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The Challenge of Producing Native Plants for the Intermountain Area

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The Challenge of Producing Native Plants for the Intermountain Area

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ABSTRACT: Germination of wildland seeds is often dependent on proper seed collection and storage. Timing, seed collection, and the moisture content of seeds in storage often influences germination. A systematic approach to germination testing often will pinpoint the type of dormancy of seeds in wildland species and lead to germination enhancement.

INTRODUCTION

Successful germination of seeds of plants collected from wildlands starts with proper collection of the seed, intactness of the collection and the handling of the freshly harvested seeds are important.

TIMING THE COLLECTION OF WILDLAND SEEDS

Many wildland plant species have indeterminate type inflorescences where flowering and maturity are continuous for extended periods. This means that seeds are ripe and falling from the inflorescences at the same time blooming is still occurring at other locations on the inflorescence. It is difficult to avoid collecting immature seeds in this situation. For determinate species that mature at one time there is the danger of the seeds shedding being dispersed and lost until they are collected slightly before maturity.

SLIGHTLY IMMATURE AND INCOMPETENT SEEDS

All seeds are not mature and ripe at the time they fall from the plant. Immature seeds do not have the same characteristics as mature seeds. Immature seeds may not be able to germinate, which means they cannot produce normal seedlings. Immature seeds are not desirable and should be removed before storage.

SEED CLEANING

Generally the sooner the seeds are cleaned and placed in storage the quicker the seeds will be ready for use in germination tests. The moisture content of the seeds can also affect the germination process. Seeds with a high moisture content may not be able to germinate, while seeds with a low moisture content may not be able to retain moisture in the seed.

SEED STORAGE

To avoid problems with storage insects, start with clean, insect-free storage containers. Do not introduce pest infestations with the seeds to be stored. Cool storage conditions lessen the chances of insect problems.

The key to seed storage is maintaining proper moisture conditions so that the seeds remain alive, but ungerminated. Remember that the amount of water that the storage atmosphere will hold as a vapor is directly related to the humidity. If you decrease the storage temperature of a sealed container, moisture condensation will occur. Storage in paper or cloth bags in a cool, dry location is satisfactory for most seeds. Once the seeds reach an equilibrium moisture content, storage in glass jars or plastic boxes is possible to avoid mold or mildew contamination. Some seeds can be stored easily in small lots, but others require special care to prevent the loss of seeds when stored together. Some seeds have inherently very short storage lives and seed stocks of these species must be removed annually.

GERMINATION TESTING

Two common determinations are made from seed tests: viability and germinability. Viability simply means the seeds are alive. It does not indicate if the seed will germinate. Viability tests may be as simple as cutting a seed or fruit with a knife blade or to determine if an embryo is present. More complex viability tests involve the use of the chemical hydrogen peroxide, after proper soaking and preparation of the seed, to detect the presence of hydrogen peroxide enzymes during the respiration process inflammation or living tissue in the seeds is evidenced by a red color change. The fact that the seeds or fruits contain living tissue does not mean the embryo will germinate. This is a common misinterpretation. For seeds of the major crop species, standards have been developed that relate the tetrazolium reaction to potential germination. These standards have not been developed for the seeds of most wildland species.

Germinability is a much more meaningful statistic for individuals interested in propagating plants from seeds. To obtain an estimate of germinability, the seeds must be subjected to a germination test. The test is conducted by an objective analysis (GSA) procedure to describe the rules for testing seeds of specific species. A standard soak of seed to remove impurities (the compress) is tested on germination paper, and 12 to 14 hours of light in darkness at 8 hours/16 hours at 8°C for 16 hours daily with light during the 8-hour period and potassium nitrate (KNO3) added to the substrate. (Unfortunately), for the seeds of most wildland species, no standard germination tests exist. The AGA has draft standards for about 100 wildland species. Until the standards are accepted and/or developed for the seeds of important wildland species, germination figures as given on seed tags are meaningless.

DETERMINING GERMINABILITY OF WILDLAND SPECIES

AFTERPENNING

The seeds of many species will not germinate soon after they are harvested. As time passes, germinability of these seeds gradually increases until they may be highly germinable. This period of time that must pass before the seeds will germinate has been termed the afterpenning requirement. These requirements are not responsive to excess water. The cannot do anything about them but wait.

This type of dormancy has been attributed to immature embryos that require post-harvest time to mature. A variant of this type of dormancy is called temperature-dependent afterpenning. In this case, seeds will not germinate at one incubation temperature (usually moderate to high incubation temperatures), but will germinate at other temperatures (usually cold incubation temperatures).

Practically, this means the nurseryman has to wait to obtain germination with the seeds of certain species. Do not confuse afterpenning with stratification. Stratification is a requirement that the dormancy does respond to external stimuli. Stratification requirements will be discussed later.

Hand Seed Coats

If seeds do not initially germinate or fail to germinate after a reasonable afterpenning period, the first germination factor to check is to see if the seeds imbibe water. This can be done by pressing the seed with a thumb or by cutting. If the interior of the seed appears shiny and hard, water has not been imbied through the seed coat. Imbied seeds would be soft and easily squashed with the thumb.

Seeds with coats that do not freely allow the passage of water are termed hard seeds.

Scariification

To break the hard seed coats some form of scarification is required. This scarification can be accomplished by pressure, etching, or chemical treatments. If the seeds are large enough, scarification may be accomplished by filling a notch in the cost or clipping so as not to injure the embryo. Seeds that are small can be scarified by mechanically abrating them in some manner. This may be as simple as rubbing the seeds between sheets of sandpaper.
Mechanical scarifiers have been developed with abrasive lined drums in which the seeds are rotated by the drum. Such chemicals that increase the degree of vilification, however, pay the price for getting some seeds to germinate by fatally injuring others. The rolls are used for scarifying seeds. Great care must be taken to not scarify seeds which have been treated with any treatments. Minimum clearance between concave bars in the polishing machine can be used to crack the seed of legumes to obtain increased germinability, but again, with some reduction in viability.

Thermal scarification is obtained by dropping seeds into boiling water and then allowing the water to cool. Such treatment may have many other influences such as thermal shock to the embryo or leaching soluble inhibitors. Thermal cracking of seed coats is facilitated at shallow depths with exposure to freezing temperatures.

Concentrated sulfuric acid is used to remove hard seed coats. This treatment is difficult to control and may have many side effects. The duration of treatment is difficult to determine for individual seed lots. Heating from the acid reaction with rinse water and hydration of the seed tissue may induce germination other than through the intended increased imbibition of water.

Always try to control the temperature of the acid-treated seeds in a water bath, rinse a small amount of acid and seeds in a large volume of water, and use a neutralizing solution after the treatment.

Stratification

Seeds that imbibe water but fail to germinate are good candidates for stratification. Do not confuse seed water uptake in stratification with seeds soaking in water at temperature fairly to germination. In most western plants these are temperatures too cold for germination. Such treatments are called cold-stratification. The duration of stratification exposure can range from a few days to many months. For prolonged stratification a substrate must be furnished for moisture retention. Historically peat has been used.

Commonly used materials include sand and vermiculite.

Naked stratification has proven effective for the seeds of some species of conifers. This is accomplished by soaking the seeds overnight in water and then placing the damp seeds in plastic bags that are sealed for the duration of the stratification.

Special stratification conditions include prolonged soaking in refrigerators with the seeds being saturated with oxygen or by using activated charcoal as a stratification medium.

Some species require specific stratification temperatures. Their seeds are very difficult to germinate without prolonged experimentation.

Nurserymen have long solved stratification problems by fall planting seeds and allowing nature to supply the treatment. For example, when the snow cover is prolonged, such practices can be quite effective. The indirect impact of snow cover is then considerably increased. A consequence of snow cover is longer periods of intact temperature or moisture conditions during the stratification period in prolonging the stratification requirement. Covering seeds in flats and covering them with sand and placing the flats outdoors on the northside of a greenhouse can provide a test environment for the stratification of seeds whose requirements are not known.

The seeds of several eastern hardwoods require periods of warm-moist stratification for germination. Some species require warm-moist stratification followed by cold-moist stratification.

Nitrate ion

The most influential factor in enhancing germination of seeds is often enrichment of the germination substrate with water soluble potassium nitrate (KNO3) at concentrations ranging from 1 to 10% (1.0 to 0.05 g per liter of water). In the field or nursery bed, flushes of spring germination may be associated, with stratification and the availability of nitrogen in the seedbed.

Gibberellic Acid

The mode of action of gibberellic acid in seed germination is not known, but very low concentrations of this growth regulator can greatly enhance germination. Concentrations of from 1 to 250 parts per million (p/m) are commonly used in germination enhancement. Solutions of gibberellic acid and potassium nitrate are more effective than either material alone. gibberellic acid can be obtained from chemical supply houses. The potassium nitrate is more easily obtained than gibberellic acid.

A good balance is needed for preparing the minute concentrations of gibberellic acid. A solution with a concentration of gibberellic acid of 0.001 grams of gibberellic acid dissolved in 1,000 milliliters of water is a 1000 parts per million solution. gibberellic acid is sold as a 1000 parts per million solution. The application is to prepare higher concentrations than needed and dilute to the desired concentration. For example, 1,000 p/m would be 1 p/l, 1000 ml of water, however, gibberellic acid crystallizes, and breaks down very rapidly under warm temperatures.

Hydrogen Peroxide

Seeds of several species, especially members of the rose family, may be treated by soaking in hydrogen peroxide solutions. Dramatic germination enhancement has been obtained with seeds of bitterbrush (Bursera tridentata), and curlyleaf mountain mahogany (Cercocarpus ledifolius).

A wide range of concentrations from 1 to 30 percent is effective. Generally, the higher the concentration, the shorter the soaking time, but the greater the risk of damaging the seeds. Hydrogen peroxide is very toxic and concentrations greater than 3 percent are particularly dangerous to handle.

Other Chemicals

A large number of other chemicals have been used to enhance germination. These include, among others, ethylene producing compounds and various sulfur compounds.

Lecithin

Many seeds are sensitive to light during germination. This light or phototropism interaction involves germination inhibition by near red light and darkness inductions by far red light. Generally, cool fluorescent light enhances germination and incandescent light should be avoided. In practicality, seeds that require light for germination have to be placed virtually on the surface of the seedbed. The seeds should be pressed into the seedbed for optimum moisture transfer.

SUGGESTED READINGS


PRODUCING BAREROOT SEEDLINGS OF NATIVE SHRUBS

Nancy Shaw

ABSTRACT: Barefoot planting stock of native shrub species is being requested for soil stabilization, range and wildlife habitat improvement, and low-maintenance landscaping projects in the Intermountain region. Seedlings of a number of species are successfully grown using modifications of techniques developed for the propagation of cuttings and introduced shrubs. Refinement of techniques and solutions to specific cultural problems in the production of individual species should improve the quality of stock being produced.

INTRODUCTION

Barefoot seedlings of introduced hardwood tree and shrub species traditionally used in windbreak and conservation plantings are routinely produced by many federal, state, and private nurseries. In the Intermountain region the need, and in some cases the legal requirement (McArthur 1981), for native species to revegetate disturbed lands has led to the production of a number of native shrubs as barefoot stock. Seed and transplant stock of species suited to specific habitat types are needed for reclamation of disturbed sites, range and wildlife habitat improvement, and low-maintenance landscaping.

The decision to use barefoot or container planting stock depends upon a number of factors:

1. Species required. Although some species are difficult to grow as barefoot stock, others have been successfully propagated (Tables 1, 2) using modifications of cultural practices developed for cuttings. Information relating to the germination and growth of related species (for example, Rosa, Phys., or Prunus spp.) has also been applied. Cultural practices are being refined based on experience gained in growing native plants at specific nursery sites. Consequently, techniques and information exist that are not presently available in the literature.

2. Characteristics of the planting site. Both container and barefoot seedlings have been successfully planted on a wide range of wildland sites.

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Although barefoot stock generally does not perform as well on adverse sites (Hodder 1970), particularly rocky areas where there is inadequate soil to pack around the root system,

3. Scheduling. The time from seed collection to lifting of barefoot stock varies from approximately 11 months for fall lifting 1-0 big sagebrush (Artemisia tridentata) to nearly 3 years for species such as Rocky Mountain maple (Acer glabrum) that are lifted as 7-0 stock. For some species sowing and lifting may be scheduled for either fall or spring.

4. Cost. Barefoot seedlings generally cost less than seedlings grown in containers. Consequently, their use may often be justified economically. Handling and transportation of barefoot seedlings must be carefully planned to protect plants from desiccation and overheating before planting (Dahlgreen 1976). However, barefoot seedlings are much less bulky than container seedlings, and if adequate storage facilities are available, they can be transported and maintained with much less difficulty and at a lower cost (Stevens 1981).

PLANNING AND SCHEDULING

For both speculation and contracting growing the source of seed or cuttings should be carefully selected. Extensive morphological and physiological variation exists among populations of individual native shrub species (Stutz 1974; Blauer and others 1979; Welch and Monser 1981). Populations vary in their range of adaptation, growth habit, growth rates, palatability, nutrient value, soil stabilizing capability, and ease of propagation. The opportunity exists to select and market transplants using seed or cuttings from populations adapted to the planting site that exhibit characteristics compatible with specific planting goals.

Seed production of many shrub species is aristic and scheduling problems may make seed collection difficult. Seed of some minor species is not harvested regularly by commercial collectors. Seed of easily rooted species may be
propagated from cuttings if seed is unavailable or difficult to germinate.

All steps in the propagation of each species must be carefully followed. Seed and cuttings must be collected during the appropriate season (see Plummer and others 1961; U.S. Department of Agriculture, Forest Service 1974; Hartmann and Parker 1981). Respect for these rules will prevent confusion and subsequent seed development in the nursery beds. Seedlings, propagated by the Chrysanthemum spp., and other species are often sold at low prices for ornamental seedlings. Purchased seed of these species may require additional cleaning for nursery use.

Seed germination and storage.

Seed lots must be cleaned carefully to obtain high purity levels. Clean seed is required to maintain uniformity of seed placement and, subsequently, seedling development in the nursery beds. Seedlings, propagated by Chrysanthemum spp., and other species are often sold at low prices for ornamental seedlings. Purchased seed of these species may require additional cleaning for nursery use.

Optimum storage conditions and the effect of various storage methods on the duration of seed viability have not been determined for most native plant species. Dry seed of sunflower (Helianthus spp.), and other species with water/irrigration seed costs will remain viable for 10 to 20 years when exposed to ambient temperature and humidity conditions in open storage (Hart 1975; Hartmann and Parker 1981). Seeds and others (1981) found that seed contamination is being produced under agricultural conditions in seed orchards or seed fields and is commercially available. The characteristics and range of adaptation of each named variety have been carefully determined. Production of shrub seed under selected propagation methods should result in improved seed quality and availability as appropriate cultural techniques are developed for each species. Other seed sources include plants of selected species grown on nursery plots, collections from selected wildland stands, or purchases from commercial seed dealers. Seed source information should be provided with purchased seed. Acceptable purity levels for seed used for wildland plantings have not been established (Plummer and others 1961). Acceptable germination levels are given in Table 1. Seed purity specifications have not been established for native shrubs. For contract growing, seed of populations known to be adapted to the planting site should be obtained.

Precise timing is essential for the collection of seed from wildland stands. Maturation dates for individual species vary, but generally, from May to July (Plummer and others 1961). In fact, the exact seed maturation date for a specific wildland stand will depend upon its geographic location and local weather conditions. This is a specific species. For general information, see Table 2. Results of a survey conducted by Hartmann and Parker (1975), conducted by Hartmann and Parker (1975).

Testing

Purity and germination or viability tests are used to provide an estimate of seed quality. Seed purity tests are subsequently used to determine the number of seed per pound. Parity and seed weight are obtained on the same test plus determination of number of seeds per pound. Germination tests are conducted by the U.S. Department of Agriculture, Forest Service, East Central Region, and the U.S. Department of Agriculture, Forest Service, East Central Region. For further information, see Table 3. Results of a survey conducted by Hartmann and Parker (1975).
Table I.--Nursery production of native plant species.

<table>
<thead>
<tr>
<th>Species</th>
<th>Seeding date</th>
<th>Root or broadcast</th>
<th>Top</th>
<th>Root</th>
<th>Lifting considerations</th>
<th>Production period</th>
<th>Harvesting</th>
<th>Propagation</th>
<th>Establishment</th>
<th>Special considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bitterbrush, silverleaf</td>
<td>Fall</td>
<td>Lateral root</td>
<td>X</td>
<td>None</td>
<td>from cuttings</td>
<td>1-0</td>
<td>X</td>
<td>Seed germination</td>
<td>1-0</td>
<td></td>
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<tr>
<td>Blueberry, silver</td>
<td>Fall</td>
<td></td>
<td>X</td>
<td>Thick</td>
<td>from cuttings</td>
<td>1-0</td>
<td>X</td>
<td>Seed germination</td>
<td>1-0</td>
<td></td>
</tr>
<tr>
<td>Balsamroot, silver</td>
<td>Fall</td>
<td>Lateral root</td>
<td>X</td>
<td>None</td>
<td>from cuttings</td>
<td>1-0 or 2-0</td>
<td>X</td>
<td>Seed germination</td>
<td>1-0</td>
<td></td>
</tr>
<tr>
<td>Camas, white</td>
<td>Fall</td>
<td></td>
<td></td>
<td>None</td>
<td>from cuttings</td>
<td>1-0</td>
<td>X</td>
<td>Seed germination</td>
<td>1-0</td>
<td></td>
</tr>
<tr>
<td>Chokecherry, comstock</td>
<td>Fall</td>
<td></td>
<td></td>
<td>None</td>
<td>from cuttings</td>
<td>1-0</td>
<td>X</td>
<td>Seed germination</td>
<td>1-0</td>
<td></td>
</tr>
<tr>
<td>Climbing, canyon</td>
<td>Fall</td>
<td>Lateral root</td>
<td>X</td>
<td>None</td>
<td>from cuttings</td>
<td>1-0 or 2-0</td>
<td>X</td>
<td>Seed germination</td>
<td>1-0</td>
<td></td>
</tr>
<tr>
<td>Common, silver</td>
<td>Fall</td>
<td></td>
<td></td>
<td>None</td>
<td>from cuttings</td>
<td>1-0</td>
<td>X</td>
<td>Seed germination</td>
<td>1-0</td>
<td></td>
</tr>
<tr>
<td>Dogwood, adelphi</td>
<td>Fall</td>
<td></td>
<td></td>
<td>None</td>
<td>from cuttings</td>
<td>1-0 or 2-0</td>
<td>X</td>
<td>Seed germination</td>
<td>1-0</td>
<td></td>
</tr>
<tr>
<td>Fireweed, silver</td>
<td>Fall, spring</td>
<td></td>
<td>X</td>
<td>Large</td>
<td>from cuttings</td>
<td>1-0</td>
<td>X</td>
<td>Seed germination</td>
<td>1-0</td>
<td></td>
</tr>
<tr>
<td>Fishhook, green</td>
<td>Fall</td>
<td></td>
<td></td>
<td>None</td>
<td>from cuttings</td>
<td>1-0</td>
<td>X</td>
<td>Seed germination</td>
<td>1-0</td>
<td></td>
</tr>
<tr>
<td>Hawthorn, white</td>
<td>Fall</td>
<td></td>
<td></td>
<td>None</td>
<td>from cuttings</td>
<td>1-0</td>
<td>X</td>
<td>Seed germination</td>
<td>1-0</td>
<td></td>
</tr>
<tr>
<td>Juniper, Rocky Mtn</td>
<td>Summer</td>
<td></td>
<td></td>
<td>None</td>
<td>from cuttings</td>
<td>1-0</td>
<td>X</td>
<td>Seed germination</td>
<td>1-0</td>
<td></td>
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<tr>
<td>Oak, Rocky Mtn</td>
<td>Fall</td>
<td></td>
<td></td>
<td>None</td>
<td>from cuttings</td>
<td>1-0 or 2-0</td>
<td>X</td>
<td>Seed germination</td>
<td>1-0</td>
<td></td>
</tr>
<tr>
<td>Mountain mahogany, silver</td>
<td>Fall</td>
<td></td>
<td></td>
<td>None</td>
<td>from cuttings</td>
<td>1-0</td>
<td>X</td>
<td>Seed germination</td>
<td>1-0</td>
<td></td>
</tr>
<tr>
<td>Rabbitbrush, fother</td>
<td>Fall, spring</td>
<td>X</td>
<td>Large</td>
<td>Top</td>
<td>from cuttings</td>
<td>1-0</td>
<td>X</td>
<td>Seed germination</td>
<td>1-0</td>
<td></td>
</tr>
<tr>
<td>Rose, woods</td>
<td>Fall</td>
<td></td>
<td></td>
<td>Large</td>
<td>from cuttings</td>
<td>1-0</td>
<td>X</td>
<td>Seed germination</td>
<td>1-0</td>
<td></td>
</tr>
<tr>
<td>Sassafras, Big</td>
<td>Fall, spring</td>
<td>X</td>
<td>Large</td>
<td>Top</td>
<td>from cuttings</td>
<td>1-0</td>
<td>X</td>
<td>Seed germination</td>
<td>1-0</td>
<td></td>
</tr>
<tr>
<td>Saltbrush, flowering</td>
<td>Fall</td>
<td></td>
<td></td>
<td>Large</td>
<td>from cuttings</td>
<td>1-0</td>
<td>X</td>
<td>Seed germination</td>
<td>1-0</td>
<td></td>
</tr>
<tr>
<td>Saltmarsh, silver</td>
<td>Fall</td>
<td></td>
<td></td>
<td>None</td>
<td>from cuttings</td>
<td>1-0 or 2-0</td>
<td>X</td>
<td>Seed germination</td>
<td>1-0</td>
<td></td>
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<td>Snowbrush, comstock</td>
<td>Late summer</td>
<td>X</td>
<td>Large</td>
<td>Top</td>
<td>from cuttings</td>
<td>1-0</td>
<td>X</td>
<td>Seed germination</td>
<td>1-0</td>
<td></td>
</tr>
<tr>
<td>Smoketree, black</td>
<td>Fall</td>
<td></td>
<td></td>
<td>None</td>
<td>from cuttings</td>
<td>1-0</td>
<td>X</td>
<td>Seed germination</td>
<td>1-0</td>
<td></td>
</tr>
<tr>
<td>Russian, thorn</td>
<td>Fall, spring</td>
<td>X</td>
<td>Large</td>
<td>Top</td>
<td>from cuttings</td>
<td>1-0</td>
<td>X</td>
<td>Seed germination</td>
<td>1-0</td>
<td></td>
</tr>
<tr>
<td>Willow, species</td>
<td>Fall</td>
<td>X</td>
<td>Extensive</td>
<td>Root</td>
<td>system</td>
<td>1-0</td>
<td>X</td>
<td>Seed germination</td>
<td>1-0</td>
<td></td>
</tr>
</tbody>
</table>

Table 1. Seedling production of native plant species.

individual native shrub species have not yet been established. Consequently, each seed laboratory has developed or adopted procedures for generating commonly tested species.

