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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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CONTENTS

GERMINATION OF SEEDS OF WILDLAND PLANTS

James A. Young, Jerry D. Budy and Raymond A. Evans

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 seeds. Both the timing of 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 suddenly being dehisced and lost unless they are collected slightly before maturity.

Slightly immature seeds are not necessarily poor germinators. The propagator has to determine the influence of maturity on germination through trials. To conduct meaningful trials, it is necessary to label the seed collection with some detail of the phenological stage of development, where the seed lot was collected, and to maintain the identity of the seed lot through germination trials.

Various maturity classes of seeds can be collected by separating collections made on the same plant, moving from early maturing south to north slope communities, or by collecting at higher elevation within the range of the species.

HANDLING FRESHLY HARVESTED SEEDS

A seed is a living organism in a resting stage, but it is most important to remember that it is alive! Freshly harvested seeds have too high a moisture content for safe storage. The moisture content of the seed must be allowed to reach equilibrium with the atmosphere. In the Intermountain area this is usually simple because the relative humidity of our air during the summer and fall is usually quite low.

For freshly harvested seeds to reach a moisture equilibrium they must be stored in such a manner to allow for free aeration. Uncoated paper or mesh bags make good storage containers for initial drying. Never use plastic bags for storage of freshly harvested seeds!

Artificial drying, especially at high temperatures, is usually not necessary, and often not desirable. Screen freshly harvested material to remove high moisture content trash. This will reduce drying time.

Fleshy fruits require prompt treatment to remove the fleshy material to avoid spoilage or mummification of the fruits.

The seeds of species collected from marsh or wetland environments often require special handling. The technique used depends on the species involved, but often it is necessary to keep the seeds in a cool, wet environment or actually stored in water to avoid acquiring dormancy or loss of viability.

SEED CLEANING

Generally the sooner the seeds are cleaned and placed in storage after they reach moisture equilibrium, the less chance of predation from birds or small mammals or contamination from insects.

Avoid rough handling of seeds during cleaning. Remember the seed is alive and the embryo can be very fragile. Never use a hammer mill in seed processing unless you have first determined by careful testing that seed viability is not being adversely affected by the process.

Proper seed cleaning makes subsequent handling of the seeds in the germination process much simpler. Especially if the seed lot contains trash or empty or obviously immature seeds, much time may be wasted sorting the material to find germinable seeds.

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SEED STORAGE

To avoid problems with storage insects, start with clean, insect-free storage conditions. Do not introduce pests 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 temperature. If you decrease the storage temperature of a sealed container, moisture condensation will occur.

Storage in paper or mesh bags in a cool, dry location is satisfactory for most seeds. Once the seeds have reached moisture equilibrium, storage in glass jars or plastic boxes is possible to avoid insect or mold contamination. Some seeds can be stored easily in small lots, but suffer losses in viability when quantities of seeds are 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 seed is 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 to determine if an embryo is present. More complex viability tests involve the use of the chemical, tetrazolium. This chemical, after proper sectioning and preparation of the seed, has the property to accept hydrogen atoms from dehydrogentate enzymes during the respiration process in viable seeds. Essentially, respiring 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 Association of Official Analysis (AOSA) prescribes the rules for testing seeds of specific species. For example, seeds of Canada bluegrass (*Poa compressa*) are tested on germination paper, at 15/25 or 15/30°C (15°C for 8 hours/30°C for 16 hours daily), with light during the 8-hour period and potassium nitrate (KNO_3) added to the substrate. Unfortunately, for the seeds of most wildland species, no standard germination tests exist. The AOSA 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

Afterripening

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 time period that must pass before the seeds will germinate has been termed the afterripening requirement. These requirements are not responsive to external stimuli. One 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 afterripening. 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 afterripening with stratification requirements where the dormancy does respond to external stimuli. Stratification requirements will be discussed later.

Hard Seed Coats

If seeds do not initially germinate or fail to germinate after a reasonable afterripening 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 thumbnail or by cutting. If the interior of the seed appears chalky and hard, water has not been imbibed through the seed coat. Imbibed seeds should be soft and easily squashed with the thumb.

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

Scarification

To break the hard seed coats some form of scarification is required. This scarification can be accomplished with mechancial, thermal, or chemical treatments. If the seeds are large enough, scarification may be accomplished by filing a notch in the coat or clipping so as not to injure the embryo. Smaller seeds can be scarified by mechanically abrading 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. Virtually any mechanical scarification that results in increased germinability results in decreased viability. In other words, you pay the price for getting some seeds to germinate by fatally injuring other seeds. Hammer mills are used for scarifying seeds. Great care must be taken to not excessively injure seeds with these treatments. Minimum clearance between concave bars in threshing machines can be used to crack the seeds 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 by fall seeding 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 has to be determined for individual seed lots. Heating from the acid reaction with rinse water and hydrolysis 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 this word with scarification. Stratification involves placing seeds in a wet environment at temperatures that are not conducive to germination. For most western plants these are temperatures too cold for germination. Such treatments are termed cool-moist stratification. The duration of stratification requirements 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 refrigerated baths that are saturated with oxygen or by using activated charcoal as a stratification substrate.

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. In cold areas where snow cover is prolonged, such practices can be quite effective. The interface between continuous snow cover and the surface of the seedbed usually is near 0°C, a near-ideal stratification environment. Any interruption of temperature or moisture conditions during the stratification period results 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 nitrate ions. The nitrate is usually supplied as potassium nitrate (KNO_3) at concentrations ranging from 10^{-1} to 10^{-3} mmoles (1.0 to 0.01 g per litter of water). In the field or nursery bed, flushes of spring germination may be associated with nitrification and the availability of nitrate 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. Combinations of gibberellic acid and potassium nitrate are often more effective than either material alone. Both of these materials can be obtained from chemical supply houses. The potassium nitrate is more easily obtained than gibberellin.

A good balance is needed for preparing the minute concentrations of gibberellic acid. A solution with a concentration of 1 p/m of gibberellic acid consists of 0.001 grams of gibberellic acid dissolved in 1,000 milliliters of water. Gibberellic acid is sold as a 10-percent active ingredient preparation, which makes the weighing simpler. One alternative is to prepare higher concentrations than needed and dilute to the desired concentration. For example, 1,000 p/m would be 1 g in 1,000 ml; however, gibberellic acid is relatively expensive and breaks down very rapidly under warm temperatures

Hydrogen Peroxide

Seeds of several species, especially members of the rose family, have their germination enhanced by soaking in hydrogen peroxide solutions. Dramatic germination enhancement has been obtained with seeds of bitterbrush (*Purshia tridentata*) and curlleaf 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 seed. Hydrogen peroxide is a very reactive chemical. 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 sulphydryl compounds.

Light

Many seeds are sensitive to light during germination. This light or phytochrome reaction involves germination stimulation by near red light and dormancy inductions by far red light. Generally cool-white florescent light enhances germination and incandescent light should be avoided.

Practically, seeds that require light for germination have to placed virtually on the surface of the seedbed. The seeds should be pressed into the seedbed for optimum moisture transfer.

SEEDBED REQUIREMENTS

Seeds have to take moisture up from the germination substrate faster than they lose it to the atmosphere. In a well-firmed seedbed, optimum germination conditions can occur with proper water management. Planting small seeds on the surface of a firmed seedbed and covering them with vermiculite can produce a quality germination environment.

Generally only seeds with external mucilage can germinate on the surface of seedbeds. Exceptions are seeds such as Russian thistle (*Salsola iberica*) with extremely rapid germination.

Even seeds with extremely low percentage germination can give satisfactory establishment if sufficient seeds are planted in a quality seedbed.

SUGGESTED READING

Bradenburg, N. R. Bibliography of harvesting and processing forage-seed, 1949-1964. ARS 42-135. U.S. Department of Agriculture, Agricultural Research Service; 1968. 17 p.

Chan, F. J.; Harris, R. W.; Leiser, A. T. Direct seeding of woody plants in the landscape. Leaflet No. 2577. University of California, Division of Agriculture Science; 1977. 13 p.

Colby, M. K.; Lewis, G. D. Economics of containerized conifer seedlings. Fort Collins, CO: U.S. Department of Agriculture, Forest Service; 1973. 7 p.

Copeland, L. O. Principles of seed science and technology. Minneapolis, MN: Burgess Publishing Co.; 1976. 368 p.

Emery, D. Seed propagation of native California plants. Santa Barbara Botanical Garden Leaflet 1(10): 81-96; 1964.

Grabe, D. F., ed. Tetrazolium testing handbook. Contribution No. 29 to the handbook on seed testing. Association of Official Seed Analysis; 1970. 62 p.

Harmond, J. E.; Brandenburg, N. R.; Klein, L. J. Mechanical seed cleaning and handling. Agriculture Handbook No. 354. U.S. Department of Agriculture; 1968. 56 p.

Harmond, J. E.; Klein, L. M. A versatile plot thresher. Agriculture Research Service Note ARS 42-4-1, U.S. Department of Agriculture; 1964. 7 p.

Harmond, J. E.; Smith, J. E., Jr.; Park, J. K. Harvesting the seeds of grasses and legumes. In: Seeds, the Yearbook of Agriculture; Washington, D.C.: U.S. Department of Agriculture; 1961: 181-188.

Harrington, J. F. Problems of seed storage. In: Heydecker, W., ed. Seed ecology; University Park, PA., and London: Pennsylvania State University Press; 1973: 578 p.

Hartman, J. T.; Kester, D. E. Sexual propagation. In: Plant propagation--principles and practice; Englewood, Cliffs, N.J.: Prentice Hall; 1968: 53-188.

Hary, E. M.; Collier, J. W.; Norris, M. J. A simple harvester for perennial grass seeds. Davis, CA: University of California, Agronomy and Range Science; 1969.

Heydecker, W., ed. Seed ecology. University Park, PA, and London: Pennsylvania State University Press; 1973: 578 p.

Hopkins, A. D. Periodical events and natural law as guides to agricultural research and practice. U.S. Monthly Weather Review Supplement. 9: 5-42; 1918.

Larsen, J. E. Revegetation equipment catalog. Missoula, MT: U.S. Department of Agriculture, Forest Service; 1980. 197 p.

McKenzie, D. W. Survey of high-production grass seed collectors. Project Record. San Dimas, CA: U.S. Department of Agriculture, Forest Service, Equipment Development Center; 1977. 13 p.

Maquire, J. D.; Overland, A. Laboratory germination of seeds of weedy and native plants. Circular No. 349. Washington Agriculture Experiment Station; 1959. 15 p.

Mirov, N. T.; Kraebel, C. J. Collecting and handling seeds of wild plants. Forestry Publication No. 5. U.S. Department of Agriculture, Civilian Conservation Corps; 1939. 42 p.

Mitrakos, K.; Shropshire, W., Jr., ed. Phytochrome. London and New York: Academic Press; 1971. 631 p.

Nord, E. C. Bitterbrush and seed harvesting: When, where, and how. Journal of Range Management 16: 258-261; 1963.

Peterson, B. O. Bitterbrush (Purshia tridentata) seed dormancy broken with thiourea. Journal of Range Management 10: 41-42; 1957.

Plummer, A. P.; Christensen, D. E.; Monsen, S. B. Restoring big-game in Utah. Utah Division of Fish and Game Publication No. 68-3; 1968. 183 p.

Schneegas, E. R.; Graham, J. Bitterbrush seed collecting by machine or by hand. Journal of Range Management 20: 99-102; 1967.

Schopmeyer, C. S., ed. Seeds of woody plants in the United States. Agriculture Handbook No. 450, U.S. Department of Agriculture; 1974. 878 p.

Spencer, J. S.; Rashelof, V. M.; Young, J. A. Safety modification for operations and transportation of the rangeland drill. Journal of Range Management 32: 406-407; 1979.

Storey, C. L.; Speirs, R. D.; Henderson, L. S. Insect control in farm-stored grain. Farmers' Bulletin No. 2269, U.S. Department of Agriculture; 1979. 18 p.

Tinus, R. W.; Stein, W. I.; Balmer, W. E., eds. Proceedings of the North American containerized forest trees seedlings symposium; 1974 August 26-29; Denver, CO. Washington, D.C.: Government Printing Office, Great Plains Agricultural Council, Publication No. 68; 1974. 458 p.

Young, J. A.; Evans, R. A.; Kay, B. L.; Owen, R. E.; Budy, Jerry. Collecting, processing, and germinating seeds of western wildland plants. ARM-W-3. Oakland, CA: U.S. Department of Agriculture, Science and Education Administration; 1981. 44 p.

U.S. Department of Agriculture. Woody plant seed manual. Miscellaneous Publication No. 654; 1948. 416 p.

U.S. Department of Agriculutre. Stored-grain insects. Agriculture Handbook No. 500, U.S. Department of Agriculture; 1979. 54 p.

In: Murphy, Patrick M., compiler. The challenge of producing native plants for the Intermountain area: proceedings: Intermountain Nurseryman's Association 1983 conference; 1983 August 8-11; Las Vegas, NV. General Technical Report INT-168. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 96 p.

PRODUCING BAREROOT SEEDLINGS OF NATIVE SHRUBS

Nancy Shaw

ABSTRACT: Bareroot 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. Shrub seedlings of a number of species are successfully grown using modifications of techniques developed for the propagation of conifers 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

Bareroot 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 bareroot 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 bareroot or container planting stock depends upon a number of factors:

1. Species required. Although some species are difficult to grow as bareroot stock, others have been successfully propagated (tables 1, 2) using modifications of cultural practices developed for conifers. Information relating to the germination and growth of related species (for example, Rosa, Rhus, 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 bareroot seedlings have been successfully planted on a wide variety of wildland sites, although bareroot 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 bareroot 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 2-0 stock. For some species sowing and lifting may be scheduled for either fall or spring.

4. Cost. Bareroot seedlings generally cost less than seedlings grown in containers. Consequently, their use may often be justified economically. Handling and transportation of bareroot seedlings must be carefully planned to protect plants from desiccation and overheating before planting (Dahlgreen 1976). However, bareroot 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 contract 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 1975; Welch and Monsen 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 erratic and scheduling problems may make seed collection difficult. Seed of some minor species is not harvested regularly by commercial collectors. Seed banks may be maintained to avoid these problems. Bareroot stock of easily rooted species may be

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propagated from cuttings if seed is unavailable or difficult to germinate.

All steps in the propagation of each species must be carefully scheduled. Seed and cuttings must be collected during the appropriate season (see Plummer and others 1968; U.S. Department of Agriculture, Forest Service 1974; Hartmann and Kester 1975; Vories 1981). Adequate time must be allotted for seed processing, testing, presowing treatments, field or laboratory stratification, and field production. Most seedlings are lifted after one year's growth in the seedbed, although a few species may require two growing seasons. Seedlings may be lifted in either the fall or spring.

Antelope bitterbrush and other native shrubs have been grown at the Lucky Peak Forest Service Nursery near Boise, Idaho, during the past 10 years. Practices employed for native shrub production at Lucky Peak will be described where applicable throughout this paper.

SEED ACQUISITION AND PROCESSING

Purchase or Collection

Named varieties of several important native shrub species have been released for commercial seed production following extensive testing by the U.S. Department of Agriculture, Soil Conservation Service, and cooperating agencies (U.S. Department of Agriculture, Soil Conservation Service 1982). Seed of these releases 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 agricultural conditions should result in improved seed quality and availability as appropriate cultural techniques are developed for each species. Other seed sources include plants of selected populations maintained at the nursery, 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 been suggested by Plummer and others (1968). Acceptable germination levels are given in table 1. Seed transfer guidelines 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 shrub species range from May to February (U.S. Department of Agriculture, Forest Service 1974; Vories 1981; Wasser 1982). The exact seed maturation date for a specific wildland stand will depend upon its geographic location and local weather conditions. Species that ripen in late fall and winter must be collected nearly a year before fall sowing. Seed maturation in stands selected for seed collection should be carefully monitored. Expected crops may not develop and seed of some species such as antelope bitterbrush or snowbrush ceanothus (*Ceanothus velutinus*) is dispersed very quickly after ripening (U.S. Department of Agriculture, Forest Service 1974; Vories 1981).

Cleaning and Storage

Seedlots must be cleaned carefully to obtain high purity levels. Clean seed is required to maximize uniformity of seed placement and subsequent seedling development in the nursery beds. Sagebrush, rabbitbrush (*Chrysothamnus* spp.), and other species are often sold at low purities for rangeland seedings. 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 sumac (*Rhus* spp.) and other species with water-impervious seed coats will remain viable for 10 to 20 years when exposed to ambient temperature and humidity conditions in open storage (Heit 1967; Hartmann and Kester 1975). Stevens and others (1981) found seed of antelope bitterbrush, fourwing saltbush (*Atriplex canescens*), and a number of other native shrub species to retain viability for at least 15 years in open storage. Fumigation or insecticides may be required to prevent infestation of open-stored seed.

Cold, dry storage increases the longevity of most medium to long-lived seeds and is desirable if seeds are to be stored for long periods. Seed should be placed in sealed, moisture proof containers and stored at 32° to 50°F (0 to 10°C). Below freezing temperatures (0° to 32°F [-18 to 0°C]) are most effective if the added cost is justified. The most effective moisture contents for cold, dry storage of native species have not been determined. Maximum safe seed moisture contents for cold, dry storage of many tree species is 9 percent. The relative humidity (R.H.) should be less than 70 percent and, if possible, less than 50 percent (Heit 1967; Hartmann and Kester 1975).

Cold moist storage (32° to 50°F [0 to 10°C]) at 80 to 90 percent humidity is required for such species as oak (*Quercus* spp.) and spring ripening maple species. Seeds of these species should not be allowed to dry prior to storage (Hartmann and Kester 1975).

