Comments

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Cover: Mesa Lake (Grand Mesa-UncompaghreGunnison National Forests, Colorado). (Photo courtesy of R. E. Grossman, USDA Forest Service, Collbran, CO)

Reforestation Technical Assistance for the Non-industrial Private Forestland Owner — Opportunity Knocks

With the recent shift in timber harvesting from Federal lands to private lands — especially to non-industrial private forestlands (NIPF) — nursery and reforestation workers have a tremendous opportunity to inform landowners regarding the best way to harvest and reforest their land. Historically, only about 10% of all NIPF owners avail themselves of technical assistance on preharvest planning for a timber sale and subsequent reforestation activities. Reasons include lack of agency technical assistance funds, hesitancy to accept Federal funds because of concerns about property rights, and possibly, a lack of multi-resource focus on the part of some public agencies. (Those reasons are the topic of another editorial-any takers?) What I would like to focus on now is the positive opportunity we have now to reach new landowners.

With the price of stumpage on an upward trajectory in all parts of the nation, many landowners are taking a more active interest in their forests, especially as a source of needed revenue. We professionals should make good use of this increased economic incentive to help landowners with their reforestation activities.

We are not implying that landowners are not doing an adequate job of reforesting their land or that there is this big backlog of unreforested land! But we are saying that we could take this opportunity to reach out to new landowners and inform them of the latest technologies and reforestation systems that are available. We have better information on all fronts-seed quality, seedling culture and storage, planting techniques, and preharvest planning. Informed landowners can make better decisions about what to ask for when they buy seedlings and what to look for when they plant them.

Many timber companies and private consultants are working with landowners to provide technical assistance; we support and encourage these efforts. We all need to work together in this effort to reach NIPF owners.

The development of the Forest Stewardship Program of the USDA Forest Service and State Foresters is another effort that is reaching out to new and existing NIPF owners. This program helps landowners with multi-resource options to manage their land. Making use of new or previously under-used plant species to accomplish various land-management objectives is a key activity of this program. For example, non-traditional species will be increasingly used in projects promoting wildlife habitat, recreation, ecological restoration and biodiversity projects, and streamside management efforts. We also need more information on proper planting techniques for these "new" species.

We expect this increased level of interest by NIPF regarding all phases of forestland management to continue in the future. As forestland owners, the NIPF sector owns 45% of all forests and 57% of all commercial timberlands in the United States. The role of NIPF's in supplying the nation's multi-resource needs is critical. We need to reach more NIPF's through a concerted effort to expand technical assistance and provide incentive programs and education.

Now is a great time for agencies to take a fresh look at their reforestation technical assistance programs and outreach strategies. Even if we double the percentage of landowners we are currently reaching, we will still have 80% of the 8 million NIPF owners managing their land without professional help! What a great opportunity!

Robert Mangold
Editor-in-Chief, ***Tree Planters' Notes***
Cooperative Forestry

Treatment of Container Seedlings in the Nursery Against Large Pine Weevil

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An experimental tunnel sprayer for treating seedlings with insecticides against the large pine weevil-Hylobius abietis *(L.)-was built and tested at the Suonenjoki Research Station and Nursery. The goal was to achieve an efficient and effective system for distributing insecticide that is also safe for the operator. Permethrin was distributed over about 80% of the seedling shoot when the inventory method was used for determination, but over 100% according to a visual check. Treating 1,000 seedlings cost $1.40 for labor and $4.21 for total costs. Treating seedlings was more efficient and economical at the nursery than at the planting site. The workers' exposure to permethrin was far below the 5-mg/m^3 limit in Finland. The measured contamination of the hands and protective clothing confirmed that the correct use of personal protective equipment in pesticide work is necessary.* Tree Planters' Notes **45(1):5-9; 1994.**

Several methods are used in combating the large pine weevil, *Hylobius abietis* (L.): either mechanical plant guards or chemical treatment of seedlings with insecticide. It is common to treat bareroot seedlings in the field by having the planter dip the seedlings individually into the chemical solution, shoots first, up to their root collars. This is considered to be an effective protective method. The treatment of container seedlings in the field before planting is not common. However, in nurseries, mass treatment using tunnel equipment or tractor sprayers constructed for this purpose is becoming more common. In some nurseries, both bareroot and container seedlings are sprayed at the nursery.

Since the banning of lindane, synthetic pyrethroids have been used increasingly in the protection of seedlings against pine weevil. Permethrin is a common pyrethroid-based product for this purpose. Permethrin is absorbed into the human system through the alimentary tract and to a lesser extent through the respiratory tract. Absorption through the skin is regarded as insignificant (Elliot et al. 1976). Permethrin has caused skin and eye irritation to operators who have been exposed to it (Kolmodin-Hedman et al. 1982a).

We hypothesized it would be safer and possibly cheaper to treat seedlings in the nursery and so decided to build and test a machine for this purpose. The equipment used in the study was built at the Suonenjoki Research Station and Nursery. The aim was to achieve an effective system (work productivity and evenness of insecticide distribution) that is capable of treating different container seedlings against pine weevil (figure 1). The working principle of the unit is shown and described in figure 2.

Materials and Methods

Research equipment. The tunnel was 2.8 m long and 1.2 m in maximum width; it weighed 220 kg. The unit was built on wheels to improve mobility. The capacity of the spray tank was about 300 dm^3 and the spray nozzles were of fan type. The unit worked from a 380-V power supply. The seedlings were treated by 2 workers, one to feed boxes into the machine and the other to take them off the conveyor and placing them on the ground or onto a pallet. A seedling box was placed on the conveyor in a normal position. Clamps on both sides of the box held it in place during spraying. Inside the tunnel, the box was tilted to a near vertical position (about 75°) to reduce the amount of pesticide solution flowing onto the growth medium (peat), that is, when tilted, the pesticide drips off the seedling by force of gravity onto the floor of the unit. The spraying took place in an enclosed space.

The unit was used to treat 1-year-old container pine seedlings. The pesticide used was a water-soluble spray powder, F-permethrin (active ingredient: permethrin, cis/trans isomeric ratio 25:75 and LDS_{50}-value of about 6,000). The concentration of the spray solution was 2% (that is, 0.5% active ingredient).

Pesticide distribution and coverage of seedlings. The pesticide distribution and coverage of the seedlings was determined using a herbicide coloring agent in water. This solution was sprayed onto seedlings, around which Kromekote® paper had been wrapped at a height of 50 mm from the surface of the growing

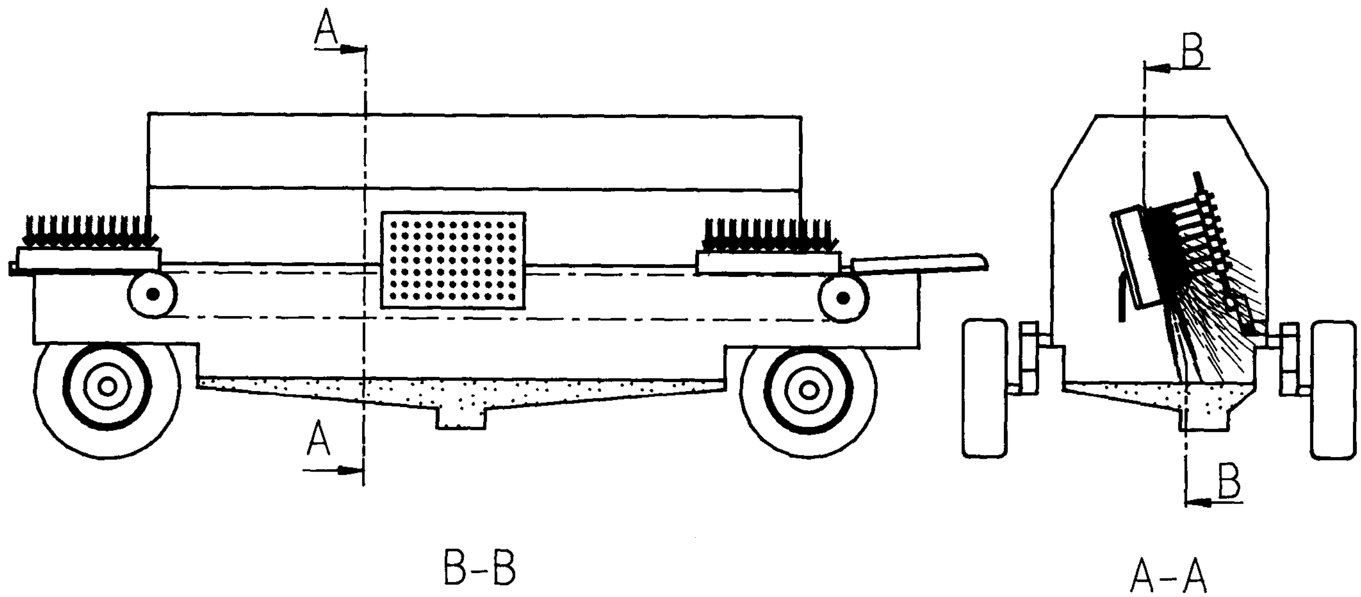

Figure 1—*Tunnel sprayer, built at the Suonenjoki Research Station and Nursery, for protection against large pine weevil.*

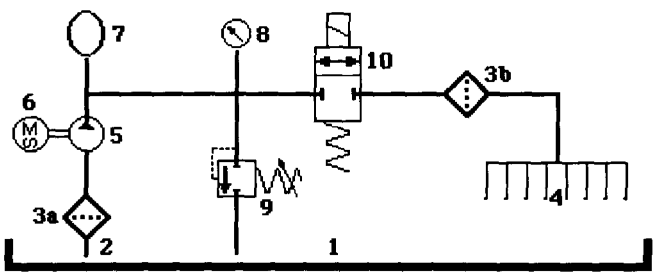

Figure 2—*The working principle of the unit. The spray solution was in the spray tank* **(1)** *from where the pump* **(5)** *sucked the solution through a suction filter* **(3a)** *into the tube system* **(2)**. *From there the solution went under pressure through a filter* **(3b)** *and was distributed to the spray nozzles* **(4)**, *type Unijet 6503. As the seedling box passed the spray nozzles it pressed a limit switch down, thus opening the magnetic valve* **(10)** *allowing the solution to flow to the nozzles. After the seedling box passed the limit switch the magnetic valve closed and the flow to the nozzles stopped. The pressure regulator valve* **(9)** *was adjusted to the required pressure, which could be followed on the pressure gauge* **(8)**. *The excess solution flowed back into the spray tank. The power of the pump* **(5)** *was 2.2 kW and its capacity was 70 dm≥/min. The pump was fitted with a pressure chamber* **(7)** *that evened out the flow of the liquid.*

medium (Higgins 1967). The coverage of 1-mm^2 grids on the 2mm-wide vertically placed strips of Kromekote paper was tallied according to classes 100%, 75%, 50%, 25% and 0% from four directions.

The seedling types in the study were Vapo® container (5 cm x 5 cm and height 8 cm) and Ecopot® (Ps-508, diameter 4.6 cm and height 7.5 cm and Ps-608, diameter 5.6 cm and height 7.5 cm) seedlings. The Vapo seedlings are in more clearly defined rows than the other types of seedling. The work productivity study material consisted of about 140,000 seedlings, equivalent to about 1,300 seedling boxes.

Operators' exposure to permethrin. Each worker wore protective garments (MIX 50/50/cotton/polyamide), peaked cap, face shield, rubber boots (Nokia), and a polyethylene apron. When preparing the spray suspension the worker used neoprene gloves (MULTITOP, France) and a respirator with a combination filter (KEMIRA A1). The workers wore cotton T-shirts, cotton trousers and shorts, and cotton socks under their protective garments.

The exposure of the workers was evaluated by industrial hygienic measurements and biological monitoring. The workers' exposure to permethrin via lungs was estimated from air samples taken with portable pumps on membrane filters in the breathing zone of the workers. Stationary air samples were installed near the application equipment about 1.5 m above ground level. Sampling times were equivalent to the application times. The contamination of the clothing and skin was estimated by patch tests. Exposure through the hands was measured from the cotton gloves worn under the protective gloves (Davis 1980).

Urine samples for biological monitoring were taken after each work day for the determination of metabolites of permethrin and for estimation of the workers' exposure to pesticide from the concentration of metabolites in urine. Filter, patch, and urine samples were analyzed in a gas chromatograph (HP 5880) equipped with a capillary column (HPl) and EC detector (Kolmodin-Hedman et al. 1982b).

The workers underwent a medical health examination before and after application work. Special care was taken to note possible symptoms that might have occurred during the work.

Results

Spray consumption and evenness. During the compilation of the study material, the spray consumption varied from 0.18 to 0.28 dm^3 per box sprayed according to the speed of the conveyor.

There was no significant difference in the distribution of pesticide between the different container types (Vapo, Ps-508, Ps-608), although the seedling growth density was greater in type Ps-508. According to the tally of the Kromekote strips (size 30 mm x 30 mm) that had been placed horizontally on the surface of the growing medium, the spray coverage for the Ps-508 seedlings was 90%; for the Ps608, 97%; and for the Vapo seedlings, 98% (figure 3).

The test unit did not function fully in the desired way. There were shortcomings-for instance, in the box-gripping mechanism on the conveyor, which holds the box in the required position, and in the mixing of the spray agent. The concentration of permethrin in the samples taken from the spray tank varied widely, indicating that the tank mixing was apparently not sufficiently effective. The reservoir collecting the run-off spray agent was separate from the main spray tank during the test to determine the evenness of distribution of spray on the seedlings. Separating the reservoir from the main tank improved the mixing of the agent.