Individual populations of a single shrub species may vary widely in propagation requirements. In addition, the prolonged stratification periods required to release the dormancy of many shrub species (Diers et al. 1981) decrease the usefulness of germination tests. Tetrazolium chloride tests of seed viability are frequently substituted for germination tests. At present, tetrazolium chloride test results for native shrubs are generally higher and more consistent than germination results, as not all viable seed will germinate under the less than optimum germination conditions provided.

Conditioning

Some native shrub species require presowing treatments to release various forms of seed dormancy (Heitz 1973). U.S. Department of Agriculture, Forest Service 1974, Diers et al. 1981; table 1). Acid or mechanical scarification, dry heat, hot water, hormone applications, and other chemical treatments are commonly used. The level of treatment required varies with accession and condition of the seedlot.

Dormancy requirements of many native shrub species are met by fall seedling, Heitz (1963) found fall seedling of many dormant species fulfilled cold stratification requirements and provided increased seedling production, more uniform stands, maximum first year production, and less disease loss compared to spring sowling. He provided fall sowling recommendations for 95 shrub species. Species requiring moist stratification may be sown during late summer or early fall, watered, and covered with a layer of polyethylene or other mulching material. Artificially stratified seed of dormant species and seed of nondormant species such as rabbitbrush and waverly (Gerardia lamarckii) may be sown in spring.

Seed should be artificially stratified if it is futilely that an adequate stratification period would be feasible in nurseries. Artificial stratification is also an alternative if seed is not available at the time of fall seeding or when fall seeding is impossible due to weather conditions. Spring sowling also provides a means of controlling seedling size.

Sowing

Some developed nursery drills such as the Liner-Drill are capable of sowing seeds with a wide range of sizes and shapes. Seeds must be carefully cleaned to facilitate uniform distribution and prevent clogging of the drill drop tube. Seed of big saphbrush, which propagates well over 2,000,000 seeds per pound (4,100,000 per kg) (Flummer and others 1961), for example, can be successfully seeded through such drills if first cleaned to a purity of 80 percent or greater. Other nursery drills that were developed for conifer seed are difficult to calibrate and cannot be used to sow small-seeded species.

Seeding Rate

Optimum seedling densities have not been established for native shrubs. Densities selected depend upon the species grown, geographic location of the nursery, size requirements for lifted seedlings, and other nursery conditions. Most shrubs grow rapidly compared to conifers and can be lifted at 1-0 stock. Fouring saltbush, blueberry elder (Sambucus cerulea), big saphbrush and related species develop extensively branched shoot systems, large taproots, and spreading, lateral root systems, particularly when grown at low densities. Although they grow rapidly, species such as common chokecherry (Prunus virginiana) and curled mountain mahogany (Cercocarpus le Pegue) usually produce one main shoot and only moderate sized root systems. Slowly developing species, such as silver buffaloberry (Shepherdia argentea) and Rocky Mountain maple may be lifted at 2-0 stock and are normally planted at higher densities than species on a 1-0 rotation. Desired densities for native plant species range from 16 to 25 per square foot (172 to 267/m2) at the Lucky Peak Nursery.

For many shrub species, the amount of seed required to produce a requested number of seedlings may be only estimated. Cutting rates and seedbed fertility figures have not been established for individual species at all nurseries because only a few seedlots have been grown to provide adequate data. In addition, these figures are not to vary with the seed accessibility being grown. At the Lucky Peak Nursery, seedbed mortality figures of 40 percent and cutting rate of 30 percent are used for all native plant species.

The following equation may be used to calculate the amount of clean seed required to grow a specified number of plantable seedlings. Data for typical seed lots and conditions for production at the Lucky Peak Nursery were used to calculate the number of seed required to produce 1,000 plantable seedlings of antelope bitterbrush and fourwing saltbush.

\[
\text{Number of seedlings required} = \frac{\text{Number of seedlings desired} \times \text{Seedbed mortality figure}}{\text{Cutting rate}}
\]
of the time the surface of the seedbed must be kept moist. Fungal infections are of concern in the production of antelope bitterbrush, flowering saltbush, mountain mahogany, and other native plants. Evergreen must be enhanced by timely sterilizing the seed or during the seed with a fungicide such as Captan (Booth 1986). If seedling movement is desired, water should be applied only sparingly.

Fertilization

Native plants are generally faster growing and less demanding of nutrients than conifers. If adequate nutrient levels are established before seeding, deficiencies of root elements are not likely to occur (Smith 1987). Nitrogen applications are usually necessary, particularly if high biomass is expected as a result of anchoring. Conifers and shrubs normally receive similar fertilizer treatments at the Lucky Peak Nursery. Two thousand pounds per acre (724 kg/ha) of 11-11-11 are incorporated into the soil prior to sowing. Ammonium nitrate (34-0-0) and superphosphate (0-4-0) are applied as side dressings.

Weed Control

Soil fungi can be applied to nursery beds before seedling to reduce weed problems. However, late August or early September fertilization with nitrogen (20 percent and 27 percent) at 240 and 345 lbs/acre (100 and 152 kg/ha) followed by seedling applications has produced unsatisfactory results in northern Plains nurseries (Kester 1983). The use of fungicides such as Mylone that eliminate root rots are less harmful to mycorrhizal fungi was recommended.

Most native shrub seedlings are weeded mechanically or by hand as recommended practices are not available for individual species. Cummer and Young (1972) believed that herbicide recommendations established for agricultural species could be transferred to related wildland shrubs following simple testing. They found that preemergence herbicides technique developed for alfalfa could be applied to several leguminous shrubs.

Several introduced hardy species as well as antelope browse are known to have been included in the western forests by our nursery (Booth 1980; Kyler 1979). Ryker (1979) found postemergence and postapplication applications of herbicide reduced growth of antelope bitterbrush and common checkbrush while postemergence and postapplication applications of 2,4-D were safe for common checkbrush. Eide has used a post-emergence herbicide, 2,4-D, on the Lucky Peak Nursery. Nursery managers should test promising herbicide treatments by applying them to test plots of individual species at the nursery site before large scale application (Sandquist and others 1985).

Pruning

Many shrub species grow rapidly, producing highly branched shoots (flowering saltbush, big sagebush) or shoots with numerous large leaves (blueberry elder, smooth squaw) during the first growing season. Large plants dominate seedlings or later gerninating seedlings, resulting in a lack of plant uniformity. Top pruning larger seedlings encourages more uniform growth and improves shoot/root ratios because smaller seedlings are released from competition. Top pruning early in the season promotes the development of more shoots on the lower stems (Williams and Banks 1976). Seedlings may also be pruned in the nursery during the dormant season or in the packing shed after lifting. These are more desirable size for packing and planting.

Roots are pruned to increase uniformity, stimulate fibrous root development, and improve shoot/root ratios. Severing the taproot of bittershurb, flowering saltbush, blueberry elder, and other species early in the growing season serves to stimulate lateral root growth. The fibrous roots that develop are stronger and less easily damaged during lifting. Pruning of vigorously growing species one or more times during the growing season at increasing depth (for example, 4.5 cm or 2 inches) also prevents the development of a normal lifting depth. If these thick taproots are damaged during lifting, the open wound can easily be infected with disease organisms.

Lateral root pruning is used to increase fibrous root development, control seedling size, and facilitate lifting. Roots of some species (for example, shrub prunings, fragrant) may intertwine in the nursery bed and must be separated by hand during sorting.

SEEDLING HARVESTING AND STORAGE

Lifting

Shrub seedlings are frequently lifted in the spring, and usually break dormancy earlier in the spring than the conifer. Most seedlings may be lifted in the fall for immediate planting, when weather and soil conditions are suitable. Lift the fall lifting and overwinter storage is a third option, especially if a higher percentage of the seedlings are planted early in the spring before weather conditions are suitable. Lift the fall lifting and overwinter seedling storage also serve to reduce the spring workload and free bed space for sowing. Seedlings should not be lifted in the fall until they are adequately hardened by exposure to low temperature or frosts, or following leaf fall (Williams and Banks 1976).

Storage

Fall-lifted seedlings of deciduous species may be held in frozen storage at 28°F (-2°C) for extended periods. Seedlings should be protected from desiccation. At the Lucky Peak Nursery all-weather bitterbrush and other shrubs may be fall-lifted for immediate planting at local sites. Seedlings not planted in 1981 were shipped in Kraft bags with polyethylene liners and stored in cold storage (Freezer 1985) for spring planting. Carpenter (1983; Carpenter, personal communication). Fall-lifted seedlings with persistent leaves are subject to mild infection if held in cold storage and may be more successfully stored by "heeling in", although the success of this technique depends upon local weather conditions. At Lucky Peak spring-lifted shrubs are refrigerated at 32° to 34°F (0° to 1°C) in freezing storage for periods of 1 to 3 months prior to planting.

VEGETATIVE PROPAGATION

Some species of native plants are more easily and economically produced from cuttings than from seed. Vegetative propagation is also used to maintain the genetic identity of stock with desirable characteristics. Such woody rooted species as willows (Salix spp.), poplars (Populus spp.), and cottonwoods are often produced from hardwood cuttings, alpine wormwood (Artemisia absinthium), Ashbush (A. abrotanum), willow (Salix spp.), and current (Ribes spp., I have grown from cuttings at the Lucky Peak Nursery in 1983; Carpenter, personal communication).

Hardwood or semi-hardwood cuttings of the Woodward species root readily and may be collected and planted without callosity. Cuttings may be made when the plants are dormant any time during the growing season. Most species that can be propagated vegetatively are grown from hardwood cuttings. Hardwood cuttings are inexpensiveness and are collected, handled, stored, and propagated. Cuttings are collected from stems near the planting site or from cutting blocks maintained at the nursery. Cuttings are taken during periods from healthy, moderately vigorous plants growing in full sunlight. Wood from the previous season is selected. Individual cuttings should include at least two buds and may be 6 inches (15 to 76 cm) in length and from 0.25 to 1.5 inches (0.6 to 3.8 cm) in diameter. Almost all hardwoods (Kent and Kester 1975; Williams and Banks 1976).

Cuttings of species that do not root readily must be treated with a substance such as indolebutyric acid, naphthaleneacetic acid, or indoleacetic acid at concentrations between 500 and 10,000 ppm (0.5 to 1.0 g per liter) commonly with higher concentration usually being more effective. Hardwood cuttings. Fungicides such as captan or benomyl may be applied in combination with auxin compounds. Cuttings should be allowed to callus for several weeks.
ABSTRACT: Crops of native plants should be planned to allow enough time for seed collection, seed processing, seed treatment and stratification, greenhouse growth, and hardening. An ideal container nursery consists of a production greenhouse, a cold frame, a shadehouse and refrigerated storage. Four propagation methods can be used to produce native plants: direct seeding, germinants, transplants, and rooted cuttings. The choice of container should consider seedling growth, species characteristics and outplanting site. Most native plants can be grown reasonably well under a standard greenhouse environment and in commercial potting mixes. The type and amount of hardening will depend on the species characteristics and the future use of the plant. Nursery managers must be aware of variation between species, seed sources, and annual seed crops. Successful growers must acquire direct experience in producing each species under their own nursery system.

INTRODUCTION

The large scale production of native plants is still a relatively new enterprise and the growing of container seedlings is in the newest production technique in western forest nurseries. Producing native plants in containers is a logical operation, however, because some species have proved difficult to grow as bare root seedlings. For example, Hovenia dulcis (Saskatoon) grows very brittle stems and fragile root systems which are sensitive to breakage during bare root lifting operations and the extensive root system of elderberry (Sambucus spp.) makes it hard to culture in seedbeds. Species such as Artemisia (Egremont)BLA) just seem to grow better in containers.

Container seedlings have been reported to have several advantages over bare root seedlings such as a shorter production period and improved survival and growth after outplanting (Stel's 1974). As already mentioned, some species are easier to grow in containers compared to bare root stock and there is no root disturbance during seedling processing. On the other hand, container seedlings suffer less transplant shock and are generally easier to plant than bare root seedlings. Instead of the limited spring planting period for bare root trees, container seedlings have been successfully outplanted during the fall and may be suitable for other planting times as well (Stel's 1974).

Although tree seedlings have been grown in containers for well over a decade, only a few nurseries are producing native plants as container seedlings. Compared to commercial tree species, very little is known about the culture of native plants in greenhouses. Many nursery managers are reluctant to try and grow natives because they have heard horror stories about the difficulty of breaking seed dormancy, and the availability and quality of native plant seeds have been unreliable.

The objective of this paper, therefore, is to discuss some of the cultural practices useful in growing native plants in containers. Because of their years of experience and good reputation in the field, the greenhouse operations of Native Plants Inc. of Salt Lake City, Utah, will be used as a model throughout the paper. Other pertinent literature will be referred to whenever appropriate.

PLANNING AND CROP SCHEDULING

Before the decision is made to produce native plants in containers, the grower should assess the potential market. This assessment requires business and marketing skills which are beyond the scope of this paper. Basically, though, there are two business approaches: (1) contract growing, or (2) speculation on future demand. Growing contracts are typically a designated number of one or more plant species which are to be grown to certain size and quality standards by a specified time. Speculative growing is often risky and requires a keen appraisal of future markets. Some nurseries like Native Plants Inc. operate with a combination of contract and speculation growing.

The market analysis should result in a list of plant species to be produced. The grower must next decide whether the species can best be propagated by seeds or by vegetative cuttings. Seed dealers should be consulted to determine seed availability as some native plants do not produce a good seed crop every year and seed of some species does not store well. The grower must be certain that he can secure enough seedlings before proceeding with the planting process.

When the crop species have been selected, the grower should develop detailed production schedules that delineate the duration and sequence of the various operations (fig. 1 & 2). Crop planning is normally done during April or May so that there is enough time to secure seed later in the summer or early fall.
If seed must be procured, the total time for crop production may take from 1 to 2 years depending on the species of native plant and the type of propagation methods used (Table 1). These rotation times are longer than for a typical conifer seedling which may only take from 6 to 12 months. The longer production period is primarily due to the problems of seed collection and processing and the extended stratification periods required for many native plant species. If seed can be obtained immediately, then the production time of some native species can be reduced to about 1 year. Most native plant seed can be collected and stored ahead of time, although storage periods vary with species. Bubble wrap (Berger 1972) can be stored under refrigeration for over 10 years, whereas prunus syrup cress (Convolvulaceae) loses viability after one year (Steve Wesson, pers. comm.). For planning purposes, however, it would be wise to use new growers to allow ample time to grow their first crop of native plants.

Table 1—Properties of four propagation methods for producing native plants in containers

<table>
<thead>
<tr>
<th>Propagation Techniques</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Seeds — Direct sowing of seed in growth containers</td>
<td>N/A</td>
<td>• Hard to control cell occupancy</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Requires thinning and consolidation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Inefficient and costly use of seed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Greenhouse time lost prior to emergence</td>
</tr>
<tr>
<td>2. Germinants — Sowing germinated seed from stratification into growth containers</td>
<td>Control of cell occupancy and seedling density</td>
<td>Sowing is slow of involves skilled labor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Efficient use of valuable seed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Good use of greenhouse space</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Accommodates variable germination rates</td>
</tr>
<tr>
<td>3. Transplants — Seedlings are grown in trays and transplanted to containers</td>
<td>Control of cell occupancy and seedling density</td>
<td>Transplanting is slow and involves skilled labor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Efficient use of valuable seed</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Good use of greenhouse space</td>
</tr>
<tr>
<td></td>
<td></td>
<td>More uniform crop development</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Can use natural or artificial stratification</td>
</tr>
<tr>
<td>4. Rooted cuttings — Vegetative cuttings are rooted in trays; transplanted to growth containers</td>
<td>N/A</td>
<td>Transplanting is slow and involves skilled labor</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Requires additional operation of sowing seed trays</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Overly dense seed trays could lower seedling vigor or lead to disease problems</td>
</tr>
</tbody>
</table>

**Production Facilitites**

Whereas many ornamental crops can be produced in a single structure, the greenhouse, native plants may require as many as four separate facilities. The ideal conditions for species 3, a production greenhouse to grow the seedlings, 2) a cold frame or shadehouse to harden plants, 3) a shadehouse to store the seedlings until they are sold and 4) refrigerated storage to maintain dormant stock for late season plantings. Native Plants Inc. has a multi-structured area consisting of greenhouses, a cold frame, and an extensive shadehouse.

The best type of greenhouse depends on several factors but most important is the nursery climate. Most native plants are best grown in areas where light and climate can be controlled to meet the growing requirements of the species. Different facilities are discussed in detail in Times and Schindler (1979).

One of the operational advantages of a fully-control greenhouse is the production of more than one crop per year; Native Plants Inc. is capable of producing twelve crops of plants per year depending on species. Some plants do not grow well when there is not enough light or water or when there is too much light or water. The most important aspect of growing native plants in a greenhouse is the availability of the proper growing conditions for a species. The greenhouse is usually covered with some type of material such as paper or plastic to control the light. It is generally linked in room temperature water for 24-48 hours and surfaces dried before sowing.

The seeding procedure begins with the calculation of the proper amount of seed for each species. The seeds are then spread on a medium to a seedling per cell. Because of the irregular shape and size of most native plants, the sowing is done by hand although a shunter or vacuum seed could be used for certain species and large seed lots. The small seed is usually covered with some type of material such as perlite or grit to hold the seed in contact with the potting soil and retard evaporation and algae growth.

The success of the direct seeding method is dependent on the accuracy of the seed information. Germination tests done in the lab and on standardized tests are available for many native shrubs and forbs. A germination test is run under ideal conditions and therefore test results may differ from greenhouse germination. Sometimes the seed is obtained just before the sowing date and so there is not enough time for seed testing.

The germination technique is defined as the sowing of germinated seed into the growth container.
Seed can be germinated in "sowed" stratification equipment. The seeds are sown in a light mist and broadcast seed by hand. Very small seed can be applied through a light mist to ensure even seed distribution. Cover the seed with a thin layer of fine-textured material such as sand-blasting grit.

Transplanting

The transplant trays are filled about 2 inches (5 cm) deep with standard potting mix and broadcast seeds are applied through a light mist to ensure even seed distribution. Cover the seed with a thin layer of fine-textured material such as sand-blasting grit.

Seeds that require stratification are sown in the fall, irritated, and moved to a cool location and protected against desiccation. This outside storage allows the seeds to naturally stratify over winter. When the trays are brought into the greenhouse in the spring, the seeds germinate readily and can be immediately transplanted. A growing schedule for this propagation method is given in fig. 2.

For seeds that do not require stratification, the transplant trays are not refrigerated. In the greenhouse, the transplant flats are kept in the same environment and germination usually occurs in 1-2 weeks. Once the seedlings grow to the cut-back stage, they are ready for transplanting. The transplanting procedure involves working the seedlings loose from the soil, making a dibble hole in the potting soil of the ground container, and transplanting a seedling into the hole. The potting soil is then fitted around the seedling and the germination trays are irrigated and moved to the greenhouse benches. An experienced worker can transplant up to 2,000 seedlings in an 8-hour day.

When all the seedlings have been removed from the transplant trays, the soil is mixed and irrigated, and the plants allowed to sprout again. Depending on the germination rate, the trays may produce up to three crops of transplant material.

Propagated cuttings are the final propagation method and are best suited for species that can be propagated by either cuttings or seeds. The cuttings may be propagated from cuttings, rubbing, air-layering, or by removing the terminal growth of the stem.

Cuttings are the final propagation method and are best suited for species that can be propagated by either cuttings or seeds. The cuttings may be propagated from cuttings, rubbing, air-layering, or by removing the terminal growth of the stem.

The propagation techniques used by Native Plants Inc. for 23 native plants are listed in table 2.

Croppings of all the species shown in the chart are propagated by one technique. Certain species are propagated more easily by cuttings when propagated in the greenhouse whereas others can be grown only during the growing season. The table also indicates the time required to produce a salable plant in the greenhouse and varies from 6-8 months.

