absorbing water from rainfall after outplanting. The container appears to be a viable alternative and is superior in many respects to other container systems.

INTRODUCTION

It has been estimated that the demand for wood products from the Southern forests of the United States would double between 1968 and the year 2000 (SFRAC, 1969). The use of containerized seedlings may play a significant role in helping to meet this demand.

A conference on containerized seedlings sponsored by the U.S. Forest Service in Louisiana in 1971 pointed out some of the needs and problem areas with containerized systems for reforestation in the Southeastern United States.[3] A goal of primary importance is a biologically sound container system with which the entire process, from seedling rearing through outplanting, can be completely mechanized. A container which appears to have the potential of attaining this goal is a coated clay container (CCC) currently being developed by the Mississippi Agricultural and Forestry Experiment Station at Mississippi State University.

This paper gives preliminary observations on some of the biological and design aspects being considered in developing the container.

The general design concept is to produce a seedling with automated procedures in a container that can last for an indefinite period under greenhouse conditions and then be machine planted. The purpose of the container then changes at outplanting from a passive containment role in the greenhouse to a beneficial role in the field. The container should not be restrictive in any way on the seedling and ideally, should be an asset to its survival and growth.

Root establishment and growth is paramount to the success of a containerized plant when outplanted, and coated clay containers have the potential for being an asset at this critical period. It is possible to include additives in the body of the tube which can be released at planting and for a period thereafter. This should enhance conditions conducive to rapid root growth in an area immediately surrounding the seedling.

The types and amounts of additives have a wide range because of the material formulation and the fabrication techniques used for the container. For instance, nutrients, phytohormones and even pesticides may be incorporated. This offers the opportunity to formulate containers for specific areas, species and other purposes. The coating prevents the release of the additives in the greenhouse but after outplanting they can be made available for utilization by the plant.

---

[1]Paper presented at North American Containerized Forest Tree Seedling Symposium, Denver, Colorado, August 26-29, 1974. Station Paper No. 2857. Mississippi Agricultural and Forestry Experiment Station, Miss. State University.

[2]Associate Forester and Associate Professor of Chemical Engineering respectively, Mississippi Agricultural and Forestry Experiment Station, Mississippi State University, Mississippi State, MS 39762.

[3]Minutes, Containerized Seedling Workshop, Alexandria, Louisiana, September 8-9, 1971. USDA Forest Service, State and Private Forestry, Southeastern Area.

BIOLOGICAL AND DESIGN ASPECTS

Material and Methods

Two of the commercially most valuable southern species, loblolly pine (Pinus taeda L.) and slash pine (Pinus elliottii Engelm.) seedlings are being used for testing. They are grown for a period of eight to twelve weeks in the greenhouse and then outplanted by hand. The Walters 3/4" x 4 1/2" bullet and the BC-CFS Styroblock 2" containers are being used for comparison with the CCC. The media is U.C. Soil Mix D, 3:1 peat moss and fine-sand, (Baker, 1957). Irrigation in the greenhouse is by overhead sprinklers and fertilization is with Rapid-Gro (23-19-17).

Several configurations of the clay container have been tried. The container presently being used is a round tube 4" x 1" O.D. with 1/8" walls and two longitudinal ribs along the inside surface (fig. 1).

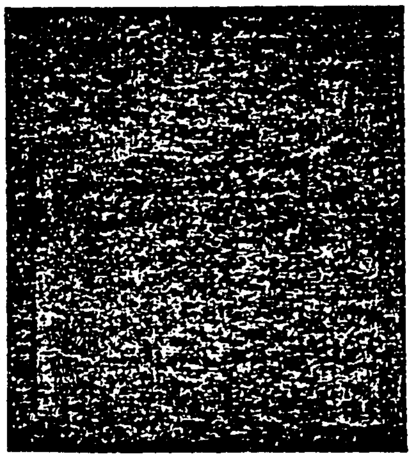


Figure 1.—Uncoated clay containers showing configuration.

The ribs serve a dual purpose. They help prevent root spiraling by orienting roots downward and also facilitate the failure of the inside coating of the tube after outplanting. The tubes are placed in racks which have bottoms of hardware cloth and the roots of the plants air prune.