Testing

Purity and germination or viability tests are used to provide an estimate of seed quality. Seeding rates are subsequently based on these tests plus determination of number of seeds per pound. Purity and seed weight are obtained following standardized procedures (AOSA 1981). Association of Official Seed Analysts (AOSA) standards for testing the germination of

Table 1.--Nursery production of native plant species

Species	Seed maturation dates[1]	Seed cleaning[2]	Acceptable purity (percent)[1]	Acceptable germination (percent)[3]	Duration of viability (years)[4]	Storage requirements[5,6,7]	Presowing treatment[8]	Stratification[5,6] Warm	Cold
								(numbers of days)	
Bitterbrush, antelope	6/25-8/15	4-2-4-5	95	90	16+	open or cold,[9] dry	none	none	60-90
Buffaloberry, silver	8/1-9/30	3-6-4	98	80	11-15	cold, dry	none	none	0-90
Ceanothus, redstem	7/10-8/15	6-4	98	85	16+	open or cold, dry	hot water	none	60
Chokecherry, common	7/25-9/15	3-6-4	98	70	4-6	cold, dry	none	none	120-160
Cliffrose, Stansbury	7/5-8/10	2-4-5	95	85	16+	open or cold, dry	none	none	30
Currant, golden	7/20-8/10	3-6-4-5	95	65	16+	dry, sealed	none	none	60
Dogwood, redosier	8/20-9/10	3-6-7-4	95	85	4-6	cold, dry	none	none	60-90
Elder, blueberry	8/15-9/25	3-6-4-5	95	50	16+	cold, dry	none	none	98
Ephedra, green	7/15-9/1	6-2-4	95	85	16+	open	none	none	none
Eriogonum, Wyeth	7/25-8/20	6-2-4	95	75	4-6	- - - -	none	none	none
Hawthorn, river	8/15-10/15	3-6-7-4	95	70	16+	cold, dry	H_2SO_4 (15 min. dry seed only)	none	84-112
Juniper, Rocky Mountain	9/1-12/30	2-6-4	98	60	16+	cold, dry	none	120	120
Maple, Rocky Mountain	8/1-9/30	2-4	90	85	0-3	- - - -	none	none	180
Mountain mahogany, curlleaf	7/10-9/1	2-4-5	90	80	16+	open or cold, dry	none	none	36
Rabbitbrush, rubber	10/15-12/30	2-4	10-15	75	0-3	open	none	none	120
Rose, Woods	9/1-11/30	3-6-4	95	70	16+	cold, dry	none	none	30-365
Sagebrush, big	11/5-1/15	1 or 2-4	8-12	80	4-6	- - - -	none	none	0-10
Saltbush, fourwing	10/20-3/1	1-4	95	50	16+	open	none	none	30-50
Serviceberry, Saskatoon	7/10-9/15	3-6-7-4	95	85	16+	cold, dry	none	none	120-180
Snowberry, common	8/10-9/15	3-6-4	95	80	7-10	open or cold, dry	H_2SO_4 (60 min)	20-60	60-300
Sumac, skunkbrush	6/20-10/10	3-6-4	95	40	16+	open or cold, dry	hot water	none	30-90
Winterfat common	9/25-11/25	2-4	50	85	0-3	cold, dry	none	none	none

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[1] Purities listed are recommended minimum acceptable levels for rangeland seedlings (Plummer and others 1968).

[2] Key: 1. Hammermill; 2. Barley debearder; 3. Dybvig with water; 4. Two screen fan machine; 5. Gravity table; 6. Dry; 7. Seed grindermacerator. Jorgenson, K.; Stevens, R., Ephraim, UT: Data on file at Great Basin Experimental Area; 1982.

[3] Recommended minimum acceptable levels for rangeland seedings. Jorgensen, K.; Stevens, R., Ephraim, UT: Data on file at Great Basin Experimental Area; 1982.

[4] Open warehouse storage. Stevens and others (1981).

[5] Vories (1981).

[6] U.S. Department of Agriculture, Forest Service (1974).

[7] Heit (1967).

[8] Treatments used at Lucky Peak Nursery.

[9] Open storage - ambient conditions. Cold, dry storage - dried seed stored under refrigeration at 0° to 50°F (-18° to 10°C) in sealed containers (R.H. of 70 percent or less).

Table 2.--Nursery production of native plant species[1].

Species	Sowing date	Hand or broad-cast sowing	Pruning Top	Pruning Root	Lifting considerations	Production period	Persistent leaves	Vegetative propagation	Special considerations
Bitterbrush, antelope	Fall[2]				Lateral roots strip easily	1-0	X[3]		Treat seed with captan
Blueberry, elder	Fall		X	X	Thick taproot	1-0			Stratified seed germinates over 2-year period.
Buffaloberry, silver	Fall					1-0 or 2-0			
Ceanothus, redstem	Fall					1-0	X		Short seed collection period. Insect predation of seeds common. Seedlings subject to damping off, stem rot.
Chokecherry, common	Fall					1-0			
Cliffrose, Stansbury	Fall				Lateral roots strip easily	1-0	X		
Currant, golden	Fall					1-0		Hardwood cuttings	
Dogwood, redosier	Fall					1-0 or 2-0			
Ephedra, green	Fall, spring				Fragile roots	1-0			
Eriogonum, Wyeth	Fall, spring			X	Taproot	1-0	X		Insect predation of seeds common.
Hawthorn, river	Fall					1-0			Dry fresh seed several weeks prior to acid treatment. Seed lots frequently do not germinate uniformly.
Juniper, Rocky Mountain	Summer					2-0	X		
Maple, Rocky Mountain	Fall					1-0 or 2-0			
Mountain mahogany, curlleaf	Fall					1-0	X		
Rabbitbrush, rubber	Fall, spring	(X)	X	X	Large taproot	1-0		Wildings	
Rose, Woods	Fall					1-0			
Sagebrush, big	Fall, spring	(X)	X	X	Large taproot	1-0	X	Wildings	
Saltbush, fourwing	Fall		X	X	Large taproot, brittle stems	1-0	X		Low seed fill.
Serviceberry, Saskatoon	Fall					1-0			
Snowberry, common	Late summer, early fall					1-0 or 2-0		Stem cuttings	Warm stratification more effective than acid treat
Sumac, skunkbush	Fall				Large taproot	1-0		Root cuttings	
Winterfat, common	Fall, spring	X	X	X	Large taproot	1-0	X		Fluffy seed - not free flowing.
Willow, Scouler			X	X	Extensive root system	1-0		Hardwood stem cuttings	

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[1] Based on production experience at Lucky Peak Nursery.
[2] Species normally sown in fall may be artificially stratified and sown in spring.
[3] Normally deciduous, but may retain leaves in nursery.

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

Individual populations of a single shrub species may vary widely in germination requirements. In addition, the prolonged stratification periods required to release the dormancy of many shrub species (Vories 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 (Heit 1971; U.S. Department of Agriculture, Forest Service 1974; Vories 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 seeding. Heit (1968) found fall seeding 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 sowing. He provided fall sowing recommendations for 55 shrub species. Species requiring moist, warm stratification may be sown during the 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 winterfat (*Ceratoides lanata*) may be sown in spring.

Seed should be artificially stratified if it is unlikely that an adequate stratification period would be provided in the nursery. 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 sowing also provides a means of controlling seedling size.

Sowing

Newly developed nursery drills such as the Love-Oyjord are capable of sowing seeds with a wide range of sizes and shapes. Seed must be carefully cleaned to facilitate uniform distribution and prevent clogging of the drill drop tubes. Seed of big sagebrush, which averages well over 2,000,000 seeds per pound (4,400,000 per kg) (Plummer and others 1968), 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 sown, 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 as 1-0 stock. Fourwing saltbush, blueberry elder (*Sambucus cerulea*), big sagebrush 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 curlleaf mountain mahogany (*Cercocarpus ledifolius*) 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 as 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 269/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. Culling rates and seedbed mortality figures have not been established for individual species at most nurseries because too few seedlots have been sown to provide adequate data. In addition, these figures tend to vary with the seed accessions being grown. At the Lucky Peak Nursery, seedbed mortality for bitterbrush is estimated to be approximately 35 percent and the culling rate 15 percent. A seedbed mortality figure of 40 percent and culling rate of 20 percent are used for all other native plant species.

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

of time the surface of the seedbeds must be kept moist. Fungal infections are of concern in the production of antelope bitterbrush, fourwing saltbush, mountain mahogany, and other native plants. Emergence may be enhanced by surface-sterilizing the seeds or dusting the seeds with a fungicide such as captan (Booth 1980). If seedling mortality is noted, 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 most elements are not likely to occur (Smith 1979). Nitrogen applications are usually necessary, particularly if high carbon-nitrogen ratios develop as a result of mulching. Conifers and shrubs normally receive similar fertilizer treatments at the Lucky Peak Nursery. Two thousand pounds per acre (2 245 kg/ha) of 6-2-0 Milorganite is incorporated into the soil prior to sowing. Ammonium nitrate (34-0-0) and superphosphate (0-46-0) are applied as side dressings.

Weed Control

Soil fumigants may be applied to nursery beds before shrub seeding to reduce weed problems. However, late August or early September fumigation with methyl bromide (98 and 67 percent) at 249 and 349 lbs/acre (280 and 392 kg/ha) followed by seeding of broadleaf species has produced unsatisfactory results in northern Plains nurseries (Riffle 1976). Poor seed germination and erratic growth during the first growing period following fumigation were attributed to decreased endomycorrhizal spores in the soil and endomycorrhizal development on seedlings (Riffle 1980). The use of fumigants such as Mylone that eliminate root pathogens but are not harmful to mycorrhizal fungi was recommended.

Most native shrub seedlings are weeded mechanically or by hand as herbicide recommendations are not available for individual species. Lohmiller 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 herbicide techniques developed for peanuts and soybeans could be applied to several leguminous shrubs.

Several introduced hardwood species as well as antelope bitterbrush and common chokecherry have been included in the Western Forest Tree Nursery Herbicide Study (Abrahamson 1980; Ryker 1979). Ryker (1979) found postsowing and postgermination applications of bifenox reduced height growth of antelope bitterbrush and common chokecherry while postsowing and postgermination applications of DCPA were safe for common chokecherry. Enide has been used as a post-emergence herbicide for antelope bitterbrush at 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 1981).

Pruning

Many shrub species grow rapidly, producing highly branched shoots (fourwing saltbush, big sagebrush) or shoots with numerous large leaves (blueberry elder, smooth sumac) during the first growing season. Large plants dominate smaller or later germinating 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 larger branches on the lower stems (Williams and Hanks 1976). Seedlings may also be top or side pruned in the nursery during the dormant season or in the packing shed after lifting to provide a more desirable size for packing and planting.

Roots are pruned to increase seedling uniformity, stimulate fibrous root development, and improve shoot/root ratios. Severing the taproot of bitterbrush, fourwing 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 taproots of rapidly growing species one or more times during the growing season at increasing depths (for example, 4, 6, and 8 inches [10, 15, and 20 cm] also prevents the development of a thick root at the 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, shrubby penstemon [*Penstemon fruticosus*]) 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 do conifers. They may also be lifted in the fall for immediate planting, when weather and soil conditions are favorable. Fall lifting and overwinter storage is a third option, especially for stock that must be planted early in the spring before weather conditions would permit lifting. 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 Hanks 1976).

Species with fragile root systems or brittle shoots are easily damaged during lifting, packing, and planting. Plants that produce extensive root and shoot systems that have not been adequately pruned are bulky and difficult to pack and plant without damaging the plants or reducing survival.

Grading

Grading criteria have not been established for most native plant species. If possible, seedling specifications should be developed with the customer before sowing. Several factors should be considered in establishing specifications for individual species and orders. First, past outplanting experience may indicate morphological or size characteristics of seedlings that are correlated with transplanting success. For example, Carpenter (1983) recommends that only those antelope bitterbrush seedlings with branched stems should be used as this characteristic seemed to be indicative of an adequate root system for field planting (table 3). Second, seedling size requirements are related to planting site conditions; larger seedlings are generally required for more adverse sites. Third, size specifications may be modified to fit the proposed planting method. Seedlings with bulky root and shoot systems are difficult to plant using standard planting tools or mechanical tree planters. Fourth, customers may have individual preferences based on planting goals or past experience.

Table 3.--Grading and first year field survival of antelope bitterbrush seedlings at Lucky Peak Nursery. Nursery bed density 17.6 seedlings per square foot (180 seedlings/m²).

	Size Class		
Grading Criteria	I	II	III
Shoots			
length (inches)	4.7 (4-6)	6.5 (6-8)	8.8 (>8.0)
branching	branches <1/3 length of main stem	branches equal main stem length	branches equal main stem length
dry wt. (g)	0.5	1.2	1.9
Roots			
length (inches)	9.5 (8-10)	9.8 (8-10)	10.7 (10-12)
description	taproot - few short lateral roots	taproot - few lateral roots	taproot - few lateral roots
dry wt. (g)	0.4	0.8	1.0
Outplanting			
Percent of plantable seedlings	13	79	8
survival (percent)	88	88	90

Storage

Fall-lifted seedlings of deciduous species may be held in frozen storage at 28°F (-2°C) for extended periods. Seedlings must be protected from desiccation. At the Lucky Peak Nursery antelope bitterbrush and other shrubs may be fall-lifted for immediate planting at local sites. Seedlings not planted are packed in Kraft bags with polyethylene liners and stored in coolers at 28°F for spring planting (Carpenter 1983; Carpenter, personal communication). Fall-lifted seedlings with persistent leaves are subject to mold 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 Kraft bags 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 easily rooted species as willows (*Salix* spp.), poplar (Populus spp.), and cottonwood are often produced from hardwood cuttings. Oldman wormwood (*Artemisia abrotanum*), Absinthium (*A. absinthium*), willow (*Salix* spp.), and currant (*Ribes* spp.) have been grown from cuttings at the Lucky Peak Nursery.

Hardwood or semi-hardwood cuttings of the wormwood species root readily and may be collected and planted immediately without callusing. Cuttings may be made when the plants are dormant or during the growing season. Most species that can be propagated vegetatively in the nursery are grown from hardwood cuttings. Hardwood cuttings are inexpensive and are easily collected, handled, stored, and propagated. Cuttings may be collected from stands near the planting site or from cutting blocks maintained at the nursery. Cuttings are taken during the dormant period from healthy, moderately vigorous plants growing in full sunlight. Wood from the previous season's growth should be selected. Individual cuttings should include at least two nodes and may be from 4 to 30 inches (10 to 76 cm) in length and from 0.25 to 1.5 inches (0.6 to 3.8 cm) in diameter (Hartmann and Kester 1975; Williams and Hanks 1976).

Cuttings of species that do not root readily may be treated with a root-promoting substance such as indolebutyric acid, naphthaleneacetic acid, or indoleacetic acid. Indolebutyric acid at concentrations between 500 and 10,000 ppm (0.05 to 1.0 percent) is commonly used with higher concentration usually being more effective for hardwood cuttings. Fungicides such as captan or benomyl may be applied in combination with rooting compounds. Cuttings should be allowed to callus for several weeks in cold storage before planting. Dormant cuttings are planted 2 to 4 inches (5 to 10 cm) apart within rows of the nursery bed with at least one bud above ground. They should be watered frequently as roots begin to develop. Willow, currant, wormwoods, poplar, and other rapid-growing species can normally be lifted as 1-0 stock.

PUBLICATIONS CITED

Abrahamson, L. P.; Burns, K. F. Western forest tree nursery herbicide study - Great Plains segment. Syracuse, NY: State University of New York; 1980. 49 p. 1979 progress report.

Association of Official Seed Analysts. Rules for testing seeds. J. Seed Tech. 6(2): 1-126; 1981.

Blauer, A. C.; Plummer, A. P.; Stevens, R.; Giunta, B. C. Characteristics and hydridization of important Intermountain shrubs. I. Rose family. Res. Pap. INT-169. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1975. 32 p.

Booth, D. T. Emergence of bitterbrush seedlings on land disturbed by phosphate mining. J. Range Manage. 33(6): 439-441; 1980.

Carpenter, R. Artificial revegetation using antelope bitterbrush - a land manager's view. In: Tiedemann, A. R.; Johnson, K. L., compilers. Research and management of bitterbrush and cliffrose in western North America; 1982 April 13-15; Salt Lake City, UT. Gen. Tech. Rep. INT-152. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1983: 118-125.

Dahlgreen, A. K. Care of forest tree seedlings from nursery to planting hole. In: Baumgartner, D. M.; Boyd, R. J., eds. Tree planting in the inland northwest; 1976 February 17-19; Pullman, WA. Pullman, WA: Washington State University Cooperative Extension Service; 1976: 205-238.

Grisez, T. J. Prunus L. In: Shopmeyer, C. A., tech. coord. Seeds of woody plants in the United States. Agric. Handb. No. 450. Washington, DC: U.S. Department of Agriculture, Forest Service; 1974: 658-673.

Hartmann, H. T.; Kester, D. E. Plant propagation. 3rd ed. Englewood Cliffs, NJ: Prentice-Hall, Inc.; 1975. 662 p.

Heit, C. E. Propagation from seed. Part II: Storage of deciduous tree and shrub seeds. Am. Nurseryman 9: 12-13, 86-94; 1967.

Heit, C. E. Propagation from seed. Part 15: Fall planting of shrub seeds for successful seedling production. Am. Nurseryman 10: 8-10, 70-80; 1968.

Heit, C. E. Propagation from seed. Part 22: Testing and growing western desert and mountain shrub species. Am. Nurseryman 13(10): 10-12, 76-89; 1971.

Hodder, R. L. Roadside dryland planting research in Montana. Highway Res. Rec. 335: 29-34; 1970.

Lohmiller, R. G.; Young, W. C. Propagation of shrubs in the nursery. In: McKell, C. M.; Blaisdell, J. P.; Goodin, J. R., tech. eds. Wildland shrubs - their biology and utilization; July 1971; Logan, UT. Gen. Tech. Rep. INT-1. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1972: 349-358.

McArthur, E. D. Shrub selection and adaptation for rehabilitation plantings. In: Stelter, L. H.; DePuit, E. J.; Mikol, S. A., tech. coords. Shrub establishment on disturbed arid and semi-arid lands; 1980 December 2-3; Laramie, WY. Cheyenne, WY: Wyoming Game and Fish Department; 1981: 1-8.

Plummer, A. P.; Christensen, D. R.; Monsen, S. B. Restoring big-game range in Utah. Publ. No. 68-3. Salt Lake City, UT: Utah Department of Fish and Game; 1968. 183 p.

Riffle, J. W. Effects of soil fumigation on growth of hardwood seedlings in a northern plains nursery. (Abstr.) Amer. Phytopathol. Soc. Proc. 3: 215; 1976.

Riffle, J. W. Growth and endomycorrhizal development of broadleaf seedlings in fumigated nursery soil. Forest Sci. 26(3): 403-413; 1980.

Ryker, R. A. Western nursery herbicide study - 1979 update. In: Proceedings of the Intermountain Nurserymen's Association meeting; 1979: 16-23.

Sandquist, R. E.; Owston, P. W.; McDonald, S. E. How to test herbicides at forest tree nurseries. Gen. Tech. Rep. PNW-127. Portland, OR: U.S. Department of Agriculture, Forest Service; 1981. 24 p.