CROPPING POTENTIAL AND POTENTIAL

The best size, shape, and volume of growth container for propagating a native plant that will survive and grow in the greenhouse (and survive the open to depict...
Table 2 - Propagation procedures for selected native plants

<table>
<thead>
<tr>
<th>Species</th>
<th>Stratification Period (Days)</th>
<th>Propagation Method</th>
<th>Production Scheduling</th>
<th>Production Scheduling</th>
<th>Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acer circinatum, vine maple</td>
<td>120-240</td>
<td>G. T.</td>
<td>Spring</td>
<td>4-9</td>
<td></td>
</tr>
<tr>
<td>Amelanchier alnifolia, serviceberry</td>
<td>120-180</td>
<td>G. T.</td>
<td>Spring</td>
<td>4-9</td>
<td></td>
</tr>
<tr>
<td>Atriplex litoralis</td>
<td>2-10</td>
<td>G. T.</td>
<td>Spring</td>
<td>4-9</td>
<td></td>
</tr>
<tr>
<td>Ceratocarya spinosa</td>
<td>6-8</td>
<td>T. S.</td>
<td>Spr.</td>
<td>3-6</td>
<td></td>
</tr>
<tr>
<td>Chamaecyparis thyoides, big sagebrush</td>
<td>0-10</td>
<td>T. S.</td>
<td>Spr.</td>
<td>3-6</td>
<td></td>
</tr>
<tr>
<td>Cercocarpus montanus, mountain mahogany</td>
<td>30-50</td>
<td>T. S.</td>
<td>Spr.</td>
<td>3-6</td>
<td></td>
</tr>
<tr>
<td>Chamaecyparis lawsoniana, rabbitbrush</td>
<td>2-10</td>
<td>T. S.</td>
<td>Spr.</td>
<td>3-6</td>
<td></td>
</tr>
<tr>
<td>Chloris decumbens, stiffgrass</td>
<td>6-8</td>
<td>T. S.</td>
<td>Summer</td>
<td>4-9</td>
<td></td>
</tr>
<tr>
<td>Chondrilla juniperoides, honey locust</td>
<td>6-8</td>
<td>T. S.</td>
<td>Summer</td>
<td>4-9</td>
<td></td>
</tr>
<tr>
<td>Ceanothus crassifolius, Rocky Mountain juniper</td>
<td>120</td>
<td>T. S.</td>
<td>Spr.</td>
<td>3-6</td>
<td></td>
</tr>
<tr>
<td>Coleus scutellarioides, singleleaf plum</td>
<td>28-90</td>
<td>T. S.</td>
<td>Any</td>
<td>8-12</td>
<td></td>
</tr>
<tr>
<td>Picea engelmannii, singleleaf burning</td>
<td>0-10</td>
<td>T. S.</td>
<td>Spr.</td>
<td>3-6</td>
<td></td>
</tr>
<tr>
<td>Pinus edulis, white fir</td>
<td>0-10</td>
<td>T. S.</td>
<td>Spr.</td>
<td>3-6</td>
<td></td>
</tr>
<tr>
<td>Pinus contorta, whitebark pine</td>
<td>0-10</td>
<td>T. S.</td>
<td>Spr.</td>
<td>3-6</td>
<td></td>
</tr>
<tr>
<td>Prunus virginiana, chokecherry</td>
<td>120-160</td>
<td>G. T.</td>
<td>Ay</td>
<td>3-5</td>
<td></td>
</tr>
<tr>
<td>Pyracantha coccinea, bitterbrush</td>
<td>60-90</td>
<td>G. S.</td>
<td>Ay</td>
<td>3-5</td>
<td></td>
</tr>
<tr>
<td>Quercus garryana, Gambel oak</td>
<td>0-10</td>
<td>G. S.</td>
<td>Fall</td>
<td>6-9</td>
<td></td>
</tr>
<tr>
<td>Rosa multiflora, shubherry rose</td>
<td>30-60</td>
<td>G. S.</td>
<td>Fall</td>
<td>6-9</td>
<td></td>
</tr>
<tr>
<td>Rubus idaeus, blackberry</td>
<td>30-64</td>
<td>T. S.</td>
<td>Spr.</td>
<td>3-6</td>
<td></td>
</tr>
<tr>
<td>Rubus fruticosus, blue elderberry</td>
<td>30-120</td>
<td>T. S.</td>
<td>Spring</td>
<td>3-5</td>
<td></td>
</tr>
<tr>
<td>Rubus idaeus, blackberry</td>
<td>30-120</td>
<td>T. S.</td>
<td>Spring</td>
<td>3-5</td>
<td></td>
</tr>
<tr>
<td>Salix amygdaloides, willow</td>
<td>60-120</td>
<td>T. S.</td>
<td>Spring</td>
<td>3-5</td>
<td></td>
</tr>
<tr>
<td>Smilax glabra, gooseneck</td>
<td>0-10</td>
<td>G. S.</td>
<td>Fall</td>
<td>6-9</td>
<td></td>
</tr>
<tr>
<td>Smilax glabra, gooseneck</td>
<td>0-10</td>
<td>G. S.</td>
<td>Fall</td>
<td>6-9</td>
<td></td>
</tr>
</tbody>
</table>

They concluded that, all other things being equal, these two native plants should be grown in the largest container possible.

The best container size for good field performance is approximately the best container for seedling growth in the greenhouse. Plants grown in large capacity containers seem to perform best in the field but require too much greenhouse space and are costly to handle and ship. The best containers also vary with plant species and environmental and soil conditions on the outsizing site.

Native Plants Inc. uses two different "shup" containers for most of their material. The 8-pack containers contain 16 cu. ft. (213 cu. cm.) and the 16-pack has a capacity of 17 cu. ft. (278 cu. cm.). Most species can be grown satisfactorily in the 16 cu. ft. container but many broadleaved species have to be produced in the larger containers because they require deeper root systems and shade out adjacent seedlings. Some native plants such as elderberry (Sambucus spp.) and mountain ash (Sambucus spp.) have massive root systems that require larger capacity containers. The density or spacing of the containers in the rock is also important because some species do not grow well at higher densities. Obviously, more work is needed to determine the best container to use for each of the native plant species.

Based on their experiences at the Native Plants' greenhouses, most native species grow well in standard potting mixes. Native Plants uses a mixture of equal parts of rockwool, vermiculite, perlite, and composted bark. They have also been using a mixture of 15-15-15 into the potting soil at 10 lbs. per cu. ft. (7.6 kg. per m.3) and Micromax at 1.5 lbs. per cu. ft. (11 per cu. m.) to supply micro-nutrients.

The potting mix should be near pH 5.5 and have an electrical conductivity (E.C.) reading of less than 2.0 mbhos.

Other researchers have reported on potting mixes for native plants. Ferguson and Nosse (1976) found that mixes containing peat moss and vermiculite, perlite, and vermiculite nutrition (Vermiculite:sp.6) seedlings to those plants at the Casa de Almeda nursery produced 40 different species of native plants using a standard 1:1:1 mix of peat moss and vermiculite. Ferguson (1980) studied 30 different potting mixes and found that there was only one mix consistently superior. He did report that a potting mix of 50 percent peat moss, 20 percent vermiculite aggregate and 20 percent vermiculite is recommended as a standard seedling substrate (1:2:2:1:1:1) and possibly other plant species native to alkaline soils. Using native soil into standard potting mixes can increase growth of some chemopod species (Nahas. per. com.). A survey of nurseries growing desert shrubs reported a wide variety of potting mixes that contained sand, cinder, peat moss, composted bark, charcoal, comminuted vermiculite, perlite, and composted soil (Anson. 1976). There is much variation in potting mixes but it appears that standard commercial potting soils are suitable for most native plants although special mixes may be desirable for some species.

GREENHOUSE CULTURE

Native shrubs have been found to grow well under normal greenhouse environments. Native Plants Inc. maintain a comfortable environment with day temperatures of 60°F ('27°C), night temperatures of 65°F (18°C), a relative humidity of 45-50 percent, 800-1200 ppm carbon dioxide and a 12-hour photoperiod period of 20 ft. candles. The SCIP project at Casa de Almeda nursery maintained a greenhouse temperature of 65°F (18°C) for the entire growing cycle and a 12-hour photoperiod (20 sec. every 3 min.) at an intensity of 20 ft. candles. Wood (pers. comm.) stresses that many native species are very sensitive to photoperiod and no greenhouse should have continuous lighting systems.

Fertilization at the Native Plants' greenhouse is completely via water only. Liquid fertilizer is added to the potting soil and Peters 20-20-20 fertilizer is injected through the irrigation system. The injected fertilizer is not applied at any time but is not an injected or pressurized application. Because of the wide variation in nutrient requirements between the different native species in the greenhouse most plants visually monitor the growth and color of the plants to determine the fertilizer type similar to that used by farmers.

Other greenhouse growers also emphasize the benefits of fertilization of native plants. The SCIP plant nutrient study showed that their nutrients through the irrigation system using a commercial 20-20-20 mix at a 6,000 lb. rate of fertilizer was applied weekly at the rate of 2 lbs. of fertilizer per 100 ft. (19 kg. per 16 ft. of) any species of bench space. Once the desired top growth was achieved, the fertilizer mix was changed to a 15-30-15 mixture. Ferguson and Nosse (1974) grow mountain mahogany seedlings with 3 different rates of 600-12-12 slowly release fertilizer and mountain mahogany (Cոмнosus соппоцис) seedlings compared to those plants at the Casa de Almeda nursery produced 40 different species of native plants ranging from 2 to 4 per cu. ft. (34 to 102 g. per 0.03 cu. ft.) of potting soil and 6-16 plant growth and significant growth differences between the rates.

THE HARDENING PHASE

The hardening phase is one of the most overlooked yet most critical periods in the growing cycle. It is relatively easy to produce an acceptable plant in the greenhouse but these plants are worthless unless they are properly conditioned so that they can survive and grow on the planting site.

Many native species grow very slowly under the optimal conditions in the greenhouse but this rapid growth consists of relatively large cells with this cell walls and little tolerance to cold temperatures. Unlike most ornamental crops, native plants do not harden out of the greenhouse but must undergo a period of hardening. Ferguson and Nosse (1976) showed that the proportion of cold hardening was one of the most difficult elements in the container production of native plants.

Hardening can be defined as the process in which growth is reduced, stored carbohydrates accumulate, and the plant becomes better able to withstand adverse conditions (Fenves and Nosse 1991). There are three major objectives of the hardening phase:

1. To minimize physical damage during handling, shipping, and planting.
2. To condition the plant to tolerate cold temperatures during refrigerated storage or after overwintering.
3. To acclimate plants to the outside environment and meet internal dormancy requirements of some species.

The type and amount of hardening depends on the individual species characteristics and the future use of the plant. Native plants produced as ornamentals must be hardened to a high enough level to ensure that the plant can be purchased and used under the conditions it will be used for. Brooker and Henry (1978) showed that native plants must be hardened before planting because they grow may only require a 4-6 week period of hardening. Many species that are planted at higher elevations during spring or fall must be able to withstand the extreme cold temperatures and perhaps even frost.

Durability is another term that is often used in conjunction with hardening. Various hardening techniques have been shown to have the ability to produce abundant new roots when planted in a favorable environment. This high 'root growth

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capacity" should increase the ability of seedlings to survive and grow on harsh sites. The role of dormancy and root growth capacity has not been studied for most native plants. Plants stored under refrigeration for extended periods should also be dormant to minimize respiration heat build-up in the storage bags. Both dormancy and cold hardiness can be induced by proper scheduling of the hardening regime.

Hardiness should be induced in stages and the process usually takes at least 6-8 weeks. The hardening begins in the greenhouse by shutting off the photoperiod lights and carbon dioxide generators and leaching excess nutrients out of the potting media. Night temperatures are decreased and the seedlings are fertilized with a low nitrogen/high phosphorus and potassium fertilizer. Some growers also induce a mild level of moisture stress between irrigations which supposedly prepares the plant for the dry conditions on the outplanting site. Drought stressing should be carefully monitored, however, because overly dry potting soil may be difficult to rewet and stressed plants may not cold harden normally. In the final hardening stages, temperatures are gradually lowered to the freezing level and tolerant plant species may even be taken slightly below 32°F (0°C).

Hardening can be achieved in either of two structures, a cold frame or a shadehouse. Shadehouses are generally used to harden crops that are taken out of the greenhouse in summer or early fall when freezing temperatures are not expected. The shadehouse consists of a frame structure that is covered with snowfence or shadecloth and is equipped with an irrigation and fertilizer injection system. Seedlings are protected from wind, intense sunlight, and light frosts in a shadehouse and usually continue to produce new roots and increase in stem diameter during favorable weather. The shadehouse also provides a good overwintering environment and such plants are well hardened by the following spring and ready for planting.

The cold frame used at Native Plants Inc. is a modified greenhouse structure which is maintained at low temperatures to promote hardening. Cold frame hardening is often necessary for crops that need to be removed from the greenhouse during freezing weather. Often, cold frames are used to induce dormancy and cold hardiness in plants before they are moved to a shadehouse for final hardening and storage.

**VARIATION BETWEEN SPECIES AND BETWEEN CROPS**

Although it is possible to grow several species of native plants under a standard greenhouse environment, nursery managers should be cognizant of the variable growth requirements and morphological characteristics of the individual species. A grower must directly experience how plants perform under his own nursery system before he will be able to consistently produce uniform crops of native plants.

Individual species will not grow the same during different growing seasons or during different years. Some species that grow best during the summer season will not perform satisfactorily if grown over the winter. Because of differences in seed crops from year to year and between seed sources, every crop of native plants will be slightly different in growth characteristics.

**CONCLUSIONS**

1. Crop planning is very important when working with native plants and a crop may take from 2 to 3 years to produce if seed is not immediately available.

2. Production of native plants may require as many as four separate facilities: production greenhouse, cold frame, shadehouse, and refrigerated storage.

3. Four propagation methods are used to produce native plants in containers: direct seeding, germinants, transplants, and rooted cuttings.

4. The best size, shape, and volume of growth container is dependent on the species of plant and characteristics of the outplanting site.

5. Standard potting mixes are adequate for many native plants but some species may require special mixes.

6. Native plants grow well under normal greenhouse environments but a grower should be aware of individual species differences.

7. Plants should be hardened in several stages by changing the growing environment and moving them to either a cold frame or shadehouse.

8. There is considerable variation between individual species and between seed collections and so each crop of native plants will perform differently.

**PUBLICATIONS CITED**


Barker, J. R.; McKell, C. M. Growth of seedling and stem cuttings of two salt-desert shrubs in containers prior to field planting. Reclamation Review 2: 85-91; 1979.
ABSTRACT: Nine disturbances can often be requeued through natural plant succession. Plants that spread by seed or seedling can be used to seed nine sites. Transplanting shrubs and trees is a common practice establishment and improves productivity species diversity. Shrubs and small species differ in their ability to establish and survive as transplant stock. Therefore, transplanting soil must be prepared to accommodate direct seeding or transplanting. Environmental conditions of the planting site dictate the of natural methods of planting. Existing bar dangerous vegetation must be controlled to allow shrub seedlings to become established.

INTRODUCTION

Reclamation of mined land normally requires planting a diverse group of woody and nonwoody species. Natural invasion of native plants into mined areas occurs too slowly to acceptably restore the site (Vore and Ton Phys 1980). Planting is required to provide soil protection (Packs: and others 1981), reduce the spread of weeds, and provide forage and habitat to animals (Kensler and Plummer 1980).

Plants also serve to establish a desirable and compatible array of species that will provide initial cover on which to develop a stable community (Faycock 1980).

Mined lands are generally harsh sites and planting a diversity of woody and nonwoody species. Species that are adapted to harsh sites and planting in areas that are not well watered or exposed to wind. Consequently, it is difficult to determine the adaptability of individual species to mined land environments.

Some species that are climax plants of undisturbed communities often fail to establish in mined areas. Unfortunately, not all species that are regarded as climax plants are considered desirable plants, are able to grow on disturbances (Smith and Baruch 1979; Nichols and MacFarlane 1980). Usually, climax plants become established in the absence of human intervention. The site has been modified by pioneer species. Many species that are initially adapted to mine sites are considered weedy plants. These may persist for only a short time, but are useful to initiate plant succession on sites. More species that are adapted to a wide range of sites, temperature extremes, and moisture conditions are the most successful for desert sites (Stark 1966). Ecotypic differences occur within most species. Each ecotype is adapted to a particular range of conditions, and if planted within its natural range the selection will do well. If moved to unnatural conditions specific ecotypes often do not always survive (Plummer 1971).

Few species have been specifically selected for their adaptability to nine disturbances. Only a limited number have been sufficiently evaluated for their performance and survival on nine spoils. Most species that are commercially available (see Appendix) have been used only for other purposes, and very few species have determined that certain species are adapted to different soil conditions, and can be used on mined and associated disturbances (Stark 1984; Alden and Posey 1981).

NATURAL INVASION OF PLANTS

Weeds and annual and short-lived perennial herbs are the principal species that invade most mined lands (Howard and Samuel 1979). However, some important woody plants also spread rapidly onto abandoned mines (Bertles and Thalman 1990). Many plants are adapted to harsh environments but spread very slowly by natural means. Invasion by plants is often hindered by factors related to seed production (Plummer 1971), seed germination, and seedling survival (Davis and others 1979; Vore and others 1981). Consequently, it is difficult to determine the adaptability of individual species to mined land environments.

Wind, movement flow of water, and rodents are agents that carry seeds onto nine sites. Under woods conditions rodents do not distribute but plant many seeds (Gert 1984). A high proportion of seed produced in wildlands stands is consumed by animals including rodents (Studer 1963). The excess is all that remains to perpetuate the species.

Rodents usually collect and store seeds of large and small species and of an edible endophyte. Usually, seeds that remain viable for an extended period are stored in caches in the soil by rodents for later consumption (Chiltonic 1971). Seeds planted as rodent cache frequency are not eaten but germinate later to form a clump of new seedlings. Shrubs that are generally not gathered and stored in caches include: alpine larch (Larix potanitsa), Sitka spruce (Picea sitchensis), desert peach (Praeco fasciculata), green sagebrush (Artemisia whipplei), and snow (Ono wood).

Rodent activity is usually confined to areas (1-5 acres). However, rodent populations and habitat are not always decreased by clearing the vegetation (Turkowski and Reynolds 1979). Yet, small animals usually do not venture to the exposed sites. As sites become vegetated, rodents inhabit the area, once plants are established on the mine begin to hear sounds, rodents gather the fruits and help further the species' progress of successional stages in plant development.

A substantial amount of seed is produced by certain species (see Appendix). Here, if other seeds have exceeded 300 pounds per acre (338 kg/ha) for antelope bitterbrush, the species has been planted in mined sites near Boise, Idaho. During years of high seed production, some species are more prolific, due to the plantings efforts of small rodents. Adopted shrubs and herbs can be selectively located on mined sites to provide rodent habitat, regulate their distribution, and thus advance the spread of select species.

Small seeded species and appended seeds are widely distributed by wind (Stoner and Esper 1939). Although a high proportion of weed species are wind propagators, some dryland species are also dispersed by this method. Although many seedling survival dryland species quickly, and perennate otherwise inaccessible species. Species that are successfully spread by wind are spread (Cipolla; parviflora), sagebrush (Artemisia spp.), and rabbitbrush (Chrysothamnus spp.).

CONSIDERED CONDITIONS INFLUENCING ARTIFICIAL SEEDING

Mined lands are usually planted soon after mining is completed. Disturbances primarily consist of arroyos or fillings, which are usually composed of uncompacted soil materials. Although surface and tillage methods may be used, mined spoils usually lack soil structure and particle aggregation that contribute to a optimum seedbed condition. Soil drainage, aeration, and moisture has been excluded. In addition, the balance, and organic matter are all poorly developed in mined areas. Therefore, seedlings must be adapted to intertidal sites, and capable of developing concurrently as young seedlings.

Grasses, broadleaf herbs, and woody species are often planted as a mix of different plants with different growth forms. These can be divided into six categories. Mixed plantings favor herbs over shrubs and trees (Jensen 1980).

Grasses that are currently needed on mixed sites are derivatives formulated for high germination larger. These highly competitive grasses develop much faster than do most native shrubs or trees. Grasses and many forbs not only germinate earlier than most shrubs, but attain a natural status much sooner. Most needed grasses reach maturity in 1 to 3 years. In contrast, shrubs may require 5 to 10 years to attain a sufficient size to be fully competitive (Plummer and others 1980). During this interim, the developing shrubs are subjected to extensive competition, and plant losses are common (Bouchard and Shinman 1981). To be fully competitive with grasses, needed shrubs and trees must possess the following traits: (1) must germinate readily, (2) seeds should produce 75% of the seedlings in the growth period should be compatible with the needs of the herbivores. Developing plants must remain competitive.

Shrubs that can survive and develop satisfactorily by direct seeding are species that would not usually be grown as transplant stock. Some plants can justifiably be transplanted or direct seeded. Seeding is usually much cheaper and easier to accomplish. Some useful shrubs that can be successfully seeded change over the following: (2) many (3) species are also dispersed by this method. Although many seedling survival dryland species quickly, and perennate otherwise inaccessible species. Species that are successfully spread by wind are spread (Cipolla; parviflora), sagebrush (Artemisia spp.), and rabbitbrush (Chrysothamnus spp.).

Natural plant succession and edaphic changes that occur after mined sites are initially planted are growing conditions and productivity of the disturbance. Some species that have been difficult to establish initially on fresh nine spoils by direct seeding or transplanting have been established at a later date. Seve shrubs and trees are frequently encountered as a result of natural regeneration, beginning 5 to 10 years after disturbance. Encroachment often occurs on sites dominated by a competitive species. As the environment of the mined areas is redeveloped, new species of plants (Frisske and Ferguson 1979).

Although fresh nine spoils are usually less productive than undisturbed sites, cultural practices and environmental factors are altered to increase the productivity by planting. Therefore, selected species must be adapted to intertidal sites, and capable of developing concurrently as young seedlings.

