Containerized Seedlings: Key to Forestation in Hawaii[1]

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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, planter 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 balledroot 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 production, transport, planting, and high survival and growth rates after field planting.

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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

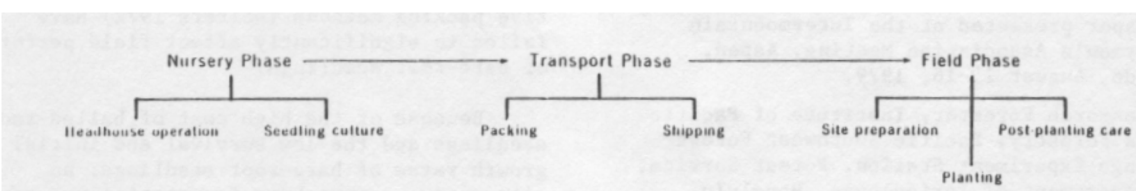

Figure 1.--Forestation phases involved in going from seed in the nursery to established tree in the forest.

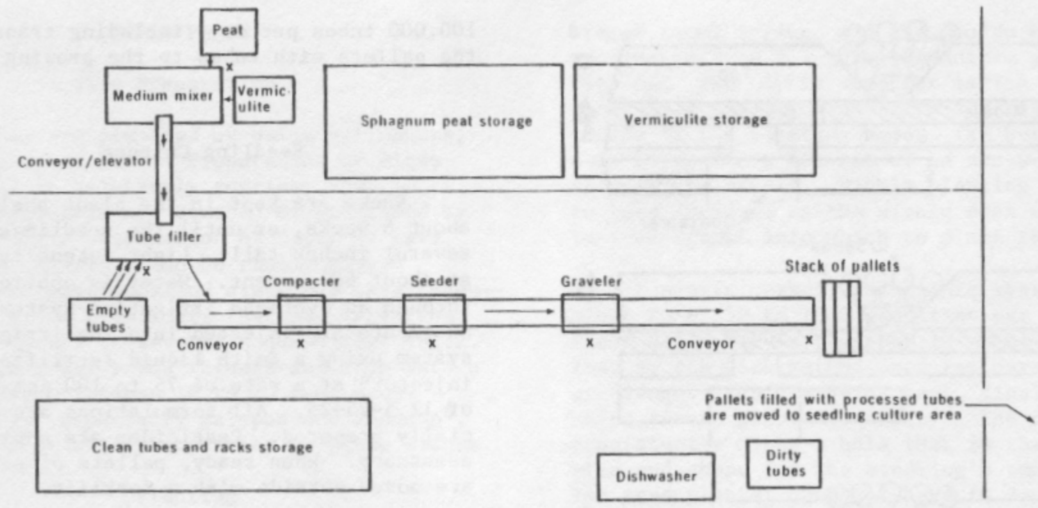

Figure 2.--Layout of headhouse showing storage of materials. and processing equipment for tubes and racks.

(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 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 selfcleaning mixer is opened and the rooting medium falls onto a conveyor-elevator. The rooting medium is carried to a hopper over a tubefilling 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.

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

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.

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

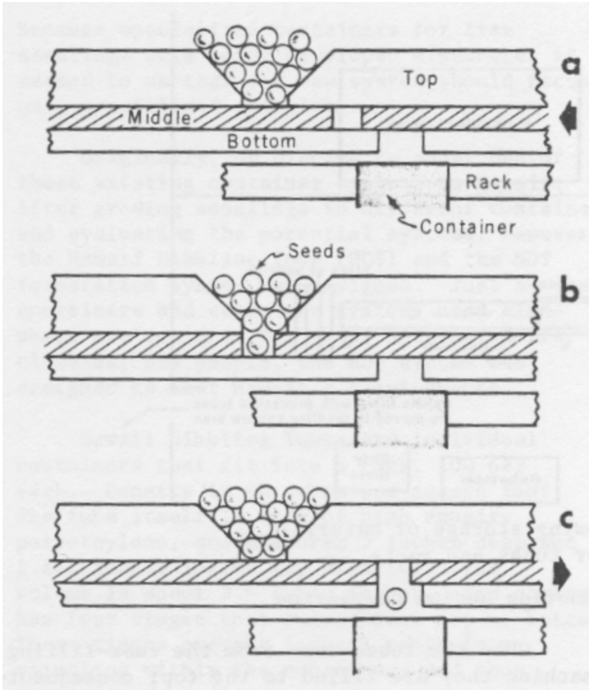

Figure 3.--Schematic of part of the Manual Seeder illustrating its operation: (a) a hole in the top plate is filled with seeds; (b) the middle plate is moved so that hole in it lines up with the hole in the top plate, a seed drops into the hole, (c) then as the middle plate is moved so that the hole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

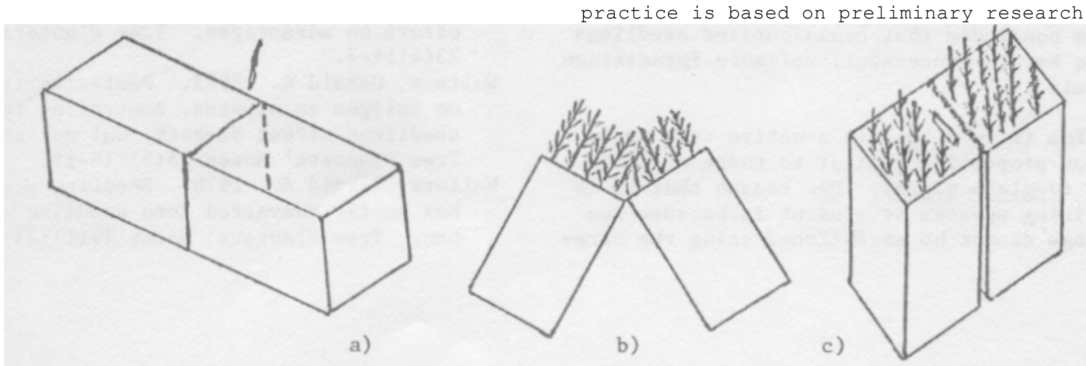

Figure 4.--Seedling packing box is easily converted to seedling carrying box by (a) cutting along premarked lines on three sides, and (b) folding the box ends together. A precut hand-hold (c) makes the box easy to carry.

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 largescale 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.