Smith, E. M. Fertilizer practices for field-grown nursery stock. Am. Nurseryman 21: 9, 62, 63, 64; 1979.

Stevens, R. Techniques for planting shrubs on wildland disturbances. In: Stelter, L. H.; DePuit, E. J.; Mikol. S. A., tech. coords. Shrub establishment on disturbed arid and semi-arid lands; 1980 December 2-3; Laramie, WY. Cheyenne, WY: Wyoming Game and Fish Department; 1981: 29-36.

Stevens, R.; Jorgensen, K. R.; Davis, J. N. Viability of seed from thirty-two shrub and forb species through fifteen years of warehouse storage. Great Basin Nat. 41(3): 274-277; 1981.

Stickney, P. F. Holodiscus discolor (Pursh) Maxim. In: Shopmeyer, C. S., tech. coord. Seeds of woody plants in the United States. Agric. Handb. No. 450. Washington, DC: U.S. Department of Agriculture, Forest Service; 1974: 448-449.

Stutz, H. C. Rapid evolution in western shrubs. Utah Sci. 34: 16-20, 33; 1974.

Vories, K. C. Growing Colorado plants from seed: a state of the art. Volume I: shrubs. Gen. Tech. Rep. INT-103. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1981. 80 p.

Wasser, C. H. Ecology and culture of selected species useful in revegetating disturbed lands in the West. Washington, DC: U.S. Department of Interior, Office of Biological Services, Fish and Wildlife Service; 1982. 347 p.

Welch, B. L.; Monsen, S. B. Winter crude protein among accessions of fourwing saltbush grown in a uniform garden. Great Basin Nat. 41(3): 343-345; 1981.

Williams, R. D.; Hanks, S. H. Hardwood nurseryman's guide. Agric. Handb. No. 473. Washington, DC: U.S. Department of Agriculture, Forest Service; 1976. 78 p.

U.S. Department of Agriculture, Forest Service. Seeds of woody plants in the United States. Agric. Handb. No. 450. Shopmeyer, C. S., tech. coord. Washington, DC: U.S. Department of Agriculture, Forest Service; 1974. 883 p.

U.S. Department of Agriculture, Soil Conservation Service. Improved plant materials. Tech. Note 42. Washington, DC: U.S. Department of Agriculture, Soil Conservation Service; 1982. 17 p. Revised annually.

In: Murphy, Patrick M., compiler. The challenge of producing native plants for the Intermountain area: proceedings: Intermountain Nurseryman's Association 1983 conference; 1983 August 8-11; Las Vegas, NV. General Technical Report INT-168. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 96 p.

PRODUCING NATIVE PLANTS AS CONTAINER SEEDLINGS

Thomas D. Landis and Edward J. Simonich

ABSTRACT: Crops of native plants should be planned to allow enough time for seed collection, seed processing, seed treatments 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 in greenhouses is the newest production technique in western forest nurseries. Producing native plants in containers is a logical operation, however, because some species have proven difficult to grow as bareroot seedlings. For example, Mormon tea (*Ephedra* spp.) has very brittle stems and fragile root systems which are sensitive to breakage during bareroot lifting operations and the expansive root system of elderberry (*Sambucus* spp.) makes it hard to culture in seedbeds. Other native plants such as Arizona cypress (*Cupressus arizonica*) just seem to grow better in containers.

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

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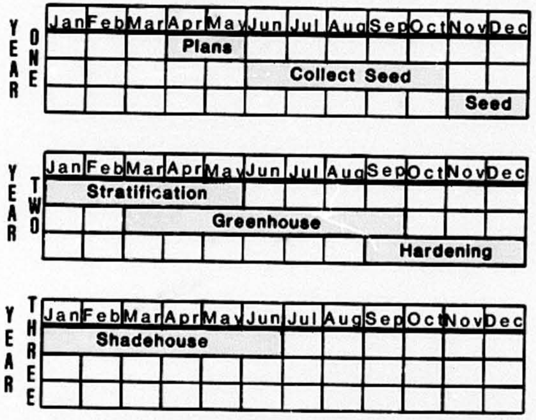

Figure 1.--Production schedule for growing native plants in containers: creeping Oregon grape (*Mahonia repens*)--germinants

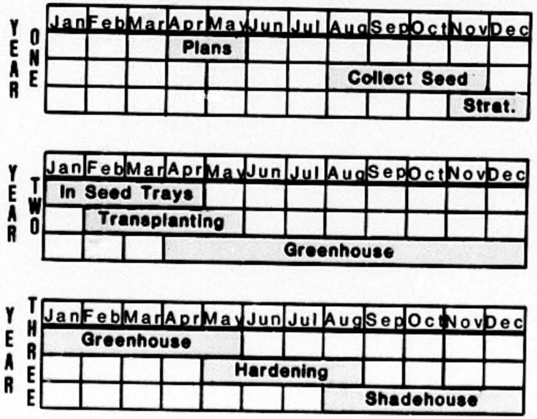

Figure 2.--Production schedule for growing native plants in containers: Rocky Mountain juniper (*Juniperus scopulorem*)--transplants

If seed must be procured, the total time for crop production may take from 2 to 3 years depending on the species of native plant and the type of propagation system (fig. 1 & 2). These rotation times are longer than for a typical conifer seedling which may take only from 8-12 months. The longer production period is primarily due to the problems with 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 storability varies with species. Butterbrush (*Purshia tridentata*) can be stored under refrigeration for over 10 years, whereas prostrate summer cypress (*Kochia prostrata*) loses viability after one year (Steve Monsen, per. comm.). For planning purposes, however, it would be wise for new growers to allow ample time to grow their first crop of native plants.

Compared with many greenhouse crops where the plants are sold directly out of the production greenhouse, native plants must be properly hardened before they are suitable for sale. This hardening period will be discussed in detail later but normally requires at least 1 month.

PRODUCTION FACILITIES

Whereas many ornamental crops can be produced in a single structure, the greenhouse, native plants may require as many as four separate facilities. An ideal container nursery consists of 1) a production greenhouse to grow the seedlings, 2) a cold frame or shadehouse to harden the 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 three-structure system 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 nurseries in the Intermountain area use fully-controlled houses which give maximum control over the environment whereas nurseries in milder climates may be able to use semi-controlled greenhouses. The advantages and disadvantages of different facilities are discussed in detail in Tinus and McDonald (1979).

One of the operational advantages of a fully-controlled greenhouse is the production of more than one crop per year; Native Plants Inc. is capable of producing two to three crops of plants per year depending on species. Some plants do not grow well during the winter season when day length is short and light intensities are low. Squawbush (*Rhus trilobata*) is very sensitive to photoperiod so crop lights are necessary to produce multiple crops (Steve Monsen, pers. comm.). Desert species just naturally grow better during the summer season.

The optimum size of greenhouse for producing native plants will vary, depending on the need for separate growing environments and the cost and operational difficulties of maintaining individual houses. Small, separate greenhouses permit the nurseryman to generate a range of environments and are also better for multiple cropping because species with different growing requirements can be sown and hardened at different times during the season. Separate houses allow more flexibility because the nursery manager can shut down some of his greenhouses and grow a smaller crop more economically. A single, large greenhouse can be designed with moveable curtains to produce compartments with different environments but the crop lights and irrigation system should also be under separate controls. On the other hand, larger houses are generally cheaper to heat and maintain, and less expensive to build than a range of smaller greenhouses.

PROPAGATION METHODS

The choice of propagation method is probably one of the most critical phases in native plant production. The majority of seedlings in forest nurseries are produced by direct seeding but the stringent stratification requirements and limited availability of many native plant seeds may require other approaches.

Native Plants Inc. uses four different methods to propagate woody plants in containers: direct seeding, germinants, transplants, and rooted cuttings (table 1). Some species such as pinyon pine (*Pinus edulis*) are only produced by one method (seed) whereas others such as common juniper (*Juniperus communis*) can be propagated by germinants or cuttings. The choice of propagation method also has its economic considerations. Direct seeding is the cheapest method because of a lower labor requirement compared to the rooted cutting technique which is more labor intensive and requires special facilities.

Direct seeding is defined as the sowing of seed into the growth container and is the standard technique for most conifer species and wildflowers. This propagation method is limited to those species with little or no dormancy requirement which works out to about 10 percent of the species produced at Native Plants Inc. The advantages and disadvantages of this method are given in table 1. If a stratification period or other pretreatment is specified, then the seed is treated prior to the planned sowing date. Otherwise, the seed is generally soaked in room temperature water for 24-48 hours and surface dried before sowing.

The seeding procedure begins with the calculation of the proper sowing density based on germination tests and past experience. Generally several seeds are sown per container and are later thinned to one seedling per cell. Because of the irregular shapes and sizes of most native plant seeds, most sowing is done by hand although a shutterbox or vacuum seeder could be used for certain species and large seed lots. The sown 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.

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

Propagation Technique	Advantages	Disadvantages
1. Seeds - Direct sowing of seed to growth containers	· Quick · Minimal handling of seed · Sowing can be mechanized · Uniform crop development	· Hard to control cell occupancy and seedling density · Requires thinning and consolidation · Inefficient and costly use of seed · Greenhouse time lost prior to emergence
2. Germinants - Sowing germinated seed from stratification into growth containers	· Control of cell occupancy and seedling density · Efficient use of valuable seed · Good use of greenhouse space · Accommodates variable germination rates	· Sowing is slow and involves skilled labor · Irregular germination rate may cause variation in crop development · Number of seedlings subject to quality of seed lot · Requires specialized stratification chambers
3. Transplants - Seedlings are grown in trays and transplanted to growth containers	· Control of cell occupancy and seedling density · Efficient use of valuable seed · Good use of greenhouse space · More uniform crop development · Can use natural or artificial stratification	· Transplanting is slow and involves skilled labor · Requires additional operation of sowing seed trays · Overly dense seed trays could lower seedling vigor or lead to disease problems
4. Rooted cuttings - Vegetative cuttings are rooted in trays and transplanted to growth containers	· Control of cell occupancy and seedling density · Not dependent on seed crops · Good use of greenhouse space · Ability to preserve desirable genetic characteristics · Some species can be produced more quickly · Maintain sexual characteristics of dioecious species	· Transplanting is slow and involves skilled labor · Some species do not root well · Requires special facilities · Most costly technique

The success of the direct seeding method is dependent on the accuracy of the seed information. Germination tests vary from lab to lab and no standardized tests are available for many native shrubs and forbs. Laboratory germination tests are 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 germinant technique is defined as the sowing of pregerminated seed into the growth container. This propagation method is best for plants with simple dormancy requirements and species with seeds too large to handle mechanically. It is particularly suitable for seed lots of variable or unknown quality because only good seed is sown in the growth container. Cell occupancy is maximized with this method as there are few blank cells and no subsequent thinning is needed. The germinant technique is used for about 15 percent of the native plant species produced at Native Plants Inc. The advantages and disadvantages are listed in table 1 and a sample production schedule is given in fig. 1.

The germinant procedure requires clean seed so seed lots should be surface sterilized with chlorox or Captan to reduce molding during stratification. The seeds are usually hydrated with a 24-48 hour soak and then prepared for the stratification chamber.

Seed can be germinated in "naked" stratification where the bare seeds are kept in a plastic bag or mixed with a moisture-holding material such as peat moss. Native Plants Inc. uses a fine-textured, sterile peat moss, mixes the seed with the moss, and places the mixture in a plastic bag in a refrigerator at 30° to 40° F (-1° to +4° C). The acid peat moss helps retard seed molds during the lengthy stratification period which can last up to 8 months. The stratification bags should be checked at least weekly until germination begins. Seeds are ready to transfer to the growth container when a white radicle becomes visible but before the radicle becomes so long that it is easily damaged. Cracked seeds are not necessarily germinating; some species of seed swell and crack long before the radicle begins to emerge. Chokecherry (*Prunus virginiana*) seeds may take several months to produce a radicle after the seed intially cracks.

The planting operation consists of pouring the stratified seed out in a tray and picking out the germinants by hand or with tweezers. The germinants are placed in a depression or small hole in the potting soil in the growth container and covered with grit or perlite. Seeds should be placed with the radicle oriented downward; if the radicle is pointed upward it will reverse itself in response to gravity which may result in a stem crook in the young seedling. The crews at Native Plants' greenhouse have been able to achieve production rates of 1500-2000 plants per person-day using this procedure. It is a good idea to double sow the last couple of rows of containers in each tray to provide extra seedlings to transplant back into any empty cells.

Once all the germinants have been planted out of the tray, the seeds are placed back into the stratification bag and returned to the refrigerator. The planting crews go through the stratification bags three times per week until the germination rate begins to decline. These bags have been maintained for as long as 8 months for some species (eg. *Prunus* spp.) and germinating seed can be used as long as mold does not become a problem.

Transplants are the third propagation method used at Native Plants Inc. and account for 65 percent of the species produced. Transplants are defined as seedlings which are grown to the cotyledon stage in trays and then transplanted into growth containers. This propagation method is best for woody plants with complex dormancy requirements or for species such as quaking aspen whose small seeds would be almost impossible to plant by hand. This technique is ideal for seed lots of variable or unknown quality. A list of the advantages and disadvantages of the transplant method is given in table 1.

The transplant trays are filled about 2 inches (5 cm.) deep with standard potting mix and broadcast seeded by hand. Very small seed can be applied through a large salt shaker to ensure even seed distribution. Cover the seed with a light application of a fine-textured material such as sand-blasting grit.

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Seeds that require stratification are sown in the fall, irrigated, and placed outside in a sheltered location and protected against dessication. This outside storage allows the seed 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 taken directly into the greenhouse. In the greenhouse, the transplant flats are kept moist by frequent hand irrigation and germination usually occurs in 1-2 weeks. Once the seedlings grow to the cotyledon stage and begin to grow primary leaves, they are ready for transplanting. The transplanting procedure consists of working the seedlings loose from the soil, making a dibble hole in the potting soil of the growth container, and transplanting a seedling into the hole. The potting soil is then firmed around the seedling and the growth containers 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, the trays irrigated, and the plants allowed to sprout again. Depending on the germination rate, the trays may produce up to three successive crops of transplant material.

Rooted cuttings are the final propagation method for native plant production. This technique consists of rooting vegetative cuttings in trays and transplanting them to growth containers. Approximately 10 percent of the species grown at Native Plants Inc. are produced by cuttings which is the best method for plants that are difficult to grow from seed or for which seed is difficult to obtain. The advantages and disadvantages of rooted cuttings are listed in table 1. At the Native Plants Inc. greenhouse, rooted cuttings are used as a last resort when the species cannot be reliably produced by another propagation technique; based on their cost figures, rooted cuttings are four to five times as expensive to produce as seedlings.

The production of rooted cuttings requires a special propagation facility which at Native Plants Inc. consists of a separate greenhouse with heated benches and a special misting system to control relative humidity. The cutting room is maintained at 70 to 75° F (21 to 24° C) and humidities approaching 100 percent. The atomized misting system is designed to maintain high humidities without overwatering the media in the cutting trays because fungal diseases quickly become damaging under saturated soil conditions. Supplemental lighting is used to extend normal day length and permit the production of rooted cuttings year round.

Cuttings are normally collected from plants in the field. The best season for collection depends on the species. Cuttings of two species of saltbush (*Atriplex cuneata* and *A. confertifolia*) rooted best when collected in spring or summer but the rooting percentage dropped markedly when cuttings were taken in the fall (Richardson and others 1979). Cuttings of some species such as big sagebrush (*Artemisia tridentata*) root better when collected during winter dormancy (Alvarez-Cordero and McKell 1979).

Native Plants Inc. currently collects most of their cutting material from "mother plants" which are older plants from the production stock at the nursery. To prevent disease spread, these mother plants are sprayed with a broad spectrum fungicide prior to collecting cuttings. Richardson and others (1979) reported that cuttings from greenhouse-grown plants rooted considerably better than field-collected cuttings for greasewood (*Sarcobatus vermiculatus*), a species that is normally difficult to propagate vegetatively.

A good step-by-step procedure for collecting cuttings is described by Norris (1983). Cuttings should be collected early in the day from new growth of active, healthy plants. Cutting the stem at an angle increases the surface exposure to increase new root production sites. All leaves should be removed from the lower third of the cutting and the cuttings should be kept in a shady, moist location. The crews at Native Plants Inc. prefer to plant the cutting the same day as it is collected.

Before the cuttings are planted, they are often treated with a special hormone to stimulate production of root primordia. These "rooting" chemicals can be made from scratch by mixing indolebutyric acid (IBA) with common talc, or you can buy commercial products such as Rootone or Hormodin. The best concentration of rooting hormone depends on many variables but, in general, the more difficult the plant is to root the higher the concentration of rooting chemical that should be used (Norris 1983). The rooting success of big sagebrush cuttings increased with increases in IBA concentration from 0.0 to 2.0 percent (Alvarez-Cordero and McKell 1979).

Treated cuttings should be inserted to a depth of 1 to 2 inches (2.5 to 5 cm) into a well-drained medium in a shallow rooting tray. The best media for rooting cuttings is subject to debate. Norris (1983) recommends a 1:1 ratio of peat to perlite or peat to fine sand. Native Plants Inc. uses different grades of sand and several combinations of sand, perlite, and potting soil. More information is needed on the best rooting media for different native plant species. Generally, the rooting medium does not contain any type of fertilizer because of a possible stimulating effect on disease organisms.

Some cuttings root quickly so it is important to begin checking the cuttings after the first week. Typically, the cuttings "callus-over" first and then produce adventitious roots from the callus tissue. Some cuttings such as those of juniper take as long as 6 months to root, so the cuttings should be inspected regularly for rooting or disease problems. Cutting success can exceed 95 percent with some species and Native Plants Inc. has achieved 75 to 100 cuttings per sq. ft. (6.9 to 9.3 per sq. m) of bench space.

The rooted cuttings should be transplanted immediately into a dibble hole in the growth container being careful to protect the new roots from injury. The transplanting procedure is inherently slower than any of the propagation methods using seeds but it is possible to reach up to a 95 percent success rate if the transplanting is performed conscientiously. The transplanted cuttings are grown under the standard greenhouse environment with special attention to irrigation during the initial period.

Another technique for producing cutting material involves the use of root sprouts. Species that regenerate by root suckers such as quaking aspen (*Populus tremuloides*) can be propagated by planting sections of lateral roots in an optimum environment and harvesting the succulent sprouts (Schier 1978). The excised roots are cut into 6 inch (15 cm.) sections and covered with potting media in a shallow tray and placed in the greenhouse. After several weeks, root sprouts will appear. These sprouts are cut off, treated with rooting hormones, and transplanted to a growth container. This technique is an effective way to propagate certain species but is quite costly in terms of the labor requirement.