The success of most plants has been based upon the response attained from planting established on newly exposed nine spoils.
Unfortunately many useful species are often discarded due to failures from initial planting, lack of survival, low growth or never improve as soil nutrients build up or the soil microfauna is established.

**VALUE OF TRANSPLANT STOCK**

Although plants may be successfully established by direct seeding, transplanting is also a viable reforestation technique. Some species that establish readily by seeding do not grow rapidly enough to provide initial ground cover for soil stabilization (Thaw 1981). Some species that may fail to establish or perform satisfactorily by direct seeding can be transplanted. This has been particularly evident with woods rose and chokecherry (Prunus virginiana) which is tolerant to poor soil conditions such as high phosphorus in southeast Idaho. Seedlings of both species germinated readily, but young plants were weak and slow to develop. Although plantings have been on reclaimed and fertilized sites, the growth performance of these small seedlings has remained unchanged. However, >60 transplant species of both species developed rapidly.

Transplants that are properly spaced can provide an immediate and effective cover. Transplanting can be most effectively used to stabilize erodible sites and promote the natural establishment of understory species. Higgins (1940) reported that >50 percent of surface erosion from rangelands was controlled by transplanting herbaceous stock of ponderosa pine (Pinus ponderosa).

Transplants can also be used to control the establishment and spread of weeds. In contrast, shrub and tree transplants may also promote the establishment of some undesirable species. Ponderosa pine transplanted along steep rangelands in central Idaho stabilized the site and served as a nurse crop for understory vegetation. The presence of the overstory canopy of woods rose, blueberry alder, and mountain huckleberry (Gaylussacia baccata) also aids in the establishment of shrubs and trees that may persist for only a few years can be highly useful in the development of satisfactory cover.

Several leguminous and nonleguminous shrubs and trees are beneficial in improving soil, moisture, and nutrient levels (Blanchette 1979). Researchers reported that eight genera of shrubs are able to fix nitrogen through the presence of rhizobium in the roots. These species can be used as companion plants to improve the performance of various understory herbs. Species of Carex species have been successfully used for this purpose on nine plots in Idaho (Hansen 1973). Leopold and others (1979) reported that establishment of a nutrient bank would occur slowly with the use of Salsola flexicaulis because this species would rapidly rebuild nutrient levels. Transplants can be used to increase the rate of plant successions. In addition, transplant stock mature quickly and continue to occur rapidly. If persistent and compatible species are planted adjacent to mined lands, and these should be protected and used. Research is needed to determine additional plants adapted to mined sites. A classification system needs to be developed to identify plant selections for disturbed situations. The system currently used in refuges makes use of soil type, elevation, and climatic zones in selecting adapted ectotypes for planting. These features should also be applicable in delineating plants for mined lands, although the edaphic conditions of mine spoil are not always comparable to undisturbed soils. However, mining does not alter climate and biotic influences. Consequently, plants that are native to a given region are still the predominant candidates for replantation trials. Figure 1. The Identiification of individual species that possess inherent characteristics such that they are able to improve the range of adaptation of the species. For example, the occurrence of different species, erectness, and kinds of sagebrush offers a wide diversity of planting stock suited to different site conditions (O'Keeffe and others 1979). Through careful selection, adapted ectotypes of other species can be used to reestablish mine spoils.

**PLANTING QUALITY STOCK**

The development of high-quality transplant stock is essential to plant survival on mined lands. Species that have poorly developed success quickly to adverse conditions. failure to recognize the quality stock accounts for many plant failures.

Growers frequently produce a uniform grade of planting stock. Materials are grown to 1-2 yr-old stage. Sometimes seedlings are also produced in rather uniform grades. Plants can be grown to 2 yr-old stage in site containers, but this is difficult to program for a site location with only a short rearing time is available.

The size and variety of transplant is vital to plant survival. Species that grow rapidly will normally survive and grow well if a healthy 1-yr-old transplant is used. Other species grow slowly, requiring a year or two to fully establish and begin any appreciable growth. Green sedges, mountain wildflower (Symphoricarpos oreophilus), mountain ash (Sorbus americana), red-osier dogwood (Cornus stolonifera), and blueberry alder (Alnus incana) develop slowly and may become established to a significant degree if planted as 2-yr-old or larger stock. Survival rates improve and growth is markedly increased.

Proper maintenance and field planting of a well-established project is essential to plant survival. Shrubs such as yew (Erica), mountain laurel (Kalmia latifolia), and mountain huckleberry (Gaylussacia baccata) should be planted no deeper than their original depth. Someamin River. When planted the plant should be dug as wide diversity as possible. shrine plats may suffer (Carr 1974). To improve shrub and tree survival the planting should not be a high density. Pot grown stock may be used to transplant species should be applied at a low rate, yet the use of time. Surface preparation and cultivation of the shrubs are well established.

No hie should be treated to aid plant survival. Impact should be kept to a minimum to allow infiltration, soil, and moisture. Root development. Transplants should be kept to a minimum to allow infiltration, soil, and moisture. Root development. Transplants should be kept to a minimum to allow infiltration, soil, and moisture. Root development. Transplants should be kept to a minimum to allow infiltration, soil, and moisture. Root development. Transplants should be kept to a minimum to allow infiltration, soil, and moisture. Root development. Transplants should be kept to a minimum to allow infiltration, soil, and moisture. Root development. Transplants should be kept to a minimum to allow infiltration, soil, and moisture. Root development. Transplants should be kept to a minimum to allow infiltration, soil, and moisture. Root development.


McIntire, E. D.; Glant, B. C.; Plummer, A. P. Shrubs for restoration of disturbed areas and disturbed areas. (5th Sci. 35: 28-33; 1974.


ABSTRACT: Methods and a fundamental philosophy for producing healthy planting stock of native wildland plants are presented. Drawing from the experience of agriculture, horticulture, and forestry, cultural and biological disease control methods are reviewed. The focus is placed on certification of planting materials, producing pathogen-free propagules, greenhouse disease control, disease prevention, controlling pathogenic in growing medium, the role of irrigation variability, and managing biological control of soil-borne diseases.

INTRODUCTION
Interest is increasing rapidly in using native wildland plants to revegetate disturbed areas and improve wildlife and livestock ranges in the western United States. Producing healthy planting stock can enhance these activities. It is important to know when to take action in preventing and controlling diseases of plants. It is generally believed that if a disease is present it will be obvious and the plant will die, or if it does not die then it must not have a disease. A plant without obvious disease symptoms is not necessarily a disease-free or pathogen-free plant. There are also examples of viruses, bacteria, fungi, and nematodes that cause only slight symptoms. The only visible injury is reduced top growth. Probably the most damage results from these "root sibbiles" as from virulent pathogens that induce obvious symptoms and kill plants rapidly. Fungal treatment to prevent seedling diseases such as damping-off often suppresses the pathogen which later induces further disease in the container plant as in the field after transplanting (Harker 1969).

A wise approach is to adopt rigid disease prevention methods regardless of present known disease problems. Certainly a little if any research effort is directed toward controlling diseases in native wildland plants. The purpose here, therefore, is to relate facets that are well developed or over the years in the horticultural and agricultural enterprises that may be of value in the wildland plant scene.

Pathogen-free Plant Propagules
Use of pathogen-free seed is an obvious first step in controlling diseases in container-grown plants as well as in nursery or direct field seeding. Several good references on seed-borne pathogen work (Harker 1956, 1972; Baker and Smith 1966; and Harman 1961). Plant pathogens are transmitted independently of disease symptoms and generally have no surface of seed or fruit parts, or they may be carried internally, including the embryo. Seed transmission may be a major factor in introducing disease to new fields,especially via planting and adjusting diseased seedling. Seed of some native plant species is not considered in the design of greenhouses. Seed infection by disease can lead to reduced sources of contamination should the greenhouse be colonized. Seedborne pathogens are seldom designed by persons with no plant disease prevention. Although elaborate systems can be devised to exclude pathogens for special purposes, relatively simple design considerations can make big improvements in inoculum operations.

Injuries to seed during cleaning, for example, cracked seed coats, serve as entry points for both seed and plant pathogens and should be avoided. Pathogen propagules such as the sclerotia (colonies) of Claviceps and seeds of Orpinace and Centaur that accompany seed can be reduced by separation during seed cleaning. Internally borne pathogens can usually be controlled by surface treatment methods, but internally borne pathogens are more difficult to control. A special study examines fungal treatments and control of seedborne pathogens in various media. This constitutes a broad area of research that is now limited primarily to cultural and biological and chemical disease-free, container-grown wildland plants.

CULTURAL CONTROL
Sanitation is the most important single guideline in the cultural control of plant disease problems of container-grown plants.

Sanitation is essential in the production, collection, cleaning, storage, and germination of seeds and is an essential factor in maintaining greenhouse and shadehouse environments and in seedling transport and planting.

Fig. 1. Basic greenhouse design for plant disease prevention.
Container filling and planting operations should not take place in greenhouse growing rooms because soil or other planting media spillage serves as an organic substrate for growth of pathogenic greenhouse floor flora.

Greenhouse benches come in almost every form and design imaginable and unfortunately many are conducive to creating disease problems. A well-designed greenhouse bench should feature a container support base that is independently supported from bench sides to avoid edges on which debris may accumulate (fig. 2). The base should also be sterile in areas where organic material can accumulate. The base should be easily removable for cleaning, decontamination, and treatment. An ideal system is one in which removable boards are engaged in the bench with cooper-nathionate. Periodically cleaning and treating boards achieves an essentially self-sterilizing base for containers (Baker 1957).

WATERING PLANTS

Placing watering methods are a vital consideration in disease prevention. To begin with, containers are commonly overfilled with growing medium, leaving no reservoir for water. As a result, excess medium is then flushed from containers and accumulates under benches to provide an organic base for microorganisms. Individual watering nozzles should be hung up and not allowed to contact the greenhouse floor where they can become contaminated with disease-inducing organisms.

Container-grown plants are almost universally overwatered, which usually leads to seedling root rot problems. Willow plants present a special problem in this regard because of their inherent variability. High variations in germination rate, growth rate, and form require selective watering. The nonselectivity of large automatic watering systems in a particular problem. Many desirable western U.S. native plants are adapted to natural environments and grow in soils with extremely low water potentials compared to the average domestically commercial. Little literature is available on the specific soil water potential requirements for seedlings. The role of soil water potential and the ecology of plant pathogens have been studied for some agricultural plant diseases (Cook and Papendick 1970). Some unpublished data on wildland shrubs (which and others, USDA Forest Service, Shrub Sciences Lab., Provo, Utah) indicate that various species, such as for example, grown in soil containers show little evidence of water stress even at -25 to -30 atmospheres. Visual judgment of the soil moisture a plant needs will probably result in overwatering. Critical measurement of soil moisture requirements is necessary to plan watering methods and consequently prevent disease.

Figure 2-A greenhouse bench designed to prevent plant disease. Note bench sides are not fixed to board support pipes, and removable boards act to minimize accumulation of debris.

Controlling Pathogens in Growing Media

Pathogen-free plant propagates and sanitary greenhouse management are of no avail without use of a controlled-pathogen growing medium. A vital component of native soil is the array of living microorganisms that exist in a dynamic equilibrium system. The system is controlled by the unique physical, chemical, and biological characteristics of specific soil and vegetative types (Baker 1964; Flinn 1958). The system is biologically buffered and permanent changes occur only with major environmental shocks. Such disruptions occur, for example, as a result of the numerous modifications incident to agricultural, greenhouse, or nursery operations.

Contaminated plant growing media can be categorized as either containing soil or as soilless. The two types require different treatments to manage pathogens and retain proper biological and physical plant growth factors (Baker 1957, 1962a, 1962b). It cannot be assumed that soilless media ingredients, for example, peat, compost, ground bark, perlite, or vermiculite are or will remain pathogen-free. It can be more safely assumed that what these media do have are low or poorly balanced microorganism populations. Treatments to eradicate or control pathogens must contend with these unique features.

Fumigation of media with chemicals is a widespread practice, although there are attending disadvantages (Baker 1957, 1962, 1963). Toxic chemicals are difficult to contain in greenhouse environments so that they may become legally complicated in urban areas. Toxic residues may remain even after long periods of aerations. Fumigants move through the soil in a concentration gradient resulting in nonuniform treatment. Broad spectrum fumigants such as chloropicrin and methyl bromide tend to "build up" and result in biological vacuums. More specific fumigants, for example, DBCP, borax, carbon disulfide, and Nemagon are available. However, pathogen populations are selected for resistance more rapidly by the more specific chemicals. Steam sterilization of media by heating to 250°F also results in biological vacuums. Both chemical and heat methods have the danger of recontamination. The drastically reduced competition in these treated soils results in rapid uninhibited growth of introduced pathogenic organisms. Time to disease may be more severe than in untreated media. Phytotoxic compounds are also formed in soils that are treated at high temperatures.

Aerated-steam treatment of plant growing media avoids most of these problems (Baker 1963). With this method, air is injected into the steam mass, producing a lower temperature vapor (fig. 3). By careful adjustment of vapor production, temperature, organisms can be selectively eliminated from the soil. Parasitic organisms tend to more specialized extremo environments than saprophytic organisms and thus tend to have lower thermal death points. Most weed seeds and many pathogenic fungi, bacteria, and viruses can be eliminated or inactivated in soil by aerated-steam treatment at 10°F to 30°F for 30 minutes, lowering a beneficial population of microorganisms (fig. 1). Remaining fungi, bacteria, and actinomycetes then increase in number and antagonistic numbers act to inhibit invasion by contaminate pathogens. Fumigant soil factors are initially leached, but return to normal. Any phototrophic organisms are at low levels. Firewood and other "wild crops" that grow profusely in sterilized soil are suppressed. The use of aerated steam is less expensive than steam sterilization because of the reduced temperature and treatment time required.

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Controlling Pathogens in Growing Media

Pathogen-free plant propagates and sanitary greenhouse management are of no avail without use of a controlled-pathogen growing medium. A vital component of native soil is the array of living microorganisms that exist in a dynamic equilibrium system. The system is controlled by the unique physical, chemical, and biological characteristics of specific soil and vegetative types (Baker 1964; Flinn 1958). The system is biologically buffered and permanent changes occur only with major environmental shocks. Such disruptions occur, for example, as a result of the numerous modifications incident to agricultural, greenhouse, or nursery operations.

Contaminated plant growing media can be categorized as either containing soil or as soilless. The two types require different treatments to manage pathogens and retain proper biological and physical plant growth factors (Baker 1957, 1962a, 1962b). It cannot be assumed that soilless media ingredients, for example, peat, compost, ground bark, perlite, or vermiculite are or will remain pathogen-free. It can be more safely assumed that what these media do have are low or poorly balanced microorganism populations. Treatments to eradicate or control pathogens must contend with these unique features.

Fumigation of media with chemicals is a widespread practice, although there are attending disadvantages (Baker 1957, 1962, 1963). Toxic chemicals are difficult to contain in greenhouse environments so that they may become legally complicated in urban areas. Toxic residues may remain even after long periods of aerations. Fumigants move through the soil in a concentration gradient resulting in nonuniform treatment. Broad spectrum fumigants such as chloropicrin and methyl bromide tend to "build up" and result in biological vacuums. More specific fumigants, for example, DBCP, borax, carbon disulfide, and Nemagon are available. However, pathogen populations are selected for resistance more rapidly by the more specific chemicals. Steam sterilization of media by heating to 250°F also results in biological vacuums. Both chemical and heat methods have the danger of recontamination. The drastically reduced competition in these treated soils results in rapid uninhibited growth of introduced pathogenic organisms. Time to disease may be more severe than in untreated media. Phytotoxic compounds are also formed in soils that are treated at high temperatures.

Aerated-steam treatment of plant growing media avoids most of these problems (Baker 1963). With this method, air is injected into the steam mass, producing a lower temperature vapor (fig. 3). By careful adjustment of vapor production, temperature, organisms can be selectively eliminated from the soil. Parasitic organisms tend to more specialized extremo environments than saprophytic organisms and thus tend to have lower thermal death points. Most weed seeds and many pathogenic fungi, bacteria, and viruses can be eliminated or inactivated in soil by aerated-steam treatment at 10°F to 30°F for 30 minutes, lowering a beneficial population of microorganisms (fig. 1). Remaining fungi, bacteria, and actinomycetes then increase in number and antagonistic numbers act to inhibit invasion by contaminate pathogens. Fumigant soil factors are initially leached, but return to normal. Any phototrophic organisms are at low levels. Firewood and other "wild crops" that grow profusely in sterilized soil are suppressed. The use of aerated steam is less expensive than steam sterilization because of the reduced temperature and treatment time required.

Figure 3- Diagram illustrating the method of aerated-steam production for heat-treatment of plant growing media.
suppressed in certain soils even though both pathogen and susceptible host are present (Riker and Cook 1959; Iam and Baker 1983). Some biological and symbiological factors are involved in these suppressive soils. Biological control and the nature of suppressive soil are at the forefront of current research on controlling soil-borne diseases of greenhouse and container-plant plants (Riker and others 1979; Chet and Baker 1981; Baker 1984; Baker and Baker 1984).

With the untreated-soil treatment method already mentioned, certain pathogens, but not all, pathogens, can be selectively eliminated from soil. The common copper-forming bacteria {copper-resistant Rhizobium spp. (Rgr. to Rhizobium)} are retained and proliferate, producing rather specific antibiotics that antagonize to pathogenesis by strains of _Pseudomonas solanacearum_, a common pathogen of container plants (Baker and others 1981; Messerer and Birkey 1983). The degree of specificity characteristic of this bacterium limits broad application. Strains of the endomycorrhizal fungus _Laccaria_ (growing on coffee plants) protect beans against _Phytophthora megasperma_ (Baker and others 1982). The disease is suppressed in soil-free systems but not in heat-treated soil. Seedling root growth, however, is also suppressed by cell-free metabolites of the fungus. Various soil-free formulations containing composted hardwood bark used as a growing medium are suppressive to _Phytophthora megasperma_ and _Fusarium oxysporum_, respectively.

Container growing media containing native soils have the advantage of a more diverse, complex microflora and rootful artificial media, with complexity comes stability and a greater chance of biological control without modifications based on extensive research, with introduction of specific antagonistic fungi into sterile or minimal media to suppress specific pathogens is reliably the risk of contaminate and introduction of a second pathogen is not influenced by the existing antagonists. In addition, the medium environment must be adapted to the selected antagonists. The potential for developing biological control with container-soil wildland plant diseases most exist. Present natural systems must be studied. Disease inducing organisms and specific antagonists need to be identified.

One must conclude that no single disease control method is a complete answer, and so we hear terms like integrated control or a holistic approach like battle goes on, and so knowledge is used in the biological control of soil-borne disease problems centers on manipulating antagonists and certain physical factors in the growing medium of container plants. Biological activity occurs by parasitism, predation, competition for nutrients, or production from metabolic products of another organism (Riker and Cook 1959). Disease development may be


Cook, R. J.; Papendrick, R. L. Soil water potential as a factor in the ecology of Fusarium roseum f. sp. cerealis "Gulmorum". Plant and Soil. 32: 131-145; 1970.


Bacteria are injected into the plant tissue, stimulating growth and increased yield. This process is referred to as bacterial infection. Bacterial infection is a significant issue for farmers, as it can lead to significant losses in crop yields. There are several types of bacteria that can cause infection in plants, including pathogens that attack specific parts of the plant, such as leaves, stems, and roots. These bacteria can spread quickly and cause serious damage to crops, leading to significant economic losses for farmers.

There are several methods for controlling bacterial infection in crops. These methods include the use of chemicals, such as fungicides, to kill the bacteria and prevent infection. Other methods include biological control, utilizing beneficial bacteria that compete with the pathogen for space and nutrients. Additionally, genetic engineering has been used to develop bacterial-resistant crops, which can help reduce the need for chemical control.

Despite these efforts, bacterial infection remains a significant problem for farmers. As the climate changes and the need for food production increases, the importance of controlling bacterial infection in crops will continue to grow. Future research is needed to develop more effective and sustainable methods for controlling bacterial infection in crops.
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SALT TOLERANCE IN DECIDUOUS SHRUB AND TREE SPECIES

Richard W. Timas

ABSTRACT: Ten species of deciduous shrubs and trees were grown in a greenhouse and irrigated with nutrient solution plus sodium sulfate, chloride, and bicarbonate to yield salt concentrations of 1.6, 4.3, 7.2, 12.1, and 16.6 mmol/L. Some were grown in full-spectrum, 100-watt fluorescent, tungsten, and American plan salt sensitive. Buffaloberry, Russian olive, and chokecherry were moderately sensitive, green ash, juniperberry, and caragana were tolerant.

INTRODUCTION

Tree nurseries in western North America frequently have salt-affected soils and salt-irrigation water (Timas 1980). Salt creates an osmotic moisture stress that reduces germination and growth, and may kill seedlings. Without careful soil and water management, the problem gradually becomes worse until the nursery is no longer able to grow certain species that it formerly grew well. In the West, because shrubettes are commonly planted on salty soils, careful choice of species is critical.

Very little quantitative information is available on salt tolerance of shrubs and trees grown for shrubettes (Carter 1980; 1979). Most of what is available is on crops plants (Richards 1934; Frauen 1967; Bunting and Bunting 1981) and horticultural varieties of shrubs and fruit trees (Brownell and others 1972; Dyer 1974; Poon and Clark 1978; Masa and Bunting 1971; Dowens and Eyring 1978; Fastner and Fort 1980). The objective of this study was to provide guidelines on salt tolerance of a variety of species commonly used for shrubettes in the northern and central Great Plains.

METHODS AND MATERIALS

Experiment 1.—Seed Germination

Green ash seed was soaked 4 days in cold running water, caragana was used dry, and all other species were cold stratified in sand as recommended by Schopmeyer (1943).