Spraying work productivity. A 2-person team treated the seedlings. One operator fed the boxes into the machine and the other took the treated boxes off the conveyor and placed them back onto the ground. In a time study of the work, in which productivity and work time distribution were measured, the distribution of the tunnel sprayer operating time was as follows:

Actual spraying work	70.3%
Transporting sprayer & conveyors	20.2%
Adjusting sprayer	0.4%
Adding pesticide and transferring from run-off reservoir	8.4%
Repairing roller conveyor	0.7%
	100.0%

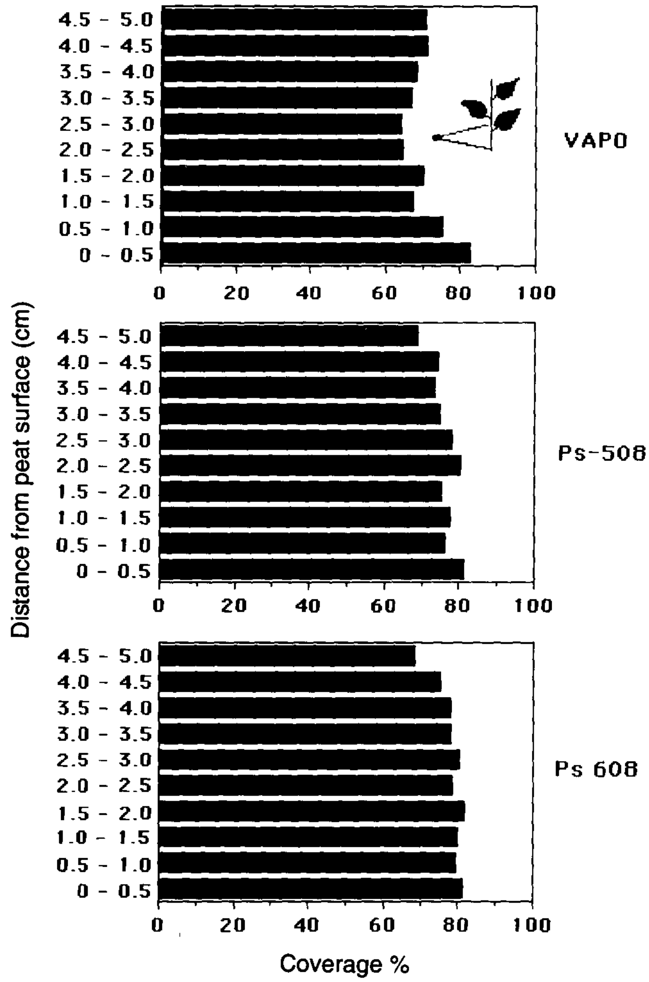

Figure 3—*The distribution of colored water on the stem of a seedling according to the Kromekote strip tally.*

The spraying work output was 4 boxes per minute. According to the operators' work time distribution, operator B had to wait part of the time (table 1). Feeding the box to the machine took 34.9% of operator A's time. This may also have included some waiting. The speed of the conveyor was 8.4 m/min during the test. The speed of the conveyor is adjustable between 5.4 and 32.6 m/min.

Costs. The annual operating time of the equipment used in the calculation was 120 hours. The operating time corresponds to the treatment of about 3 million seedlings. The hourly operator costs used were $10.50. The team comprised two operators.

On the basis of the aforementioned values, the tunnel sprayer costs were $11/hour. The cost of the pesticide was $70.20/kg. The consumption of pesticide solution was 0.18 to 0.28 dm^3 per box, depending on

Table 1-*Operators' working time without interruptions*

Operation	Operator A	Operator B
Go to box	23.2%	28.3%
Take box	16.3%	25.4%
Carry box	25.6%	20.8%
Feed box into machine	34.9%	
Position box on ground		13.9%
Wait	-	11.6%

output. When using the average consumpton of 0.2 dm^3 of 2% solution in the calculations, the actual use of pesticide was 4 g/seedling box. The cost of pesticide was $2.80/1,000 seedlings, when the box contained 100 seedlings. The output of spraying work used in the calculations was 4 boxes per minute. The total costs of the treatment were $4.21/1,000 seedlings.

Workers' exposure to permethrin. The permethrin concentration in the air was low and varied between the detection limit up to 140 : g/m^3. The highest concentrations were measured in stationary samples during the dilution of powder formulation (table 2).

The patch tests revealed that the contamination of the clothes was 230 to 4,300 : /cm2/hr in the dilution work and 320 to 600 : g/cm^3/hr in the treatment of seedlings and in maintenance work. In some cases, almost half of the amount of the pesticide on the protective clothing was found in the patches that were inside the clothes. Skin contamination was, however, estimated to be low. The urine concentrations of the metabolites of permethrin were in all cases below the detection limit of the method. This also proves that the workers' exposure during the application work was minimal.

The amount of permethrin in the cotton gloves was 0.06 to 2.00 mg. This proves that the hand protection was not complete, partly because the preparation of the application equipment was done without using protective gloves. The highest values of permethrin on the cotton gloves were noted after this kind of work. The workers complained about irritation and itching on their faces during the work, but no specific exposure-related symptoms were found in the health examination after the work.

Discussion

Our findings are limited in that the prototype equipment was used during this study only. However, the knowledge and experience acquired show that the working principle of the sprayer is worth developing.

The effect of tilting the box to reduce the flow of pesticide to the growth medium could not be evaluated in this study. This would require a separate test comparing the spraying operation in horizontal and near-vertical boxes. Equipment to treat seedling boxes in the nursery beds using tractor-mounted sprayers are in use today. It would be appropriate to continue the study and compare the aforementioned alternatives.

The distribution of the spray agent on the surface of the shoot was approximately 80%, according to the inventory method that was used. According to a visual check, however, the seedlings were completely treated. It is possible that the use of Kromekote paper and colored water is not a completely reliable method for such small seedlings and such growth density. It would also be appropriate to conduct a feed test with pine weevil after treatment.

The cost of pesticide was $2.80 and the cost of handling was $1.40/1,000 seedlings. The treatment of seedlings in the nursery is generally more justifiable and is considerably more economical than treatment in open terrain. According to Tervo (1989) the cost of treatment per hectare was $13.20 to 33.60 per 1,000 seedlings when carried out using a backpack sprayer after planting in open terrain. The equivalent cost of treatment in the nursery would be approximately $4.20 per 1,000 seedlings. The treatment of bareroot seedlings against pine weevil, for instance using the sprayer with the recycling principle, should be studied more closely (Tervo et al. 1991).

The occupational exposure limit for permethrin in Finland is 5 mg/m^3. According to the results of the occupational hygienic measurements, the exposure of the workers was far below this value. The concentrations of the metabolites of permethrin in the urine samples taken after the work shift were below 0.05 mg/ml. The measured contamination of the hands and protective clothing, however, proved that correct use of personal protective equipment in this work is necessary.

Table 2 – *Air concentrations of permethrin in the breathing zone and at the stationary sampling points during the dilution of spraying solution and during the application of the seedings*

	Permethrin (: g/m^3)		
Object	Mean	Range	n
1. Worker A (personal sample)	5.3	0.4 --23.7	5
2. Worker B (personal sample)	2.2	0.4 -- 7.7	5
3. Dilution of spraying solution (stationary sample)	64.5	23.7-137.5	3
4. Feeding conveyor of the applicator (stationary sample)	< 0.5		3
5. On the side of the applicator (stationary sample)	< 0.5		3
6. Conveyor for applicated seedlings (stationary sample)	< 0.5		3

Some workers complained about irritation and itching on their faces during the work, but no specific symptoms that could be related to pesticide exposure were found in the heatlh examination done after work. These kind of symptoms are reported t0 be typical for workers exposed to Synthetic pyrethroids (Kolmodin-Hedman et al. 1982a).

Powder-formulated pesticide was used in this study. There is a risk for elevated inhalation exposure during the dilution of the spraying solution liquid. We therefore recommended that workers use a respirator. equipped with a filter against fine aerosols during the dilution of spraying solution. The use of suspension would decrease the exposure of workers (Metker et al. 1977).

The preparation and maintenance of the application equipment increased contamination of the gloves. When protective clothing gets wet from the spraying solution in this work, it seems that a considerable amount of pesticide penetrates the garment. It is therefore advisable to change the protective clothing after preparation work, and to take a shower if the contamination of the clothes is obvious.

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Simple and Inexpensive Method for Extracting Wood Density Samples From Tropical Hardwoods

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A method for extracting wood density samples from living trees with high-density wood is described. A carpenter's auger is used to extract wood chips from a hole of known dimensions. The chips are dried and weighed, and the standard formula — ovendry weight divided by green volume — is used to calculate density. For illustrative purposes, a comparison is made with a water immersion method for samples collected from four tree species with woods of varying densities. The auger method, if used correctly, appears to yield an accurate measurement of wood density. Moreover, it is rapid, simple to use, and employs very inexpensive equipment. Tree Planters' Notes **45(1):10-12;1994.**

Wood density is an important characteristic that is selected for by tree geneticists. Destructive sampling tends to be counterproductive. Determining wood density— the weight in grams per cubic centimeter of wood at a given moisture content— is accomplished in four steps. These are extraction of the sample, determination of its volume, drying of the sample, and calculation. Wood density can be determined by several methods, principally variations in the method of extraction of the sample from the tree trunk and in how the volume of the sample is determined. A few other systems estimate density indirectly. An example is the pilodyn system, a type of penetrometer. Density is estimated from the hardness of the wood as indicated by resistance to penetration. The system may be used in the field but can only give an indication of the density of the surface layer.

The most common method for determining wood density is to saw samples from boards after a tree is milled. The volumes of the samples are determined by measuring them or immersing them in water and noting the rise in water volume. The weight at a standard moisture content (usually ovendry) is used to complete the calculation. This is obtained by drying the sample until no further loss of moisture occurs.

To collect samples from living trees within studies or protected areas has required the use of an increment borer. The increment borer extracts a small cylindrical piece of wood of known diameter, and the length of this piece is measured to calculate the volume of the sample.

The increment borer is a useful tool for collecting samples from living trees, although it has a few drawbacks. Increment borers with smaller diameters may compress some of the samples, but this can be avoided by using the largest (12-mm) bits available. Although samples from increment borers come just from the more dense lower trunk, and often over-represent the heartwood and under-represent the sapwood, Wahlgren and Fassnacht (1959) conclude that increment cores extracted at breast height can be safely used to estimate whole-tree density of southern pines. Field sampling of tropical hardwoods presents problems not encountered with pines. Trees with hard and dense woods are very difficult to sample with an increment borer, which must compress the wood in a ring around the core in order to enter. Also, increment borers are often too expensive for many foresters in developing countries where tropical hardwoods grow.

In response to this problem, I developed a simple method for extracting wood density samples from living trees with inexpensive equipment. I believed it to be original and could find no other forester or scientist aware of it. However, reviewing old references on the use of increment borers for wood density, I found the theory for the method described and suggested as an alternative to the increment borer for extracting samples from southern pines (Paul and Baudendistel 1956). Those authors apparently did not test the method.

Materials and Methods

The samples are collected with a carpenter's auger ("brace and bit"). Auger bits are available at hardware stores in a wide variety of sizes and lengths. Any convenient diameter bit may be used. A brace and bit of good quality costs about US $20. The pieces of equipment used for field collection of samples are shown in figure 1. A ventilated oven is also necessary for ovendry determinations. Airdry determinations, which are much less precise, can be obtained without such equipment. A balance capable of weighing to the nearest 0.1 g (0.003 ounce) is also required.

The point within the tree to be sampled is accessed by boring through the bark to a previously decided standard depth in the wood. Depending on the demands of the study or the peculiarities of the species, this may be the surface of the sapwood, some point within the sapwood, or the start of the heartwood (as noted by a color change). Chips produced in boring the preparatory hole are discarded. The preparatory hole is brushed out and its depth measured with a ruler. This is the starting depth of the sample. To catch the chips for the sample, a plastic bag should be tucked on one of its sides into a string or ribbon tied around the tree, tacked to the tree, or held by an assistant underneath the hole. As the chips are caught in the bag, the borehole is extended to another previously decided depth such as the pith. After the auger is withdrawn, the chips remaining in the hole are collected using a flattened stick or thin spatula and added to the sample. It is important to withdraw all the chips (and also not to lose any), because any chips not included in the sample will bias the results. The ending depth of the hole is noted. The chipped sample is placed in a cloth or paper bag or in a pan and dried in a ventilated oven until no further weight loss is noted. The final weight is recorded to the nearest 0.1 g.

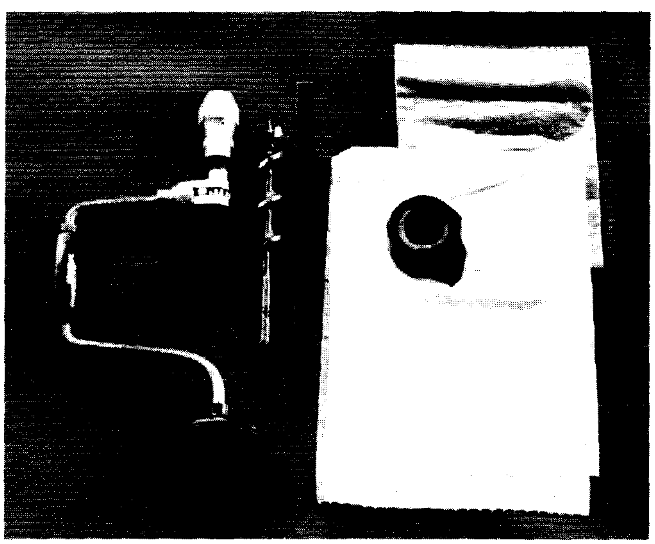

Figure 1—*The equipment required for collecting wood density samples by the auger method.*

The density of the sample is calculated by the formula:

$$\text{Density} = \frac{\text{Sample weight (g)}}{\text{Volume of the hole (cm}^3\text{)}}$$

The volume of the hole, or the volume formerly occupied by the sample, is calculated using the formula:

$$\text{Volume} = (3.1416\ D_b^2/4)\ (D_e - D_s)$$

where:

D_e = ending depth
D_s = starting depth
D_b = diameter of the bit.

Comparison With Standard Methods

The auger method and the increment core method are conceptually similar and should give comparable results. The core method takes its volume from an undisturbed core; the auger method uses a chipped sample extracted from an undisturbed hole (the sides of the hole are not compressed by the slicing action of the bit). The tiny holes created by the guide screw of the auger bit could be a source of error; however, the holes are present at the start and at the finish and, in effect, cancel one another.