PROPAGATION OF SELECTED NATIVE PLANT SPECIES

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

The stratification periods recommended in Seeds of Woody Plants in the United States (USDA 1974) illustrate the wide ecotypic variation in some species (e.g. Woods rose, 30-365 days) and lack of data for other species. The propagation methods listed are those most commonly used and some native plants can be propagated by more than one technique. Certain species are produced more easily during a particular season in the greenhouse whereas others can be grown any time during the year. Cropping time indicates the amount of time required to produce a saleable plant in the greenhouse and varies from 3-16 months.

GROWTH CONTAINER AND POTTING MEDIA

The best size, shape, and volume of growth container for producing a native plant that will survive and grow well in the field is a subject that is still open to debate. Ferguson and Frischknecht (1981) recommended a container that is 6 to 8 in. (15 to 20 cm) deep and has a volume of 15 to 25 cu. in. (245 to 410 cu. cm.). Barker and McKell (1979) grew four-wing saltbush (*A. canescens*) and greasewood in four sizes and types of containers ranging from 6 to 70 cu. in. (98 to 1147 cu. cm.) and found that shoot length, shoot biomass, and root biomass all increased with size of container.

Table 2 - Propagation procedures for selected native plants

Species	Stratification Period (Days)1/	Propagation Method2/	Production Scheduling	
			Season3/	Cropping Time (mos)
Acer circinatum, vine maple	120-240	G, T	Spring	4-5
Amelanchier alnifolia, serviceberry	120-180+	G, T, S	Any	3-4
Arctostaphylos spp., manzanita	0-210	T, C	Any	4-6
Artemesia tridentata, big sagebrush	0-10	T, S	Spr, Sum	3-4
Atriplex canescens, fourwing saltbush	30-50	T, S	Spr, Sum	3-4
Cercocarpus montanus, mountain mahogany	30-90	G	Any	4-6
Chrysothamnus nauseosus, rabbitbrush	0-120	T	Spr, Sum	3-4
Cowania mexicana, cliffrose	?	G, S	Spr, Sum	6-8
Ephedra viridis, Mormon tea	-	T, S	Summer	4-6
Juniperus scopulorum, Rocky Mountain juniper	240	T	Spr, Sum	12-16
Pinus monophylla, singleleaf pinyon	28-90	S	Any	8-12
Populus angustifolia, narrowleaf cottonwood	0	T, C	Summer	3-4
Populus tremuloides, quaking aspen	0	T, S	Spr, Sum	3-4
Potentilla fruticosa, shrubby cinquefoil	-	T, C	Any	3-5
Prunus virginiana, chokecherry	120-160	G, T, S	Any	3-5
Purshia tridentata, bitterbrush	60-90	G, S	Any	4-8
Quercus gambelii, Gambel oak	-	G, S	Fall	6-8
Rhus trilobata, skunkbush sumac	30-90	G, S	Any	4-6
Rosa woodsii, Woods rose	30-365	T, C, S	Spr, Sum	3-5
Sambucus cerulea, blue elderberry	30-210	T, S	Spring	3-5
Shepherdia argentea, buffaloberry	0-90	T, S	Summer	4-6
Symphoricarpos oreophilus, mountain snowberry	60-300	T, C, S	Spring	4-6
Yucca glauca, yucca	0	S	Spring	4-6

1/ USDA-FS. 1974. Seeds of woody plants in the United States. Agric. Handbook No. 450. 883 p.

2/ S = seed; G = germinants; T = transplants; C = cuttings

3/ Spr = Spring crop; Sum = Summer crop

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 not necessarily the best container for seedling growth in the greenhouse. Plants grown in large capacity containers generally perform best in the field but require too much greenhouse space and are costly to handle and ship. The best container also varies with plant species and environmental and soil conditions on the outplanting site.

Native Plants Inc. uses two different "tubepak" containers for most of their species: the 6-pack containers contain 13 cu. in. (213 cu. cm.) and the 5-pack has a capacity of 17 cu. in. (279 cu. cm.). Most species can be grown satisfactorily in the 13 cu. in. container but many broadleaved species have to be produced in the larger cells because their large leaves intercept irrigation and shade out adjacent seedlings. Some native plants such as elderberry (*Sambucus* spp.) and mountain-ash (*Sorbus* spp.) have massive root systems that require larger capacity containers. The density or spacing of the containers in the rack 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 natives grow quite well in standard potting mixes. Native Plants uses a mixture of equal portions of four materials: peat moss, vermiculite, perlite, and composted bark. They also incorporate a starter fertilizer mix (Osmocote 14-14-14) into the potting soil at 10 lbs. per cu. yd. (7.6 per cu. m.) and Micromax at 1.5 lbs per cu. yd. (1.1 per cu. m.)to supply micronutrients.

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

Other researchers have reported on potting mixes for native plants. Ferguson and Monsen (1974) found that mixes containing peat moss and vermiculite produced better mountain-mahogany (*Cercocarpus ledifolius*) seedlings compared to those containing sand. The SEAM project at the Coeur d'Alene nursery produced 40 different species of native plants using a standard 1:1 mix of peat moss and vermiculite. Ferguson (1980) studied 39 different potting media and found that no one mix was consistently superior. He did report that a potting mix of 50 percent peat moss, 30 percent arcillite aggregate and 20 percent vermiculite is recommended for Bonneville saltbush (*A. bonnevillensis*) and possibly other plant species native to alkaline soils. Mixing native soil into standard potting mixes can increase growth of some chenopod species (Monsen, pers. comm.). A survey of nurseries growing desert shrubs reported a wide variety of potting mixes that contained such diverse components as sand, cinder, peat moss, composted bark, charcoal, sawdust, vermiculite, perlite, and native soil (Anon. 1979). Obviously, 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. uses a uniform environment with day temperatures of 80°F (27°C), night temperatures of 65°F (18°C), a relative humidity of 30-40 percent, 800-1500 ppm carbon dioxide and a 24-hour intermittent photoperiod of 40 ft. candles. The SEAM project at Coeur d'Alene nursery maintained a greenhouse temperature of 65°F (18°C) for the entire growing cycle and intermittent photoperiod lights (20 sec. every 3 min.) at an intensity of 20-40 ft. candles. Monsen (pers. comm.) stresses that many native plants are very sensitive to photoperiod and so greenhouses should have continuous lighting systems.

Fertilization at the Native Plants' greenhouse is applied by two methods, Osmocote 14-14-14 fertilizer is added to the potting soil and Peters 20-20-20 soluble fertilizer is injected through the irrigation system. The injected fertilizer is not applied at any standard rate but is custom-applied based on experience. Because of the wide variation in nutrient requirements between the different native plant species, the grower must visually monitor the growth and color of the plants and fertilize based on experience.

Other greenhouse growers also emphasize the benefits of fertilization of native plants. The SEAM project applied all their nutrients through the irrigation system using a commercial 20-20-20 mix at a 1:100 injection ratio. This solution was applied weekly at the rate of 2 lbs. of fertilizer per 500 ft. (0.9 kg. per 46 sq. m.) of bench space. Once the desired top growth was achieved, the fertilizer mix was changed to a 15-30-15 mixture. Ferguson and Monsen (1974) grew mountain-mahogany seedlings with 3 different rates of Osmocote 18-6-12 slow release fertilizer ranging from 1 to 4 oz per cu. ft (34 to 102 g. per 0.03 cu. m.) of potting soil and found no 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 plant species grow very rapidly under the optimal conditions in the greenhouse but this rapid growth consists of relatively large cells with thin cell walls and little tolerance to cold temperatures. Unlike most ornamental crops, native plants cannot be sold directly out of the greenhouse but must undergo a period of hardening. Ferguson and Monsen (1974) stated that the proper amount of cold hardening was one of the most difficult problems 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 (Penrose and Hansen 1981).

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 outplanting.

3. To acclimatize plants to the outside environment and satisfy 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 usually require much less hardening compared to plants produced for a high elevation revegetation project. The two most important factors to consider in designing a hardening program are the planting date and the climate of the outplanting site. Most greenhouse nurseries are located at low elevations where the growing season begins earlier than at higher elevation planting sites. Native plants that will be planted in an environment that is similar to that where they were grown may only require a 4-6 week period of hardening. Plants that are outplanted at higher elevations during spring or fall must be able to tolerate colder temperatures and perhaps even frost.

Dormancy is another term that is often used in conjunction with hardiness. Dormant conifer seedlings have been shown to have the ability to produce abundant new roots when planted in a favorable environment. This high "root growth 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 respirational 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 droughty 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

Alvarez-Cordero, E.; McKell, C. M. Stem cutting propagation of big sagebrush (*Artemisia tridentata* Nutt.) J. Range Manage. 32(2): 141-143; 1979.

Anonymous. Soil mixes for greenhouse and nursery growth of desert plants. Desert Plants 1(2): 82-89; 1979.

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.

USE OF SHRUBS ON MINE SPOILS

Stephen B. Monsen

ABSTRACT: Mine disturbances can often be revegetated through natural plant succession. Plants that spread well by natural seeding can be used to seed mine spoils. Transplanting shrubs and herbs on mine sites hastens plant establishment and improves productivity and species diversity. However, shrub species differ in their ability to establish and survive as transplant stock. Therefore, planting sites must be prepared to accommodate direct seeding or transplanting. Environmental conditions of the planting site dictate the type of material and methods of planting. Existing herbaceous vegetation must be controlled to allow shrub seedlings to become established.

INTRODUCTION

Rehabilitation of mined land normally requires planting a combination of herbs and woody species. Natural invasion of native plants onto mined sites usually occurs too slowly to acceptably restore the site (McKell and Van Epps 1981). Planting is required to provide soil protection (Packer and others 1981), reduce the spread of weeds, and provide herbage and habitat to animals (Monsen and Plummer 1978).

Plantings also serve to establish a desirable and compatible array of species that will provide initial cover and ultimately develop a stable community (Laycock 1980).

Mined lands are generally harsh sites and plantings are not always successful. Seeding or transplanting may fail even when adapted species are used. Considerable differences exist between the microsites and soil conditions of mine spoils compared to undisturbed locations (Sindelar 1980). Consequently, it is difficult to determine the adaptability of individual species to mined land environments.

Species that are climax plants of undisturbed communities often are planted on mine spoils. Unfortunately, not all species that are regarded as climax, and usually considered desirable plants, are able to grow on disturbances (Eberly and Dueholum 1979; McGinnies and Nicholas 1980). Usually climax plants become established after the site has been modified by pioneer species. Many species that are initially adapted to mine spoils are considered weedy plants. These may persist for only a short time, but are useful to initiate plant succession (Stark 1966).

Species that are adapted to a wide range of soils, temperature extremes, and moisture conditions are the most successful species for harsh sites (Stark 1966). However, 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 1977).

Few plants have been specifically selected for their adaptability to mine disturbances. Only a limited number have been fully evaluated for their performance and survival on mine spoils. Most species that are currently used are native or introduced species that have been used mostly for other purposes. However, research has determined that certain species are adapted to infertile soils, and can be used on mined and associated disturbances (Stark 1966; Aldon and Pase 1981).

NATURAL INVASION OF PLANTS

Weedy annuals 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 (Butterfield and Tueller 1980). Many plants are adapted to mine disturbances but spread very slowly by natural means. Invasion by plants is often hindered by factors related to seed production (Plummer 1977), seed germination, and seedling survival (Sabo and others 1979). The quality and quantity of seed produced on wildlands varies greatly and can be influenced by unpredictable climatic conditions and insects (U.S. Department of Agriculture 1974).

Winds, overland flow of water, and rodents are agents that carry seeds onto mine sites. Under wildland conditions rodents not only distribute but plant many seeds (West 1968). A high proportion of seed produced in wildland stands is consumed by animals including rodents (Bradley 1968). The excess is all that remains to perpetuate the species.

Rodents usually collect and store seeds of large fruited species and seed that consists of an edible endosperm. Usually, seeds that remain viable for an extended period are stored as caches in the soil surface by rodents for later consumption (Sherman and Chilcote 1972). Seeds planted as rodent caches frequently are not eaten but germinate later to form a cluster of new seedlings. Shrub seeds that are normally gathered and stored in caches include: antelope bitterbrush (*Purshia tridentata*), desert peachbrush (*Prunus fasciculata*), green ephedra (*Ephedra viridis*), Martin ceanothus (*Ceanothus martinii*), Saskatoon serviceberry (*Amelanchier alnifolia*), and Woods rose (*Rosa woodsi*).

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Rodent activity is usually confined to areas offering overstory protection. However, rodent populations and habitat are not always decreased by clearing the vegetation (Turkowski and Reynolds 1970). Yet, small animals usually do not venture onto barren mine wastes or exposed sites. As sites become vegetated, rodents inhabit the area. Once plants that are established on the mine begin to bear seeds, rodents gather the fruits and help further the species and progress of successional stages in plant development.

A substantial amount of seed is produced by certain plants. Clean seed yields have exceeded 300 pounds per acre (338 kg/ha) for antelope bitterbrush grown on a planted site near Boise, Idaho. During years of high seed production many species increase dramatically due to the planting efforts of small rodents. Adapted 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 appendaged seeds are widely distributed by wind (Mirov and Kraebel 1939). Although a high proportion of weedy species is spread by the wind, many useful species are also dispersed by this method. Wind-carried seeds often spread plant species quickly, and populate otherwise inaccessible sites. Species that are successfully spread by wind include: Apache-plume (*Fallugia paradoxa*), sagebrush (*Artemisia* spp.), penstemon (*Penstemon* spp.), and rabbitbrush (*Chrysothamnus* spp.).

CONDITIONS INFLUENCING ARTIFICIAL SEEDING

Mined lands are usually planted soon after mining is completed. Disturbances primarily consist of overburden material or tailings composed of unconsolidated soil materials. Although topsoil and fertilizer may be added, mine spoils usually lack soil structure and particle aggregation that contribute to a optimum seedbed condition. Soil drainage, aeration, microorganism content, nutrient balance, and organic matter are all poorly developed for supporting a combination of plants (Frischknecht and Ferguson 1979).

Although fresh mine spoils are usually less productive than undisturbed sites, cultural practices often are not employed to improve tilth and productivity before planting. Therefore, planted species must be adapted to infertile sites, and capable of developing concurrently as young seedlings. Grasses, broadleaf herbs, and woody species are often planted together. Assembly of a mixture of plants with different growth forms creates serious problems of competition among young seedlings. Mixed plantings favor herbs over shrubs and trees (Jensen 1980).

Grasses that are currently seeded on most mined sites are derivatives formulated for high germinability and seedling vigor. 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 mature status much sooner. Most seeded 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 1968). During this interim, the developing shrubs are subjected to extensive competition, and plant losses are common (Booth and Schuman 1981). To be fully competitive with grasses, seeded shrubs and trees must possess the following traits: (1) seeds must germinate readily, (2) seedlings must develop rapidly, (3) seasonal growth periods should be compatible with the seeded herbs, and (4) 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 include: basin big sagebrush (*Artemisia tridentata tridentata*), low sagebrush (*Artemisia arbuscula*), fourwing saltbush (*Atriplex canescens*), winterfat (*Ceratoides lanata*), snowbrush ceanothus (*Ceanothus velutinus*), rubber rabbitbrush (*Chrysothamnus nauseosus*), Wyeth eriogonum (*Eriogonum umbellatum*), prostrate summer cypress (*Kochia prostrata*), antelope bitterbrush, and thinleaf alder (*Alnus tenuifolia*).

Natural plant succession and edaphic changes that occur after mined sites are initially planted change the growing conditions and productivity of the disturbance. Some species that have been difficult to establish initially on fresh mine spoils by direct seeding or transplanting have been successfully established at a later date. New shrub and tree seedlings are frequently encountered as a result of natural reproduction, beginning 5 to 10 years after a site has been reclaimed. The encroachment often occurs on sites dominated by a competitive understory of herbs. However, the environment of some disturbances is so harsh that only a limited number of species establish and persist. Little improvement can be expected for a considerable period of time on these areas.

The success of most plants has been based upon the response attained from plantings established on newly exposed mine spoils.

Unfortunately many useful species are often discarded due to failures from initial plantings. Growing conditions improve as soil nutrients build up or the soil microflora is established.

VALUE OF TRANSPLANT STOCK

Although plants may be successfully established by direct seeding, transplanting is also a viable revegetation technique. Some species that establish readily by seeding do not grow rapidly enough to provide initial ground cover for soil stabilization (Shaw 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 melanocarpa*) planted on phosphate mines in southeastern Idaho. Seedlings of both species germinated erratically and young plants were weak and slow to develop. Although plantings have been established on topsoiled and fertilized sites, the growth performance of these small seedlings has remained unchanged. However, 2-0 transplants of both species developed rapidly.

Transplants that are properly spaced can provide an immediate and effective cover. Transplanting can be effectively used to stabilize erodible sites and promote the natural establishment of understory species. Megahan (1974) reported that over 50 percent of surface erosion from roadfills was controlled by planting 1-year-old bareroot 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 understory species. Ponderosa pine transplanted along steep roadcut and fill slopes in central Idaho stabilized the sites and served as a nurse crop for understory herbs (Monsen 1974). The presence of the overstory canopy of Woods rose, blueberry elder (*Sambucus cerulea*), and redstem ceanothus (*Ceanothus sanguineus*) also aids in the establishment of other species. Shrubs and trees that may persist for only a few years can be highly useful in the development of satisfactory cover.

Some leguminous and nonleguminous shrubs and trees are beneficial in improving soil nutritive levels. Klemmedson (1979) reported that eight genera of shrubs are able to fix nitrogen through actinomycete nodulation. These species can be used as companion plants to improve the performance of various understory herbs. Species of *Ceanothus* have been successfully used for this purpose on mine spoils in Idaho (Monsen 1974). Langkamp and others (1979) reported that reestablishment of a nutrient bank would occur slowly with the use of Acacia (*Acacia pellita*), and that pasture legumes would rapidly rebuild nutrient levels.

Transplants can be used to increase the rate of plant succession. In addition, transplant stock matures quickly and community changes occur rapidly. If persistent and compatible species are planted initially, a predesigned community structure can be arranged. This is an important feature, as many planted species do not attain full prominence until a mature and stable plant composition is achieved.

FACTORS AFFECTING TRANSPLANT SUCCESS

Factors that affect transplant survival are similar to those that influence seedling establishment. However, a significant difference is that transplanting usually eliminates the need for a prepared seedbed. The principal factors that reduce transplant survival are: (1) planting unadapted species and ecotypes; (2) carelessness in planting; (3) insufficient soil moisture resulting from inadequate site preparation and planting at the wrong time of year; and (4) use of poor quality planting stock.