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Experiment 2.—Seeding Growth

Five Colorado State眼界百合, each with 30 cervices with a volume of 600 ml per cavity, were filled with 11% past-normal plus 5% percent forest soil to make through endomicrotuba. Three seeds were planted in each cavity, five blocks for each of the 10 species. The blocks were arranged in greenhouse benches in randomized groups of 10, one block of each species. Each group was tested as needed with a nutrient solution plus sodium sulfate, chloride, and bicarbonate to yield an electrical conductivity (EC) of 1.6, 4.3, 7.2, 12.1, and 16.6 mmol/L (table 1). The salt solubility of the Lincoln-Vegeta series at St. Mary, S.D. (table 1) corresponds approximately to solution 2. The relative proportions of sodium sulfate, chloride, and bicarbonate were selected to be the same as in the irrigation water of Lincoln-Nebraska, which EC of 1,500 mmol/L (about 1,000 ppm solids) and is rated "suitable for limited irrigation." Water supplies of other nurseries vary in composition considerably, but these tests are usually the ones causing the greatest problems.

After germination, the seedlings were thinned to one per cavity, leaving the largest. The remaining seedlings were allowed to grow 14 weeks. After this time, some of them were as large as they could be in the container without acceptable growth restriction, and differences between seedlings grown in different salt concentrations were clearly evident. The blocks of seedlings were photographed and survivors were counted. Stem height and the length of two fully mature leaves were measured on each seedling.

For each species and treatment, a regression equation was calculated with height, leaf length, or survival as a function of salt concentration (measured by EC). Eight equation forms were tried using the Weibull-Backlund 1925 family regression program General Statistics Vol. 1, pages 9825-15004. The one with the highest F' was used to calculate the salt concentration at which growth or survival was reduced by 25 percent compared to growth or survival with nutrient solution only.

RESULTS AND DISCUSSION

Experiment 1.—Seed Germination

Russian olive and caragana germinated well at all salt concentrations, and neither total germination nor germination energy declined noticeably at high salt concentrations (table 1). Germination energy of buffaloberry declined steadily with increasing salt concentration, but total germination remained high throughout. 1.2 mmol/L. Total germination of green ash and honesuckle declined somewhat, and germination energy was greatly reduced by high salt concentration. Total germination and
Table 2.—Total germination and germination energy of seven species in nutrient solution with increasing concentrations of sodium chloride, sulfate, and bicarbonate. Within species values followed by the same letter are not different at the 5 percent level by Goodman’s test.

<table>
<thead>
<tr>
<th>Species</th>
<th>Total germination</th>
<th>Germination energy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Solution conductivity (mmhos/cm)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.6</td>
<td>4.5</td>
</tr>
<tr>
<td>Lilac (Syringa vulgaris L.)</td>
<td>73 a</td>
<td>54 b</td>
</tr>
<tr>
<td>Crabapple (Malus baccata (L.) Borkh.)</td>
<td>40 a</td>
<td>24 b</td>
</tr>
<tr>
<td>Honeysuckle (Lonicera tatarica L.)</td>
<td>33 a</td>
<td>30 ab</td>
</tr>
<tr>
<td>Green ash (Fraxinus pennsylvanica Marsh.)</td>
<td>88 a</td>
<td>71 c</td>
</tr>
<tr>
<td>Caragana (Caragana arborescens Lam.)</td>
<td>87 b</td>
<td>96 a</td>
</tr>
<tr>
<td>Russian olive (Eleagnus angustifolia L.)</td>
<td>84 c</td>
<td>94 b</td>
</tr>
<tr>
<td>Buffaloberry (Shepherdia argentea (Pursh) Nutt.)</td>
<td>90 a</td>
<td>91 a</td>
</tr>
</tbody>
</table>
Table 3.—Salt concentration (measured by conductivity) causing a 25 percent reduction in growth or survival, compared to nutrient solution with EC of 1.6 mmoles/cm

<table>
<thead>
<tr>
<th>Species</th>
<th>Height</th>
<th>Leaf length</th>
<th>Percent survival</th>
<th>Height</th>
<th>Leaf length</th>
<th>Percent survival</th>
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</thead>
<tbody>
<tr>
<td>Honeysuckle</td>
<td>2.2</td>
<td>3.3</td>
<td>3.3</td>
<td>55</td>
<td>32</td>
<td>71</td>
</tr>
<tr>
<td>(Linaria vulgaris L.)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crabapple</td>
<td>2.6</td>
<td>6.0</td>
<td></td>
<td>.54</td>
<td>.67</td>
<td>NS</td>
</tr>
<tr>
<td>(Malus baccata (L.) Norr.)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lilac</td>
<td>3.6</td>
<td>4.1</td>
<td>15.7</td>
<td>.70</td>
<td>.71</td>
<td>.92</td>
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<tr>
<td>(Sorbus aucuparia L.)</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>American plum</td>
<td>6.3</td>
<td>7.1</td>
<td>5.0</td>
<td>.35</td>
<td>.78</td>
<td>.69</td>
</tr>
<tr>
<td>(Prunus americana Marsh.)</td>
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<tr>
<td>Buffaloberry</td>
<td>7.6</td>
<td>8.2</td>
<td>16.6</td>
<td>.33</td>
<td>.29</td>
<td>.33</td>
</tr>
<tr>
<td>(Zapflia argentea (Pers.) Satt.)</td>
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<td></td>
<td></td>
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<tr>
<td>Russian olive</td>
<td>8.3</td>
<td>&gt;16.6</td>
<td>16.6</td>
<td>.30</td>
<td>.20</td>
<td>NS</td>
</tr>
<tr>
<td>(Elaegnum angustifolium L.)</td>
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<td></td>
<td></td>
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<tr>
<td>Chokecherry</td>
<td>8.7</td>
<td>9.6</td>
<td>16.6</td>
<td>.30</td>
<td>.60</td>
<td>NS</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green ash</td>
<td>11.7</td>
<td>8.6</td>
<td>&gt;16.6</td>
<td>.42</td>
<td>.30</td>
<td>NS</td>
</tr>
<tr>
<td>(Prunus pennsylvanica Marsh.)</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juneberry</td>
<td>11.8</td>
<td>14.5</td>
<td>&gt;16.6</td>
<td>.51</td>
<td>.26</td>
<td>NS</td>
</tr>
<tr>
<td>(Amelanchier alnifolia (Satt.) Satt.)</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Caragana</td>
<td>&gt;16.6</td>
<td>5.1</td>
<td>&gt;16.6</td>
<td>.07</td>
<td>.23</td>
<td>NS</td>
</tr>
</tbody>
</table>

1Regression equation not meaningful.

**CONCLUSIONS AND RECOMMENDATIONS**

1. Crabapple, lilac, American plum, and honeysuckle are sensitive to salt. They should not be grown at a nursery with saline irrigation water or soil not outplanted into saline soils.

2. Buffaloberry, Russian olive, chokecherry, green ash, Juneberry, and caragana are salt tolerant. These species should not be grown at nursery sites near high salinity regions.

3. It was found that the height and leaf length of honeysuckle, crabapple, and lilac decreased with increasing salt. Russian olive also showed a significant reduction in height at 16.6 mmoles/cm. Russian olive is a potential species for use in salt-affected soils. Its tolerance to salt makes it an ideal choice for use in saline environments.

4. Crabapple and American plum were the most tolerant species of the ones tested. They were able to grow in nutrient solutions with high salt concentrations, indicating their potential for use in saline environments.

5. The results of this study suggest that species with low salt tolerance, such as Russian olive, may be used in areas with moderate salinity, whereas species with high salt tolerance, such as crabapple and American plum, may be used in areas with high salinity.

6. Further research is needed to determine the long-term effects of salinity on the growth and survival of these species.

**Figure 1**—Decreasing growth with increasing salt concentration (measured by EC) of (A) lilac, a salt sensitive species and (B) Russian olive, a salt tolerant species.
CONTAINERIZED SEEDLING PRODUCTION FOR FOREST REGENERATION IN THE PACIFIC NORTHWEST

James M. Sedore

ABSTRACT: The containerized seedling continues to be a valuable regeneration option during this time of economic stress. Recent developments in plug-1 culture and seedling storage are described.

INTRODUCTION

As you know, these are hard times for the timber industry. The lack of timber harvesting has reduced the demand for regeneration seedlings. Seedling supplies were in excess of industry needs for two years at our operations, and we saw no indication of any impending leap to the previous levels. Greenhouse operations throughout the Northwest have had to respond to this change, and the response has been varied. One operation has been almost totally mothballed; another is planning to consolidate two facilities into one; another is operating at less than 40 percent capacity and is looking to move and build a smaller, more efficient operation. Another operation has diversified and is growing vegetables in some of their greenhouses. It has been a time to prioritize and to reevaluate the value and role of the container program after little more than a decade since its birth. Although some operations have gone by the wayside, the containerized seedling has retained a place in the regeneration effort.

It is obvious that the conditions under which we work in the Pacific Northwest differ significantly from the conditions in the Intermountain states, especially the region of the Southwest. I hope that the stock or Spencer-Lemire books for Utah, the most common container type in the Southwest.

GREENHOUSES

The average production facility in the Northwest produces from two to four million seedlings per year, although two facilities produce over eight million seedlings. Other companies own and operate the largest container complexes for their own wood regeneration needs. They also compete for public regeneration contracts. The greenhouse operation differs on the state-of-the-art at the time the greenhouses were built. The most popular greenhouse design at this time calls for a fiberglass roof with roll up sidewalls. The typical configuration call for heating the greenhouse to 20°C, through May and minimal heating from October through January. Passive cooling or active cooling with exhaust fans and evaporative coolers occurs during the hotter months of June through September.

There, therefore, the structure must facilitate both heating and cooling to provide proper growing conditions throughout the year.

Barrel
Fuel represents up to 15 percent of the cost of our seedlings. Several operations have made significant reductions in their fuel bills by solarizing later and by switching from diesel oil to natural gas. Natural gas is the most popular fuel source in the Northwest because of large supplies from Canada. Solar collection may be used more in the future. Our use and use the limited solar radiation we receive does not compete with gas at this time. A recent greenhouse energy conversion system is being used by the Bureau of Land Management at Colton, Oregon. The ECM uses infra-red heating in one of their two greenhouses. They report a 30 percent energy savings over their forced-air system. They also believe that the quality of their stock has not diminished.

BENCHES AND CONTAINER TYPES

Bench layouts vary from broad growing troughs, wooden 2” x 4” saw horses, iron flat bars, aluminum L-bars, and tile eliminating bench tops. The most popular container types are hydroblocks in either the 24 or 48 size. Common seedlings grow in a 24 are transplanted to become plug-1s, and 48s, are shipped directly to the forest. Other containers have been used such as a bench table, and other stock or Spencer-Lemire books for Utah, the most common container type is the hydroblock.

SONING AND FERTILIZING

Most of our sow with some type of vacuum sower which picks up the seed per hole from a tray of seed. The seed then falls into the cell when the vacuum is turned on to ensure a uniform in each cell and then to this. Soluble fertilizers are mixed according to each grower’s preference and injected into the watering system. Fertilizer regimens vary according to species, time of year, and current status as indicated by fallar and soil analysis. Most growers monitor their soil and fertilizer analysis with a private consultant. As is common with many plants, the growth curve of most conifer species is used to a sigmoid curve. Growth starts slowly, then increases in rate, and finally tapers off in the fall. To produce a quality seedling, it is necessary to find the balance between overfeeding, which produces


SOMMER, A. J.; BEERMAN, L. Elongation of shoot leaves is exposed to several levels of matrix potential and NaCl-induced matrix potential of soil water. Agron. J. 7(3): 848-852; 1979.


GOODMAN, L. J. Similarity of the conditions under which we work in the Pacific Northwest differ significantly from the conditions in the Intermountain states, especially the region of the Southwest. I hope that by this stock or Spencer-Lemire books for Utah, the most common container type is the hydroblock.
succulent, top heavy seedlings and underfeeding which produces a stunted, starved seedling.

PLUG-1's

If sown in a bareroot seedbed, many of our seedlings such as Abies, Tsuga, and Thuja do not grow quickly the first few years. Commonly we grow these seedlings for one year in the greenhouse and then transplant them at the nursery. These seedlings may be transplanted either in the summer (August, in our area) or in the spring. We call these seedlings Plug-1's. In the nursery transplant bed, they can develop into large enough seedlings to withstand deer and elk browsing or vegetative competition. The shoot of a Plug-1 Tsuga is similar to a 2-1 Tsuga, but the roots of a Plug-1 are more support the shoot. The hemlock transplant bed does not have to be shaded or misted as the seed bed requires, and each crop uses valuable nursery bed space for only one year rather than three.

PLUG CULTURE

Back at the greenhouse, seedlings destined to go directly to the forest are kept unshaded and exposed to broader and broader temperature ranges. If you keep temperatures and fertility levels high, you produce a large, succulent shoot at the expense of an adequate root system and caliper. Seedlings, grown in this way, leave the greenhouse unprepared for the vigors of the forest and are commonly frozen back, desiccated or pushed to the ground by the first snow. Our goal is to produce a seedling with a large caliper and good buds, tall enough to compete with surrounding vegetation and with enough roots to support the shoot.

Techniques for inducing budset vary by species. It is common for Pseudotsuga to be leached, moisture stressed, and then fed a low nitrogen, high phosphorus and potassium fertilizer in September to form large, mature buds for winter planting. However, Tsuga appears to respond best to full light exposure in July and a balanced fertilizer each time the seedling requires moisture. Shading has become less and less popular among Northwest growers. Although many of our trees will grow well under shade, when these seedlings are removed from a shaded house and planted in a nursery or clear-cut reforestation site, the seedlings drop their foliage and must struggle to break bud and begin growing. To avoid this we attempt to grow the seedlings without shade.

SEEDLING STORAGE

We have all struggled with the problem of holding seedlings at lower elevations for late planting at higher elevations. All too often the seedlings break bud in the shelterhouse before the planting site is ready or accessible. Moving these succulent seedlings in the spring from a warm, protected nursery to some cold, harsh site is a frustrating experience for both the nurseryman and the forester. Growers in the Northwest have several different approaches to the problem of seedling storage and I'll share several of these approaches with you.

The Washington State Department of Natural Resources moves their seedlings out of the greenhouse into shelterhouses in June. Here they remain until packaged for field planting which traditionally begins the first week of January. At our location, we feel that this is the time when the seedlings are fully dormant. The seedlings are sprayed thoroughly with a foliar fungicide to reduce damage from storage molds and stored at 2°C in poly-lined boxes. The seedlings are kept at this temperature during transport and until the day of planting. All seedlings stored this way should be planted by June. Seedlings to be spring transplanted in the nursery as plug-1's may be stored in this way or kept in the shelterhouse. Container stock is transplanted in mid-March, and plug transplanting is completed by early April, two weeks before bud burst of Pseudotsuga in our area. Seedlings are therefore stored above freezing for 1 to 20 weeks. Storage molds have not been a major problem in our program although we lose a few trees each year. Many nurseries use this method of cooler storage for coastal and low elevation seedlings.

The Weyerhaeuser Company freezes most of their high elevation container stock at 1 to 2°C. The seedlings are packaged in January and February after having received 400 to 600 hours of exposure to temperatures below 4°C. Thawing takes from one to two weeks in a shaded warehouse at 4 to 15°C before the seedlings are shipped to the planting site. Seedlings are planted shortly after thawing. For more information, contact Steve Hee at Weyerhaeuser Regeneration Center in Rochester, Washington.

The Industrial Forestry Association is a group of timber companies who share a nursery system for the reforestation of their individual lands. IFA does freezer-store container seedlings on request according to vulnerability criteria. There are three vulnerability criteria: (1) coastal seed sources, (2) seedlots which have had a history of winter damage in the nursery and (3) seedlots that are likely to suffer significantly from storage molds. Late in the fall, frost hardiness testing is begun. The lethal temperature for 50 percent LT is established by means of controlled freezing tests. If the seedlings have achieved a set LT, they are considered leafable and storable. Seedlings may be stored frozen for six months. Large quantities may be thawed en masse at 4°C, but this takes up to six weeks. Small quantities may be thawed in a matter of days at 15°C. Pseudotsuga, Picea, and Abies do not appear to have any problem with this treatment. Although Tsuga roots are sometimes damaged. For more information, contact Sally Johnson at the IFA.
THE NURSERY TECHNOLOGY COOPERATIVE:
A COORDINATED EFFORT TO IMPROVE SEEDLING QUALITY
Mary L. Duryea and Steven K. Oml

ABSTRACT: The Nursery Technology Cooperative (NTC) was established July 1, 1982 to improve the productivity of the Pacific Northwest's forest tree nursery industry. The NTC and the other two cooperatives (tree improvement and vegetation management) in the Department of Forest Science are aimed at helping to solve r-orientation problems beginning with seed and ending with a free-to-grow forest stand. Membership categories in the NTC include (1) nurseries, (2) seedling users, and (3) specialist organizations. Problem areas for Cooperative study are identified and prioritized by Cooperative members. Our first study, investigating the effects of top pruning on seedling morphology and field growth and survival, has been installed at six nurseries. Pruning is in progress for a long-term Cooperative study examining the effects of selected herbicides on weed growth and seedlings. Other activities in the Cooperative include (1) a nursery pathology research project, (2) a tissue culture/vegetative propagation project, (3) continuing education (production of a nursery manual), (4) technical assistance (compilation of lists of specialists available to help members), (5) information gathering (collection of state-of-the-art information on compost, tillth, and drainage), and (6) a seeding evaluation program.

INTRODUCTION
Origin of The Nursery Technology Cooperative
Because of the importance of the forest nursery industry, a task force was appointed by the Oregon State Forester and the Dean of the School of Forestry, Oregon State University (OSU), to study the report on the status of forest nursery management technology in the Pacific Northwest. The task force found that the forest nursery industry wanted research and educational assistance and that a Nursery Technology Cooperative (NTC) be established at OSU to address these needs. The Nursery Technology Cooperative (NTC) was officially established July 1, 1982.

Objectives
The objective of the Cooperative is to improve the productivity of the Pacific Northwest's forest tree nursery industry through an integrated program of coordinated studies, information sharing, and technical assistance.

Examples of specific needs to be met through cooperative action include:
1. Better nursery-specific cultural prescriptions for the improvement of nursery productivity.
2. Improved soil management guidelines for the maintenance of long-term nursery productivity.
3. More effective coordination of nursery and outplanting techniques.
4. Better information sharing among nurseries and between nurseries and related groups such as reforestation foresters and researchers.

Who Cooperates?
The three cooperatives in the Department of Forest Science at OSU have been established to help solve reforestation problems beginning with seed and ending with a free-to-grow forest stand. The Tree Improvement Research Cooperative, headed by Thomas Adams, coordinates genetic and breeding research on Pacific Northwest tree species to enhance tree improvement efforts in the region. The Nursery Technology Cooperative, by helping to increase nursery productivity, will add in the better utilization of improved seed and the matching of high quality seedlings to planting sites. At the outplanting stage the CRANTS Cooperative, headed by Steven Kadan, works to coordinate research on methods of controlling competing vegetation in commercial forests of the Pacific Northwest.

Cooperatives enable us to:
1. Define and study useful problems.
2. Reduce fixed costs per cooperative to study these problems.
3. Investigate treatment x site interactions.

4. Rapidly use results.
5. More effectively share information by using OSU as a clearinghouse.

Organization
Fifteen members from state and federal agencies and industry participated in the Cooperative in its first year (Appendix 1). A Technical Committee and a Policy Committee assist the NTC leadership. The Policy Committee advises the Cooperative on short-term decisions concerning program strategy, size, and support. The Technical Committee helps to identify and prioritize problems and assists in planning, installing, and measuring Cooperative studies. Together, the Policy and Technical Committees guide the activities of the Cooperative, insuring that efforts are focused on real problems.

The NTC membership categories (and annual member fees) are: (1) nurseries (large—$5,000 and small—$1,500), (2) seedling users (full—$9,000 and partial—$5,000), and (3) specialist organizations ($2,000 to $4,000). All members (except for the nursery user members) have representation on the Technical and Policy Committees, and are directly involved in nursery and outplanting studies. Seedling user monitoring members receive study results only, and do not participate in guidance.

ACTIVITIES
Cooperative Studies
Problem areas for study are identified and prioritized by Cooperative members. Top pruning and weed control will be investigated in our first short-term and long-term studies, respectively.

Top pruning.—This study was installed in May, 1983, to examine the effects of top pruning on 240 Douglas-fir seedling morphology, survival, and growth. Top pruning is a common practice in western nurseries (fig. 1); however, there is little information about the effects of top pruning. Treatments for the experiment included different pruning heights, two different times of application, and one multiple pruning. The entire experiment, with one seed zone, was installed at three nurseries; a smaller version, involving fewer treatments, was installed at another nursery. In addition, a common garden study, including seedlings from all seed zones, will be established at the OSU McDonald Forest. The growth and survival of nonpruned seedlings will be monitored for up to three years.

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Continuing Education

The Forest Nursery Manual: Production of Bareroot Seedlings includes 30 chapters covering specific topics such as nursery site selection, fertility management, and seedling storage (fig. 1). However, the authors have already done much to ensure that the manual will be revised every 5 years. After 1982, the manual for the OSU Forest Service, State and Private Forestry, Region 6.

Other Cooperative Projects

Two other OSU projects are connected with the OSU Nursery Pathology Research Project, headed by Everett Hansen, and the Tissue Culture/Propagations Project, headed by Joe Zera. Both projects are meeting Cooperative objectives, although both are funded by sources other than OSU's cooperative annual fees.