To illustrate some advantages and cautions in using the auger method, a comparison was made with the water immersion method, a standard method for determining wood density of sawn samples (American Society for Testing and Materials 1967). Four species of trees that exhibit a range in wood density — *Anthocephalus cadamba* (Roxb.) Miq., *Dialium guianense* (Aubl.) Sandwith, *Pinus caribaea* Morelet, and *Tabebuia heterophylla* (DC.) Britton — were selected.

Replicated samples for both methods were taken from a single tree of each species. Ten auger samples using a 2.54-cm (1.0-in) diameter bit were withdrawn in a close-spaced, vertical row of holes beginning at about 1.5 m and ending at about 1.2 m (4 to 5 ft) above the ground. Samples were taken beginning at 10 to 15 mm (0.4 to 0.6 in) in from the cambium and going approximately to the center of the tree. The tree was cut down, and a rough board on the radial section adjacent to the auger holes about 0.5 m (20 in) long and 1.5 cm (5/8 in) thick was cut with a chainsaw, also from near breast height. Generally, 20 samples for the water immersion method were cut from this board with a table saw. The samples were cubes about 1.5 cm (0.6 in) on an edge, from a position roughly midway between the bark and the pith, and spaced along the 0.5-m (20-in) piece. The volume of the solid samples were determined by first soaking them in distilled water and then immersing them in a graduated cylinder and noting the change in water level. Afterwards, both the solid and the chipped samples were dried at 105 /C (221 /F) in a ventilated oven and reweighed on an analytical balance until no further weight reduction was noted.

Mean densities (10 to 20 samples) for the four species measured by the two methods with their standard deviations and coefficients of variation are presented in table 1. The coefficients of variation are low (3 to 10%) for both sample methods. The variances of the two methods were homogeneous at the 5% level of confidence using the F-test for equality of two variances (Snedecor and Cochran 1967). An unpaired t-test showed that the means of densities measured by the two methods were not significantly different at the 5% level of confidence, with the tree species pooled.

Discussion

The auger method gave mean densities that were comparable to, though not identical with, those obtained by the water immersion method. The numerical differences in the results, particularly within species, almost certainly arose because the water immersion method essentially measured density at a point midway between the cambium and the pith whereas the auger method measured a rough average across most of that radius. Differences in density between sapwood and heartwood and the presence of soft cores due to rapid juvenile growth inject additional variation both within and between species. Any sampling procedure should be designed to measure the desired portion or portions of a tree in a representative fashion. Many methods and variations are available for determining wood density. Because there are often difficulties in comparing results from different methods, it is always best to use only one method within a study or survey.

Table 1 - *Comparison of ovendry wood densities in four trees of four species obtained by the water immersion method and the auger method*

Species & method	n	Mean	Standard deviation	Coefficient of variation (%)
Anthocephalus cadamba				
Immersion	20	0.26	0.009	3.3
Auger	10	0.34	0.036	10.5
Dialium guianense				
Immersion	20	0.88	0.056	6.3
Auger	10	0.84	0.035	4.2
Pinus caribaea				
Immersion	18	0.48	0.028	5.8
Auger	10	0.40	0.015	3.8
Tabebuia heterophylla				
Immersion	20	0.49	0.018	3.7
Auger	10	0.54	0.017	3.1

Conclusions

The auger method, used correctly, appears to accurately measure wood density. The new method is rapid-field collection time is about 10 minutes per sample-and it is capable of extracting samples from hard hardwoods. Moreover, it is simple to use, and the equipment is very inexpensive.

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Tree Shelters Improve Establishment on Dry Sites

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Improving plant establishment on arid and semi-arid sites can be very difficult. In addition to providing water and soil capable of supplying the nutrients required for growth (including necessary soil symbionts such as rhizobia and mycorrhizal fungi if appropriate), the planter must provide protection from grazing, abrasion from blowing sand, mechanical wind damage, and temperature extremes. This paper reviews the nature of these problems and examines the results from field tests and observations in the California desert on the effects of TUBEX Treeshelters™ with several species. Plants grown with Treeshelters generally showed markedly improved survival and growth. Tree Planters' Notes **45(1):13-16; 1994.**

Although soil moisture and nutrients are often considered the primary limitations for plant establishment, more recent studies suggest that herbivory may be equally important (McAuliff 1986, Bainbridge and Sorensen 1990, Bainbridge and Virginia 1990). Newly established or transplanted seedlings are often the most succulent plants available and can be subjected to heavy grazing pressure. Rodents, rabbits, reptiles, domestic and feral livestock, and insects easily devour and kill young plants unless adequate protection is provided. Rabbits *(Sylvilagus auduboni),* blacktail jack rabbits *(Lepus californicus),* and rodents (presumably *Citellus* and *Neotoma* spp.*)* have proven most detrimental to desert planting efforts. Rabbits have even heavily browsed transplants of the highly resinous creosote bush.

Observations from a series of field studies suggest that grazing pressure on perennial shrub species decreases from mesquite *(Prosopis glandulosa),* palo verde *(Cercidium floridum),* four-winged saltbush *(Atriplex canescens),* bur sage *(Ambrosia dumosa),* creosote bush *(Larrea divaricata),* bladderpod *(Cleome isomeris),* to smoke tree *(Psorothamnus spinosus).* Although rabbits seem to be the principal herbivore, tooth marks suggest that smaller rodents are also active. Although they are not a problem on the experimental sites, feral animals can also be very destructive in the desert. Burros have eliminated bur sage from thousands of hectares of range near Lake Mead by repeated heavy browsing. The seedlings of most species tested can survive repeated herbivory (to half centimeter stubs) if they are irrigated, but when plants are moisture-stressed the results are usually fatal.

Protection from the wind can also be essential for establishment in dry environments (Virginia and Bainbridge 1987). High winds and blowing sand can damage and kill plants (Mosjidis 1983). Observations of eroded buildings and utility poles in California's Coachella Valley demonstrate the abrasive effects of wind-carried sands. The potential for sand blast damage at a site can be evaluated by placing a vertical piece of railroad chalk (2.5 cm diameter, 15 cm tall) on a metal pin at the soil surface. This chalk clearly shows the intensity of sand abrasion and direction of maximum impact. In addition to sand blast effects, plants may be damaged or killed by the mechanical action of high winds. Young tree seedlings (with only cotyledons) have been blown out of the ground. Multiple branching is a common response to wind damage. Wind-borne sand also fills in plant collars and makes irrigation difficult. Drying winds increase the moisture stress of young seedlings. Protection can reduce evapotranspiration and water stress. This appears to be most critical in the first 6 to 12 weeks after outplanting.

Although freezing is not often considered important in the low desert, many native plants are very sensitive to below-freezing temperatures, and frost may play a major role in distribution patterns of desert plants (Bowers 1980). Freezing temperatures are not uncommon on winter nights with clear skies, and frost damage has frequently been observed on unsheltered seedlings in the Coachella Valley. Hard freezes, however, only occur only about once every 10 years. The freeze of 1978 was particularly severe and resulted in widespread damage and mortality for many desert species (Lenz and Dourley 1981). Tree shelters should provide some protection damage against freezing.

Many strategies can be used for plant protection, including tree shelters, rock mulch, plastic or metal screens, plant collars, repellent, straw stubble, dead branches, or shade screens (Bainbridge and Virginia 1990). Although all of these may prove worthwhile for specific site problems and species, tree shelters have proved to be effective in many studies in temperate environments (Potter 1991, Windell 1992) and may be the best option for most situations.

Materials and Methods

TUBEX Treesheiters ™ – 75-mm-diameter twin-wall plastic tubes available in various heights and two colors, tan (used here) and white - have been evaulated on a range of restoration and revegetation sites in the California desert, where precipitation is below 75 mm and potential evaporation as high as 3,627 mm/yr (Hughes 1963).

Initial tests were conducted on a highway revegetation site near the Salton Sea (Bainbridge 1991) using 3-cm-tall mesquite seedlings with 21-cm roots (from Ray Leach C-10 supercells). These trees were given less than 20 liters of water per plant over the 6-month establishment period (figure 1). This test compared growth and survival of seedlings in 3 treatments with 10 trees per treatment:

- 24-inch TUBEX Treeshelters™
- 3-inch-diameter white plastic pipe of similar height
- Rigid plastic-mesh seedling protectors from International Reforestation Suppliers

The second test was performed at Anza-Berrego Desert State Park (1991), comparing the survival and growth of bur sage, creosote bush, and saltbush seedlings with and without TUBEX Treeshelters™ (11 replications per treatment). Seedlings were spaced 2 m apart down the tire tracks of abandoned roads in a randomized treatment structure. Once again, only limited water could be provided, less than 8 liters of water total per plant.

The third test was planted in the same area in 1992 using 48 matched pairs planted with TUBEX Treeshelters™ or with no protection. Ocotillo seedlings 1 to 2 cm tall from Supercells were planted in three blocks with spacings of 1 to 2 m between seedlings and 3 to 10 m between pairs. These also received less than 8 liters of water.

Results

Survival for the various trials is presented in figure 2. At the Salton Sea site there was 100% mortality in the IRS rigid plastic-mesh seedling protector group, poor survival in the white pipe shelters, but excellent survival in Treeshelters. Mesquite trees in TUBEX Treeshelters™ reached 3 to 4 m height in 2 years. At

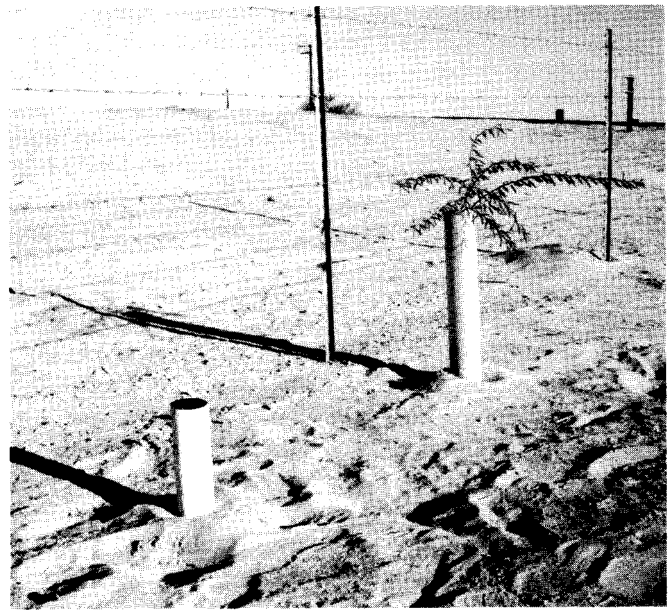

Figure 1—*One-year-old seedling of Mesquite* (Prosopis glandulasa) *growing in a Tubex Treeshelter along Highway 86 near the Salton Sea, CA.*

Anza-Borrego Desert State Park, survival of ocotillo and saltbush was dramatically better with Treeshelters. After the second summer in the field, no control saltbush plants were alive, compared to roughly 45% survival with shelters. Creosote bush with TUBEX performed better than without, but the difference was the smallest for any of the species studied.

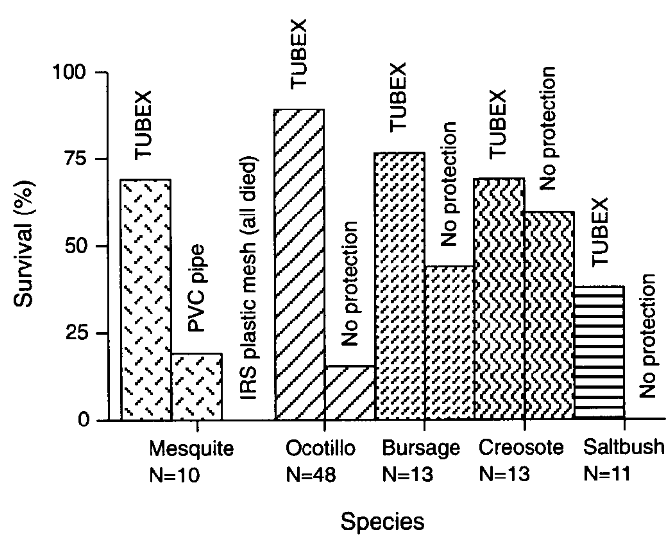

Figure 2—*Benefits of TUBEX Treeshelters in the low desert of southern California.*

Discussion

TUBEX Treeshelters™ have proved to be very beneficial for mesquite, four-winged saltbush, ocotillo, and many other species. Although Treeshelters do not provide complete protection against herbivory, they do reduce grazing. Wind scour exposes the bottoms of some Treeshelters (reducing wind protection) and blows others away (despite metal pins), but survival and growth generally increases. The benefits for creosote bush were limited to the first few months; after the establishment phase the Treeshelters reduced growth and vigor of this desert dominant, perhaps as a result of increased heat stress (Sorensen 1993).

Treeshelters have worked well with both minimal and intensive irrigation. They have improved irrigation efficiency by minimizing water loss and reducing waste when water is poured directly into the shelter sealed at the soil surface. This may prove very helpful for establishing plants on sloping sites.

One minor problem resulting from Treeshelter use has been changes in plant shape caused by the relatively narrow tubes. Spreading plants may develop a mushroom shape, which may be both aesthetically unpleasant and detrimental to long-term survival. Protection comparable to Treeshelters can be provided in larger diameters by wrapping a wire cage with bubblepack plastic. Treeshelters can also trap lizards and birds. Birds nested in the top of several Treeshelters in a planting project in Arizona and delayed plant growth. Nets or cross-threaded fishing line at the top of the shelter can minimize bird problems. Leaving a vertical stick in the shelter will enable lizards to climb out.

The increased cost of tree shelters (TUBEX 24-inch cost $2.15 compared to IRS Mesh protector 24-inch at $0.18) is easily offset by modest increases in survival on remote sites, where total planting costs may exceed $10 per tree. TUBEX Treeshelters™ have worked well in the desert, but it is clear that they are not well suited for long-term use on all species. Plants with upright growth forms and rapid growth in the summer seem to be most responsive to TUBEX Treeshelters™. However, the tree shelters can be more generally recommended for reducing transplant shock during the first 1 to 3 months after outplanting.