Planting Adapted Species and Ecotypes

Species that are reared and planted on wildland sites in the West normally include selections that are native to the planting site. Seed and vegetative cuttings often are collected from the planting area. If this is not possible, stock is obtained from similar vegetative types growing in separate areas. In addition, various grasses, forbs, and shrubs have been developed for rangeland plantings.

However, few native or introduced species have been specifically developed for mined sites. Although numerous plants have been established on mined lands, their persistence and areas of adaptability have not been fully determined. Considerable differences have been recorded in the survival and initial growth rates of ecotypes when planted on mined sites. Different strains or ecotypes of many native shrubs could be used to select sources that have vigorous seedling adaptability to infertile soils.

Growers should be aware of the differences that occur among ecotypes of a particular species, and seek to raise stock that is adapted to specific soil and climatic conditions. Mined sites should be evaluated before planting to assure that adequate time is given to program the vegetation efforts, collect sufficient adapted seed, and rear transplant stock.

Plants that inhabit the site before mining may not be adapted to the mine spoils. Present State and Federal laws often require mining companies to restore native plant species to reclaimed areas. Although the use of adapted native plants is often advisable, many mined sites are not capable of immediately sustaining the dominant species of the undisturbed site.

Some species and ecotypes are currently available that are adapted to mined lands, and these should be promoted and used. Research is needed to develop 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 reforestation makes use of soil types, elevation, and climatic zones in selecting adapted ecotypes for planting. These features should also be applicable in delineating plants for mined lands, although the edaphic conditions of mine spoil are not entirely comparable to undisturbed soils. However, mining does not completely alter climatic and biotic influences. Consequently, plants that are components of original sites are still candidates for initial revegetation trials. Equally important is the identification of individual species that possess inherent characteristics that contribute to the range of adaptation of the species. For example, the occurrence of different subspecies, ecotypes, and kinds of sagebrush offers a wide diversity of planting stock suited to different site conditions (McArthur and others 1974). Through careful selection, adapted ecotypes of other species can be used to revegetate mine spoils.

Site Preparation and Planting

Transplanting does not require the intensive surface preparation treatment required for direct seeding, yet most mines usually utilize both revegetation techniques. Surface tillage and fertilization are required to enhance the survival of the seeded species. Seeding is frequently done to control soil erosion and surface runoff. Transplanting may be superimposed over the existing seeding. This usually does not create serious problems if transplant needs are recognized.

Transplants can usually compete with newly sown grass. However, if the grass is heavily seeded and fertilized, shrub transplants may suffer (Jensen 1980). Therefore, to improve shrub and tree survival the seeding should not be at a high rate. Fertilization of herbaceous species should be applied at a low rate, yet the seeding can be refertilized after the shrubs are well established.

Mine spoils should be treated to aid plant survival. Compact soils should be ripped to allow infiltration, aeration, and root development. Transplants should also be fertilized. Fertilizer tablets placed in the planting hole significantly aided tree growth in an Idaho trial (Megahan 1974).

Woody species that grow slowly and require 2 or 3 years to fully establish should be interspaced in strips or clearings separate from more competitive species (Giunta and others 1975). The planting areas should be delineated according to site conditions to assure that species are planted in adapted locations. It is not necessary to plant the entire site in a grid pattern. Species can be transplanted in groups, clusters, or mixes to provide diversity.

Planting Quality Stock

The development of high-quality transplant stock is essential to plant survival on mine wastes. Specimens that are poorly developed succumb quickly to adverse conditons. Failure to acquire and plant quality stock accounts for many planting failures.

Growers frequently produce a uniform grade of planting stock. Materials are grown to 1-0 or 2-0 size classes. Container-grown stock is also produced in rather uniform grades. Plants can be grown to different age and size classes, but this is difficult to program for a mine location when only a short rearing time is available.

The size and type of transplant is vital to plant survival. Species that grow rapidly will normally survive and grow well if a healthy 1-0 transplant is used. Other species grow slowly, requiring a year or two to fully establish and begin any appreciable growth. Green ephedra, mountain snowberry (*Symphoricarpos oreophilus*), mountain-ash (*Sorbus scopulina*), roundleaf buffaloberry (*Shepherdia rotundifilia*), skunkbush sumac (*Rhus trilobata*), and spiny hopsage (*Grayia spinosa*) do poorly when planted as 1-0 stock, but perform much better when planted as 2-0 or larger stock. Survival rates improve and growth is markedly increased.

Proper maintenance and field planting of a well-conditioned transplant is essential to plant survival. Shrubs such as Wyeth eriogonum, bush penstemon (*Penstemon fruticosus*), and prostrate ceanothus (*Ceanothus prostratus*) begin growth early in the season and must be lifted and planted as dormant stock, otherwise survival is very low.

Container-grown stock or ball and burlap materials are useful in planting rocky sites. However, high-quality bareroot stock will perform satisfactorily. Planting large pads and root sections as wildlings has proven successful with species of aspen (*Populus tremuloides*), oak (*Quercus* spp.), and other plants (Crofts 1978).

Mine plantings require special attention. Sites often are rocky and planting is impared. Without particular care, plants may fail simply because of poor handling. Care must be taken to follow normal planting guides.

PUBLICATIONS CITED

Aldon, E. F.; Pase, C. P. Plant species adaptability on mine spoils in the Southwest: a case study. Res. Note RM-398. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1981. 3 p.

Booth, Terrance D.; Schuman, Gerald E. Shrub reestablishment research at the High Plains Grasslands Research Station. In: Stelter, L. H.; DePuit, E. J.; Mikol, S. A., tech. coord. Proceedings, shrub establishment on disturbed arid and semi-arid lands; 1980 December 2-3; Laramie, WY. Cheyenne, WY: Wyoming Game and Fish Department; 1981: 81-88.

Bradley, Glen W. Food habits of the antelope ground squirrel in southern Nevada. J. Mammal. 49(1): 14-21; 1968.

Butterfield, Richard I.; Tueller, Paul T. Revegetation potential of acid mine wastes in Northern California. Reclamation Rev. 3: 21-31; 1980.

Crofts, Kent A. Coal mine reclamation in Colorado. In: 32nd annual report, vegetative rehabilitation and equipment workshop; 1978 February 5-6; San Antonio, TX. Missoula, MT: U.S. Department of Agriculture, Forest Service; 1978: 43-45.

Eberly, L. W.; Dueholm, K. H. A program to reestablish and study prairie grassland and assess effect of fire. J. Minnesota Acad. Sci. 45(2): 8-11; 1979.

Frischknecht, Neil C.; Ferguson, Robert B. Revegetating processed oil shale and coal spoils on semi-arid lands. Interim report, Interagency Energy/Environment R&D Program. Ogden, UT: U.S. Department of Agriculture, Forest Service, and U.S. Environmental Protection Agency; 1979. 47 p.

Giunta, B. C.; Christensen, D. R.; Monsen, S. B. Interseeding shrubs in cheatgrass with a browse seeder-scalper. J. Range Manage. 32: 398-402; 1975.

Howard, G. S.; Samuel, M. J. The value of fresh-stripped topsoil as a source of useful plants for surface mine revegetation. J. Range Manage. 32: 76-77; 1979.

Klemmedson, J. O. Ecological importance of actinomycete nodulated plants in the western United States. Bot. Gaz. 140 (Suppl.): 591-596; 1979.

Jensen, Bernie. Mine and roadside revegetation in Montana. In: Proceedings of Intermountain Nurseryman's Association and Western Forest Nursery Association. Gen. Tech. Rep. INT-109. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980: 129-134.

Langkamp, Peter J.; Swinden, Lindsay B.; Dalling, Michael J. Nitrogen fixation (acetylene reduction) by *Acacia pellita* on areas restored after mining at Groote Eylandt, Northern Territory, Aust. J. Bot. 27: 353-361; 1979.

Laycock, W. A. What is successful reclamation?--a look at the concepts of adaptability, productivity, cover, and diversity of seeded species. In: Northwest Colorado land reclamation seminar. I: proceedings; 1980 November 18; Steamboat Springs, CO: 1980: 1-17.

McArthur, E. D.; Giunta, B. C.; Plummer, A. P. Shrubs for restoration of depleted ranges and disturbed areas. Utah Sci. 35: 28-33; 1974.

McGinnies, W. J.; Nicholas, P. J. Effects of topsoil thickness and nitrogen fertilizer on the revegetation of coal mine spoils. J. Environ. Qual. 9: 681-685; 1980.

McKell, C. M.; Van Epps, G. A. Comparative results of shrub establishment on arid sites. In: Stelter, L. H.; DePuit, E. J.; Mikol, S. A., tech. coord. Proceedings, shrub establishment on disturbed arid and semi-arid lands; 1980 December 2-3; Laramie, WY. Cheyenne, WY: Wyoming Game and Fish Department; 1981: 138-154.

Megahan, Walter F. Deep-rooted plants for erosion control on granitic road fills in the Idaho Batholith. Res. Pap. INT-161. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1974. 18 p.

Mirov, N. T.; Kraelbel, Charles J. Collecting and handling seeds of wild plants. Civilian Conservation Corps Forestry Publ. No. 5 Washington, DC: U.S. Department of Agriculture, Forest Service, California Forest and Range Experiment Station; 1939. 42 p.

Monsen, S. B. Plant selection for erosion control of forest roads of the Idaho Batholith. Pap. 74-2559. Chicago, IL: American Society of Agricultural Engineers; 1974. 18 p.

Monsen, S. B.; Plummer, A. P. Plants and treatments for revegetation of disturbed sites in the Intermountain area. In: Wright, R. A., ed. The reclamation of disturbed arid lands. Albuquerque, NM: University of New Mexico Press; 1978: 155-174.

Packer, P. E.; Clyde, C. C.; Israelson, E.; Farmer, E.; Fletcher, J. Erosion control during highway construction-A manual of principles and practices for erosion. Washington, DC: National Academy of Science, Transportation Research Board; 1981. 36 p.

Plummer, A. P. Revegetation of distrubed Intermountian area sites. In: Thames, J. L., ed. Reclamation of use of disturbed land in the Southwest. Tucson, AZ: University Arizona Press; 1977: 302-339.

Plummer, A. P.; Christensen, D. R.; Monsen, S. B. Restoring big game range in Utah. Publ. 68-3. Salt Lake City, UT: Utah Division of Fish and Game; 1968. 183 p.

Sabo, D. G.; Johnson, G. U.; Martin, W. C.; Aldon, E. F. Germination requirements of 19 species of arid land plants. Res. Pap. RM-210. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1979. 26 p.

Sherman, Robert J.; Chilcote, William W. Spatial and chronological patterns of *Purshia tridentata* as influenced by *Pinus ponderosa*. Ecology. 53(2): 294-298; 1972.

Shaw, Nancy. Propagation and outplanting shrubs on mine sites. In: Stelter, L. H.; DePuit, E. J.; Mikol, S. A., tech. coord. Proceedings, shrub establishment on distrubed arid and semi-arid lands; 1980 December 2-3; Laramie, WY. Cheyenne, WY: Wyoming Game and Fish Department; 1981: 47-56.

Sindelar, B. W. Achieving revegetation standards on surface mined lands. In: Adequate reclamation of mined lands?--symposium; Billings, MT; 1980: 22-1--22-15.

Stark, N. Review of highway planting information appropriate to Nevada. College of Agriculture Bull. No. B-7. Carson City, NV: Desert Research Institute, University of Nevada; 1966:1-290.

Turkowski, Frank J.; Reynolds, Hudson G. Response of some rodent populations to pinyon-juniper reduction on the Kaibab Plateau, Arizona. The Southwestern Nat. 15(1): 23-27; 1970.

U.S. Department of Agriculture, Forest Service. Seeds of woody plants in the United States. In: Shopmeyer, C. S., tech. coord.; Agricultural Handbook No. 450. Washington, DC: U.S. Department of Agriculture, Forest Service; 1974. 883 p.

West, Neal E. Rodent-influenced establishment of ponderosa pine and bitterbrush seedlings in central Oregon. Ecology. 49(5): 110-1011; 1968.

In: Murphy, Patrick M., compiler. The challenge of producing native plants for the Intermountain area: proceedings: Intermountain Nurseryman's Association 1983 conference; 1983 August 8-11; Las Vegas, NV. General Technical Report INT-168. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 96 p.

TOWARD PRODUCING DISEASE-FREE CONTAINER-GROWN NATIVE WILDLAND PLANTS

David L. Nelson

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 design and management for disease prevention, controlling pathogens in plant growing medium, the role of native-host genetic 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 affect roots only slightly. The only visible injury is reduced top growth. Probably as much damage results from these "root nibblers" as from virulent pathogens that induce obvious symptoms and kill plants rapidly. Fungicidal treatment to prevent seedling diseases such as damping-off often only suppresses the pathogen which later induces further disease in the container plant or in the field after outplanting (Baker 1965).

A wise approach is to adopt rigid disease prevention methods regardless of present known disease problems. Currently, little if any research effort is directed toward controlling diseases in the production of wildland planting stock. The purpose here, therefore, is to relate facets of existing knowledge developed over the years in the horticultural and agricultural experience that may be of value in the wildland plant scene.

Becoming aware is a major step in preventing plant disease problems. A long-standing principle in plant pathology is that action must be taken in advance to prevent disease problems. The goal of producing disease-free planting stock is also a responsibility, from a biological standpoint, that must be considered. There are several basic reasons for emphasis on producing disease-free planting materials. Clearly, the production of healthy planting stock is essential. It is important to avoid introduction of seed-borne pathogens to new field sites via planting stock. After outplanting, failure of the plant from a disease that did not express obvious symptoms during container culture is an important but more subtle problem. The responsibility to produce disease-free stock extends beyond the marketing stage of containerized plants.

How can an emerging native wildland plant industry organize itself to discharge this responsibility? Through an interaction of private, State, and Federal interests, an improved certification program should be developed. Certification of various plant attributes is already in progress at State and private concerns, plant introduction stations, and plant material centers across the West. The purpose here is to stress certification against plant disease. Benefits can be realized. Disease prevention should focus on certification in three basic areas: (1) seed-borne and vegetative-propagule-borne pathogens, (2) producing disease-free planting stock, both bare-root and containerized, and (3) a rigidly defined and controlled genetic base for seed collections.

Various methods have been used to prevent plant disease in container-grown planting stock. These methods have included seed certification, cultural sanitation, chemical seed treatment, pesticidal drenches, soil fumigation, heat treatment of planting media, vegetative propagule disease indexing, apical shoot tip culture, biological control, and pathogen suppressive growing media. These constitute a broad area of information; and this discussion will be limited primarily to cultural and biological means of producing 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 seed. Sanitation also is an essential factor in maintaining greenhouse and shadehouse environments and in seedling transport and planting.

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 pathogens are: Baker 1956, 1972; Baker and Smith 1966; and Harman 1983. Plant pathogens may accompany seed independently as spores, resting structures, host debris, infested soil, and nematode galls. They may be carried passively, attached to the surface of seed or fruit parts, or they may be carried internally, imbedded in host seed tissue.

Seed dissemination of pathogens is a natural biological mechanism that has evolved as a mode of transmission in space, from season to season and from plant generation to generation. Seed-borne pathogens are not always transmitted, but when they are, they are usually a source of severe loss. Viruses are frequently seed transmitted. They usually infect gametes and persist during seed development. Mechanically transmitted viruses infest seed coats and are then transmitted to seedlings. Bacteria commonly infect developing embryos. They also enter the seed through the funiculus and reside in cavities of the seed coat or on outer layers of the embryo and endosperm. Fungi have numerous mechanisms for infecting seed and transmission to seedlings. The smuts of grasses invade embryos, and Fungi Imperfecti commonly infect seed coats and pericarps.

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 (ergots) of *Claviceps* and seeds of *Orobanche* and *Cuscuta* that accompany seed can be removed by separation during seed cleaning. Externally borne pathogens can usually be controlled by surface chemical treatment, but internally borne pathogens are more difficult to control requiring penetrating chemicals. To some extent thermotherapy has been successful in killing internally borne pathogens. Hot water, dry hot air, and aerated steam have been used effectively to eliminate pathogens. Aerated-steam treatment of seed has promising advantages (Baker 1969). Temperature can be controlled more accurately, seeds are left drier, there is less leaching, there is less damage to seeds, and the margin between pathogen thermal death point and seed damage is wider.

Prevention of seed-borne pathogens begins in the field with production of disease-free plants. Other methods include apical meristem culture, indexing and certification. Certification programs should be organized to establish tolerance levels for seed-borne pathogens. In the emerging native wildland seed industry what is the status of knowledge on seed-borne pathogens? Has action been taken to establish even the potential of what is inevitable? In the wildland scene a sound program must begin with gaining knowledge of seed-borne pathogens and their recognition by the collector.

Greenhouse design

Having achieved acceptable control of seed-borne pathogens, the focus can then turn to seed germination and growth of containerized plants in greenhouse culture. Commonly, if not almost universally, prevention of plant disease is not considered in the design of greenhouses. Here again, enhancing sanitation to reduce sources of contamination should be the guideline. Greenhouses and adjoining headhouses are seldom designed by persons with insight into plant disease prevention. Although elaborate systems can be devised to exclude pathogens for special purposes, relatively simple design considerations can make big improvements in routine operations.

Contamination can be avoided or greatly reduced if, in the headhouse, container and equipment cleaning and preparation and media treatment activities are in a room separate from container filling and planting activities. These rooms should be separated by a buffer room to reduce contaminate passage. A vestibule should join the headhouse and greenhouse planting growing rooms to allow independent access to rooms with distinct activities (fig. 1). The usual single-room thoroughfare type headhouses or separate buildings that require outside transport of materials to greenhouses are unacceptable because contamination is likely.

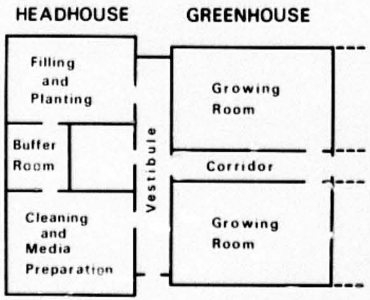

Figure 1.--Basic headhouse-greenhouse design for plant disease prevention.

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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.

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 pathogens on greenhouse floors.