The base material chosen for the container was a mixture of clay, sand and water. The clay is a readily available Kaolinite called Parkes Ball Clay which has good extrudibility and good green strength. Good extrusion characteristics allow the container tube to be extruded with thin wall sections and good green strength will allow the container to be mechanically handled in the unfired state without breakage either in the greenhouse or during mechanical outplanting.

The coating used was a Ceresin wax with a melting point of 73-78° C. The higher melting point waxes are probably necessary to prevent excessive softening that can occur due to high temperatures in the greenhouse.

The CCC was fabricated with a laboratory model extrusion machine by commonly used extrusion techniques. Coatings were applied by submerging the clay container in a bath of Ceresin wax for various times and temperatures, depending on the desired thickness.

The weight of the CCC is from 45 to 50 grams or about 4 times the weight of the Walter plastic bullet. A possible reduction in weight can be achieved by reducing the wall thickness and also incorporating lighter materials into the extrusion material mix. It is estimated from the cost of the base and coating materials and the low cost fabrication techniques that the cost of the CCC will be from 1-2¢ per container in large quantities.

Results and Discussion

In greenhouse tests to date, the coated container has been satisfactory. It maintains its shape and rigidity, a necessary requirement to facilitate automatic machine planting. Germination and growth in the CCC compares very favorably with the other containers. The wax coatings tried have not been detrimental to seedling development.

Field trials have been initiated but results at this time are inconclusive. In late May a limited number of CCC 12-week-old slash pine were outplanted by hand with a soil auger. A portion of the outer coating of the tube was removed at planting to enable the wall material to absorb water, expand and become soft. Plants in uncoated clay containers were used as controls.

After 3 weeks in the field, roots were well established out of the bottom of the tube. Lateral roots which had grown through the container walls were beginning to appear (fig. 2).

After 4 weeks, survival is 97% for all plants, and lateral roots have grown through the walls of many of the coated containers (fig. 3B,C).

Examination showed roots escape the inner coating, the area of main concern, in three different ways: 1) They can grow through cracks. 2) Root tips can mechanically penetrate the coating material, and 3) Roots can chemically penetrate the coating material. The third type of penetration appears to be the result of a reaction between root exudates and the wax.

In the uncoated containers, lateral roots were well developed through the walls indicating the base clay material is easily penetrated (fig. 3A). The clay material may even be of

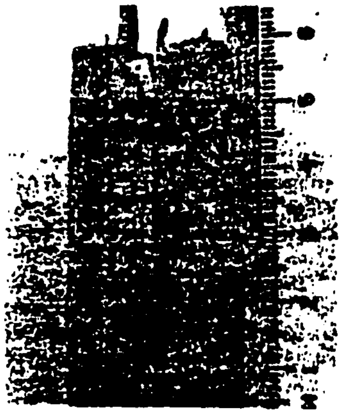


Figure 2.--Container with portion of outer coating and wall removed showing lateral root development.

Figure 3.—Slash pine root development 4 weeks after outplanting: A, Uncoated container; B,C, coated clay container - laterals beginning to appear; D,E, 4-1/2" Bullets.

benefit to the plant by improving the cation exchange capacity of the soil surrounding the roots.

Results indicate that water uptake by the clay is important for lateral root escape from the CCC. After the first moderate rainfall the tubes absorb enough water to expand and become soft. This allows the inner coating to crack, usually along the ribs, allowing root escape. Also, the inner coating is no longer backed up by the hard clay enabling root tips to force their way through the walls of the container (fig. 4). This method of root escape can be of considerable importance with the CCC system if most plants are capable of this, since it allows a more normal root development pattern.

The type of wax appears to be a significant factor for root escape. It is apparent that root tips more easily penetrate some waxes than others. Also, there is no chemical reaction between roots and some types of wax.

Figure 4.—Inner coating of container showing slash pine root tips which have forceably penetrated the wax (X3.5).

As stated previously, for a container system to work most advantageously, from the biological standpoint, the container should not present a handicap to root development. The coated clay container allows lateral root growth and the open bottom allows unimpeded downward root growth thus the container does not appear to be unduly restrictive in this respect.

In the biological and engineering areas of the design studied thus far, the CCC shows promise for a complete container regeneration system that has many advantages with respect to other container systems.

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Question: What prevents the clay containers from disintegrating and roots escaping while still in the greenhouse?

Elam: The wax coating is on both inner and outer surfaces.