TUBEX Treeshelters™ have been very effective in the desert, but the wide range of available shelters should also be evaluated. It is likely that the plant response to other shelters with different colors (changed wavelengths, light intensity, radiation balance) and construction, (single versus twin wall) construction will be significantly different.

The value of tree shelters will also be related to irrigation method and watering schedule, fertilizer, amendments, weed control, and the interaction of these factors with the microclimate created by the shelter (Sorensen 1993). In addition, there are costs associated with the reduced light—as much as 50% of available light is eliminated with the tan TUBEX Treeshelters™. Plant response to these conditions will depend on the ability of the plant to acclimate, or at least tolerate, low light and high temperatures.

Sources of Tree Shelters

Many companies have followed the lead of TUBEX and introduced tree shelters in the last 2 years. These are commonly translucent tubes of various configurations and materials. The benefits and costs of using these under a wide range of conditions and with different species are still uncertain (Windell 1993). The following models are commercially available in the United States at this time:

TUBEX Treeshelters™ (now marketed as Supertubes)
Treessentials Company
75 Bidwell Street, Suite 105
St. Paul, MN 55107
(800)248-8239

TUBEX Supertubes come in a wide range of heights. They nest in groups of four and are strong and easy to install. They can be reused for several years.

TreePee™
Baileys
44650 Hwy 101, Box 550
Laytonville, CA 95454
(707)984-6133

The TreePee shelters are made of recycled polyethylene with UV stabilizer. The shelter is a 24-inch tall cone (8'-inch base with 4-inch top) with 3 built-in mounting pins.

Tree Pro™
Tree Pro Tree Protectors
445 Lourdes Lane
Lafayette, IN 47905
(317) 463-1011

The Tree Pro shelters are made of single-faced polyethylene and are assembled on-site. The top is flared to reduce damage.

Tree Sentry™

Tree Sentry
PO Box 607
Perrysburg, OH 43552
(419) 872-6950

The Tree Sentry is an open rolled tube made of recycled polyethylene. This allows for the shelter to be opened to look at the seedling.

BLUE-X™

All Season Wholesale Nursery
10656 Sheldon Woods Way
Elk Grove, CA 95624
(916) 689-0902

The Blue-X shelters are made of rolled recycled X-ray film. They can be cut to desired size. The rolled tubes are relatively stiff.

Conclusion

Plant establishment on dry sites requires careful attention to many factors, and plant protection has not always received sufficient attention. Transplanting projects in the desert have showed that TUBEX Treeshelters™ improve seedling survival and growth with minimal water use and maintenance. They can be generally recommended for the first few months after outplanting and are likely to dramatically improve survival and growth with plants with upright growth forms. The ultimate goal may be the development of an integrated container/shelter system that minimizes root disturbance and planting cost as the plant is moved from the nursery to the field.

Acknowledgments

Special thanks to John Rieger, NaDene Sorensen, Laurie Lippitt, Ross Virginia, and Bill Steen. Thanks to Matt Fidelibus, Debbie Waldecker, and NaDene Sorensen for review. Support provided by the California Department of Transportation, California State Parks, and The Canelo Project.

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Tree Planter's Notes, Volume 45, No. 1 (1994)

Nursery Drawings Available From the Missoula Technology and Development Center

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Engineering drawings for 53 various types of nursery equipment that have been developed or improved by Forest Service nurseries in recent years are available. Tree Planters' Notes 45(1):17-20;1994.

For over 30 years the Missoula Technology and Development Center (MTDC) has provided technical support to Forest Service nurseries. The Center has worked on development projects that provided improved equipment, materials, and techniques for cone processing, sowing, lifting, and cultivating. By working closely with Forest Service nursery personnel, MTDC has contributed to the improved efficiency and safety of these operations. In addition to development projects, the Center's Nursery Technical Services Program furnishes engineering consultation support to all nurseries. Under this project MTDC prepares engineering drawings for equipment that has been custom-designed by nursery personnel. All these drawings and the drawings developed from MTDC nursery projects are available in both reduced size and in full 36- x 24inch construction drawings to **all readers** of *Tree Planters' Notes.* Sample drawings are shown (figures 1-4). To order any of these drawings, contact Dick Hallman, Program Leader, Missoula Technology and Development Center, Building 1, Fort Missoula, Missoula, MT 59801 (telephone, 406-3293946; DG, R.Hallman:ROIA).

Nursery Drawings

Coeur d'Alene Nursery, Coeur d'Alene, Idaho.
CDN-1 Nursery Path Cultivator (figure 1)
CDN-2 Box Storage Rack and Conveyor
CDN-3 Dewinger
CDN-4 Sander
CDN-5 Watering Boom
CDN-6 Container Washer
CDN-7 CDN Vertical Root Pruner
CDN-8 Cone Tumbler
CDN-9 Plastic Tarp Roller

Lucky Peak Nursery, Boise, Idaho.
LPN-1 Seed Packing Carousel
LPN-2 Seedling Storage and Hauling Trailer
LPN-3 Tractor Mounted Irrigation Pipe Hauling Rack
LPN-4 Seedling Hauling Trailer Field Type
LPN-5 Root Cut Off Saw
LPN-6 Vertical Root Pruner
LPN-7 Root Growth Potential System

Wind River Nursery, Carson, Washington.
WRN-1 Seed Rack
WRN-2 Shade Green
WRN-3 Pruning Saw Guard Arm

Saratoga Tree Nursery, Saratoga Springs, New York.
STN-1 Evans Weeding Cart

W. W. Ashe Nursery, Brooklyn, Mississippi.
WWA-1 Mulch Spreader (figure 2)
WWA-2 Tarp Roller

Southwestern Region, Albuquerque, New Mexico.
SWR-1 1&3 Hectoliter Boxes

Mt. Sopris Nursery, Carbondale, Colorado.
MSN-1 Container Filler

Humbolt Nursery, McKinleyville, California.
HN-1 Tub Washer
HN-2 Bag Washer
HN-3 Plastic Tarp Roller

Southern Forest Experiment Station, Stoneville, Mississippi.
SFES-1 Herbicide Applicator
SFES-2 Ultimate Stoneville Applicator

Hammer Mill Paper Co., Selma, Alabama.
HPC-1 Seedling Top Pruner

J. Herbert Stone Nursery, Central Point, Oregon.
JHSN-1 Mulch Spreader

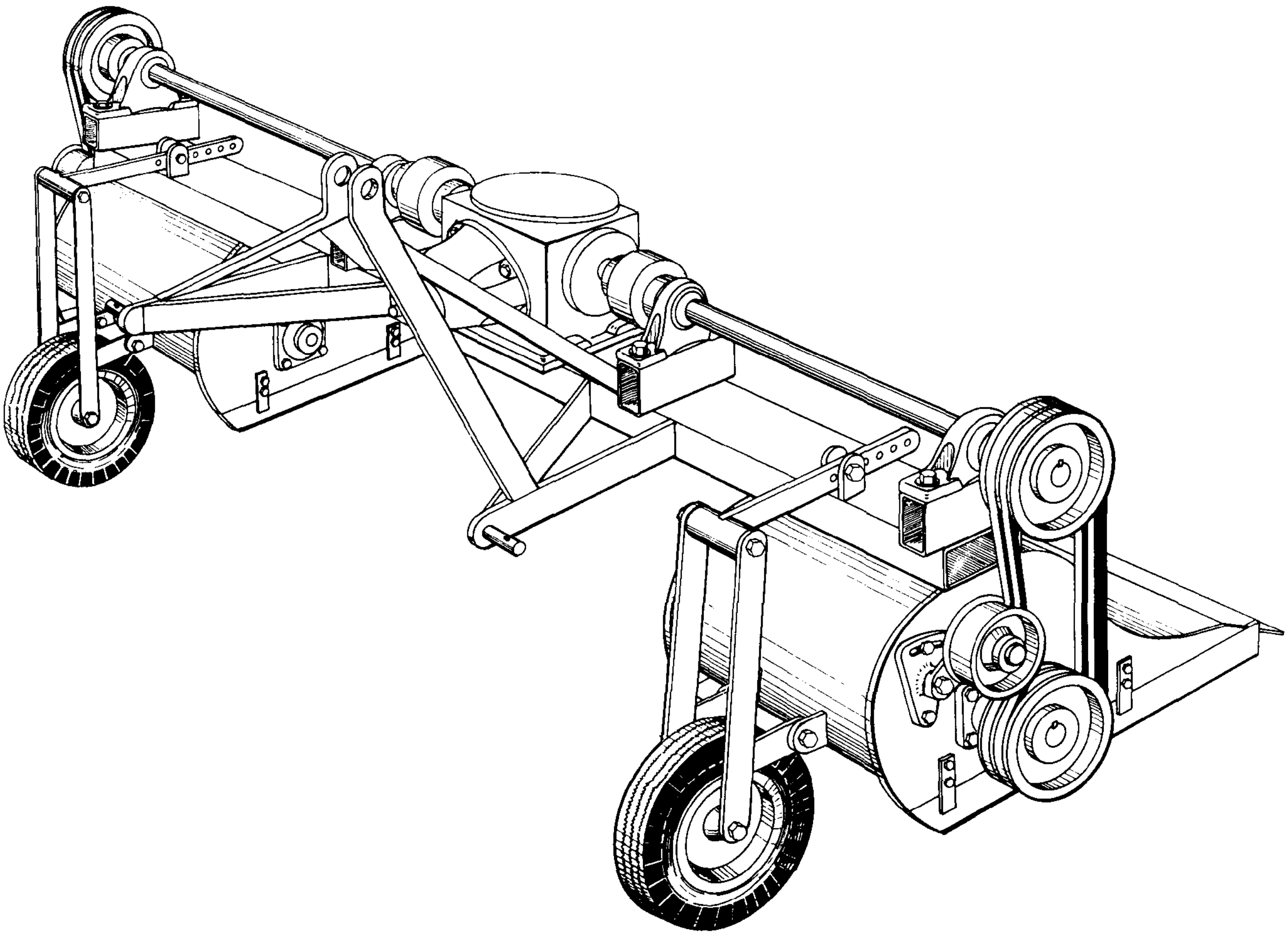

Figure 1—*Nursery path cultivator (CDN-1).*

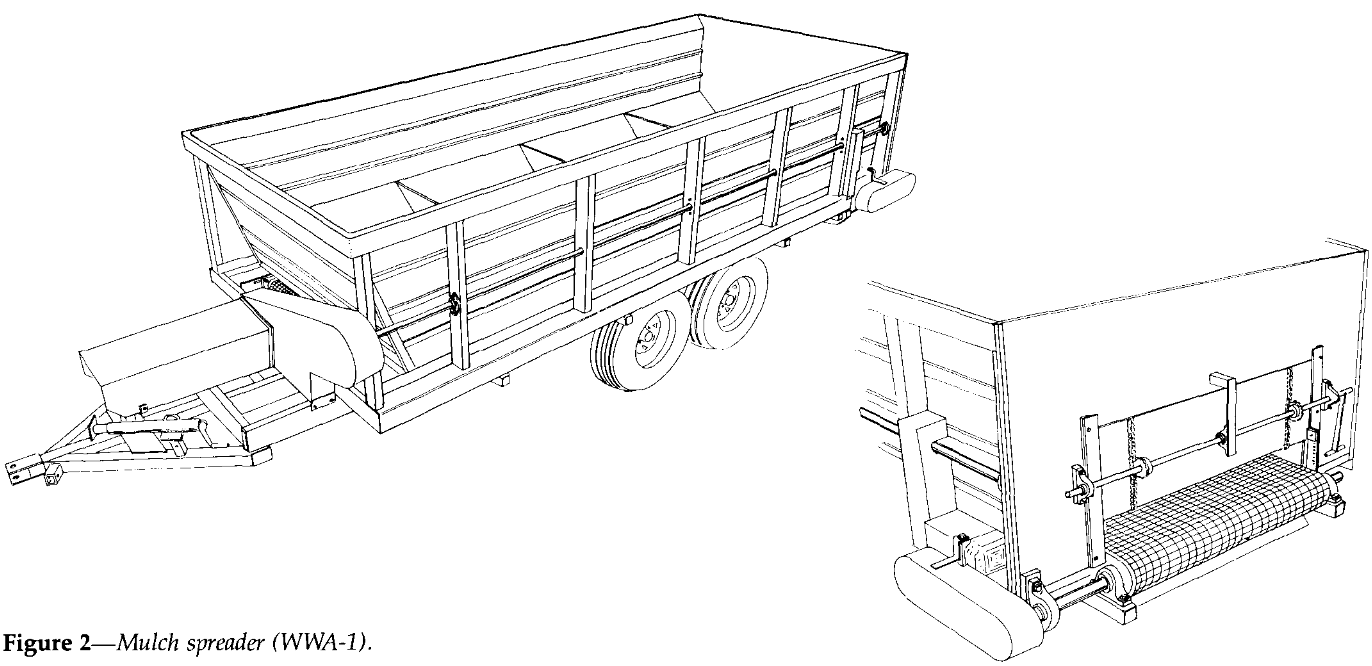

Figure 2—*Mulch spreader (WWA-1).*

Missoula Technology and Development Center, Missoula, Montana.