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 avoided edges on which debris may accumulate (fig. 2). The base should also minimize areas where organic material can accumulate. The base should be easily removable for cleaning, decontamination, and treatment. An ideal system is to use removable boards impregnated with cooper-naphthenate. Periodically cleaning and treating boards achieves an essentially self-sterilizing base for containers (Baker 1957).

Watering Plants

Plant 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. Wildland plants present a special problem in this regard because of their innate variability. Wide variation in germination rate, growth rate, and form requires selective watering. The nonselectivity of large automatic watering systems is a particular problem. Many desirable western U.S. native plants are adapted to semiarid environments and grow in soils with extremely low water potentials compared to the average domesticated ornamental. Little literature is available on the specific soil water potential requirements of seedlings. The role of soil water potential and the ecology of plant pathogens have been studied for some agricultural plant diseases (Cook and Papendrick 1970). Some unpublished data on wildland shrubs (Welch and others, USDA Forest Service, Shrub Sciences Lab., Provo, Utah), indicate that various species, sagebrush for example, grown in 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.

Controlling Pathogens in Growing Media

Pathogen-free plant propagules 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 dynamically fluctuating equilibrium. The system is controlled by the unique physical, chemical, and biological environmental characteristics of specific soil and vegetative types (Baker 1961; Elton 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.

Containerized 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, sawdust, 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, 1961, 1965). Toxic chemicals are difficult to contain in greenhouse operations and their use may become legally complicated in urban areas. Toxic residues may remain even after long periods of aeration. Fumigants move through the soil in a concentration gradient resulting in nonuniform treatment. Broad spectrum fumigants such as cloropicrin and methyl bromide tend to "overkill" and result in biological vacuums. More specific fungicides, for example , PCNB, Dexon, carbon disulphide, 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 212° 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. Loss 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 1962a). With this system, air is injected into the steam mass, producing a lower temperature vapor (fig. 3). By careful adjustment of vapor temperature, organisms can be selectively eliminated from the soil. Parasitic organisms tend to have more specialized enzyme systems 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 140° F for 30 minutes, leaving a beneficial population of microorganisms (fig. 4). Remaining fungi, bacteria, and actinomycetes then increase in number and antagonistic members act to inhibit invasion by contaminate pathogens. Fungistatic soil factors are initially lowered, but return to normal. Any phytotoxins produced are at low levels. Fire molds or "weed fungi" 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.

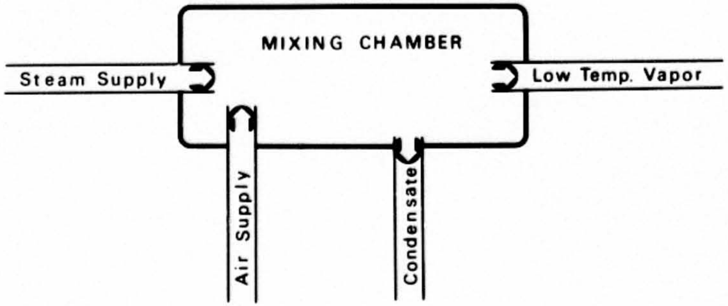

Figure 3.--Diagram illustrating the method of aerated-stream production for heat-treatment of plant growing media.

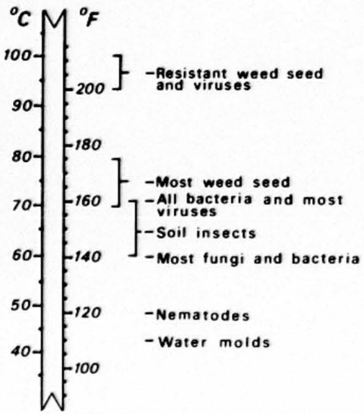

Figure 4.--Temperature scale illustrating the thermal death zones of plant pathogenic fungi, bacteria, viruses, and other soil organisms and weed seeds when subjected to moisture and heat, in most cases for 30 minutes (adapted from Baker 1957).

Aerated-steam treatment of soil is a prelude to and a valuable research tool in achieving biological control of soil-borne plant pathogens.

BIOLOGICAL CONTROL OF PLANT PATHOGENS IN CONTAINER MEDIA

The environment, host plant, and pathogen are not mutually exclusive. These three elements interact to result in plant disease. The host and pathogen are reciprocal biological environmental elements and also influence and are influenced by the physical environment. Cultural methods of managing plant disease are primarily directed toward manipulating the physical environment. The host plant, pathogen, and other biotic elements are the focus of biological control. The objective of biological control is not necessarily to eliminate disease, but to reduce it to a tolerable level.

Genetic Variability of Plants

Genetic resistance, tolerance, and susceptibility to pathogens are of fundamental importance in natural and manipulated biological control schemes. A basic difference exists in the genetic nature of wildland plants and domesticated plants. This is the native, relatively unaltered genetic variability of wildland plants. While this characteristic presents formidable problems for standardized cultural procedures, it is a virtue in providing disease resistance that must be rigidly protected. Variability is a basic factor in the survival and evolution of plant species. It must be protected at each step in the manipulation of native plants to be used for revegetation or range and wildlife habitat improvement. Methods used at each step must be studied carefully for impact on variability--from seed base selection, seed collection, seed cleaning, seed storage, pregermination treatment, and germination culture to seedling culture and plant establishment whether it be direct seeding or planting bare-root or containerized stock. Use of narrow line, vegetatively produced planting stock in wildland revegetation projects should be seriously questioned.

Cultural predisposition of container-grown plants to various pathogens is a two-fold problem in disease prevention. There could be loss from disease in containerized plant production or the potential for loss extended in time. If, for example, 50 percent of a native plant population is susceptible to a root rot when soil environment tends toward the anaerobic, one might predict predisposition to certain pathogens when container-grown plants are overwatered. The surviving population could then have a narrowed range of variability with which to confront their environment when outplanted.

To take advantage of naturally existing biological control systems now functioning in the wildlands of the West, it is important, in fact imperative, than an extreme effort is made to return revegetation plants (via containerized stock, bare-root, or seed) in near their native genetic state. Systematic seed collection methods need to be developed toward maximizing the preservation of the genetic amplitude of plant populations of interest. The plague of achieving disease resistance in agricultural plants has been the loss of native gene pools through the plant selection, improvement, and breeding sequence of domestication. Through history, plant pathologists and plant breeders have searched for lost genes by returning to native populations. Must the native wildland plant venture repeat the costly mistake of losing native variability?

Managing Biological Control

Biological control of soil-borne disease problems centers on manipulating antagonists and certain physical factors in the growing medium of container plants. Antagonistic activity occurs by parasitism, predation, competition for nutrients, and inhibitions from metabolic products of another organism (Baker and Cook 1974). Disease development may be suppressed in certain soils even though both pathogen and susceptible host are present (Baker and Cook 1974; Liu and Baker 1980). Both biological and nonbiological 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-grown plants (Henis and others 1979; Chet and Baker 1980; Scher and Baker 1980).

With the aerated-steam treatment method already mentioned, certain pathogens, but not all pathogens, can be selectively eliminated from soil. The common spore-forming bacterium Bacillus subtilis Cohn emend Praznowski is retained and proliferates, producing rather specific antibiotics that are antagonistic to reinvasion by strains of Rhizoctonia solani Kuhn, a common pathogen of container plants (Baker and others 1967; Olsen and Baker 1968). The degree of specificity characteristic of this bacterium limits broad application. Strains of the ectomycorrhizal fungus Laccria accata (Scop.:Fr.) Berk. & Br. protect Douglas fir (Pseudotsuga menziesii [Mirb.] Franco) against Fusarium oxysporum Schlect. emend Snyd. & Hans., which induces a root rot of seedlings (Sylvia and Sinclair 1983). 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 cimmamomi Rands, Rhizoctonia solani, and Fusarium oxysproum, respectively root rot, damping-off, and wilt inducers (Hoitink and others 1977; Nelson and Hoitink 1983; Chef and others 1983). A dual mechanism has been suggested, attributed to antagonistic fungi (for example, Trichoderma harzianum Rifai) and heat-stable chemical inhibitors. Modification of soil factors such as pH and moisture levels can induce suppressiveness in a conducive soil. Parasitism of Rhizoctonia by Trichoderma is enhanced with these modifications.

Container growing media containing native soils have the advantage of a more diverse, complex microbiota than soilless 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 soilless media to suppress specific pathogens there remains the risk of contamination and introduction of a second pathogen not influenced by the existing antagonists. In addition, the medium environment must be adapted to the selected antagonist. The potential for developing biological control with container-grown wildland plant diseases must exist. Existing 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--the battle goes on. Regardless and undoubtedly, sanitation and good housekeeping will continue to be in order.

PUBLICATIONS CITED

Baker, K. F. Development and production of pathogen-free seed of three ornamental plants. Plant Dis. Rep. Suppl. 238: 68-71; 1956.

Baker, K. F. ed. The U.C. system for producing healthy container grown plants. Manual 23. Berkeley, CA: University of California, Calif. Agr. Exp. Sta.; 1957. 332 p.

Baker, K. F. Control of root-rot diseases; section 5, the pathogenesis of root degeneration. In: Toronto: University of Toronto Press; Recent Advances in Botany 1: 486-490; 1961.

Baker, K. F. Principles of heat treatment of soil and planting material. J. Austr. Inst. Agric. Sci. 28: 118-126; 1962a.

Baker, K. F. Thermotherapy of planting material. Phytopathology. 52: 1244-1255; 1962b.

Baker, K. F. Disease-free plants. In: Symposium, a look into the future; 1965 October 26 and 27. Dedication of the Kenneth Post Laboratories, New York State Flower Growers, Inc., and Cornell University; The Kenneth Post Foundation; 1965. 9 p.

Baker, K. F. Aerated-steam treatment of seed for disease control. Hort. Res. 9: 59-73; 1969.

Baker, K. F. Seed pathology. In: Kozlowski, T. T., ed. Seed biology. Vol. 2. New York: Academic Press; 1972: 317-416.

Baker, K. F.; Cook R. J. Biological control of plant pathogens. San Francisco, CA: W. H. Freeman Co.; 1974. 433 p.

Baker, K. F.; Flentje, N. T.; Olsen, C. M.; Stretton, H. M. Effect of antagonists on growth and survival of Rhizoctonia solani in soil. Phytopathology. 57: 591-597; 1967.

Baker, K. F.; Smith, S. H. Dynamics of seed transmission of plant pathogens. Annu. Rev. Phytopathol. 4: 311-334; 1966.

Chef, D. G.; Hoitink, H. A. J.; Madden, L. V. Effects of organic components in container media on suppression of Fusarium wilt of chrysanthemum and flax. Phytopathology. 73: 279-281; 1983.

Chet, I.; Baker, R. Induction of suppressiveness to Rhizoctonia solani in soil. Phytopathology. 70: 994-998; 1980.

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

Elton, C. S. The ecology of invasions by animals and plants. New York: John Wiley and Sons; 1958. 181 p.

Harman, G. E. Mechanisms of seed infection and pathogensis. In: Symposium on deterioration mechanisms in seed; 73d annual meeting of the American Phytopathological Society; 1981 August 3; New Orleans, LA. Phytopathology. 73: 326-329; 1983.

Henis, Y.; Chaffer, A.; Baker, R. Factors affecting suppressiveness to Rhizoctonia solani in soil. Phytopathology. 69: 1164; 1979.

Hoitink, H. A. J.; VanDoren, D. M.; Schmitthenner, A. F. Suppression of Phytophthora cinnamomi in a composted hardwood bark potting medium. Phytopathology. 67: 561-565; 1977.

Liu, S.; Baker, R. Mechanism of biological control in soil suppressive to Rhizoctonia solani. Phytopathology. 70: 404-412; 1980.

Nelson, E. B., Hoitink, H. A. J. The role or microorganisms in the suppression of Rhizoctonia solani in container media amended with composted hardwood bark. Phytopathology. 73: 274-278; 1983.

Olsen, C. M.; Baker, K. F. Selective heat treatment of soil, and its effect on the inhibition of Rhizoctonia solani by Bacillus subtilis. Phytopathology. 58: 79-87; 1968.

Scher, F. M.; Baker, R. Mechanism of biological control in a Fusarium-suppressive soil. Phytopathology. 70: 412-417; 1980.

Sylvia, D. M.; Sinclair, W. A. Suppressive influence of Laccaria laccata on Fusarium oxyporum and on Douglas-fir seedlings. Phytopathology. 73: 384-389; 1983.

In: Murphy, Patrick M., compiler. The challenge of producing native plants for the Intermountain area: proceedings: Intermountain Nurseryman's Association 1983 conference; 1983 August 8-11; Las Vegas, NV. General Technical Report INT-168. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 96 p.

host tissues are quickly infected and colonized (Sutherland and Van Eerden 1980).

Within the disease cycle, the fungus may become inactive (latent) following conidial dispersal or infection (figure 1). However, when inoculum is abundant and environmental and host susceptibility conditions are conducive, "aggressive pathogenicity" occurs (Jarvis 1980a). Conducive environmental conditions include high relative humidity, cool temperatures, and free surface moisture on foliage. Host susceptiblity factors include nutrient imbalances causing seedling stress and presence of senescent tissues for saprophytic buildup of inoculum (Sutherland and Van Eerden 1980). When conditions for infection are ideal and inoculum abundant, latent periods are short and epidemics can occur quickly (Jarvis 1980a).

Symptoms of *Botrytis* infection usually become apparent when crowns of conifer seedlings begin to close and affected seedlings usually occur in isolated pockets (Gillman and James 1980; James and others 1982). The fungus usually first attacks senescent tissues at the base of seedlings and then spreads to surrounding live host material (Smith and others 1975; Sutherland and Van Eerden 1980). Symptoms on infected seedlings include needle necrosis, twig and stem lesions, and mortality.

MANAGEMENT

Controlling Botrytis blight is difficult because the pathogen is capable of attacking all plant parts at almost any stage of their growth and in storage (Maude 1980). The best approach to control is to avoid conditions that are suited for disease buildup. This includes controlling stocking by reducing density to improve air circulation among seedlings (Cooley 1981), which means producing fewer trees per unit area. However, this is compensated by higher quality, disease-free seedlings. If possible, irrigation during periods of host susceptibility should also be limited (Cooley 1981). Adding drying agents to irrigation water to expedite drying of foliage may also help reduce infection. Fertilization should also be done properly. For example, too much fertilizer may cause seedlings to burn, providing ideal infection courts for *Botrytis* (Sutherland and Van Eerden 1980), and too little fertilizer may stress seedlings making them more susceptible to infection (Cooley 1981). Another important cultural practice to reduce loss from Botrytis blight is sanitation, aimed primarily at reducing inoculum. Sanitation practices include periodic removal of infected plants and plant debris, and cleaning greenhouse benches and floors with a surface sterilant between crops (Cooley 1981). Potential inoculum sources outside greenhouses, especially those upwind, should be eliminated when possible.

As containerized production of conifers has increased, Botrytis blight has become more important. As a result, many growers have had to rely on fungicides to keep losses at acceptable levels. Several fungicides either used operationally or showing promise for future use are listed in table 1. Some of the more important of these are discussed below.

Benomyl is a systemic fungicide that has been used operationally since the early 1970's. When it was first introduced, benomyl provided excellent control of many diseases over a wide range of crop plants. As a result, many growers began to use it exclusively to control Botrytis blight, especially in greenhouses (McCain 1978; Miller and Fletcher 1974). However, as early as 1971 tolerance to benomyl by *Botrytis* was evident (Bollen and Scholten 1971). Since then, there have been many reports of tolerance to this fungicide by different pathogens on a variety of crops including ornamental flowers, vegetables, fruit crops, and conifer seedlings (Cooley 1981; Gillman and James 1980; James and Gilligan 1983; Jarvis and Hargreaves 1973; Miller and Fletcher 1974). Simple tests have been developed to quickly assay presence of tolerant fungal strains. These involve growing the test organisms on nutrient media amended with the fungicide. Such tests have been used to evalute tolerance of *Botrytis* strains to benomyl and other fungicides throughout the West. Results indicate that tolerance of *Botrytis* to benomyl is so widespread that this chemical is usually ineffective and no longer recommended for use in most nurseries (Cooley 1981; Gillman and James 1980; James and Gilligan 1983).

Chlorothalonil is another fungicide that has been commonly used to control *Botrytis* in greenhouses. However, its ability to adequately control the disease has often been reduced, especially after continued use (James and Gilligan 1983). Recent tests indicate that some *Botrytis* populations in Oregon, Montana, and Colorado are tolerant to chlorothalonil (Cooley 1981; Gillman and James 1980; James and Gilligan 1983). Although tolerance to chlorothalonil is not as widespread as with benomyl, it is fairly common and has been shown to develop quickly in greenhouses (James and Gilligan 1983).

Captan is a general protective fungicide that is fairly effective against *Botrytis* (James and others 1982). However, tolerant strains to this fungicide have also been shown to exist (Cooley 1981; Gillman and James 1980; James and Gilligan 1983; Parry and Wood 1959).

Dicloran is an effective fungicide against *Botrytis* diseases (James and others 1982), even though tolerance of natural *Botrytis* strains has been found (Cooley 1981; Gillman and James 1980; James and Gilligan 1983; Webster and others 1970). Tolerant strains of the fungus can also easily develop in the laboratory (James, unpublished). Therefore, dicloran should not be used repeatedly unless rotated with other fungicides.

Two relatively new fungicides should also be mentioned. Iprodione was originally developed for turf diseases (Danneberger and Vargas 1982; Sanders and others 1978) and shows strong toxicity towards *Botrytis* (Pappas and Fisher 1979; Powell 1982). Vinclozolin is a chemical with specific action against *Botrytis* and related fungi (Pappas and Fisher 1979; Ritchie 1982). Iprodione has been tested against Botrytis blight of conifers and shows excellent promise (James and others 1982). Vinclozolin was also tested, but showed extensive phytotoxicity to western larch seedlings at label rates (James and Genz 1983). Both fungicides require more field tests and need to be registered for use on conifers. Previous tests (Cooley 1981; James and Gilligan 1983; Leroux and others 1977; Pappas and others 1979) indicate that strains of *Botrytis* tolerant to ipriodione and vinclozolin exists, although not in large numbers. Tolerant strains can also develop rapidly to these fungicides in the laboratory (James, unpublished).

Apparently none of the fungicides currently available can be considered completely effective against all *Botrytis* strains likely to be encountered. As a result, fungicide useage should be limited to the minimum amounts necessary for effective disease control. Also, different fungicides should be used in rotation so as not to exert selective pressure on *Botrytis* populations to develop tolerance. Rotated fungicides should have different modes of action, i.e. systemic chemicals alternated with broad spectrum protectants (Cooley 1981; James and Gilligan 1983).