Nursery pathology research project. -- The broad goal is to provide the biological information necessary to predict and prevent disease outbreaks in nurseries. The initial focus of the project will be on the various fog diseases that have caused substantial losses in recent years. In preliminary work, a systemic isolation can be made from blighted seedlings at a Pacific Northwest nursery to identify suspected pathogens. These isolates, plus those from the other participating nurseries, will be tested for pathogenicity.

Tissue culture/vegetative propagation project. -- The objective of this project is to develop techniques for producing large quantities of superior forest trees by means of tissue culture. The approach has been to measure growth hormones in culture to determine which hormones produce the desired results.

Work to date has resulted in the development of techniques to isolate and detect plant hormones in extremely small quantities. These techniques have been used to measure auxin in callus cultures and in other shoot tips. In another study, another class of growth hormones, auxins, were measured in suspension cultures of Douglas fir. The results of these studies indicate that the growth hormones required for embryogenesis (producing whole plants from cell cultures) are probably very specific, and that the growth hormones that have been used in previous attempts to produce embryogenesis are probably not the ones that are actually required.

Future work will include a broadening of the objective to include other methods of propagating cuttings, such as microcuttings, and the problems associated with these techniques.

Forest Nursery Manual: Production of Bareroot Seedlings

Mary Duryea and Tom Landis, Editors

I. Development of the Nursery Manual: a synthesis of current practices and research

II. Developing a Forest Tree Nursery

III. Starting the Bareroot Seedling

IV. Managing the Soil and Water

V. Culturing the Bareroot Seedling

VI. Harvesting and Planting the Bareroot Seedling

VII. Selected Topics in Nursery Management

VIII. Upgrading Nursery Practices

Figure 3. -- Major Sections in the 3-chapter Forest Nursery Manual.

Seeding Physiology and Fertilization will be the title of the Physiology Working Group Technical Session to be held at the Society of American Foresters National Convention in Portland, Oregon, 1983. The one-day session will include both overview and specific research reports concerning the effects of following physiology on fertilization success, with major emphasis on soil quality and plant-site manipulation. The proceedings of the session will be published in 1984.

Technical Assistance

As part of their commitment to improve information flow and research, we are consulting lists of specialists who would like to help nurseries and reforestation groups. Questionnaires (fig. 3) have already been sent to insect disease, nursery, wood control, and irrigation specialists of OSU and the USDA Forest Service, State and Private Forestry, Region 6.

Users of these specialists include agricultural and industrial engineers, weed physiologists, crop scientists, and horticulturists. The list of specialists for insect and disease, soil, and irrigation problems will be sent to Cooperative members.

Members are encouraged to contact specialists directly from the lists when the need for technical assistance arises. However, they may also receive help from the OSU staff in making contacts with specialists by stating their specific problem on a Technical Assistance Request Form. The OSU staff will consult immediately to these requests by providing ways to approach the stated problem.

Information Gathering

Cooperative members have expressed a need for being informed of the state-of-the-art knowledge on several topics. Soil management (title/consultant) has been selected as the problem area in which information gathering is currently needed. The OSU staff is presenting the literature and collecting relevant material. A summary, available to all members, will follow.

Seeding Evaluation Program

The purpose of the OSU Seeding Evaluation Program is to improve techniques for assessing seedling quality. As part of this program, the OSU provides a seedling vigor evaluation for stress testing service. More than 250 seedling lots were evaluated this year on a few sites. This procedure is designed to identify poor quality seedlings and to assess the growth and survival of planted seedlings placed in a growth room environment to obtain seedling characteristics. Although the procedure has been very useful, work continues to refine the tests. A study is being conducted to determine the effectiveness of the current procedure in predicting field survival under uniform planting conditions. We are also examining the relationship between the vigor evaluation results and standard measurements of root growth capacity. This investigation will indicate whether these two assessment procedures are consistent in predicting field survival or, perhaps, are complementary and could be used together to improve prediction accuracy. The study began in March, 1983.

SPECIALIST QUESTIONNAIRE

Nursery Technology Cooperative

1. a. Would you be interested in being involved in the Nursery Technology Cooperative? (Check yes or no)

   Yes  No

2. b. In what cooperative efforts might you be willing to participate? (Check yes or no for each starred (*) area below)

   Yes  No

(1) *Workshop teaching?

(2) *Studies?

(3) *Team problem solving and providing technical assistance through a Cooperative?

(4) *Individual direct consulting?

(5) *Others? (please specify below)

Figure 4. -- Page one of the questionnaire being sent to specialists in the West.

Another recently completed study in the STC Seeding Evaluation Program was developing a specific procedure for deterring damage to seedlings which have been unintentionally frozen during cold storage. In this study, we found that a pressure chamber could be effectively used to identify this type of injury. Results indicate that the change in plant mist-
ture stress (PMS) of potted seedlings during the first week after freezing can generally predict whether or not they will survive. The PMS of damaged seedlings tends to increase much more rapidly than that of non-injured seedlings. A more complete description of this study is reported by Douglas McCreary in this proceedings.

LOOKING AHEAD

In its second year the NBC staff is (1) coordinating the NBC studies (for pruning, weed control), (2) providing continuing education programs (Physiology Workshop at the SARE National Convention, publication of the Forest Nursery Manual), (3) updating the Seedling Evaluation Program, (4) supporting other projects within the NBC (Chemistry Technology, Tissue Culture/Vegetative Propagation), (5) providing technical assistance (Compilation of specialists lists), and (6) gathering, information on soil management, and, given continued Technical Committee interest, a soil management study plan will be prepared.

APPENDIX I

Members of the Nursery Technology Cooperative.

Nurseries:

Lava Nursery, Inc.
Oregon State Department of Forestry, D. L. Phillips Forest Nursery
USDA Forest Service, Rogue River National Forest, J. Herbert Stone Nursery
Washington State Department of Natural Resources, et.
Mike Walker Nursery
Waynesburg Company

Seeding Users:

BMN—Coos Bay District
BMN—Eugene District
BMN—Medford District
BMN—Oregon State Office
BMN—Roseburg District
BMN—Salem District
USDA Forest Service, Impqua National Forest

Specialist Organizations:

USDA Forest Service, Pacific Northwest Forest and Range Experiment Station
USDA Forest Service, Pacific Northwest Forest and Range Experiment Station
USDA Forest Service, State and Private Forestry, Region 6


Douglas D. McCreary
Research Assistant in the Department of Forest Science, School of Forestry, Oregon State University, Corvallis, Oregon.

ABSTRACT: During cold storage, seedlings are sometimes accidentally frozen. A study to determine if a pressure-chamber device could be used to detect the extent of this type of injury indicated that the change in plant moisture stress of potted seedlings during the first week after freezing is a reliable measure for predicting seedling survival.

INTRODUCTION

Storage of bare-root seedlings is often a necessary step in the reforestation of millions of acres, as labor, geographic, and climatic constraints make it virtually impossible to plant seedlings immediately after they are lifted. It is well established that the temperature during storage can greatly affect seedling quality (Hooking and Nolan 1971). Currently, most conifer seedlings are stored between 0° and 5°C because cold temperatures reduce respiration and inhibit the development of harmful molds. But, despite improvements in the overall quality of reforestation facilities, occasional equipment malfunction results in seedlings being exposed to subfreezing temperatures. Such exposure can be especially injurious to root systems, which are more sensitive to freezing than shoots.

Unfortunately we know little about the tolerance of roots to this type of injury, nor is there a simple and effective method of identifying its extent. When such a storage problem is discovered and it must be decided whether seedlings should be discarded or planted, there is little on which to base a decision. Consequently, in December 1982, as part of the Nursery Technology Cooperative at Oregon State University, we initiated a study to determine if a pressure-chamber device could be effectively used to identify seedlings that were severely damaged by accidental freezing during storage.

METHODS

One hundred, 2-year-old Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco) seedlings from a common seed source were randomly divided into 10 equal groups for 10 temperature treatments. Each group was placed in a sealed plastic bag in a freezing chamber programmed to remain 1 hour at +1°C. The temperature was then lowered at the rate of 2°C per hour. We removed the first bag at -3°C and continued to remove one bag every half hour at each drop of 1°C until the temperature was -12°C. Immediately after removal from the freezing chamber, each bag was placed in a cold room (4°C) and left overnight to thaw gradually.

The day after thawing, all seedlings were tagged with their freezing-treatment number and planted randomly in pots. One seedling from each treatment was planted in each pot.

The following day, a small lateral branch from each seedling was removed and placed in a pressure chamber to determine its plant moisture stress (PMS). This procedure was repeated on the fourth and sixth days after potting. PMS was recorded as a positive number, so that an increase indicated greater water deficit within the seedlings. The night before each PMS determination, all pots were watered to field capacity to ensure similar soil moisture conditions for each pot on each evaluation date.

The seedlings were maintained for 2 months in a growth room under a 16-hour photoperiod and constant 22°C temperature. During this time, the pots were watered regularly and soil moisture remained fairly high. At the end of this period, we recorded the percentage of dead seedlings from each of the 10 freezing treatments and calculated the average PMS per treatment for each evaluation date. For each treatment, we calculated the average absolute increase and average percentage increase in PMS between the first and fourth and the first and sixth days after planting.

We then determined if there was a significant relationship between freezing temperature and PMS on each date. Next we calculated correlation coefficients for the relationships between mortality and absolute and percentage changes in PMS over all treatments. Finally, we determined the average PMS for seedlings that lived and those that died and tested for significant differences. All reported differences were significant at P < 0.01 unless otherwise stated.

RESULTS

Twenty of the original 100 seedlings died during the frost-free assessment period. Figure 1 shows mortality percentages for each freezing treatment. Sixteen of the dead seedlings were from the two lowest temperatures, which indicates that among seedlings of the seed source used,
change are more reliable after 5 days than after 3 days.

CONCLUSIONS

Our initial hypothesis was that accidental freezing during cold storage can injure root systems, so that seedlings cannot take up water and maintain an adequate moisture status once they are planted. The data are consistent with this view. Seedlings killed by the freezing treatments were more stressed over time than seedlings that lived, although they initially had lower PMS. An initial reduction, also found by Risby and Brown (1974) and Timilsina (1974), is apparently caused by internal rupturing of cells and release of water into the xylem. Over time, the transpirational demand probably depletes the available water in the seedlings, and PMS rises rapidly as the water is not replenished by the injured root system.

Because we found considerable variability in the initial PMS values of seedlings receiving the same freezing treatment, and because the change in PMS was so closely correlated with lethal injury, we believe that the procedure of determining seedling moisture status once a week after planting and some 5 days later is a more reliable technique for predicting injury than a single PMS measurement. The exact magnitude of change in PMS that indicates severe freezing damage, however, is not clear. In this study, a 4-fold increase between the first and sixth days reliably indicated seedling mortality; those with less than a 4-fold increase in PMS lived. The 4-fold separation value predicted the final survival status of 97 percent of the seedlings. In preliminary results from another trial, however, a 3-fold increase during the first week after planting indicated mortality. In this second trial, there was little or no change in the PMS values over time for most surviving seedlings, in contrast to the rough doubling of PMS between the first and sixth days for surviving seedlings in the study reported here.

Although some calibration must be done to perfect the technique, the data clearly suggest that a pressure chamber can be a very useful tool in identifying freezing injury caused by unintentional freezing during cold storage. The assessment procedure outlined is simple, requiring only a pressure chamber and a small amount of greenhouse or growth-room space, and it can be completed within a week after the suspected injury occurs.

PUBLICATIONS CITED


Quaking aspen (Populus tremuloides Michx.) regenerates almost exclusively by root suckers in the western United States, even though female clones produce abundant viable seed. During the past decade, interest in propagating aspen for use as an ornamental and for reforestation of forest land has increased. To satisfy these diverse needs for aspen planting stock, nurserymen have a choice between sexual and asexual propagation. Criteria for clone selection, seed collection and storage, propagation techniques, and the advantages and limitations of sexual and asexual propagation are discussed.

**INTRODUCTION**

Quaking aspen (Populus tremuloides Michx.) has the widest distribution of any native tree species in North America (Powell 1965). This significant fact suggests that quaking aspen can grow under a vast range of environmental conditions. Thus, if aspen could be successfully propagated, it could be used widely as an ornamental and for reforestation and land reclamation. In the western United States, this important species relies almost entirely upon vegetative regeneration from root suckers. Female clones, however, produce many viable seeds.

Interest in propagating quaking aspen for use as an ornamental and for reforestation surged during the past decade. Vegetative propagation techniques have been developed (Schier 1978b) and have specific applications. However, seed propagation is less labor intensive and is used by some nurserymen to produce large quantities of planting stock.

I will present various factors that nurserymen should consider and the implications between sexual and asexual methods of propagation.

**ASEXUAL PROPAGATION OF QU AKING ASPEN**

Quaking aspen clones have numerous long, lateral roots in the top 6 inches of the soil profile. Such roots may develop and become a younger generation of clones that are genetically identical to the trees of the parent clone.

Robert B. Campbell, Jr. is a botanist with the Intermountain Forest and Range Experiment Station, USDA Forest Service, located at the Forestry Sciences Laboratory, Logan, Utah.

Many amateur and professional landscape architects transplant these natural suckers, or seedlings, for ornamental purposes. When the suckers are dug up, the soil usually falls away exposing the root system. Typically, the transplant's root system consists of only a 12- to 18-inch segment of lateral root from the parent clone. Once transplanted, the wildings usually grow slowly at first and develop small leaves. Generally, they have few, if any, branch roots at the time they are removed. When planted, they have an established root system in adequate; consequently many wildings do not survive after transplanting (Schier 1982).

A few commercial landscape architects report good survival and growth of transplanted aspen when the suckers have well-developed, independent root systems. They are careful to keep the root ball tightly bound, which protects the fragile new roots. Sharp shovels are used to minimize root damage, which can be an infection site for pathogens. It is best to transplant aspen in the dormant stage. Survival can be excellent when aspen 3 to 5 inches in diameter at breast height (d.b.h.) and 18 to 20 ft tall are carefully transplanted with a 44-inch tree spade. (Personal communication with Ron Nefelt of Landscape's Service, Steamboat Springs, Colo.)

Another nurseryman substantially improves the survival and vigor of transplanted wildings as follows: (1) Wildings are selected from undisturbed clones where the regeneration varies in size and age. (Fertilization is common when wildings come from clones with a history of disturbance as characterized by many suckers of the same age.) (2) When trees 3 to 5 inches d.b.h. are transplanted, the roots are dug and only those trees that are firmly rooted in all four directions are selected. (3) After transplanting, the aspen are given three applications of a fertilizer and one hydraulic injection of the fertilizer into the root system. (4) The transplants are then covered with a tarp and a soil mix that retains moisture. (Personal communication with Jerry North of Rocky Mountain Tree Experts, Lakewood, Colo.)

Methods have been developed to artificially propagate quaking aspen vegetatively (Schier 1978b). Though labor intensive, these methods offer a way to produce rooted clones of vigorous growth. I want to dispel the myth that vegetatively propagated aspen clones have slow growth. Aspen trees propagated vegetatively in years ago at Logan, Utah, are now 32 ft tall.

**Clone Selection**

In 1976, aspen suckers were propagated vegetatively from 10 healthy and 10 deteriorating clones in Logan, Utah (Campbell 1980) describe the site and sucker characteristics. The two groups of clones differed appreciably with respect to sucker density, basal area, and mortality.

The rooted sucker cuttings were planted in tubes 2.5 inches in diameter by 10 inches long, filled with perlite/morxingite (1:1) and placed in the greenhouse. The next spring the suckers were transplanted to pots nonamend (3:2) in 1-gal pots and moved to the lathhouse. Under the direction of Dr. George A. Schier, the young trees were transplanted during spring 1978 to a common garden plot near Canyon 3 miles northeast of Logan, Utah.

A total of 439 aspen were planted randomly in 15 rows of 32 clones each in a 6.4-ft square. Soil amendments and fertilizers were used to establish the hybrid sprinlers provided regular but moderate irrigation. After 2 years at the nursery, the trees had substantial variation in height growth. In order to standardize subsequent vegetative growth, all stems were cut off at ground level in the spring of 1979. Thus, all new suckers started from established root systems. As new suckers arose, a dominant sucker was selected; all other remaining and subsequent suckers were cut off.

The new suckers are now in their fourth growing season, and some trees are over 12 ft tall. Data recorded include: height growth for each year, the number of suckers, the length of the longest three laterals, and stem form. Preliminary results indicate substantial variation in these morphological traits occurs between clones. It is obvious for the time of leaf flush, leaf size and shape. and the height and number of laterals. In the greenhouse, the common garden plot illustrates well the genetic control of these characteristics in aspen.

The survival rate in the common garden is an important factor in selecting clones. In 1977, 40 of the 439 aspen planted, only three died; two were stolen. Although a few trees have poor growth, at least 95 percent have acceptable growth.

Many factors should be considered when selecting a clone for vegetative propagation. To the trees in the clone have a desired shape and appearance? Is the soil type ideal for root collection? Are there abundant (or sufficient) lateral roots near the soil surface? Are the roots collected have a high quality to sucker, and will the sucker cuttings develop roots? (Trelintum trials are suggested to determine the clone’s sucker/ rooting capabilities.) These questions relate to specific factors that vary greatly among clones in nature.

**Tree Height may be a misleading guide for acceptance or rejection of a prospective clone. Environmental conditions, particularly those related to available moisture, strongly influence height growth. One should expect trees vegetatively propagated from a clone with tall trees to grow normally; however, I have seen suckers propagated from clones with short trees on a poor site grow unusually fast and tall in a better environment.**

**Barnhans and Nelson (in press) indicate that aspen clones vary in susceptibility to Nezara, a fungal leaf blight. They surveyed about 1,000 acres of aspen in northern Utah during a recent epidemic year for Nezara. Resistance or lightly infected aspen trees occupied only 18 percent of the total area. They suggest that the best control of this leaf blight, particularly for ornamentation, would be to select for highly resistant clones.**

**Sucker Collection and Storage**

Schier (1978b) explains in detail the root collection process. He mentions specific advantages for using a pruner, an anti-trap primer, and a moist cloth bag for collecting lateral roots that range from 0.5 to 1.0 inch in diameter.

The season of root cut collection can significantly alter the amount of roots collected. During the spring flush and early shoot growth, the roots of aspen have a number of shoots, which reduces sucker formation (Schier 1973). Schier (1978a) indicates that clones collected during the clone's dormant stage (spring, early summer, or fall) typically yield more suckers than those collected during active growth. He notes that early spring collections are easier to make and result in less root damage because the soil is still moist.

Peralta (1978) and Schier (1978a) report that the number of aspen suckers is not related to the length of the root cuttings. Because the length of the cuttings are not be used for the convenience of tray size and available space.

Schier and Campbell (1978) suggest that in some situations it may be useful to hold aspen roots in cold storage for several months before the root collection process. For example, nurserymen could have the flexibility to collect....
roots from clones at different times, hold them in cold storage, and then plant the roots at the same time. This growing season for the new suckers could be lengthened if the roots were cut after the dormant season, and then planted in the greenhouse during late winter. Schier and Campbell (1978) treated root segments with benomyl, washed them in moisture paper, and stored them in plastic bags, and stored them in the dark at 4° F for up to 2 weeks. In general, the cold storage did not significantly alter the number of suckers produced by the roots. They suggest that roots from most clones can be stored for extended periods of time and still produce suckers suitable for propagation. Even after storing root cuttings for 3 weeks, three clones for 12 months in a cold room, if some suckers still arose from the roots. When the remaining root from each clone was cut at 18 months, they were rotten and did not sucker.

Propagation Method

Briefly, procedures developed by Schier (1978b) to vegetatively reproduced aspen are: (1) Collect lateral roots from desirable clones. (2) Clean the roots, out to suitable lengths, treat root segments with benomyl, and plant them horizontally at a depth of 0.5 inch in trays of vermiculite. (3) Place the trays in a greenhouse, water lightly each day, and allow the root segments to grow for 4 weeks. (4) Cut the new suckers from the root segments, treat the suckers' bases with indolebutyric acid (IBA), and plant the sucker cuttings in vermiculite (1:1). (5) Put these cuttings in a rooting bench for 2 to 3 weeks at room temperature. (6) Transplant the rooted cuttings to containers with root proliferation vermiculite (1:1) and apply a complete fertilizer. (7) Supplemental light is being tried to maintain the temperature between 50° and 75° F. Aspen have winter chilling requirements that are satisfied at 36° to 50° F.

Sexual Propagation

Female aspen clones produce highly visible seed in the spring (Fowells 1965; McWhirter 1979). Growing aspen from seed is less labor intensive than the asexual methods described above. Some nurserymen are growing seeding aspen on a production scale. Native Plants, Inc., in its nursery has several hundred thousand aspen seedlings growing in containers, both as bare root stock and in containers (personal communication with Mike Alder, Native Plants, Inc., Salt Lake City, Utah).

I will comment on several clones that may be useful to nurserymen who wish to propagate aspen from seed.

Clone Selection

Not all aspen clones bear seeds. Typically, aspen have imperfect flowers arranged in catkins. With few exceptions, all of the catkins produced in a clone will be imperfect, as the literature suggests that the male to female ratio of aspen clones was constantly high. From my general observations, 20 to 25 percent of the clones in the West will not set seed in any given year, and male clones with seed is a major limitation for clone selection.

Before flowering, the winter floral buds usually can be picked apart and carefully observed with a hand lens to determine the sex. The best time to determine the clone's sex is mid- to late spring when the catkins are extended. The male catkins have a cluster of purple anther sacs on each scale bract. The female catkins have a single, green, tree-shaped capsule at the base. Although catkin disintegration rapidly after shedding pollen or seed, it is possible to identify the clone's sex usually will remain on the upper layer throughout most of the winter. Furthermore, it is possible to determine in the presence of female or male catkins, with dependable use of the new seedlings. Nevertheless; because of genetic recombination the seedlings will be a least 36° to 50° F.