MEDS 303 Cone Inspection Table
427 Nursery Cultivator NC-5&6
517 Horizontal Root Pruner
6067 MEDC Tree Seed Dewinger M1977
684 Synchronous Thinner
687 Manual Seedling Thinner
695 Mycorrhizae Applicator
748 MEDC Tree Seed Dewinger M1984 (figure 3)
785 Progeny Seeder Model 1
795 MEDC Stake Driver
796 Root Mist Chamber
800 Seedling Counter PC Board
818 Seedling Counter
841 Sandia Cone Cutter
842 Isozyme Lab Tray
848 Pollen Applicator
849 Isozyme Accessories
850 Seedling Box Lifter (Side Mounted) (figure 4)
851 Orchard Seed Harvester R8
856 Pollen Collector Head (pattern)
858 Progeny Seeder
865 110-Volt AC Field Storage Unit
866 Isozyme Lab Gel Slicer
876 Cyclone Pollen Collector Model 1
893 Vial Pollinator
901 Root Pruner

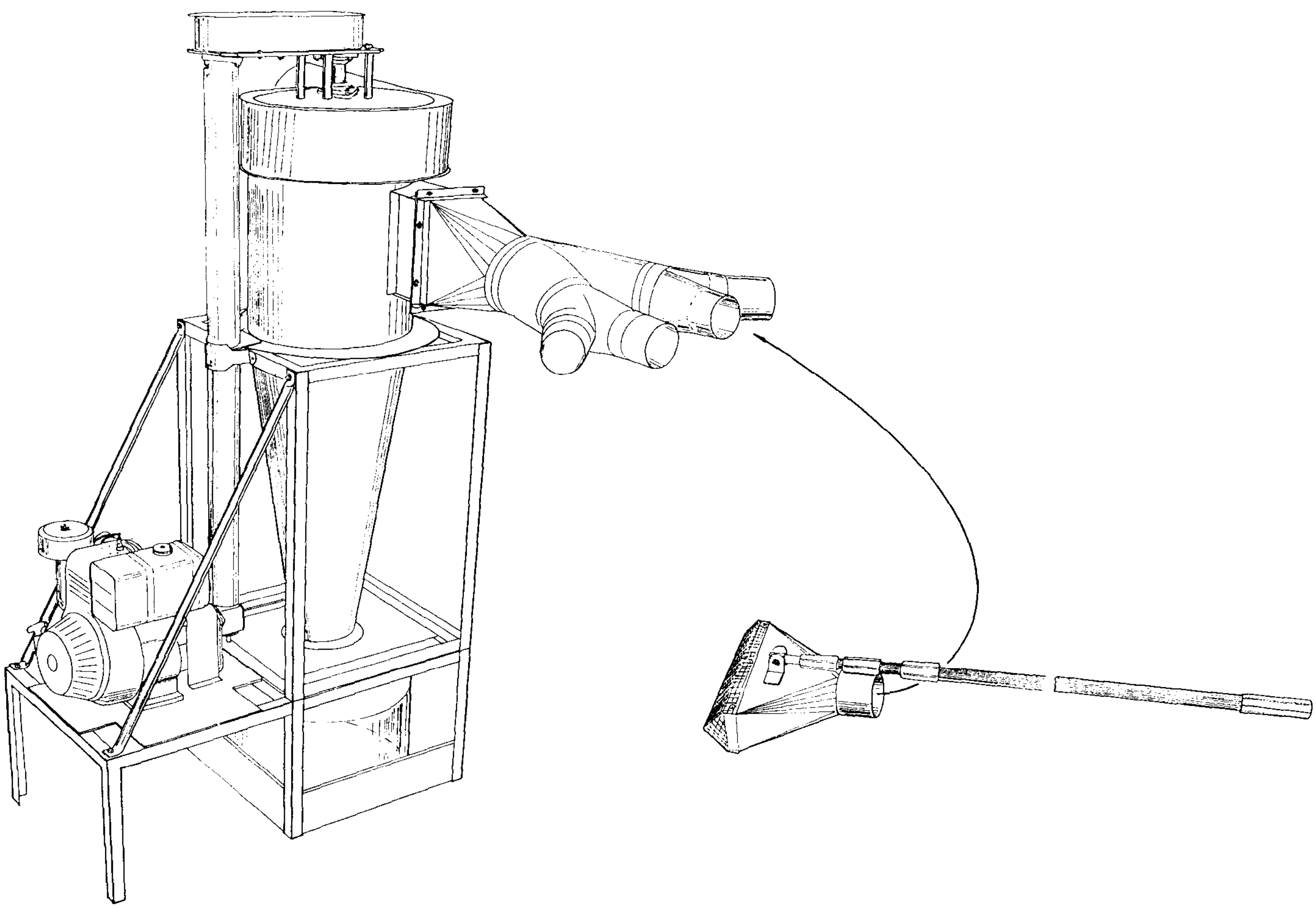

Figure 3—*MEDC tree seed dewinger (M 1984).*

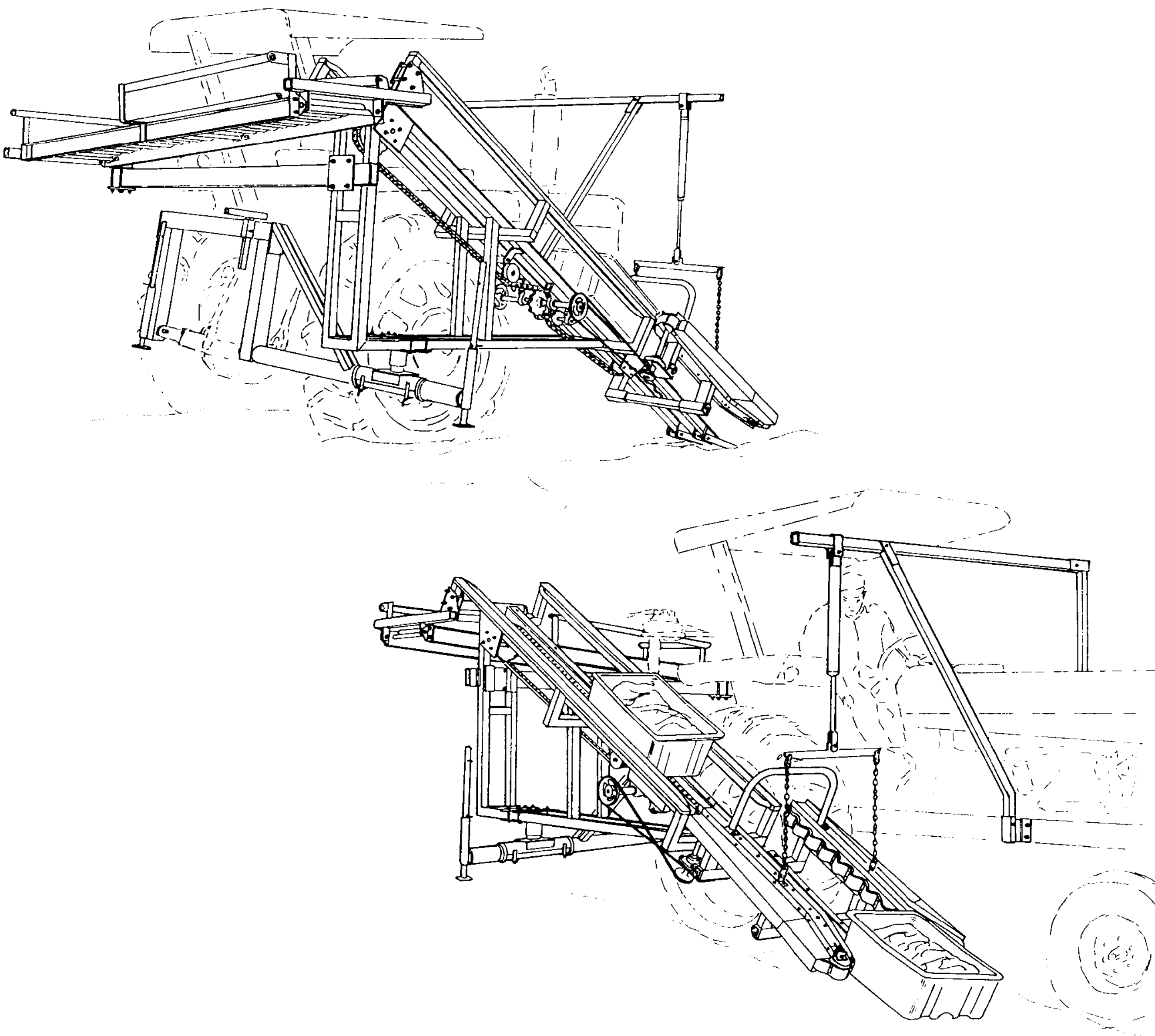

Figure 4—*Side-mounted seedling box lifter (850).*

Tree Planter's Notes, Volume 45, No. 1 (1994)

Aerial Lifts for Working in Tree Tops

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Engineers at the Missoula Technology and Development Center have identified aerial lifts as the most versatile and safe vehicles for work in tree crowns. Recent improvements in hydraulic and mechanical systems have made these lifts more appropriate for seed orchard tasks. There are two categories of lifts. Vertical-horizontal lifts are either self-propelled or mounted on a trailer or truck; they can be used to reach high places but are limited in the amount of weight they can hold. Vertical lifts are self-propelled units with relatively large platforms. Their height reach is limited to 182.8 m (60 feet), but they can lift up to 12,700 kg (28,000 pounds). Lifts suited for most seed orchard tasks can be rented or purchased. Tree Planters' Notes 45(1):21-25;1994.

Aerial lifts are the most versatile and safe method for working in tree crowns according to a recent investigation conducted by Missoula Technology and Development Center (MTDC) engineers. Forest Service emphasis on tree improvement has increasingly required workers in both orchards and wild stands to accomplish their tasks 9 m (30 feet) or more above the ground. Timber managers want to know the most efficient, safe method for jobs like collecting genetically superior cones and pollen, gathering samples for determining the effects of acid rain, or assessing disease and insect damage.

In 1992, the Washington Office Timber Management Staff Group assigned MTDC the task of investigating the problems associated with working in tree crowns. Center engineers were asked to identify available equipment and determine its safety, economy, and versatility. Many different systems were examined, including bucket and ladder trucks, extendable platforms, fixed towers, tethered balloons, cranes, and portable scaffolding. Their conclusion was that aerial lifts are the most practical, safe method for accomplishing seed orchard tasks. Although aerial lifts have been used for many years, recent improvements in hydraulics and mechanical systems have improved the utility and safety of this equipment. Seed orchard workers and others who must work in the tree crowns should find aerial lifts that meet their particular needs.

Aerial lifts are capable of moving workers or materials from ground level to various elevations up to 30 m (100 feet). They require 1 or 2 people to operate and can cost from $20,000 to $100,000, depending on their sophistication. They are marketed under a variety of different names such as construction lifts, boon lifts, aerial work platforms, and mobile platforms. In general, they can be broken down into two categories; (1) those that raise the load both vertically and horizontally and (2) those that are capable only of vertical lift.

Vertical-Horizontal Lifts

General characteristics. These lifts can be either self-propelled (figure 1), trailer-mounted (figure 2), or truck-mounted (figure 3). The self-propelled units are readily available through construction equipment rental agencies. They must be towed to the work area but are fully mobile once on site. Self-propelled units have a height capability up to 45 m (150 feet) and a life capacity of 227 kg (500 pounds). Most are available with rough terrain features such as oscillating axles, 4-wheel steering, 4-wheel drive, and high-flotation tires. Some designs have a grade capability of up to 25% with the boom retracted and down. Self-propelled units weigh 2,495 to 17,237 kg (5,500 to 38,000 pounds). Trailer-mounted units must be towed at all times. The lift operator must lower and leave the platform even for a short move, unless a second prime mover driver is employed. These units usually have a lower lift capacity (181 kg or 1400 pounds) and lift height (20 m or 65 feet) than self-propelled or truck-mounted units. Trailer units weigh 2,495 to 15,786 kg (5,500 to 35,000 pounds).

Truck-mounted units have the greatest reach (up to 67 m or 210 feet) and are completely mobile. They also require the operator to lower and leave the platform to move the unit if a second operator is not available. Their rough-terrain capability and overall weight are dictated by the type of vehicle on which they are mounted.

Most manufacturers make several types of vertical-horizontal lifts that vary the mechanism used to raise the load. These mechanisms can be telescoping stick booms, telescoping boom sections with articulated joints, or a combination of both (figure 4). Although each design has its own advantages and disadvantages, seed orchard managers should consider those units with articulated joints or jib booms, or what is sometimes called "extend-a-reach/over-and-down" capability. This allows the operator to raise the boom over a tree and then lower the end section and platform into the crown without moving the boom through the limbs. This is not always possible with a straight stick boom.