For effective control of Botrytis blight, cultural practices, such as better sanitation, providing adequate air circulation, and reducing irrigation, should be combined with rotated use of different fungicides. Cultural practices can reduce fungal inoculum and alter environmental conditions necessary for infection, whereas fungicides can protect susceptible plant tissues from infection. The combination of both procedures is necessary for an effective control strategy.

Table 1.--Fungicides used to control Botrytis blight in containerized conifer nurseries.

Fungicide	Trade names	Manufacturers	Chemical name
benomyl	Benlate® Tersan 1991® Benomyl	Dupont Lilly Miller	Methyl-1-(butylcarbamoyl)-2 benzimidazole carbamate
captan	Captan Orthocide®	Stauffer Chevron	N-[(Trichloromethyl)thio]-4-cyclohexene-1, 2-dicarboximide
chlorothalonil	Bravo 500® Daconil 2787®	Diamond Shamrock	Tetrachloroisophthalonitrile
copper	Tri-Basic®	CP Chemical Phelps-Dodge Cities Service	Basic copper sulfate
dicloran	Botran®	Tuco	2,6-Dichloro-4-nitroaniline
ferbam	Carbamate	Dupont	ferric dimethyldithiocarbmate
iprodione	Chipco 26019® Rovral®	Rhone-Poulenc	3(3,5-dichlorophenyl)-N-(1-methylethyl)-2,4-dioxo-1-imidazolidinecarboximide
mancozeb	Fore®	Dupont	Contains 16% maganese, 2% zinc and 62% ethylenebisdithiocarbamate ion/maganese ethylenebisdithiocarbamate plus zinc ion.
maneb	Dithane M-45®	Rhom & Haas	maganese ethylene bisdithiocarbamate
thiophanate-methyl	Zyban®	Mallinckrodt	dimethyl[(1,2-phenylene)bis(iminocarbonothyioyl)]bis (carbamate)
thiram	Thylate®	Dupont	Tetramethylthiuram disulfide
vinclozolin	Ronilan® Ornalin®	BASF Mallinckrodt	3-(3,5-dichlorophenyl)-5-ethenyl-5-methyl-2,4-oxazolidinedione
zineb	Zineb Dithane 278®	Rhom & Haas	zinc ethylenebisdithio-carbamate

PUBLICATIONS CITED

Blakeman, J. P. Behaviour of conidia on aerial plant surface. In: Coley-Smith, J. R.; Verhoeff, K.; Jarvis, W. R., eds. The biology of *Botrytis*. London: Academic Press; 1980: 115-151.

Bollen, G. J.; Scholten, G. Acquired resistance to benomyl and some other systemic fungicides in a strain of *Botrytis cinerea* in cyclamen. Net. J. Pl. Path. 77: 80-90. 1971.

Coley-Smith, J.R. Sclerotia and other structures of survival. In: Coley-Smith, J. R.; Verhoeff, K.; Jarvis, W. R., eds. The biology of *Botrytis*. London: Academic Press; 1980: 85-114.

Cooley, S. J. Fungicide tolerance of *Botrytis cinerea* isolates from conifer seedlings. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region; 1981. 13 pp.

Danneberger, T. K.; Vargas, J. M., Jr. Systemic activity of iprodione in *Poa annua* and post-infection activity for *Drechslera sorokiniana* leaf spot management. Plant Disease 66(10): 914-915. 1982.

Gillman, L. S.; James, R. L. Fungicidal tolerance of *Botrytis* within Colorado greenhouses. Tree Planters' Notes 31(1): 25-28. 1980.

James, R. L. Engelmann spruce needle blight at the Coeur d'Alene nursery, Idaho. Rept. 80-21. Missoula, MT: U. S. Department of Agriculture, Forest Service, Northern Region; 1980. 5 pp.

James, R. L.; Genz, D. Fungicide tests to control Botrytis blight of containerized western larch at the Champion Timberlands Nursery, Plains, Montana. Rept. 83-12. Missoula, MT: U. S. Department of Agriculture, Forest Service, Northern Region; 1983. 7 pp.

James, R. L.; Gilligan, C. J. Fungicidal tolerance of *Botrytis cinerea* from the Flathead Indian Reservation greenhouse, Ronan, Montana. Rept. 83-5. Missoula, MT: U. S. Department of Agriculture, Forest Service, Northern Region; 1983. 15 pp.

James, R. L.; Woo, J. Y.; Malone, P. Evaluation of fungicides to control Botrytis blight in western larch seedbeds at the Coeur d'Alene nursery, Idaho. Rept. 83-6. Missoula, MT: U. S. Department of Agriculture, Forest Service, Northern Region; 1983. 8 pp.

James, R. L.; Woo, J. Y.; Myers, J. F. Evaluation of fungicides to control Botrytis blight of containerized western larch and lodgepole pine at the Coeur d'Alene nursery, Idaho. Rept. 82-17. Missoula, MT: U. S. Department of Agriculture, Forest Service, Northern Region; 1982. 13 pp.

Jarvis, W. R. Epidemiology. In: Coley-Smith, J. R.; Verhoeff, K.; Jarvis, W. R., eds. The biology of *Botrytis*. London: Academic Press; 1980a: 219-250.

Jarvis, W. R. Taxonomy. In: Coley-Smith, J. R.; Verhoeff, K.; Jarvis, W. R., eds. The biology of *Botrytis*. London: Academic Press; 1980b: 1-18.

Jarvis, W. R.; Hargreaves, A. J. Tolerance to benomyl in *Botrytis cinerea* and *Penicillium corymbiferum*. Plant Pathology 22: 139-141. 1973.

Leroux, P.; Fritz, R.; Gredt, M. Etudes en laboratoire de souches de *Botrytis cinerea* Pers., resistantes á la dichlozoline, au dichloran, au qunitozene, á la vinchlozoline et au 26019 RP (ou Glycophene). Phytopathol. Z. 89: 347-348. 1977.

Maude, R. B. Disease control. In: Coley-Smith, J. R.; Verloeff, K.; Jarvis, W. R., eds. The biology of *botrytis*. London: Academic Press; 1980: 275-306.

McCain, A. H. Nursery disease problems - containerized nurseries. In: Gustafson, R. W., ed. Western forest nursery council and Intermountain Nurseryman's Association: conference and workshop proceedings; Eureka, CA; 1978: B139-142.

McCain, A. H.; Smith, P. C. Evaluation of fungicides for control of Botrytis blight of container-grown redwood seedings. Tree Planters' Notes 29(4): 12-13. 1978.

Miller, M. W.; Fletcher, J. T. Benomyl tolerance in *Botrytis cinerea* isolates from glasshouse crops. Trans. Br. Mycol. Soc. 62(1): 99-103. 1974.

Pappas, A. C.; Cooke, B. K.; Jordan, V. W. L. Insensitivity of *Botrytis cinerea* to iprodione, procymidone and vinclozolin and their uptake by the fungus. Plant Pathology 28(1): 71-76. 1979.

Pappas, A. C.; Fisher, D. J. A comparison of the mechanisms of actions of vinclozolon, procymidone, iprodione and prochloraz against *Botrytis cinerea*. Pesticide Science 10: 239-246. 1979.

Parry, K. E.; Wood, R. K. S. The adaptation of fungi to fungicides: adaptation to captan. Ann. Appl. Biology 47(1): 1-9. 1959.

Powell, C. C. New chemicals for managing disease on glasshouse ornamentals. Plant Disease 66(2): 171. 1982.

Ritchie, D. F. Effect of dicloran, iprodione, procymidone, and vinclozolin on the mycelia growth, sporulation, and isolation of resistant strains of *Monilinia fructicola*. Plant Disease 66(6): 484-486. 1932.

Sanders, P. L.; Burpee, L. L; Cole, H., Jr.; Duich, J. M. Control of fungal pathogens of turf grass with the experimental iprodione fungicide, R. P. 26019. Plant Dis. Reptr. 62(6): 549-553. 1978.

Smith, R. S., Jr.; McCain, A. H.; Srago, M. D. Control of Botrytis storage rot of giant sequoia seedlings. Plant Dis. Reptr. 57(1): 67-69. 1973.

Sutherland, J. R.; E. Van Eerden. Diseases and insect pests in British Columbia forest nurseries. Joint Rept. No. 12. British Columbia Ministry of Forests, Canadian Forestry Service; 1980. 55 pp.

Webster, R. K.; Ogawa, J. M.; Bose, E. Tolerance of *Botrytis cinerea* to 2,6-Dichloro-4-nitroaniline. Phytopathology 60(10): 1489-1492. 1970.

In: Murphy, Patrick M., compiler. The challenge of producing native plants for the Intermountain area: proceedings: Intermountain Nurseryman's Association 1983 conference; 1983 August 8-11; Las Vegas, NV. General Technical Report INT-168. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 96 p.

SALT TOLERANCE OF 10 DECIDUOUS SHRUB AND TREE SPECIES

Richard W. Tinus

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 with conductivity of 1.6, 4.5, 7.2, 12.1, and 16.6 mmhos/cm. Honeysuckle, crabapple, lilac, and American plum were salt sensitive. Buffaloberry, Russian olive, and chokecherry were moderately sensitive. Green ash, juneberry, and caragana were tolerant.

INTRODUCTION

Tree nurseries in western North America frequently have salt-affected soils and salty irrigation water (Tinus 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 shelterbelts 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 shelterbelts (Carter 1980; 1979). Most of what is available is on crop plants (Richards 1954; Branson 1978; Maas and Hoffman 1977; Rathert and Doering 1981) and horticultural varieties of shrubs and fruit trees (Bernstein and others 1972; Dirr 1974; Francois and Clark 1978; Maas and Hoffman 1977; Townsend 1980; Pasternak and Forti 1980). The objective of this study was to provide guidelines on salt tolerance of a variety of species commonly used for shelterbelts 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 (1974).

Seed was germinated in petri dishes containing filter paper, 100 seed per dish, five dishes per species. Each of the five dishes per species was moistened with one of the nutrient solutions plus sodium chloride, sulfate, and bicarbonate listed in table 1.

The dishes were covered, enclosed in plastic bags to retard evaporation, and placed in a germinator with a 12-hour day (fluorescent light) at 30° C and a 12-hour night at 20° C. Humidity ranged from 60 to 100 percent.

Germinants were counted and removed every few days, and moisture was replenished as needed with distilled water. The experiment was terminated after 45 days. Total germination and germination energy (average percent per day to 50 percent of maximum germination) were calculated. Significant differences between salt levels within species were determined by Goodman's (1964) test.

Experiment 2.--Seedling Growth

Fifty Colorado State styroblocks, each with 30 cavities with a volume of 400 ml per cavity, were filled with 1:1 peat-vermiculite plus 5 percent forest duff to inoculate with endomycorrhizal fungi. Three seeds were planted in each cavity, five blocks for each of the 10 species. The blocks were arranged on greenhouse benches in randomized groups of 10, one block of each species. Each group was watered as needed with a nutrient solution plus sodium sulfate, chloride, and bicarbonate calculated to have an electrical conductivity (EC) of 1.6, 4.5, 7.2, 12.1, and 16.6 mmhos/cm (table 1). The soil salinity of the Lincoln-Oakes Nurseries at Bismark, N.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-Oakes, which has EC of 1,500 mmhos (about 1,000 ppm solids) and is rated "suitable for limited irrigation." Water supplies of other nurseries vary in composition considerably, but these ions 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 appreciable growth restriction, and differences between seedlings watered with 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 measurement, 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 Hewlett-Packard 9825A family regression program (General Statistics Vol. I, tape 09825-15004). The one with the highest r^2 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 2). Germination energy of buffaloberry declined steadily with increasing salt concentration, but total germination remained high through 12.1 mmhos/cm. Total germination of green ash and honeysuckle declined somewhat, and germination energy was greatly reduced by high salt concentration. Total germination and

Table 1.--Composition of nutrient and salt solutions in parts per million

Component	Solution number 1	2	3	4	5
EC (mmhos/cm)	1.6	4.5	7.2	12.1	16.6
N as NO_3^-	229	224	220	211	202
N as NH_4^+	67	66	64	62	59
P as $H_2PO_4^-$	27	27	26	25	24
K^+	155	152	149	143	136
S as $SO_4^=$	142	139	136	131	125
Ca^{++}	212	208	204	195	187
Mg^{++}	48	47	46	44	42
Fe^{+++}	4	4	4	4	4
B as H_3BO_3	0.5	0.5	0.5	0.5	0.5
Mn^{++}	0.5	0.5	0.5	0.5	0.5
ZN^{++}	0.05	0.05	0.05	0.05	0.05
CU^{++}	0.02	0.02	0.02	0.02	0.02
Mo as $MoO_4^=$	0.01	0.01	0.01	0.01	0.01
Na^+	0	786	1,572	3,144	4,716
Cl^-	4	105	210	420	630
$SO_4^=$	0	922	1,844	3,688	5,532
HCO_3^-	0	732	1,464	2,928	4,392
TOTAL	889	3,416	5,943	10,998	16,052

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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.

Species	Total germination					Germination energy				
	Solution conductivity (mmhos/cm)					Solution conductivity (mmhos/cm)				
	1.6	4.5	7.2	12.1	16.6	1.6	4.5	7.2	12.1	16.6
	percent					percent/day				
Lilac (*Syringa vulgaris* L.)	73 a	54 b	40 c	19 d	1 e	1.63	1.13	0.82	0.33	0.02
Crabapple (*Malus baccata* (L.) Borkh.)	40 a	24 b	12 c	4 d	3 d	1.23	0.56	0.32	0.09	0.06
Honeysuckle (*Lonicera tatarica* L.)	33 a	30 ab	22 b	6 c	5 c	0.79	0.94	0.76	0.24	0.22
Green ash (*Fraxinus pennsylvanica* Marsh.)	88 a	71 c	80 b	61 d	58 d	4.2	2.7	2.9	2.0	1.4
Caragana (*Caragana arborescens* Lam.)	87 b	96 a	85 bc	75 c	89 ab	5.4	4.8	7.1	3.5	3.5
Russian olive (*Eleagnus angustifolia* L.)	84 c	94 b	100 a	62 d	82 c	10.4	7.4	8.1	4.7	6.5
Buffaloberry (*Shepherdia argentea* (Pursh) Nutt.)	90 a	91 a	78 b	86 a	66 c	11.3	9.7	8.4	6.5	2.6

2/6

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 mmhos/cm

				Regression quality (r^2)		
Species	Height	Leaf length	Percent survival	Height	Leaf length	Percent survival
	- - - -	mmhos/cm	- - - -			
Honeysuckle (Lonicera tatarica L.)	2.2	3.3	3.3	.55	.32	.71
Crabapple (Malus baccata (L.) Borkh.)	2.6	6.0	--[1]	.54	.67	NS
Lilac (Syringa vulgaris L.)	3.6	4.1	15.7	.70	.71	.92
American plum (Prunus americana Marsh.)	6.3	7.1	5.0	.35	.78	.69
Buffaloberry (Shepherdia argentea (Pursh) Nutt.)	7.6	8.2	>16.6	.33	.29	.33
Russian olive (Eleagnus angustifolia L.)	8.3	>16.6	>16.6	.30	.18	NS
Chokecherry (Prunus virginiana L.)	8.7	9.6	>16.6	.30	.60	NS
Green ash (Fraxinus pennsylvanica Marsh.)	11.7	8.6	>16.6	.42	.30	NS
Juneberry (Amelanchier alnifolia (Nutt) Nutt.)	11.8	14.5	>16.6	.51	.36	NS
Caragana (Caragana arborescens Lam.)	>16.6	5.1	>16.6	.07	.23	NS

[1] Regression equation not meaningful.

germination energy of crabapple and lilac declined precipitously with the first increment of salt, and germination was almost nil at 16.6 mmhos/cm.

Experiment 2.--Seedling Growth

Table 3 lists the 10 species tested in order of increasing salt tolerance as measured by height growth. As expected, leaf length was reduced by about the same degree as stem height (Sepaskhah and Boersma 1979), except that leaf length response of Russian olive was more nearly in keeping with field observation than height response. Russian olive has a reputation for being highly salt tolerant. Bernstein and others (1972) report that the salt tolerance of a related species, silverberry (Eleagnus pungens), is also high; the threshhold for reduction of growth in silverberry is 9.4 mmhos/cm. Caragana also showed high salt tolerance when measured by height reduction, but not when measured by leaf length. It is possible that reduced leaf length is part of the species' adaptive reaction to moisture stress. This agrees with field observations because caragana flowers and grows vigorously in early summer, when moisture is normally adequate, but yellows and begins dropping its leaves in August, when moisture stress is frequently high.

As with germination, height growth and leaf length of honeysuckle, crabapple, and lilac decreased rapidly with increasing salt. Maas and Hoffman (1977) also report that apple (Malus sylvestris L. Mill) is salt sensitive. American plum was sensitive, as expected, in comparison with Prunus domestica (Richards 1954; Maas and Hoffman 1977), but chokecherry (Prunus virginiana L.) was surprisingly tolerant, especially with respect to survival.

Once established, most species survived well at much higher salt concentrations than were required to suppress growth. Exceptions were honeysuckle and American plum. Survival information is thus useful to tree planters for site selection, but

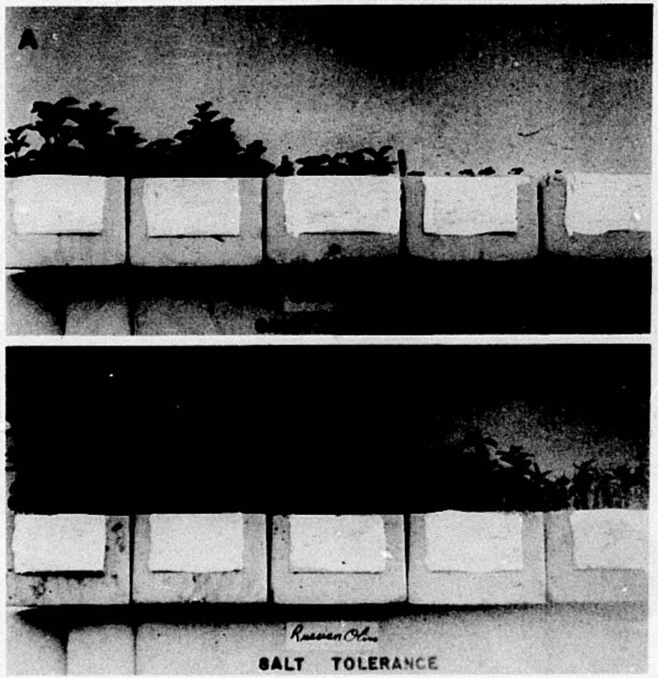

Figure 1.--Decreasing growth with increasing salt concentration (measured by EC) of (A) lilac, a salt sensitive species and (B) Russian olive, a salt tolerant species.

not to nurserymen, whose product must reach a certain size within one or two growing seasons.