Seed Collection

Aspen flowering is controlled in part by temperature. Because of this, the same clone may vary up to 1 week in date of flowering from year to year. Temperature also affects flowering phenology along with other factors (1:1). Each flowering year the earliest flowering beginning at the lower elevations. To minimize the problem of seed collection, the female catkins usually begin to emerge in mid- to late April. The male catkins are smaller clusters of purple anther sacs begin to shed pollen. Following pollination, some 1 month later as the leaves begin to flush out, the female catkins elongate as the seeds mature and increase in size. One to 2 seeds are produced per capsule. The open capsule and seed is a fluff of cotton-like hairs.

Rather than collecting the cotton-like fluff in the field, use a long probe to cut branches from trees with female catkins about a week before the seed would ordinarily be shed. The catkins can then be used in the laboratory.

A method commonly used in Europe for seed harvest from European aspen (Populus tremula) will also work well for quaking aspen. In addition, a large outplanting of seedling stock tends to maintain the genetic variation available in the gene pool. Such variation is a benefit to reforestation and land reclamation because it enhances the adaptability and survival of the total outplanting. Some aspen clones have nearly equal large numbers of planting stock that are more feasible to grow from seed.

In contrast, vegetative propagation yields more nursery genetically identical material. Nurserymen can select for the superior clones and propagate those that need the aspen. A nurseryman's goal for annual propagation of aspen is promising with many possibilities for new advances. Fast, dense culture, another form of vegetative propagation, is currently being used by Native Plants, Inc. to grow hundreds of thousand of aspen clones from a single seedling that has successful treatments (personal communication with Mike Alder, Native Plants, Inc., Salt Lake City, Utah).

I stress two recommendations that apply to both methods. General wisdom indicates that clones selected for either root or seed collection should be in the same general area and elevation as the anticipated outplanting, whenever possible. Also, aspen respond best when the fertilizers applied contain a full complement of microelements.

Aspen can be readily propagated by either sexual or asexual methods, both of which have unique advantages. I am not challenging to capitalize on these advantages to produce aspen stock tailored for specific uses.


installation of experimental nursery beds fol-
lowed procedures developed by Benson and Eise
pahr (1961) and modified by Benson and Doby (1972).
Within a 1.24 m x 1.59 m area, (live 1.19 m x 1.54 m)
area were excised to a depth of 93 cm for each to accommodate a 1.22 m x 2.34 m x 2.14 m wood
frame into which ainged soil frame with standard
window screen. Plywood boards divided each
frame into equal quadrants to a depth of
93 cm. Polyethylene plastic lined the main frame
soil side walls to the same length.
The excavated soil was combined with horticulture-
grade peat moss to establish four nursery bed
soil media (1) soil; (2) 1/4 peat, 3/4 soil; (3) 3/4 peat,
1/4 soil; and (4) 1/2 peat, 1/2 soil (by volume). In
addition, elemental sulfur was added at the rate of
853 kg/ha (210 lb/acre) per treatment. Physical
and chemical properties of media were determined
and routine soil test procedures employed by the Soil
and Water Testing Laboratory, New Mexico State
University.

Each bed frame was covered with plastic to
fumigate all experimental plots with methyl
benzene. The following day, frame trays were
lifed and the beds were aerated for 18 hours.

Aspen seeds were sown at the spacing recommended
by IPC (Benson and Doby, 1972); to produce
140-160 seedlings per 1/2 m². For future emergence,
these seedlings were thinned. Beds were irrigated
with a well perforated drip tubing. Fertilizer was applied via irrigation
water at the rate of 113 kg/ha N, 45 kg P, and
75.3 kg K.

Treatments were randomized within frames. Within
the 30 cm x 91 cm area within each quadrant,
12 seedings were labeled in order to record
seedling height and height measurements, repeated
for two-week intervals. Seedling density for each
of these 30 cm x 30 cm composites was recorded
prior to harvest.

Seventeen weeks from sowing, seedlings were
teased with a spade and exposed in plastic bags.
Ten trees were harvested from each subplot.

Results show that the relationship between
seedling height and soil moisture in
peat-amended media is significant
at the 0.05 level. A quadratic relationship is observed
between seedling height and soil moisture
in peat-amended media.

The data indicate that peat-amended
media are more productive than
non-peat media, and that
the relationship between
seedling height and
soil moisture is
significant at
the 0.05 level.

The relative importance of physical and chemical
properties derived from peat was not determined.

APPLIED OVER AN EXTENSIVE AREA, PEAT AMENDMENTS
would be costly and a local substitute should
be sought. In northern New Mexico old composted
wood chips can be obtained and may provide a satis-
factory substitute (Monte and others, 1971).

The disadvantages of fresh sawdust and farm
yard manure were discussed by Aronson and
Sadrieh (1971), who also recommended peat
application rates and procedures.
CREATURES OF AUSTRALIAN PINE AND SQUAMOS SPICE
SEEDLEGS IN MIX-CONTAINERS

Hansch Khatamian and Faded 3, Al-Musa

ABSTRACT: Australian pine (Pinus elliottii Engelm and) and norway spruce (Picea abies L.) containers were seeded in selected mini-containers filled with Jiffy Mix and placed in a greenhouse eighteen weeks from germination. The stem length of both species was greatest in Box Timus intermediates in Box Hillson, Square Container and Ear Paper; smallest in laser tube, Stermack 8 and Stermack block 2. The shoot and root dry weight of spruce specimens reduced with the use of mini-containers. Seedling crow grew equal in all containers. The ratio of the root dry weight/container volume (g/cm³) of both species was higher in the smaller containers.

INTRODUCTION

In recent years, there has been a gradual shift from field-grown, nurse-root nursery stock to container production. The increased use of containerized seedlings in nurseries and forestry production is due to the advantages of better plant survival and growth, extension of the planting season, and adaptability to mechanical planting. Growth of tree seedlings in mini-containers under controlled-environment conditions has been studied by various authors (Smatz 1974, Barnett 1976, Johnson 1975). Generally, there are three categories of containers used in forestry and ornamental plant production: tube, block, and plug (Barnett 1981). Containerized seedlings have a root system which holds the growing medium when removed from the container, and when planted the roots make immediate contact with the soil (Smatz 1972). Easy plug extraction depends upon the proper development of the root system, media, moisture content of the plug and the construction of the container wall (Barnett 1976). Usually, four to five months is needed to produce growing seedlings with root system; suitable for transplanting into larger containers or the field, or for sale (Smatz 1972, Thomas 1980).

Contribution No. 93-265-F, Department of Horticulture, Kansas Agricultural Experiment Station.

Hansch Khatamian is associate professor of Forestry, Kansas State University, Manhattan, KS.

Johnson is presently assistant professor of Plant Production at King Saud University, Riyadh, Saudi Arabia.

Materials and Methods

Australian pine (Pinus elliottii Engelm. and) and norway spruce (Picea abies L.) containers were grown in selected mini-containers to evaluate their effects on growth and seedling quality. Table 1. Containers/seedling dimensions

<p>| Table 1. Containers/seedling dimensions |</p>
<table>
<thead>
<tr>
<th>Composition</th>
<th>Top Dim. (cm)</th>
<th>Length (cm)</th>
<th>Width (cm)</th>
<th>Depth (cm)</th>
<th>Volume (cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stermack 8</td>
<td>Polystyrene</td>
<td>3.0</td>
<td>22.5</td>
<td>12.1</td>
<td></td>
</tr>
<tr>
<td>Stermack 8</td>
<td>Polystyrene</td>
<td>3.0</td>
<td>13.5</td>
<td>13.1</td>
<td></td>
</tr>
<tr>
<td>Book Hillson</td>
<td>Polystyrene</td>
<td>3.0</td>
<td>3.8</td>
<td>12.1</td>
<td></td>
</tr>
<tr>
<td>Book Hillson</td>
<td>Polystyrene</td>
<td>3.0</td>
<td>18.1</td>
<td>352.6</td>
<td></td>
</tr>
<tr>
<td>Cylinder Ear Paper</td>
<td>Unplastic</td>
<td>6.2</td>
<td>10.2</td>
<td>352.6</td>
<td></td>
</tr>
<tr>
<td>Containers referred to in the text as small, in Stermack 7, Stermack 8, and Ear Paper.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Containers referred to in the text as large, in Box Hillson, Book Hillson, Square Bottomless and Cylinder Ear Paper.</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The design and shape of the nursery containers have been improved recently. Some mini-containers now have vertical ribs or grooves along the container wall with drainage holes at the bottom. The ribs are intended to direct the roots downward and therefore prevent stunting of roots (Dickenson and Whitcomb 1978; Times and Wossom 1974).

Research has shown that container volume and diameter influence plant growth, and there is a minimum volume below which growth is impaired. The ratio of the root dry weight/container volume (g/cm³) of both species was higher in the smaller containers.

At the eighteenth week, the plants were harvested. The development of the root system in each container was visually evaluated. The plant shoots and roots were dried at 65ºC for 48 hours for dry weight determination. The experimental design was a split plot in a random block with seven containers and two species replicated four times. The growth rate measurements were determined randomly by selecting six plant samples from each container and species.

Root and Shoot Ratio

The root/shoot dry weight ratio of pine seedlings was greatest in Ear Paper which gave the smallest root system (table 2). The Ear Paper was formed in a cylinder which had smooth walls and no ribs. Circulating and air-placing primary lateral roots near the top root was common in cylinder containers. Times (1975) and Asplund (1968) observed the same disadvantage observed with the Ear Paper container use the root portions of the paper wall into the adjacent tar paper pots. This makes normal difficulty, damps the root morphological results in lots of roots. This is likely the reason for lower root dry weight of the species grown in Ear Paper containers. This problem for paper containers and noted by Strachan (1972), which did not have a greater root/shoot dry weight ratio in the large volume containers: Ear Paper, Box Hillson (table 2).

Root Quality

The extensiveness, flesheness, and uniformity of the root system were taken into consideration when visual evaluations on root quality were made. The Australian pine produced a very good root system in all containers tested except for Ear Paper. The root system of spruce was good in laser tube, Stermack 8 and Stermack block 2. The plugs of both species indicated a more fibrous and dense root system in test tubes and Stermack containers (fig. 1). The plant seedlings were grown that were quickly and easily extracted (figs. 2 and 3).
Table 2. Effect of various containers on stem length (cm), dry weight (g), root quality and root dry weight/container volume ratio (mg/cm³) of Austrian pine and Norway spruce seedlings.

<table>
<thead>
<tr>
<th>Container</th>
<th>Stem Length (cm)</th>
<th>Dry Weight (g)</th>
<th>Root Quality*</th>
<th>Root Dry Weight/Container Volume Ratio (mg/cm³)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shoot</td>
<td>Root</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Styroblock 7</td>
<td>4.2a</td>
<td>0.92a</td>
<td>3.2b</td>
<td>2.5bc</td>
</tr>
<tr>
<td>Styroblock 8</td>
<td>4.6bc</td>
<td>1.19a</td>
<td>3.5b</td>
<td>2.70a</td>
</tr>
<tr>
<td>Leach Tube</td>
<td>4.2c</td>
<td>1.35a</td>
<td>3.2b</td>
<td>2.8%</td>
</tr>
<tr>
<td>Book Hillion</td>
<td>5.0a</td>
<td>1.11a</td>
<td>3.26a</td>
<td>2.6b</td>
</tr>
<tr>
<td>Book Tubes</td>
<td>5.7a</td>
<td>1.31a</td>
<td>3.99b</td>
<td>3.9b</td>
</tr>
<tr>
<td>Square Bottomless</td>
<td>4.7bc</td>
<td>1.34a</td>
<td>3.97bc</td>
<td>4.4a</td>
</tr>
<tr>
<td>Cylinder Tube</td>
<td>4.1bc</td>
<td>1.23a</td>
<td>4.51a</td>
<td>4.4b</td>
</tr>
</tbody>
</table>

*Means of 24 seedlings each of 4 replications.

The square containers were effective for the production of a good root system in both species (fig. 3). The smaller and tapered containers produced a more dense root system than the large container by the eighteenth week post-germination. It has been suggested (Allison 1974 and Sjöberg 1974) that the tapered cavity design with rigid and ribbed walls of RL single seedling container (Leach Tube), or the Styroblocks, influences the root growth resulting in fibrous well-developed and balanced root system. Barnett (1982) showed that pine seedlings grown in Styroblocks performed better than those grown in other containers.

CONCLUSION

Selection of containers should be based on the preference of a particular plant species. Smaller and tapered containers such as the Styroblock 7, Styroblock 8 and Leach Tube can be used to grow pine, spruce or similar plant seedlings over shorter periods of up to six months. The larger containers such as the Book and Square may be used successfully over a longer period. Many studies have focused on the effect of container shape and configuration on plant growth, but yet it is not known whether the actual material which containers are made of has any influence on root development and growth. Effects from various types of mini-containers on the seedling performance after transplanting need further research.

PUBLICATIONS CITED


Description

The dryland planter is designed to be mounted on the rear of a tractor. It features hydraulic leveling devices, hydraulic power to a
scourer, rotating case mounted on a movable carriages and two packing spades. The machine plants containerized shrubs or trees quickly and
effectively. The leveling device and high
clearance enable the platform to be moved on rough ground or
moderate slopes, while ensuring smooth placement of the containers. The containerized root system and aper
holes allow sufficient moisture uptake and
unrestricted root growth for better survival.

The planter is automatic and controlled from the tractor. When the planter is positioned, the
platform is leveled with hydraulic cylinders.
The Aper and the scourer is placed on the
module, removing any compaction vegetation from around the
hole. The scouring containing the fillings
rotates and the scourer moves forward on the
platform, dropping a seedling into the hole. The packing spades fill the soil around
the seedling. Planting rate is estimated at more than one per minute.

Specifications

Carousel capacity: 24 seedlings
Aaper diameter: 76 to 127 cm

Planting spade (case): 52 to 75 kW

TREE TRANSPLANTER

Function

The tree transplanter system (fig. 3) was
designed to transplant small trees and large
shrubs that grow naturally around the mining
site to the revegetation area. The trailer is an important part of the system because it
greatly reduces overall transplanting costs by
reducing the transport time required for each
tree. Up to 24 trees per day can be transplanted with
the tree transplant trailer system. The
front-end loader-mounted tree spade is very
maneuverable and can negotiate slopes up to
20 percent.

Description

The system consists of a Vermeer Model 15-44A
Tree Spade mounted on an Oskomrs 880 articulated
front-end loader and a specially built trailer
consisting of two rows of four cone-shaped pods.
The pods are 112 cm in diameter and 108 cm deep.

Eight soil plugs are removed from the transplant
site, loaded into the trailer, and transported
to the transplant supply area. They are then
replaced in the trailer with selected trees
and shrubs that are transported back to the
transplant site and planted. The front-end
loader-mounted tree spade drops the trees or
plugs, places them in the trailer pods, and
toes the trailer between the transplant site
and transplant supply area.

Specifications—Trailer

Overall width: 2.1 m with walkway removed
Height: 2.1 m

Powered by: 2.72 kW

Capacity: 8 trees or plugs or 3,922 kg

Depth: 112 cm diameter, 109 cm deep

Power requirements: 40 kW recommended

Specifications—Tree Transplanter

Bale (cone) depth: 46 to 152 cm

Tree size: to 25 cm diameter (maximum
tree size may vary with type of root structure)

Mountings: tractor, trailer, truck or
front-end loaders

Figure 2.—Tree transplanter revegetates claimed mine sites with trees and shrubs.

Figure 3.—Dryland sodder preserves topsoil and its vegetation for later replacement on reshaped spoil materials.
SPRINGER

Function
The sprinker (fig. 4) undercuts and gathers sprigs, or portions of rhizomatous stems, that can produce roots and shoots. The harvested sprigs are then spread out on the area to be revegetated and covered with soil.

Description
The sprinker is a modified potato harvester. It consists of a undercutting blade and a pair of wide, inclined conveyors. The conveyors are long rods attached between two chains and spaced 1.8 m apart. A third conveyor across the top of the machine moves the harvested material to the side where it is dumped into a truck or piled in windrows. The sprinker is towed and lowered by a tractor.

After the shrubs are moved, the sprinker is pulled through the stand, cutting the roots well below the surface. The cutting action lifts the soil and shrubs onto the conveyors. The soil is shaken loose and falls through the spaces in the conveyors to the ground. The harvested rhizomatous shrubs, or sprigs, are gathered and carefully planted on the reclaimed area.

Specifications
Width: 1.5 m
Depth: 80 cm
Power requirements (drawbar): 60 to 75 kW

Figure 4.—Sprinker disc up rhizomatous material for planting on reclaimed areas.

Figure 5.—Blade makes depressions in soil that trap moisture, creating favorable conditions for plant growth.

BASIN BLADE

Function
The basin blade (fig. 5) scoops out large basins or depressions along slopes. Moisture accumulates in these basins to provide favorable microclimate for plant establishment. The large basins reduce wind erosion. They also provide the advantages of terracing with fewer hazards and less expense. They collect runoff and trap snow and blowing topsoil. The furrows formed by the undercutting blades help retain broadcast seed and fertilizer and promote increased infiltration.

Description
The basin blade is a large, crescent-shaped, heavy steel blade mounted on the rear of a crawler tractor. The blade is mounted on a parallelogram multiplier Shank. It is raised, lowered, and tilted hydraulically. Several replaceable undercutting teeth are located on the bottom edge of the blade.

The tractor is driven along the contour of a slope and the blade is periodically raised and lowered to form large depressions. Seed is then broadcast along the slope.

Specifications
Width: 3 m
Depth: 90 cm
Power requirements (flywheel) 256 to 276 kW

BEEDER CUGGER

Function
The beeder (fig. 6) creates numerous depressions in the soil surface. These depressions provide a suitable microclimate for plant establishment by increasing moisture availability, reducing wind and water erosion, and providing shade.

Description
The beeder consists of three to five semicircular, heavy steel blades attached to solid arms. Each blade has three undercutting teeth along the bottom edge. The arms are attached to a heavy-duty frame with apture-loading mechanisms. They may be mounted in either one or two-row configurations. The frame is supported with side shores that are periodically raised and lowered to allow the blades to scoop up depressions. The unit is operated hydraulically and features positive depth control and automatic up and down cycling. A nozzle sprayer is mounted on the rear of the machine to broadcast seed into the depressions.

Specifications
Implement width: 3.4 m
Depression width: 0.9 to 1.2 m
Depth: 15 to 30 cm recommended
Power requirements (drawbar): 37 kW minimum

Figure 6.—Beeder makes depressions in soil and simultaneously seeds area to establish plant cover.

PRELIMINARY TRIALS ON UPGRADING PLATANUS OCCIDENTALIS

WITH THE HELMUTH ELECTROSTATIC SEED SEPARATOR

Robert P. Karralt and Richard E. Helmuth

ABSTRACT: The electrostatic seed separator is a recently invented seed conditioning machine which uses the force of an electrostatic field to separate particles of different area and weight. It has been successfully used to size, clean, and improve germination of Platanus occidentalis seed. The seed separator also should be useful on other tree seed.

INTRODUCTION

Upgrading refers to steps that exceed basic cleaning which improve the quality of seed. Therefore, upgrading includes removing empty seed, fungus or insect damaged seed, and stones or pitch. Sizing seed can also be considered upgrading because speed of germination can vary for different seed sizes. Several authors have stressed the importance of upgrading and how to accomplish it (Belcher 1978; Bonner 1978).

Sycamore (Platanus occidentalis L.) seed is generally low in viability and difficult to upgrade because of its small size. The electrostatic seed separator was tested on sycamore to determine how it might resolve this problem.

Principles of Electrostatic Separator

An elementary demonstration of the electrostatic movement of particles includes lifting particles of paper with a piece of plastic that has been charged by rubbing it with a dry cloth. The paper is drawn to the plastic by an electrostatic field. Heavier seed can be separated from lighter seed by the same principle if the strength and design of the electrostatic field is carefully controlled.

The Helmuth electrostatic seed separator consists of a hanging electrode and adjustable ground plates (fig. 1). Voltage applied to the stationary electrode creates an electrostatic field between the electrode and the ground. As seed is poured between the ground and the electrode by the vibratory feeder, the static field carries the lighter seed and impurities towards the ground. The stronger the static field, the farther the particles will be pulled. The strength of the field is controlled by adjusting the voltage applied to the electrode. For each seed lot, there is a voltage that produces a maximum distance between the lightest and heaviest seeds being separated. This voltage must be determined by trial during processing just like adjusting other seed conditioning equipment. Using a voltage higher than the one producing the maximum speed will only move all the seeds closer to the movable ground and not give any better separation. The purpose of the ground's mobility is to adjust the distance so the seed can separate. When the seeds have reached the bottom of the static field, they are collected in a tray. Adjustable vanes in the collection tray keep the fractions separated.

Robert P. Karralt is Seed Processing Specialist, USDA Forest Service, Southeastern Region, National Tree Seed Laboratory, Dry Branch, Ga.

Richard E. Helmuth is inventor of the electrostatic seed separator and President of the Helmuth Corporation, Carmel, Ind.

1Mention of trade names is only to identify equipment used and does not imply endorsement by the U.S. Department of Agriculture. U.S. patents have been granted on this equipment.

Figure 1.—Diagram of the electrostatic seed separator.
Table 1: Germination and germination value computed on full seed basis.