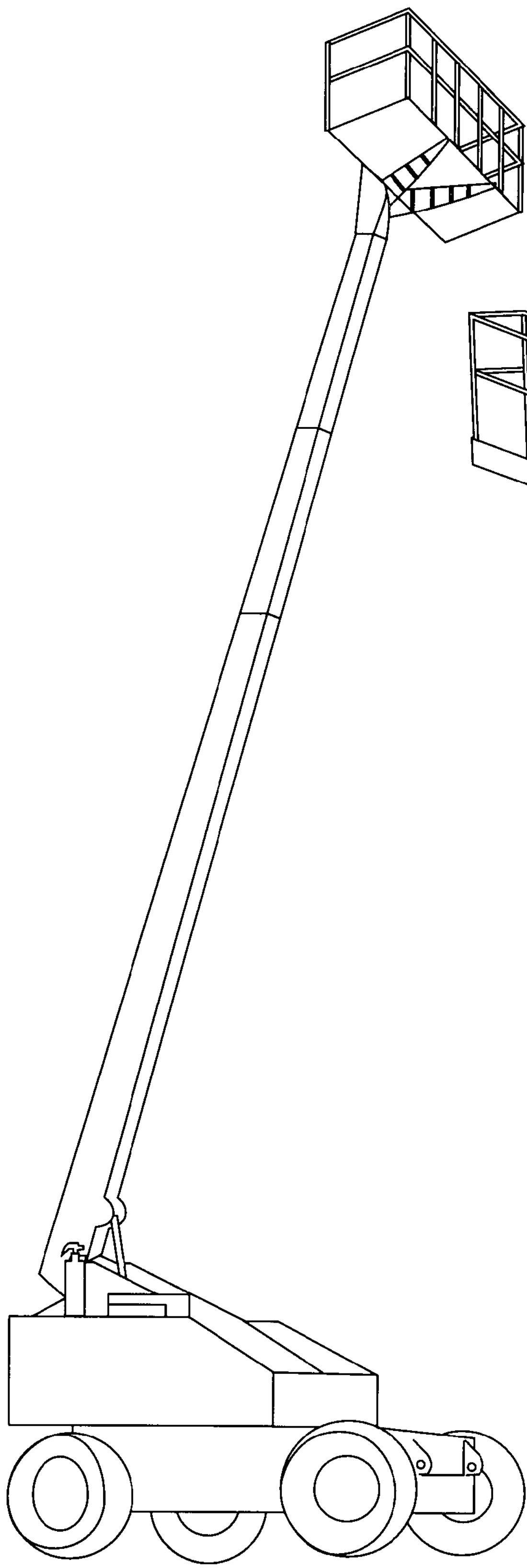

Figure 1—*Self-propelled vertical–horizontal lift.*

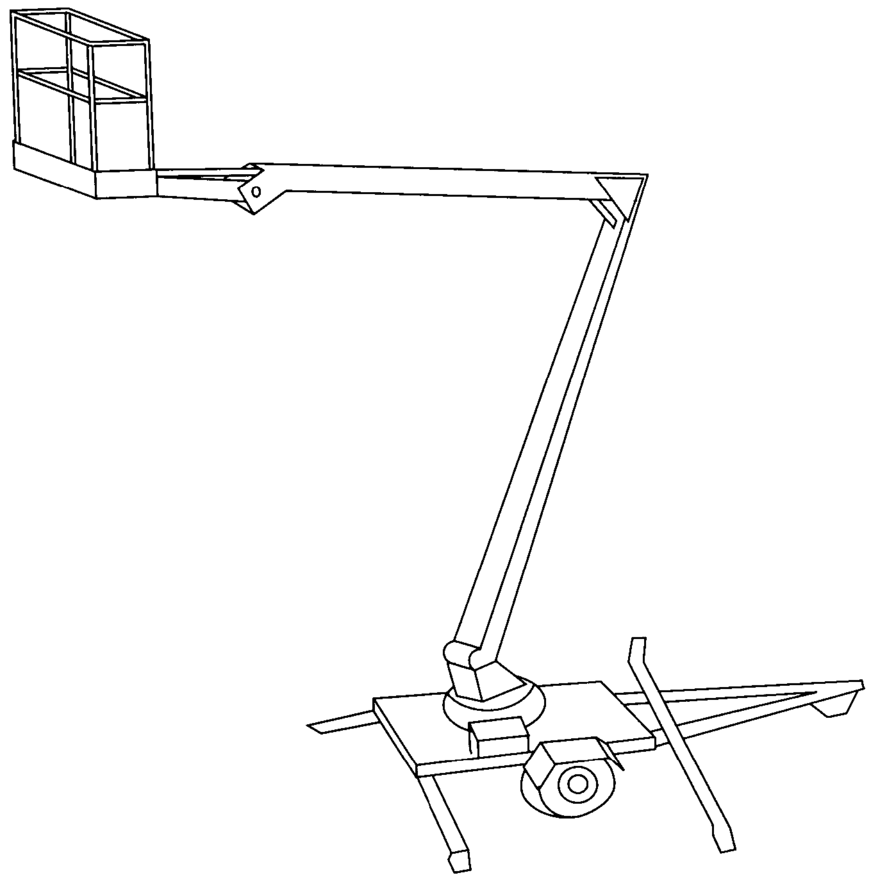

Figure 2—*Trailer-mounted vertical–horizontal lift.*

Platform sizes vary. Trailer-mounted units usually are available with a one-person fiberglass bucket. Self-propelled units use a steel platform generally about 0.7 by 1.5 by 1.1 m (2.5 by 5 by 3.5 feet). Truck-mounted units may have either a bucket or platform.

Vertical-horizontal lift units are available with LPG, gasoline, or diesel engine power. They feature full--function controls in the bucket or platforms, and a duplicate set of ground controls for emergency use. All platforms should have lift sensor-alarms and safety harnesses. Most are self-leveling and can be power rotated. Hydraulic and 110-V AC outlets are available.

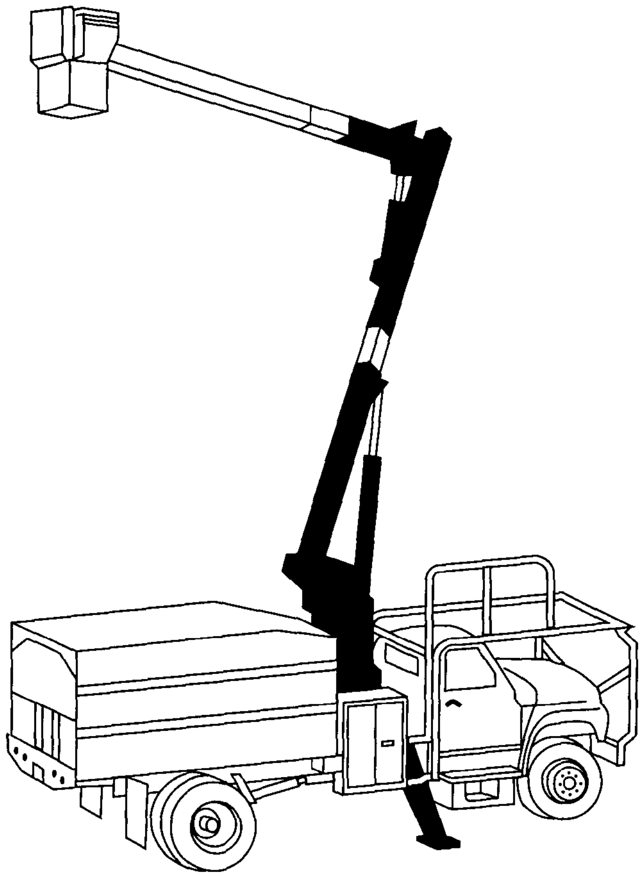

Figure 3—*Truck-mounted vertical–horizontal lift.*

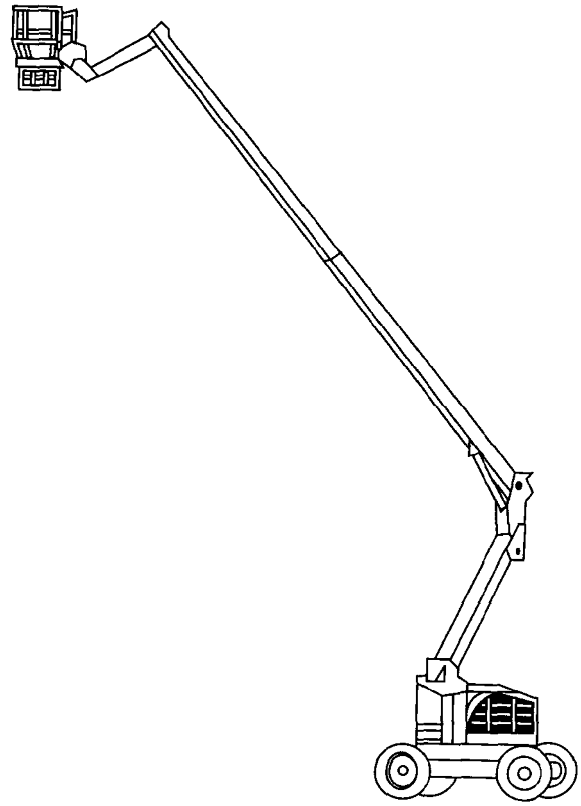

Figure 4—*Tire-mounted vertical–horizontal lift.*

Typical specifications.
Platform height up to 30.5 m (100 ft)
Horizontal reach 15.2 m (50 ft)
Capacity 454 kg (1,000 lbs) restricted, 227 kg (5001bs) unrestricted
Weight 10,433 kg (23,000 Ibs)
Gasoline engine
Platform controls
Ground controls
360-degree rotation
Platform rotator
Oscillating front axle
4-wheel steering
4-wheel drive
Jib boom
4-mph speed
25% gradability (boom down)
0.86 rpm swing speed
Self-propelled
1.1 m (3.75 ft) tail swing
0.7 x 1.5 x 1.1 m (2.5 x 5 x 3.5 ft) platform

Advantages and limitations. Because of their extensive lateral movement, vertical-horizontal lifts allow an operator to work adjacent areas such as the tops of closely spaced trees, without moving the whole machine. This lateral movement capability allows an operator to access tree tops without pushing the work platform through the lower tree branches and to move the machine without fully lowering the platform.

Self-propelled units are capable of being operated and moved by one individual from the work platform. Truck-mounted and trailer-mounted units do not have this capability. In all cases, moving the equipment with the boom extended is limited to 5-degree (or less) slopes.

Vertical-horizontal units have a high reach capability, but usually cannot lift as great a weight as vertical lifts. They also, as a general rule, have smaller work platforms.

The lift operators must work while restrained by a safety belt. All operators should be thoroughly trained. Most dealers and rental organizations offer a 4- to 8-hour training package with each unit.

Vertical Lifts

General characteristics. The majority of these unit are self-propelled (figure 5). Most also are capable of operating on rough terrain with features such as 4-wheel drive and 4-wheel steering, oscillating axles, and super grip tires. Some have a gradability rating of 30% with the platform down.

Most vertical lifts employ a scissors-type mechanism, but there are some designs that utilize folding or telescoping lattice booms. These generally have a working height of less than 9 m (30 feet) and are not considered in this report. Vertical scissors lifts can handle more weight than lifts capable of horizontal movement. Some vertical lifts can raise 1,179 kg (2,600 pounds). Height however is usually limited to 18.3 m (60 feet). These units can weigh up to 12,701 kg (28,000 pounds).

Vertical lifts generally have larger work platforms than vertical-horizontal lifts, with dimensions approaching 1.8 by 3.1 m (6 by 10 feet). Some have manually extendable ends to further increase the work area. Many units have a platform that can be hydraulically moved in a longitudinal direction several feet to facilitate positioning.

Platform accessories include a 5-degree slope tilt sensor with alarm, safety belt, AC and DC power outlets, and platform controls for all functions. LPG, gasoline, or diesel power is available with these units.

Typical specifications.

Platform height up to 18.3 m (60 ft)
Capacity to 680 kg (1,500 lbs)
Gasoline engine
Platform controls
Ground control override
End of platform extendible 0.9 m (3 ft)
Rough terrain capability
Self-propelled
4-mph speed
20% gradability (platform down)
2.1 x 5.2 x 1.1 m (7 x 17 x 3.5 ft) platform

Advantages and limitations. Vertical lifts usually are self-propelled units capable of being operated and moved at the work site by one individual. They usually have larger work platforms than those found on vertical-horizontal equipment and they can also lift more weight.

However, their working height is limited, and they must extend up through the branches to reach the top of trees. This requires the platform to be lowered before the unit can be moved to adjacent trees. And, because there is limited lateral movement, the work

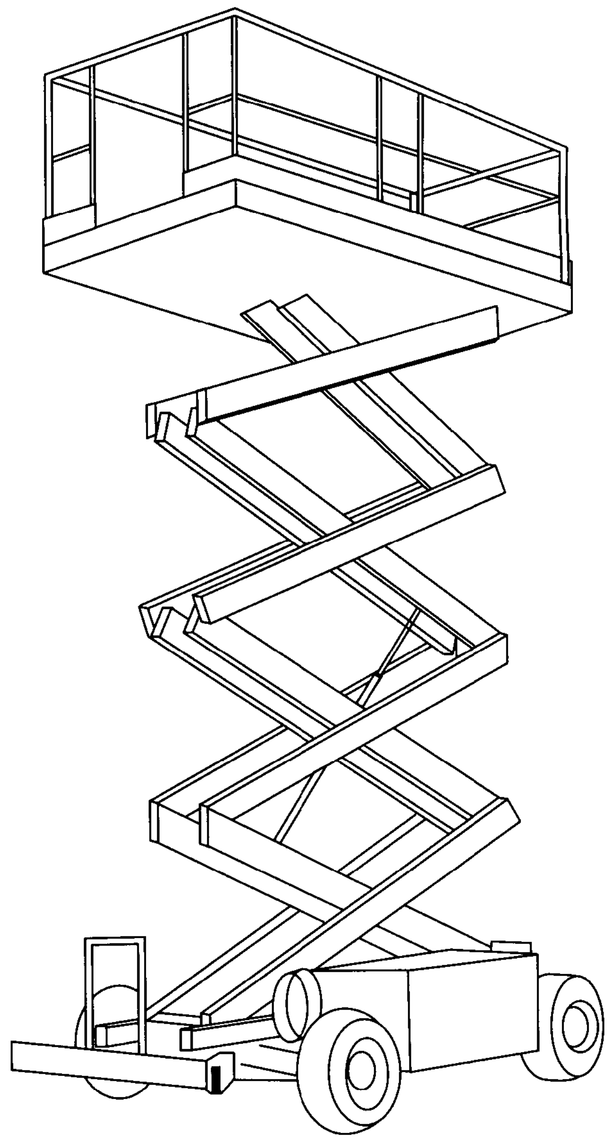

Figure 5—*Self-propelled vertical scissors lift.*

area from one setting is limited. Therefore, the operator must move the complete unit more often than would be necessary with a vertical-horizontal machine.

As with the vertical-horizontal units, the operator must work while restrained by a safety belt. All operating personnel should attend a training session before working with this equipment. Also, as with the other lifts, the operation of vertical lifts is limited to a 5-degree maximum slope.

Summary

Supervisory personnel should carefully analyze the job to be done before deciding on the type of machine to rent or purchase. Aerial lifts offer a wide range of capabilities and advantages, but each also has its disadvantages and limitations. Choosing the most suitable aerial lift can create a safe work environment, reduce labor costs, and accelerate or expand the working being done.

For current information on specific products, please contact the following manufacturers:

Snorkel
PO Box 65
St. Joseph, MO 64504-0065
(913) 989-4481

JLG Industries, Inc.
JLG Drive McConnellsburg, PA 17233-9502
(717) 485-5161

Genie Industries
PO Box 69
Redmond, WA 98052
(206) 681-1800

Simon Aerials, Inc.
10600 West Brown Deer Road
Milwaukee, WI 53224
(414) 355-0802

Calavar Corp.
PO Box 21447
Waco, TX 76702-1447
(817)666-4545

Mayville Engineering Co.
715 South Street
Mayville, WI 53050-1810
(414) 387-4500

Aero Lift
15 Fairfield Place
West Caldwell, NJ 07006
(201) 575-7487

Hi-Ranger, Inc.
PO Box 177
Waukesha, WI 53187-0177
(414) 547-1000

The Use of Rootdips on North American Conifer Seedlings: A Review of the Literature

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Many foresters are root dipping their bareroot conifer seedlings before planting or have done so in the past. This paper discusses different rootdip substances and reviews the many research studies on root dipping published in the last 25 years. Root dipping can help tree seedlings maintain water in their roots before planting. However, rootdips do not improve seedling survival after planting on harsh sites and they have been shown to be detrimental during storage. Tree Planters' Notes 45(1):26-31; 1994.