<table>
<thead>
<tr>
<th>Fraction</th>
<th>Original</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Germination</td>
<td>88</td>
<td>92</td>
<td>87</td>
<td>93</td>
<td>91</td>
<td>89</td>
<td>85</td>
</tr>
</tbody>
</table>

According to the data obtained, the electrostatic separator appears to have definite potential to effectively upgrade small seed. Other species that might be effectively upgraded would include birch, sweetgum and cedars such as white spruce. In a preliminary trial, reduced purity was visually much improved with the 36 inch separator. There were no laboratory test data. In the nurseries, the upgraded seed will give more uniform germination, although previous year uniform density seeders, greater numbers of seedlings per pound of seeds, and more efficient use of nursery space.

Publications Cited
Atlanta, Ga. USDA Forest Service. Southeastern Res. pp 96-105.


Survival, Growth, and Root Form of Containerized Jeffrey Pine

TEN YEARS AFTER PLANTING

J. D. Rudy and E. L. Miller

ABSTRACT: To evaluate the effect of various container systems on survival and growth, trials established in 1971 were reexamined in 1983. In addition, 20 seedlings were excavated in order to determine the effect of container type on root development. After 10 years, the container type had a significant effect on survival and height growth. Root form and the number of lateral roots were also influenced by container type.

INTRODUCTION

Since the early 1970's, containerized seedling systems have been developed and tested throughout the United States. The early work was concerned largely with the development of an acceptable and suitable container. Early experimental container types were available in various sizes, shapes, and materials. These containers were either placed with the seedling or removed just prior to planting. Over the past decade, evaluation of the various containers has been based on early field performance, production costs, and technical problems.

The rapid evolution of containerized planting systems has resulted in a tremendous need to expand research findings. Fortunately, much of the information has been made available through conference proceedings. In 1981, the Canadian Forestry Service sponsored a workshop on container planting (Balaban 1979). The first international conference held in Denver brought together much of the knowledge and experience available on containerized plantings (Hoff and others 1978). The first conference held in 1974, the Southern Containerized Forest Seedling Conference (Galvin and Gallant 1981), held in Dixie Forest, 1980, and the Canadian Containerized Forest Seedling Symposium (Gaskin and others 1981) updated much of the available information on containerized seedling systems.

This research was supported by funds allocated from the multiple-stem cooperative forestry research program.

Jerry D. Rudy is Assistant Professor of Forestry, Dept. of Range, Wildlife, and Forestry, University of Nevada Reno. E. L. Miller is Associate Dean of Resident Instruction, College of Agriculture and Professor of Forestry, Dept. of Range, Wildlife and Forestry, College of Agriculture, University of Nevada Reno.

Although information has rapidly accumulated since the early 1970's, long term studies on growth and development are lacking. The development and evaluation of containerized systems will be influenced by biological performance under field conditions. Considerable discussion has dealt with the potential problem of root deformation resulting from containerized seedlings. This simulation was developed to the root form of bare-root and containerized seedlings (Van Rendel and Kinghorn 1970); the overall effect of root containerization on field performance is still not well documented. The primary objective of this paper is to report on ten year survival, growth, and root form of containerized seedlings established on an adverse site.

The materials and methods used in establishing the original trial in 1973 are discussed in the North American Containerized Forest Seedling Symposium (Miller and Rudy 1974). Survival, height, and root collar diameter were measured in June, 1983. Five seedlings of each container type were excavated by hand in order to remove the root system extending 10 cm from the container. No attempt was made to recover the entire root system. After excavation, the number of lateral roots extending from the container was recorded and the diameter of the top root at the bottom of the container was measured. The seedling was secured at the root collar, and shoot and root green weights were determined.

Container Types

The container types included in the 1973 trial and reexamined in 1983 are described in Table 1. The Japanese paper trays used in 1973 were plastic coated and inadequate polishing of polypropylene plastic trays in 1973. The trays are similar to today's most common plastic boxes and are a significant improvement over the methods used in 1973. The root containers are made of willow and paperboard box stock, similar to that used in milk cartons. The polypropylene coating (1973) is intended to keep plants viable until the greenhouse, but is not thick enough to provide plants when subjected to the field conditions.
Table 1.—Description of containers evaluated.

<table>
<thead>
<tr>
<th>Container Type</th>
<th>Bag Width</th>
<th>Bag Depth</th>
<th>Lid Width</th>
<th>Lid Depth</th>
<th>Material</th>
<th>Rooting</th>
<th>Volume</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(cm)</td>
<td>(cm)</td>
<td>(cm)</td>
<td>(cm)</td>
<td></td>
<td>(cm²)</td>
<td>(cm³)</td>
</tr>
<tr>
<td>6-Paperpot</td>
<td>2.0</td>
<td>7.9</td>
<td>5.0</td>
<td>20.0</td>
<td>Treated paper</td>
<td>25.1</td>
<td>392.7</td>
</tr>
<tr>
<td>4x4-Conrned</td>
<td>2.0</td>
<td>16.0</td>
<td>5.0</td>
<td>22.0</td>
<td>Plastic mesh</td>
<td>28.3</td>
<td>461.3</td>
</tr>
<tr>
<td>12x-Conrned</td>
<td>2.0</td>
<td>12.0</td>
<td>5.0</td>
<td>20.0</td>
<td>Plastic mesh</td>
<td>27.7</td>
<td>417.8</td>
</tr>
<tr>
<td>12-Brant</td>
<td>2.54</td>
<td>12.0</td>
<td>6.45</td>
<td>30.5</td>
<td>Polyethylene cover</td>
<td>75.0</td>
<td>1227.0</td>
</tr>
</tbody>
</table>

*Side of square.

Results

Survival and Growth

After 10 years, the survival was very similar to the first-year survival (Table 1). Compared to the Conrned containers, the treatment mortality was relatively low. The highest survival and root growth after 10 years was evident with the Conrned containers. The results indicated a highly significant difference (P < .05) in survival between the Conrned containers and the paper and cardboard containers. After nine years, the difference in height was apparent, but not significant. The significant difference (P < .05) in height growth was not revealed until after ten years. The seedlings in Brant containers showed the lowest height and diameter growth. The poor field performance of the Brant seedlings appears to be related to the root form and in Brant in the following section.

Table 2.—Mean survival, diameter and height of Jeffrey pine seedlings outplanted in 1972.

<table>
<thead>
<tr>
<th>Container Type</th>
<th>Survival1</th>
<th>Survival2</th>
<th>Diameter1</th>
<th>Diameter2</th>
<th>Height1</th>
<th>Height2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(%)</td>
<td>(%)</td>
<td>(cm)</td>
<td>(cm)</td>
<td>(cm)</td>
<td>(cm)</td>
</tr>
<tr>
<td>4x4-Conrned</td>
<td>80°</td>
<td>65°</td>
<td>3.7</td>
<td>3.7</td>
<td>37.3</td>
<td>37.3</td>
</tr>
<tr>
<td>12-Conrned</td>
<td>50°</td>
<td>45°</td>
<td>3.2</td>
<td>3.2</td>
<td>36.5</td>
<td>36.5</td>
</tr>
<tr>
<td>12-Brant</td>
<td>50°</td>
<td>45°</td>
<td>3.2</td>
<td>3.2</td>
<td>36.5</td>
<td>36.5</td>
</tr>
<tr>
<td>6-Paperpot</td>
<td>50°</td>
<td>45°</td>
<td>3.2</td>
<td>3.2</td>
<td>36.5</td>
<td>36.5</td>
</tr>
</tbody>
</table>

*Numbers with the same superscript are not significantly different.

Root Form

Examination of the containerized seedlings revealed that field performance was largely affected by the design and shape of the container. Paper- and cardboard containers performed best with the Conrned containers. The results indicated a highly significant difference (P < .05) in survival between the Conrned containers and the paper and cardboard containers. After nine years, the difference in height was apparent, but not significant. The significant difference (P < .05) in height growth was not revealed until after ten years. The seedlings in Conrned containers showed the lowest height and diameter growth. The poor field performance of the Conrned seedlings appears to be related to the root form and in Conrned in the following section.

Figure 1.—Root penetration of a Jeffrey pine through a 12-Conrned ten years after outplanting.

Figure 2.—Root penetration of a Jeffrey pine through a 6-Paperpot ten years after outplanting.

Figure 3.—Root penetration of a Jeffrey pine through a 4x4-Conrned ten years after outplanting.

Figure 4.—Root penetration of a Jeffrey pine through a 12-Brant ten years after outplanting.

Characteristics of the excavated seedlings are shown in Table 3. The Conrned seedlings had a greater number of lateral roots penetrating through the container sidewall, a larger tap root emerging from the bottom of the container, and a greater biomass than the Conrned and Paper- pot seedlings. There was a highly significant difference (P < .05) in the mean number of lateral roots between the Conrned and both the Conrned and Paperpot seedlings (Table 3). Also, the Paperpot seedlings had significantly (P < .05) greater root penetration through the sidewall than the Conrned seedlings. The lack of lateral root penetration for the Conrned seedlings may account for the poor field performance. In addition, after the containers were removed from the excavated seedlings (Fig. 3-12), root problems were not evident on the Conrned seedlings. Although the Conrned seedlings developed lateral roots (Fig. 11), the laterals were confined within the container and became quite deformed after ten years of restricted growth (Fig. 12).
Table 3.—Mean root and shoot characteristics of cultivated Jeffrey pines ten years after outplanting in four container types (5 samples per container type).

<table>
<thead>
<tr>
<th>Container Type</th>
<th>Lateral Roots¹</th>
<th>Tip Root Diameter (cm)</th>
<th>Green Weight Root Shoot (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 x 6 Conrowed</td>
<td>19.6²</td>
<td>2.12</td>
<td>383.1</td>
</tr>
<tr>
<td>12-Conrowed</td>
<td>15.6¹</td>
<td>2.26</td>
<td>406.1</td>
</tr>
<tr>
<td>12-Zigzag</td>
<td>9.9</td>
<td>2.29</td>
<td>227.7</td>
</tr>
<tr>
<td>S-Paperpot</td>
<td>1.0</td>
<td>1.26</td>
<td>112.4</td>
</tr>
</tbody>
</table>

¹Means with the same superscript are not significantly different.

DISCUSSION

The results of this study indicate some interesting, as well as significant, findings regarding the relationship between container type and field performance. The highest survival and best growth occurred on those seedlings outplanted in Conrowed containers while the poorest survival and growth occurred on the Zigzag and Paperpot containers.

The most significant finding was the lack of lateral root penetration through the Zigzag containers. Although the manufacturer's intention with the plastic coating is to keep the plant roots divided during the rooting stages in the greenhouse, the thin coating apparently prevented lateral roots from penetrating through the sidewalls, even ten years after outplanting. The manufacturer does recommend punched holes for quicker lateral root extension on containers longer than four inches. The results of this study support the recommendation.

More importantly, and perhaps of significance in the development and evolution of an acceptable container, was the relationship between growth and lateral root development. In this study, the best growth was obtained on seedlings outplanted in containers where lateral root development was unrestricted. The poorest growth resulted where lateral root development was restricted. Denton and Stein (1978) reported the poorest growth after seven years on Douglas-fir and noble fir outplanted in one-quart milk cartons. Although their studies were conducted on favorable sites, the milk cartons remained intact and the main laterals were almost entirely contained within the carton. They also reported greater height growth on seedlings outplanted in Conrowed containers, in either milk cartons or cardboard tubes. Lines (1978) has suggested that holes or slits be incorporated into the upper sides of solid wall containers to increase surface laterals for seed firming; however, the results of this study indicated that better growth and development resulted where lateral root development was unrestricted.

The growth and development of seedlings outplanted in Conrowed containers also disprove some of the early fears of root construction problems associated with the plastic mesh type of container. Although Barrett (1982) reported that blacklock pine roots can become severely constricted in the plastic mesh three years after outplanting, the results of this study indicated that the lateral roots can break apart the plastic mesh. The Conrowed material has been manufactured in various degrees of flexibility, and the material used in this study was less flexible than the material used in the study. However, Denton and Stein (1978) tested the same Conrowed material as used in this study.
and reported girdling on the lateral roots. They found that the lateral roots penetrating the plastic were smaller in diameter than those penetrating paper-fiber pots. The root constrictions problem associated with plastic mesh containers may reduce growth somewhat. However, the problem appears to be relatively minor and apparently short-lived compared to the root restriction problem associated with solid wall containers.

CONCLUSIONS

The acceptance of a container type for any system will depend on a number of variables. The field performance of unplanted seedlings will help evaluate the containers presently available and will aid the development of future containers. The higher survival and better overall growth obtained with the plastic mesh containers suggest the importance of unrestricting lateral root development. The root constrictions which did appear on the laterals due to the plastic mesh did not appear to adversely affect the seedling growth and development compared to the effect of restricted lateral root development found on the cardboard containers. Although a biodegradable plastic mesh container would appear promising, the relatively high cost of biodegradable plastic has discouraged further development (Barnett 1982; Barnett and McElroy 1981).

PUBLICATIONS CITED


ABSTRACT: Initial data indicate containerized ponderosa pine (Pinus ponderosa, Rocky Mountain form) tree seedlings fertilized in a greenhouse in early May can be moved to a shadehouse in early June and successfully grown in Albuquerque, N.M. Data also indicate that ponderosa pine seedlings sown in early February can be removed from the greenhouse as early as late March or early April and may survive a July outbreak at the same location.

INTRODUCTION

On May 2, 1981, three baskets of seed, each containing 13 ponderosa pine seedlings (21.5 cubic inch plastic bowls), were sown at the Bureau of Indian Affairs (BIA) greenhouse in Albuquerque, N.M. A flat, N.M. seed source was used. Two seeds per cavity were sown. There was a crop of ponderosa pine (Pinus ponderosa, Rocky Mountain form) containerized tree seedlings present in the greenhouse that had been sown in early February 1981. Therefore, abortion conditions were not optimal. The production greenhouse currently maintains a triple crop schedule in which approximately 79,000 containerized tree seedlings per crop. The purpose of this study was to determine the potential for four crops annually. On May 3, 1981, two baskets each containing 52 containerized tree seedlings were removed from the greenhouse and placed in the shadehouse. These baskets were part of the crop that was sown in early February 1981, and were from a flat, N.M. seed source. It was felt that the weather was too cold to move the seedlings into the shadehouse earlier.

DISCUSSION AND RESULTS

The BIA facility in Albuquerque, N.M., is a 35° to 40°F double poly-nest style greenhouse with a shadehouse 1/2 of the total. The fertilizer used in April 1980–20 was Peters 1:1:1 for the greenhouse, Peters NP-15 for the after-shade, and Peters 5-10-10 in the shadehouse, and Peters 15-15-15 for trace element addition in both the greenhouse and shadehouse.

In an attempt to determine if crop production could be increased, the remainder of the seed source, each containing 13 ponderosa-Genius Tins (31 cubic inch plastic bowls), were sown on May 2, 1981. These baskets of seeds were then placed with a crop of ponderosa pine containerized tree seedlings until 5/23/81.

The temperatures that were maintained in the greenhouse were within the optimum range for seedling growth in the "hodder" traps, but they were not optimum for "termination."

During the period the seedlings were watered Monday, Wednesday, and Friday, and were fertilized within one tablespoon full 20-20-20.

Table 1 lists the daily temperature extremes in the greenhouse from 5/2 to 6/10. In the shadehouse the seedlings received the following:

A. June 6 – water and fertilizer with shadehouse lines 2 lb. 9-45-15-POM/4 Pt. water.
B. June 10 – water from greenhouse lines.
C. June 13 – water and fertilizer with shadehouse lines 2 lb. 9-45-15-POM/4 Pt. water.
D. June 16 – water from greenhouse lines.
E. June 21 – water and fertilizer with shadehouse lines 2 lb. 9-45-15-POM/4 Pt. water.
F. June 24 – water from greenhouse lines.

The greenhouse crop and seedlings were moved to the shadehouse on June 1, 1981.

In the shadehouse the seedlings received the following:

A. June 6 – water and fertilizer with shadehouse lines 2 lb. 9-45-15-POM/4 Pt. water.
B. June 10 – water from greenhouse lines.
C. June 15 – water and fertilizer with shadehouse lines 2 lb. 9-45-15-POM/4 Pt. water.
D. June 20 – water from greenhouse lines.
E. June 24 – water and fertilizer with shadehouse lines 2 lb. 9-45-15-POM/4 Pt. water.
F. June 29 – water from greenhouse lines.
G. July 4 – water and fertilizer with shadehouse lines 2 lb. 9-45-15-POM/4 Pt. water.
H. July 2 – water from greenhouse lines.
I. July 7 – water and fertilizer with shadehouse lines 2 lb. 9-45-15-POM/4 Pt. water.
J. July 12 – water from greenhouse lines.
K. July 17 – water and fertilizer with shadehouse lines 2 lb. 9-45-15-POM/4 Pt. water.
L. July 22 – water from greenhouse lines.

The maximum possible number of seedlings was 52 per basket.

Containerized seedlings are grown for spring and summer outplanting. Seedlings sown in the nursery are scheduled for outplanting at the beginning of the growing season. In the case of the northern species, it is to produce a seedling that would subsequently overwinter in the greenhouse. Currently the seedlings are cut away and have no secondary needle development. Chromatographically, these seedlings are one month older than those in the greenhouse. They are then scheduled for production in all phases of growth than those that have been in a fully controlled greenhouse for ten weeks.

On May 3, 1981, two baskets, each containing 52 ponderosa pine containerized tree seedlings were moved to the shadehouse. These seedlings were sown in early February 1981 from a N.M. seed source. The seedlings were not moved to the shadehouse until low temperature could be assured to be above 10°F.

Table 1 lists daily maximum, minimum, and current temperature in the greenhouse from 5/2 to 6/10.

The temperatures that were maintained in the greenhouse were within the optimum range for seedling growth in the "hodder" traps, but they were not optimum for "termination."

Table 2 lists the measurements of the shadehouse on June 1, 1981.

Table 3 lists the daily maximum, minimum, and current temperature in the greenhouse from 4/29 to 6/7/81.

Table 4 lists the measurements of the shadehouse on June 1, 1981.

Table 5 lists the measurements of the shadehouse on June 1, 1981.
Temperatures were recorded from a maximum/minimum thermometer located on the north end of the shadehouse. The thermometer was not set up according to Weather Service specifications. The 50% shade provided by the shadehouse did not prevent the thermometer from being exposed to direct sunlight, therefore, the day time highs are "sun" temperatures. The low temperatures may be considered representative.

One value of the temperature recordings is to demonstrate the temperature extremes the seedlings in the shadehouse experienced. Recordings were stopped on June 7 because a freeze was no longer considered a possibility and the purpose of recording temperatures was to document any freeze that occurred.

Table 4 records the maximum, minimum, mean, mode, and median for height and caliper in inches from two baskets of seedlings from the crop sown in February 1983 and moved to the shadehouse May 3, 1983. The measurements were taken on August 1, 1983.

Table 4.—Measurements of seedlings removed from the greenhouse 5/3/83 as of 8/1/83.

<table>
<thead>
<tr>
<th>Basket</th>
<th>Max.</th>
<th>Min.</th>
<th>Mean</th>
<th>Mode</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3/8</td>
<td>1/16</td>
<td>0.157</td>
<td>1/8</td>
<td>5/32</td>
</tr>
<tr>
<td>2</td>
<td>7/32</td>
<td>3/32</td>
<td>0.144</td>
<td>1/8</td>
<td>1/8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Basket</th>
<th>Height (Inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>6 7/8</td>
</tr>
</tbody>
</table>

Basket number 1 contained 52 seedlings and basket number 2 contained 50. The maximum possible number of seedlings per basket was 52.

The seedlings removed in May are shorter and have much woodier stems than those removed from the greenhouse in June.

The seedlings in the shadehouse were watered Monday and Thursday mornings and fertilized with 2 lbs. 9-45-15+STEM/6 qts. water through the shadehouse lines along with the rest of the shadehouse seedlings. These seedlings were moved back into the greenhouse on May 23, 1983, for flushing and stressed in the shadehouse. The Monday and Thursday watering 9-45-15 fertilizer was reinstated after stressing.

Table 5 records the maximum, minimum, mean, mode, and median of baskets from the crop sown in early February 1983, and moved to the shadehouse on June 7, 1983.

Table 5.—Measurements of seedlings removed from the greenhouse 6/7/83 as of 8/1/83

<table>
<thead>
<tr>
<th>Basket</th>
<th>Max.</th>
<th>Caliper (Inches)</th>
<th>Min.</th>
<th>Mean</th>
<th>Mode</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3/32</td>
<td>1/16</td>
<td>0.119</td>
<td>1/8</td>
<td>1/8</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>5/32</td>
<td>3/32</td>
<td>0.124</td>
<td>1/8</td>
<td>1/8</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Basket</th>
<th>Height (Inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>7</td>
</tr>
</tbody>
</table>

Basket number 1 contained 52 seedlings and basket number 2 contained 52. The maximum possible was 52 seedlings.

CONCLUSIONS

Initial results indicate the potential for four crops of containerized ponderosa pine tree seedlings annually at the BIA greenhouse facility in Albuquerque, N.M. The smaller seedlings should survive the harsh planting sites in New Mexico, but only a survival study can determine this field survival and growth is the bottom line. One month, early May to early June, growth in a greenhouse with subsequent shadehouse growth appears to be enough to produce a seedling that will overwinter in a shadehouse in Albuquerque, N.M. During an on-site inspection by Dr. Richard W. Tinus on July 20, 1983, he stated that these conclusions at that time seemed to be valid.

The purpose of this paper is to indicate the possibility of increasing crop production from three to four crops annually at the BIA greenhouse in Albuquerque, N.M. The problems of an administrative study in a production greenhouse are obvious. While all selections made were random, 2 baskets out of 1,523 may not be a large enough sample, therefore, a statistical analysis was not performed. The potential may exist, however, and therefore further research is needed.

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KEYWORDS: native plant production, land reclamation, planting techniques, shrub adaptation, nursery practices

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