North American foresters often look for products and methods that can improve the survival and growth of planted tree seedlings. Root dipping is one practice that has been used. Root dipping is the process of coating the root system of bareroot seedlings with some kind of moisture--holding or growth-stimulating substance before planting.

Rootdips of various types have been used on conifer seedlings for 40 years. Foresters and nursery managers have root-dipped seedlings to prevent them from drying out in storage, to prevent roots from desiccating at the planting site, and to improve seedling survival and growth after planting.

The substances that are being or have been used for root dipping generally fit into one of four categories: (1) soil slurries; (2) vermiculite or ground sphagnum moss; (3) hydrophilic gels; and (4) other materials, including organic compounds, bioregulatory compounds, pesticides, or other chemicals.

Soil slurries are most often made from clay or loam soils mixed with water to form a thick mixture. When coated on the root system, the clay particles hold water tightly and resist drying.

Number 4 agricultural grade **vermiculite** has been used with water to make a rootdip that does not hold moisture as tightly as clay particles. Ground vermiculite has been used to a limited extent, as has ground peat moss. Ground vermiculite suspended in water has texture and other properties similar to those of a clay slurry.

There are four kinds of **hydrophilic gels** used in agriculture (Johnson 1985):

1. Hydrolyzed starch-polyacrylonitrile graft co-polymers
2. Urea-formaldehyde resin foams
3. Vinyl alcohol-acrylic acid co-polymers
4. Cross-linked acrylamide co-polymers

These gels can absorb between 40 and 500 times their weight in water. The amount of water held by the expanded gel depends on the chemistry of the polymer and the conditions under which it was formed, as well as the chemical composition of the soil solution (Johnson 1984). Some of the commercial hydrophilic gels that have been used for root dipping include Agricol®, Aquagel®, Collatex®, Terra Sorb®, Hydrosource®, Broadleaf P4®, Waterlock®, and Viterra®.

Other chemicals and bioregulatory substances have also been tried for root dipping. Some of them contain humic substances or products of fermentation. Manufacturers claim that these products increase seedling survival and growth by enhancing nutrition or environments for beneficial microorganisms, or through other, secret processes. They are unlike the rootdip substances I have just described because they do not attempt to hold water in the root zone. Instead, they attempt to increase seedling vigor or provide nutrients.

History

Root dipping was conceived in the late 1950's as a way to protect southern pines against desiccation when their roots were exposed to sun and wind (Slocum and Maki 1960). This procedure was often called "puddling" and used a thick slurry made from clay soil and water (Hermann 1962, Rook 1970, Slocum and Maki 1960). Puddling was later used to protect the seedlings from desiccation during storage (Dierauf and Marler 1969 & 1971, Broerman and Hamner 1966, Mullin and Hutchinson 1977, Williston 1967, Mullin and Bunting 1979). Other substances that held water were also tried throughout North America.

In the early 1970's the USDA Forest Service's Intermountain Region made root dipping in a vermiculite and water mixture a standard step in preparing bareroot seedlings for planting. Vermiculite, like clay, is able to absorb and hold water that would otherwise evaporate or drip off the roots. A variation of the vermiculite method was developed on the Targhee National Forest. A pump was used to keep the vermiculite suspended in water. The pump ground the vermiculite to form a slurry that looked, felt, and acted much like day slurry. Other readily available materials that can hold water, such as ground peat moss (Dahlgreen 1976) and sawdust (Rook 1970), also have been used.

The hydrophilic gels appeared in the late 1960's and have gained popularity as they have improved over the years. Testing began in the early 1970's (Owston and Stein 1972, Miller and Reines 1974, Mullin and Hutchinson 1977). The purpose of hydrophilic gels, like many other rootdips, is to coat the roots with water-filled granules that gradually release loosely bound water as the soil dries around planted seedlings. Early formulations tended to deteriorate after only a few months of use in the soil. However the most recently developed polyacrylamide formulations can last more than 5 years.

Effectiveness

Table 1 presents the results of a number of rootdip studies on conifer seedlings. Most of the references deal with clay and hydrophilic gel slurries. The effects of root dipping seem to vary with the species, site, and methods of study.

In table 1, the studies are classified into three categories:

- Seedlings were root dipped before storage to determine the impacts on storage.
- Seedlings were root dipped and then intentionally exposed to dry air, sun, and/or wind for a given length of time to determine if the rootdip can ameliorate the harmful effects.
- Seedlings were root dipped and not exposed to dehydrating conditions to see if the rootdip has beneficial effects after planting.

Within each group of research studies, the reported results were mostly in agreement.

In the first category, the investigators found that rootdips can be detrimental to seedlings during storage (Williston 1967, Dierauf and Marler 1969, Owston and Stein 1972).

Research in the second category indicates that clay slurries and hydrophilic gels can prevent desiccation and increase seedling survival when roots are exposed to dry air for extended periods before planting (Williston 1967, Dierauf and Marler 1969 & 1971, Owston and Stein 1972, Tabor and Davey 1966, Goodwin and Williams 1980). However, when planting stock is properly handled and protected against detrimental exposure, as in the third category, almost all of the studies show rootdips do not increase seedling survival or growth (table 1).

In the third category, some research shows rootdips to be least effective under droughty conditions where the most improvement in seedling performance might be expected (Echols and others 1990, Sloan 1994). Magnussen (1986) showed that a Waterlock® rootdip increased the survival of white spruce during 2 weeks of drought after planting but had no effect if the drought lasted longer than 2 weeks. Similarly, Tung and others (1986) found that Terra Sorb® delayed some Douglas-fir mortality by 2 to 3 weeks during summer but did not affect season-end survival or growth. Echols and others (1990) improved loblolly and shortleaf pine survival on a moderate site using Terra Sorb® but there was no improvement using the rootdip on a harsh site. They suggest that the rootdip may have helped the seedlings planted on the moderate site through a short-term drought.

This seems to indicate that the amount of water held by rootdips is sufficient to keep the seedlings alive for a short time. However, it is not great enough to change dry planting site water relations over the course of a summer. Another reason for the short-term effects of the rootdips is that as a seedling establishes itself in the soil, its root system expands beyond its original form where the rootdip substance remains. The new roots, the more efficient water absorbers, leave the rootdip particles behind as the roots grow out from the seedling. Then, as the rootdip particles dry, they contract, leaving an air space next to the roots until the dry conditions subside.

There were many other studies in the third category (table 1). Kroll and others (1985) improved loblolly pine survival using a Terra Sorb® rootdip on a droughty site. The other studies reported no improve-

Table 1-*Summary of results for published rootdip field studies with North American conifers*

Species	Study type	Results	Reference
Douglas-fir *Pseudotsuga menziesii* (Mirb.) Franco	3	Symbex® rootdip did not affect seedling survival or height growth after 3 years.	Dunsworth (1985)
	2	Rootdips prevented desiccation in root systems exposed for 40 minutes. Xanthan gum was more effective than clay or alginate. All three of the rootdips increased plant moisture stress during storage.	Owston and Stein (1972)
	3	Terra Sorb® rootdip delayed 1st-year mortality but did not affect seedling season-end survival or growth.	Tung and others (1986)
Douglas-fir *Pseudotsuga menziesii* var. *glauca* (Beissn.) Franco	3	Vermiculite, peat moss, and Viterra© rootdip treatments did not increase seedling survival or growth.	Ryker (1981)
	3	Neither vermiculite nor vermiculite slurry improved seedling height or root growth. Thick slurries were detrimental.	Sloan (1994)
Noble fir *Abies procera* Rehd.	1,2	Rootdips prevented desiccation in root systems exposed for 40 minutes. Clay was more effective than xanthan gum or alginate. All three of the rootdips increased plant moisture stress during storage.	Owston and Stein (1972)
Jack pine *Pinus banksiana* Lamb.	3	Terra Sorb® and Terra Verde® rootdips did not consistently increase seedling survival.	Alm and Stanton (1990)
	3	Agricolg rootdip and clay rootdip treatments did not increase seedling survival or growth.	Mullin and Hutchinson (1977)
Loblolly pine *Pinus taeda* L.	1	Benomyl® fungicide added to clay rootdip is detrimental during storage.	Boyer and South (1987)
	2,3	Clay root dipping before packing increased survival when seedling's roots were exposed for 5 to 50 minutes. Little difference when roots were not exposed.	Dierauf and Marler (1969)
	2,3	Clay root dipping improved survival and growth of seedlings following exposure of roots, but did not increase survival of unexposed seedlings.	Dierauf and Marler (1971)
	3	Terra Sorb® rootdip increased survival on a moderate site, but did not increase survival on harsh sites.	Echols and others (1990)
	3	Clay slurry and Terra Sorb® rootdips did not increase seedling growth or survival.	Goodwin (1982)
	2	Clay rootdip increased survival of seedlings exposed for 15 and 30 minutes before planting.	Goodwin and Williams (1980)
	3	Seedling survival was poor on droughty site. Terra Sorb® rootdip increased survival. Clay rootdip increased survival slightly.	Kroll and others (1985)
	2	Alginate increased the time to total stomatal closure during moisture stress in a greenhouse.	Miller and Reines (1974)
	2	Clay rootdip increased survival for seedlings with roots exposed for up to 30 minutes and grown in a greenhouse. Rootdip had no effect on early growth.	Tabor and Davey (1966)
	1	Packaging with hydrophilic gels improved seedling survival over packaging with clay slurry.	Venator and Brissette (1982)
	1,2	Clay root dipping before packing decreased the effects of exposure but was detrimental to unexposed seedlings.	Williston (1967)
Lodgepole pine *Pinus contorta* Dougl.	3	Vermiculite, peat moss, and Viterra® rootdip treatments did not increase seedling survival or growth.	Ryker (1981)
	3	Vermiculite, vermiculite slurry, and Terra-Sorb® did not improve survival, or seedling root growth.	Sloan (1994)

Table 1-*Summary of results for published rootdip field studies with North American conifers*

Species	Study type	Results	Reference
Longleaf pine *Pinus palustris* Mill.	1	Prestorage Benomyl® and clay rootdip increased seedling survival over clay slurry rootdip.	Barnett and others (1988)
Ponderosa pine *Pinus ponderosa* Laws.	3	Vermiculite, peat moss, and Viterra® rootdip treatments did not increase seedling survival or growth.	Ryker (1981)
	3	Vermiculite, vermiculite slurry, and Aquagel® did not improve survival or shoot and root growth.	Sloan (1994)
	3	Hydrophilic gel impregnated with auxin (IBA) increased seedling growth and survival. 2,4-D was detrimental when used with hydrophilic gel.	Tuskan and Ellis (1991)
Red pine *Pinus resinosa* Ait.	3	Waterlock® did not increase seedling survival or growth during imposed drought.	Magnussen (1986)
	3	Clay rootdip decreased survival.	Mulin and Bunting (1979)
Shortleaf pine *Pinus echinata* Mill.	1	Prestorage Benomyl® and clay rootdip increased seedling survival over clay slurry rootdip.	Barnett and others (1988)
	3	Terra Sorb® rootdip increased survival on a moderate site, but did not increase survival on harsh sites.	Echols and others (1990)
Slash pine *Pinus elliottii* Engelm.	1	Seedlings were compared for more than 8 weeks of storage without refrigeration. Some seedlings were root dipped in clay, some were stored in sphagnum moss, and others were stored in poly-lined kraft bags. No difference in survival up to 4 weeks. Less than acceptable survival after 8 weeks.	Broerman and Hammer (1966)
	3	Seedling survival was very poor on droughty site, Terra Sorb and clay rootdips did not increase survival.	Kroll and othres (1985)
White pine *Pinus strobus* L.	1,2	Clay root dipping before packing increased survival when seedling's roots were exposed for 5 to 50 minutes. Decreased survival when roots were not exposed.	Dierauf and Marler (1969)
	3	Clay rootdip did not increase survival.	Mullin and Bunting (1979)
Black spruce *Picea mariana* (Mill.) B.S.P	3	Agricol® rootdip and clay rootdip treatments did not increase seedling survival or growth.	Mullin.and Hutchinson (1977)
Engelmann spruce *Picea engelmannii* Parry .	3	Vermiculite, peat moss, and Viterra® rootdip treatments did not increase seedling survival or growth	Ryker (1981)
	3	Neither vermiculite nor vermiculite slurry improved seedling height or root growth. Thick slurries were detrimental.	Sloan (1994)
White spruce *Picea glauca* (Moench) Voss	2,3	Terra Sorb® increased survival following root exposure but did not when roots were protected.	Alm and Stanton (1990)
	3	Waterlock® rootdip increased survival during the first 2 weeks of drought after planting, Did not increase survival or growth when drought lasted longer than 2 weeks.	Magnussen (1986)
	3	Clay rootdip did not increase survival in three tests and was detrimental in a fourth.	Mullin and Bunting (1979)

Study type t = seedlings were root dipped before storage to determine the effects on storage; type 2 = seedlings were root dipped before storage and then intentionally exposed to dry air, sun, and/or wind; type 3 = seedlings were root dipped and not exposed to dehydrating conditions to see if the rootdip had beneficial effects after planting.

ment in seedling performance due to root dipping of Douglas-fir (Dunsworth 1985, Tung and others 1986, Ryker 1981, Sloan 1994), jack pine (Aim and Stanton 1990, Mullin and Hutchinson 1977), loblolly pine (Dierauf and Marler 1971, Goodwin 1982), lodgepole pine (Ryker 1981, Sloan 1994), ponderosa pine (Ryker 1981, Sloan 1994), red pine (Magnussen 1986), slash pine (Kroll and others 1985), white pine (Dierauf and Marler 1969, Mullin and Bunting 1979), black spruce (Mullin and Hutchinson 1977), Engelmann spruce (Ryker 1981, Sloan 1994), and white spruce (Aim and Stanton 1990, Magnussen 1986, Mullin and Bunting 1979). The evidence overwhelmingly indicates that rootdips did not improve seedling survival when the seedlings were not intentionally exposed to sun or wind.

Hydrophilic gel rootdips have another use that is worthy of note. Some researchers use hydrophilic gels to deliver growth hormones or other substances to the seedling. Tuskan and Ellis (1991) loaded a hydrophilic gel with indol-3--butyric acid (IBA) and 2,4-dichlorophenoxyacetic acid (2,4-D) for root dipping ponderosa pine seedlings. Although there were no differences in the greenhouse, IBA increased survival and growth in the field. However, the 2,4-D was detrimental to survival and growth in the greenhouse and in the field tests. More studies to test hormones, pesticides, and other substances for root dips and to determine if hydrophilic gels are the most effective means of delivering these substances to the seedlings are needed.

Rootdips can be beneficial in protecting seedlings from exposure to sun and wind. However, tree planters must resist thinking that they can use root dipping to restore seedling vigor after seedlings have been damaged by improper handling. Proper handling of bareroot seedlings includes guarding against root exposure. Rootdips are not a miracle cure. We must do everything we can to protect bareroot seedlings from damage and to maintain their vigor, whether the seedlings are root dipped or not.

Summary

Several kinds of rootdip formulations have been used during the last 40 years. The most popular are the clay slurries and the hydrophilic gels. One purpose of root dipping is to prevent seedlings' root systems from drying out between the nursery bed and the planting hole. Rootdips have been shown to be detrimental to seedlings during storage. Rootdips do moderate the damaging effects of seedling exposure to sun and wind for a short time.

A second purpose of rootdips is to increase survival and growth of the seedling after planting. Most of the studies reported here show that they do not increase survival or growth under very dry conditions and are merely an added expense. The effects of rootdips under more moderate to moist conditions have not been studied. Considering that root exposure is so harmful to a bareroot seedling, there is no reason to allow it. If seedling root systems are not exposed to drying agents, root dipping is unnecessary.

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Spin-Drying Soaked Tree Seed Before Prechilling Improves Seed Handling

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The traditional nursery method for pretreating dormant tree seeds is to soak the seeds and incubate them under cold, moist conditions – a so-called prechill (or sometimes stratification). But wet seeds of many species germinate prematurely during pretreatment and/or clump together and foul sowing machinery. This study shows that spin-drying wet tree seed is a simple and harmless method for surface-drying soaked seed, After spin-drying, seeds were at a high enough moisture content to respond to dormancy breakage, and by the end of a 6-week prechill were surface dry, free flowing, and suitable for immediate sowing. None of the seeds germinated prematurely. Tree Planters' Notes 45(1):32-35; 1994.

Commercially available tree seeds usually exhibit dormancy. The seeds of most temperate broadleaved species are completely unable to germinate until dormancy is broken. They often require the application of a lengthy (3 to 18 months) moist chilling period – a so-called prechill or stratification. These seeds are said to be "deeply" dormant. In contrast, most temperate conifer and a few broadleaved species germinate without prechilling, but only slowly and over a narrow range of temperatures. These seeds are commonly described as "shallowly" dormant. Prechilling for much shorter durations (1 week to 3 months) improves the nursery emergence of shallowly dormant seeds because it speeds up germination rate, increases germination capacity, and widens the range of temperatures over which germination can occur (Allen 1960, Barnett 1979, Gosling 1988, McLemore 1966).

The traditional method of prechilling shallowly dormant seeds is to soak them in water for about 48 hours, drain off the excess water, and incubate the seeds in a loosely tied polyethylene bag at approximately 4/C (Allen and Bientjes 1954, Hosner et al. 1959, Edwards 1986). However, this method of prechilling leaves a thin film of water adhering to seeds, which can cause significant problems both during and after prechilling. For example, after prechilling, wet seeds clump together and cannot be sown without fouling sowing machines. The seeds must therefore be surface-dried. This not only occupies significant time at an extremely busy period in the nursery but must also be done carefully to avoid either killing the seeds or inducing secondary dormancy. In addition, during prechilling, some seeds lose their dormancy earlier than others and in the presence of surface moisture begin to germinate before the others have experienced the full benefits of dormancy breakage. Stopping pretreatment at the first signs of premature germination means that some seeds must be sown when they are still dormant. But if pretreatment is continued beyond the first signs of premature germination (which is unavoidable, for example, if sowing is delayed by bad weather) then even larger numbers of seeds will have their radicles broken and be killed by surface-drying or passage through the seed sower.

Clearly, the development of a harmless and preferably simple method of surface-drying wet tree seed is highly desirable. One that can be applied before prechilling would offer the advantage of reducing the chances of premature germination during an extended prechill period. Spin-drying has previously been successfully used in research studies on vegetables and vegetable seeds (McKee J. M., personal communication) and this paper reports on the use of a household spin-drier (clothing) to surface-dry soaked seeds and so improve the handling of seeds of eight shallowly dormant tree species during prechilling and sowing.

Materials and Methods

Seed. Seed of two broadleaved species [common alder (CAR), *Alnus glutinosa* (L.) Gaertn.; Italian alder (IAR), *Alnus cordata* Desf.] and five conifer species [Japanese larch (JL), *Larix kaempferi* (Lamb.) Carr.; Sitka spruce (SS), *Picea sitchensis* (Bongard) Carr.; Scots pine (SP), *Pinus sylvestris* L.; Douglas-fir (DF) *Pseudotsuga menziesii* (Mirbel) Franco.; western red cedar (RC), *Thuja plicata* Donn ex D.Don] were obtained from the Forestry Commission, Forest Management Division. The seed lots were selected for this study because International Seed Testing Association (ISTA) double tests had shown that germination rate and in some instances rate and germination percentage at the end of the prescribed period was increased by prechilling – therefore the seeds were shallowly dormant. (ISTA double tests are equivalent to AOSA paired tests, that is, germination rate and capacity are compared with and without prechilling for the same seed lot.)

Soak treatment. Forty-five to fifty-five grams of seed (depending on species) were soaked in 3 times their own volume of water at 4 /C for 48 hours.

Spin dry treatment. Soaked seeds of each species were placed in separate fine-net nylon bags, firmly secured by tying at the top. The bags containing seeds were spun in a household spin-drier (figure 1) at approximately 1,100 x g for 10 minutes (or until water stopped dripping from the spindrier).

Prechill treatment. Soaked, spun seeds were free flowing and did not clump together. Seed of each species was transferred to a separate 250-gauge polyethylene bag that was loosely tied (to prevent excessive moisture loss, but allow gaseous exchange through the neck) and incubated in the dark, at 4 /C for 6 weeks.

Combined treatments. Combinations of the above treatments included

1. Untreated control
2. Soak only
3. Soak and spin
4. Soak, spin, and 6-week prechill

Moisture content (MC) determination. Moisture contents were determined following the ISTA low-temperature oven method (ISTA 1985) and expressed on a fresh-weight basis. Two 5-g subsamples were taken for each determination.

Germination. Seeds were germinated on a Copenhagen tank following the ISTA prescription for each species. Four replicates of 100 seeds were sown on moist filter paper, randomized, and then incubated at an alternating 20/30 /C-20 /C for 16 hours in the dark and 30 /C for 8 hours illuminated with 11 Wm-2 light from warm white fluorescent tubes. Germination was assessed every other day, and seeds were counted as having germinated when the radicle was at least 3 times the length of the seed. The maximum germination percentage (germination capacity) was reached at 42 days.

Mean germination time (MGT) is a common method for expressing germination rate as a single figure. In this study we calculated it using a modification of the formula of Bewley and Black (1985) according to Jones and Gosling (1994). It is equivalent to the average time taken for an average seed to germinate.

Figure 1—*Using the spin-dryer to prepare soaked tree seeds.*

Statistical analysis. The effects of different treatments on germination capacity and MGT were tested by analysis of variance and when appropriate, Duncan's multiple range test. Each species was analyzed separately. An angular transformation was applied to all percentage data prior to analysis to homogenize variances.

Results and Discussion

Moisture contents. Preliminary trials showed that the seeds of all the species investigated attained their maximum moisture content (MC) after 48 hours. Only soaked seeds needed to be carefully surface-dried with paper towels before MC's were determined. Soaked and spun seeds; and soaked, spun and, prechilled seeds had dry surfaces, flowed freely and thus did not need further surface-drying before MC determination.

Table 1 shows the moisture content (MC) percentages (fresh-weight basis) of seeds exposed to different soak, spin, and prechill treatments. The initial MC of dry-stored conifer seeds (DF, SS, JL, SP, RC) was 6 to 8%. This rose to between 30 to 40% after 48 hours of soaking. Dry-stored broadleaved seeds (CAR, IAR) were at approximately 12% MC and increased to between 48 to 55% after a similar soak period. It would therefore appear that the seeds of the two species of broadleaved trees used in this study attain a higher moisture content at full imbibition than the seeds of the conifers.

Subsequent spin-drying did not cause the MC values for seeds of either conifers or broadleaved trees to vary. Even after spin-drying plus 6 weeks of prechill at 4 /C, there was no appreciable change in MC.

Clearly, spin-drying imbibed seed of the above seven species was a simple and effective method of removing surface water from soaked seed without reducing the seeds internal moisture content.

Germination. *Germination capacity.* The germination of most species reached a maximum under the conditions chosen between 14 to 21 days (not shown). However, SS and DF were slower to germinate than this. To ensure that germination capacity had been reached in all cases and for consistency between species, all germination tests are therefore measured and reported at 42 days.

Table 1-*Moisture content percentages (fresh-weight basis) for shallowly dormant tree seeds exposed to different soak, spin, and prechill treatments*

Treatment	Moisture content (%) DF	SS	CAR	JL	IAR	RC	SP
Untreated	8	6	13	9	12	6	7
Soak	33	32	55	36	48	39	31
Soak & spin	34	33	55	37	52	38	29
Soak, spin, & 6-wk prechill	34	33	55	37	52	37	28

DF = Douglas-fir, SS = Sitka spruce, CAR -= common alder, JL = Japanese larch, IAR = Italian alder, RC = Western redcedar , SP = Scots pine.

Table 2 shows the maximum percentage germination and mean germination times for seeds exposed to different soak, spin, and prechill treatments.

It can be seen that few of the treatments had a significant effect on maximum germination percentage (germination capacity) of any of the species, under the optimal germination conditions chosen. For example, soaking had no significant effect on the germination capacity of DF, CAR, JAR, RC, or SP in comparison to untreated seeds; but it did significantly increase the germination capacity of SS by 7% and significantly decrease the germination capacity of JL by 12%. Nevertheless, any harmful effects of soaking on JL disappeared after the spin or spin plus prechill procedures. The germination capacity of soaked plus spun seeds and soaked, spun, and prechilled seeds was either as good as, or better than, that of untreated seeds for all species. Of particular importance, it should be noted from a comparison of germination capacities between soaked and soaked plus spun seeds, that there were no instances of spin-drying significantly reducing germination capacity.

The overall effect of combining soak, spin, and prechill was, therefore, to bring about statistically significant improvements to the germination capacity of SS and IAR in comparison to untreated seeds. A combined soak, spin, and prechill did not significantly reduce the germination capacity of any of the remaining species (DF, CAR, JL, RC, or SP).

Germination rate (MGT). The germination rate of seeds has a significant effect on the establishment and survival of tree seedlings in nurseries (Haasis 1928). Early emergence lengthens the growing season, and more synchronous emergence leads to better seedling uniformity. In addition, an increase in germination rate under optimal conditions with prechilling indicates that prechilling will widen the range of temperatures over which many seeds will germinate. Together these three effects result in more useable seedlings at the end of the growing season. Mean germination time (MGT) is one method of expressing germination

Table 2-*Maximum percentage germination (MPG) and mean germination times (MGT) for shallowly dormant seeds of 7 tree species exposed to different prechill treatments*

Treatment	DF MPG	DF MGT (days)	SS MPG	SS MGT (days)	CAR MPG	CAR MGT (days)	JL MPG	JL MGT (days)	IAR MPG	IAR MGT (days)	RC MPG	RC MGT (days)	SP MPG	SP MGT (days)
Untreated	9 a	13 a	80 b	15 a	71 a	8 a	39 a	10 a	27 b	12 a	86 a	12 a	95 a	7 a
Soak	94 a	13 a	87 a	12 b	71 a	7 b	27 b	9 b	23 b	12 a	84 a	11 b	92 a	5 b
Soak & spin	92 a	13 a	88 a	13 c	75 a	7 b	39 a	8 b	46 a	12 a	89 a	11 b	94 a	6 b
Soak, spin, & 6-wk prechill	92 a	5 a	86 a	5 d	73 a	4 c	42 a	4 c	41 a	5 b	94 a	6 c	95 a	4 c

For each species, treatments not sharing the same letter are significantly different at $P < 0.05$. MPG = maximum germination percentage, MGT = mean germination time; DF = Douglas-fir, SS = Sitka spruce , CAR = common alder, JL = Japanese larch, IAR =Italian alder, RC= western redcedar, SP = Scots pine.

rate as a single figure, and MGT is shown with the germination capacity figures in table 2. It is the average time taken for an average seed to germinate, hence a decrease in MGT indicates faster germination and therefore a beneficial effect.

The MGT of DF and IAR was unaffected by soaking compared to untreated control, whereas the MGT of all other species decreased significantly with soaking. Subsequent spinning had no significant effect on MGT for any of the species except SS, where it was increased by 1 day. However, even this increase was more than reversed by the 6-week prechill, so that for every species the combination of soak, spin, and prechill resulted in significantly faster germination than any other treatment, with MGT often reduced by over 50% .

Conclusion

Spin-drying wet tree seed of the two broadleaved tree and five conifer species used in this study is a simple and harmless method of surface-drying soaked seeds. The spun seeds are at a high-enough moisture content for germination capacity and rate to benefit from subsequent chilling. And at the end of the 6-week prechill the seeds are surface-dry, freeflowing, and suitable for immediate sowing.

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