Because of the need to keep this experiment small and simple, only one germinating dish of 100 seed and only one block of 30 seedlings per species per treatment was used. For statistical purposes, the individual seed or seedling was treated as the unit of replication. Strictly speaking, however, there was no replication. Furthermore, variability was great, and the regression equations used yielded confidence limits so great that only the broadest comparisons between species can be made. Thus, although the results were quite obvious even without measurement (fig. 1), they should be considered indicative and not definitive.

CONCLUSIONS AND RECOMMENDATIONS

1. Crabapple, lilac, American plum, and honeysuckle are sensitive to salt. They should not be grown at a nursery with salty irrigation water or soil nor outplanted into salty soils.
2. Buffaloberry, Russian olive, chokecherry, green ash, juneberry, and caragana are salt tolerant. Their growth should not be limited at most western nurseries because of salt problems, and they should be able to tolerate the saltiness of most western soils where shelterbelts are planted.

PUBLICATIONS CITED

Bernstein, L.; Francois, L. E.; Clark, R. A. Salt tolerance of ornamental shrubs and ground covers. J. Am. Soc. Hortic. Sci. 97(4): 550-556; 1972.

Branson, R. L. Soluble salts, exchangeable sodium, and boron in soils. In: Reisenauer, ed. Soil and plant tissue testing in California; University of California, Division of Agricultural Science Bull. 1879: 42-45; 1978.

Carter, M. R. Iron chlorosis of Colorado spruce and Scots pine. In: Indian Head Nursery 1979 annual report, Prairie Farms Rehabilitation Administration, Indian Head, Saskatchewan; 1979: 35.

Carter, M. R. Effects of sulfate and chloride soil salinity on growth and needle composition of Siberian larch. Can. J. Plant Sci. 60: 903-910; 1980.

Dirr, M. A. Tolerance of honeylocust seedlings to soil-applied salts. HortScience 9(1): 52-54; 1974.

Francois, L. E.; Clark, R. A. Salt tolerance of ornamental shrubs, trees and iceplant. J. Am. Soc. Hortic. Sci. 103: 280-283; 1978.

Goodman, Les. Simultaneous confidence intervals for contrasts among multinomial populations. Annals of Math. Stat. 35(2): 716-725; 1964.

Maas, E. V.; Hoffman, G. J. Crop salt tolerance--current assessment. Journal of the Irrigation and Drainage Division. Proceedings of the American Society of Civil Engineers 103(IR2): 115-134; 1977.

Nassery, H. Salt-induced loss of potassium from plant roots. New Phytol. 83: 23-27; 1979.

Pasternak, D.; Forti, M. A technique for early selection of salt-resistant plants. In: Ben-Gurion University of the Negev, Research and Development Authority, Applied Research Institute, Scientific Activities 1978-79. Beer-Sheva, Israel; 1980: 59.

Rathert, G.; Doering, H. W. Influence of extreme K:Na ratios and high substrate salinity on plant metabolism of crops differing in salt tolerance. J. Plant Nutrition 4(3): 261-277; 1981.

Richards, L. A., ed. Diagnosis and improvement of saline and alkali soils. Agric. Handb. 60. Washington, DC: U.S. Department of Agriculture; 1954. 160 p.

Schopmeyer, C. S., technical coordinator. Seeds of woody plants in the United States. Agric. Handb. 450. Washington, DC: U.S. Department of Agriculture; 1974. 883 p.

Sepaskhah, A. R.; Boersma, L. Elongation of wheat leaves exposed to several levels of matric potential and NaCl-induced osmotic potential of soil water. Agron. J. 71(5): 848-852; 1979.

Tinus, R. W. Nature and management of pH and salinity. In: Proceedings of North American Forest Tree Nursery Soils Workshop; 1980 July 28-August 1; Syracuse, NY. USDA Forest Service, Canadian Forestry Service and State University of New York; 1980: 72-86.

Townsend, A. M. Response of selected tree species to sodium chloride. J. Am. Soc. Hortic. Sci. 105(6): 878-883; 1980.

In: Murphy, Patrick M., compiler. The challenge of producing native plants for the Intermountain area: proceedings: Intermountain Nurseryman's Association 1983 conference; 1983 August 8-11; Las Vegas, NV. General Technical Report INT-168. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 96 p.

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 orders have been reduced for two years at our operations, and we see 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 by sharing what we are doing in the Northwest, you might get an idea or two that you can apply at your operations.

GREENHOUSES

The average production facility in the Northwest produces from two to four million seedlings per year, although two facilities produce over eight million per year. Private timber companies own and operate the largest container complexes for their own forest regeneration needs. They also compete for public regeneration contracts. The greenhouse layouts and designs differ based 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. Common regimes call for heating the greenhouse to 20 C., through May and minimal heating from October through January. Passive cooling through roof vents or active cooling with exhaust fans and evaporative coolers occurs during the hotter hours of June through September. Therefore, the structure must facilitate both heating and cooling to provide proper growing conditions throughout the year.

ENERGY

Fuel represents up to 15 percent of the cost of our seedlings. Several operations have made significant reductions in their fuel bills by sowing 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, but the cost to collect and use the limited solar radiation we receive does not compete with gas at this time. A recent greenhouse energy conservation technique is being used by The Bureau of Land Management at Colton, Oregon. The BLM 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 T-bars, and aisle eliminating bench tops. The most popular container type is the Styroblock in either the 2A or the 4A size. Commonly seedlings grown in a 2A are transplanted to become plug-1's, and 4A's, are shipped directly to the forest. Other containers have been used such a Leech tubes for genetic stock or Spencer-Lemaire books for *Thuja*, but the most common container type is the Styroblock.

SOWING AND FERTILIZING

Most of us sow with some type of vacuum sower which picks up one seed per hole from a tray of seed. The seed then falls into the cell when the vacuum is broken. It is most common to multiple sow to ensure a germinant in each cell and then to thin. Soluble fertilizers are mixed according to each grower's preference and injected into the watering system. Fertilizer regimes vary according to species, time of year, and nutrient status as indicated by foliar and soil analysis. Most growers contract their soil and foliar analysis with a private consultant. As is common with many plants, the growth curve of most conifer species that we grow is a sigmoid curve. Growth starts slowly, gradually 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

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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 mop-like which can more easily 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 leeched, 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 one week later the seedlings are packaged 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 liftable 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. Omi

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 two other cooperatives (tree improvement and vegetation management) in the Department of Forest Science are aimed at helping to solve reforestation 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. Planning is in progress for a long-term Cooperative study examining the effects of selected herbicides on weeds 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 compaction, tilth, and drainage), and (6) a seedling 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 and report on the status of forest nursery management technology in the Pacific Northwest. The task force found that the forest nursery industry wanted more research and educational assistance, and proposed that a Nursery Technology Center be established at OSU to address these needs. The Nursery Technology Cooperative (NTC) was officially established July 1, 1982.

Objective

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 are:

1. Better nursery-specific cultural prescriptions for the improvement of seedling physiological quality.
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.

Why Cooperatives?

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 genetics 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 aid in the better utilization of improved seed and the matching of high quality seedlings to planting sites. At the outplanting stage the CRAFTS Cooperative, headed by Steven Radosevich, helps 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 cooperator to study these problems.
3. Investigate treatment x site interactions.

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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 Leader on 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 membership fees) are: (1) nurseries (large--$6,000 and small--$3,000), (2) seedling users (full--$4,000 and monitoring--$2,000), and (3) specialist organizations ($2,000 to $4,000). All members (except for the seedling user monitoring 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.

Figure 1.--Top pruning with a rotary mower at the D.L. Phipps Forest Nursery (Oregon State Department of Forestry).

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 2+0 Douglas-fir seedling morphology, survival, and growth. Top pruning is a common practice in western nurseries (fig. 1); however, there is little available information about the effects of top pruning. Treatments for the experiment include two different pruning heights, two different times of application, and one multiple pruning. The entire experiment, with one seed zone was replicated at three nurseries; a smaller version, involving fewer treatments, was included so that more seed sources could be tested. In total, six nurseries (fig. 2) and nine seed zones are involved in the study. Test seedlings from each seed zone will be planted on sites located within their respective zones. 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 outplanted seedlings will be monitored for up to three years.

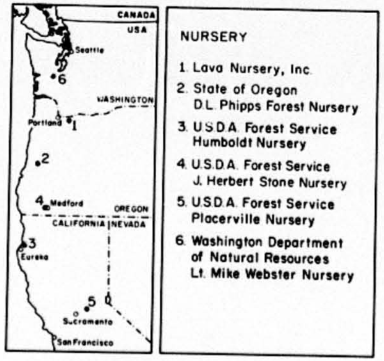


Figure 2.--Map showing the location of the six nurseries where the top pruning study has been installed.

Weed control.--Planning is in progress for a long-term Cooperative study that will examine the effect of selected herbicides on weeds and seedlings. Presently used methods of weed control (e.g., handweeding, fumigation) are costly and may be detrimental to tree seedlings and soil microorganisms. The objective of this study will be to screen new and currently available herbicides for their effectiveness in controlling weeds without injuring conifer seedlings. Additionally, we want to determine the residual effect of herbicides on weeds and crop species.

Other Cooperative Projects

Two other OSU projects are connected with the NTC: the Nursery Pathology Research Project, headed by Everett Hansen, and the Tissue Culture/Vegetative Propagation Project, headed by Joe Zaerr. Both projects are meeting Cooperative objectives, although both are funded by sources other than 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 top blight diseases that have caused substantial loss in recent years. In preliminary work, systematic isolations have been made from blighted seedlings at a Pacific Northwest nursery to identify suspected pathogens. These isolates, plus those from three other participating nurseries, will be tested for pathogenicity. Timing, environmental, and predisposing factors that influence infection will be determined for the identified pathogens.

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 cultures and 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 cultured buds. Cytokinins, another class of growth hormones, were measured in suspension cultures of Douglas-fir. The results of these studies indicate that the growth hormone requirements for embryogenesis (producing whole plants from cell cultures) probably are very specific, and that the growth hormones that have been used in previous attempts to produce embryogenesis are probably not the ones that should be used.

Future work will include a broadening of the objective to include other methods of propagation, such as the rooting of cuttings, and the problems associated with those techniques.

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. 3). A comprehensive survey of Northwest nurseries provided the authors of each chapter with information on current cultural practices. In addition, each chapter contains a state-of-the-art review of nursery research. A workshop held at OSU in October, 1982 previewed the manual for over 250 people. The manual will be published this summer, 1983. Both the Manual and the workshop have been co-sponsored with the USDA Forest Service, State and Private Forestry, Region 6.

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 30-chapter Forest Nursery Manual.

Seedling Physiology and Reforestation Success will be the title of the Physiology Working Group Technical Session to be held at the Society of American Foresters (SAF) National Convention in Portland this October, 1983. The one-day session will include both overview and specific research reports concerning the effects of seedling physiology on reforestation success, with major emphasis on stock quality and planting site manipulation. The proceedings of the session will be published in 1984.

Technical Assistance

As part of our commitment to improve information flow and technical assistance, we are compiling lists of specialists who would like to help nurseries and reforestation people. Questionnaires (fig. 4) have already been sent to insect/disease, soils, weed control, and irrigation specialists, seedling physiologists, and silviculturists. A very positive response has been received--many have expressed a strong desire to be involved in workshops, Cooperative studies, and problem solving. Other specialists who will be contacted include agricultural and industrial engineers, seed physiologists, crop scientists, and horticulturists. The list of specialists for insect and disease, soil, and irrigation problems have been sent to Cooperative members.

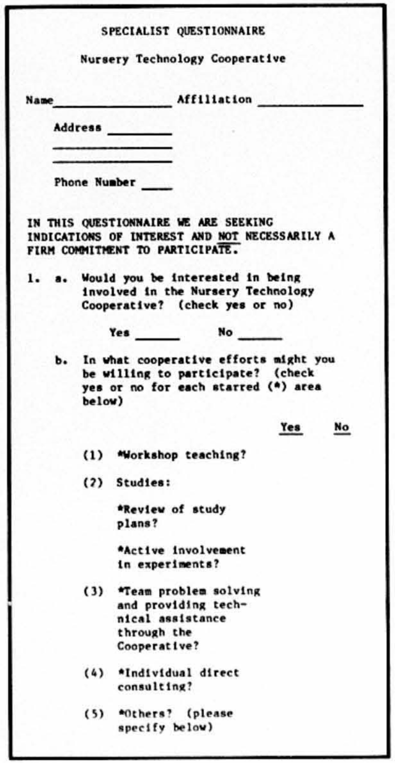
Members are encouraged to contact specialists directly from these lists when the need for technical assistance arises. However, they may also receive help from the NTC staff in making contacts with specialists by stating their specific problem on a Technical Assistance Request Form. The NTC staff responds 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 (tilth/compaction/drainage) has been selected as the problem area in which information gathering is currently needed. The NTC staff is presently reviewing the literature and collecting relevant material. A summary, available to all members, will follow.

Seedling Evaluation Program

The purpose of the NTC Seedling Evaluation Program is to improve techniques for assessing seedling quality. As part of this program, the NTC provides a seedling vigor evaluation (or stress testing) service. More than 250 seedling lots were evaluated this year on a fee basis. This procedure is designed to identify poor quality lots by monitoring the growth and survival of potted seedlings placed in a growth room after exposure to hot-dry conditions. Although this procedure has been very useful, work continues to refine the test. 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

Name ________________ Affiliation ________________

Address ________
____
____

Phone Number ____

IN THIS QUESTIONNAIRE WE ARE SEEKING INDICATIONS OF INTEREST AND NOT NECESSARILY A FIRM COMMITMENT TO PARTICIPATE.

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

Yes ______ No ______

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:		
*Review of study plans?		
*Active involvement in experiments?		
(3) *Team problem solving and providing technical assistance through the 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 NTC Seedling Evaluation Program was aimed at developing a specific procedure for detecting 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 moisture 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 NTC staff is (1) coordinating the NTC studies (top pruning, weed control), (2) providing continuing education programs (Physiology Workshop at the SAF National Convention, publication of the Forest Nursery Manual), (3) updating the Seedling Evaluation Program, (4) supporting other projects within the NTC (Nursery Pathology, 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. Phipps Forest Nursery

USDA Forest Service, Rogue River National Forest, J. Herbert Stone Nursery

Washington State Department of Natural Resources, Lt. Mike Webster Nursery

Weyerhaeuser Company

Seedling Users:

BLM--Coos Bay District

BLM--Eugene District

BLM--Medford District

BLM--Oregon State Office

BLM--Roseburg District

BLM--Salem District

USDA Forest Service, Umpqua National Forest

Specialist Organizations:

USDA Forest Service, Pacific Northwest Forest and Range Experiment Station

USDA Forest Service, Pacific Southwest Forest and Range Experiment Station

USDA Forest Service, State and Private Forestry, Region 6

In: Murphy, Patrick M., compiler. The challenge of producing native plants for the Intermountain area: proceedings: Intermountain Nurseryman's Association 1983 conference; 1983 August 8-11; Las Vegas, NV. General Technical Report INT-168. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 96 p.

USING A PRESSURE CHAMBER TO DETECT DAMAGE TO SEEDLINGS ACCIDENTALLY FROZEN DURING COLD STORAGE

Douglas D. McCreary

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 bareroot seedlings is often a necessary step in the reforestation of conifers, 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 (Hocking and Nyland 1971). Currently, most conifer seedlings are stored between 0° and 3°C because cold temperatures reduce respiration and inhibit the development of harmful molds. But, despite improvements in the overall quality of refrigeration facilities, occasional equipment malfunctions result 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 (+1°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 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 assessment 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 2-month 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,

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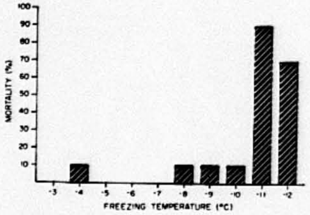

Figure 1.--Final mortality of seedlings, by freezing treatment.

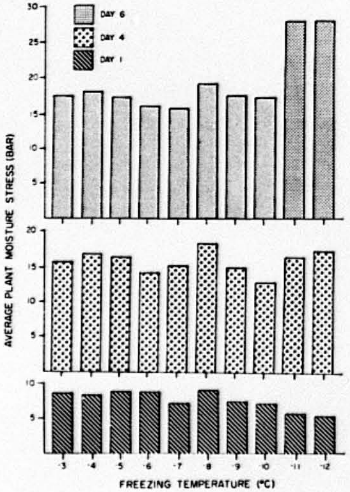

Figure 2.--Average plant moisture stress of seedlings, by treatment and day of evaluation.

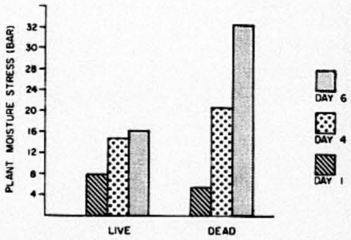

Figure 3.--Average plant moisture stress of surviving and dead seedlings.

the threshold temperature for lethal damage (-11°C) was quite uniform. Figure 2 shows average PMS by treatment for each assessment date. There are three interesting things to note: first, that average PMS for all treatments increased over time; second, that first-day PMS tended to be lower in the colder treatments (freezing temperature and PMS were significantly and positively correlated); and third, that this initial trend dramatically reversed during the following 5 days. Seedlings from the two coldest treatments had the highest average PMS values on the sixth day after planting, and freezing temperature and PMS were significantly (P = 0.05) and negatively correlated.

The relationships between lethal freezing injury and PMS (fig. 3) show that seedlings that died had significantly lower initial PMS values that then rose precipitously. Seedlings that lived had higher initial PMS values that increased gradually between the first and fourth days and then remained relatively unchanged. PMS on the sixth day, and the percentage difference between the first and sixth days, were significantly higher for those seedlings that eventually died.

As might be expected from this discussion, the percentage of dead seedlings from a given freezing treatment was closely correlated with the absolute and percentage increase in PMS for that treatment. There was a strong correlation between mortality and both absolute and percentage increases in PMS for both measurement intervals (days 1 to 4, days 1 to 6). Significant correlation coefficents were:

Percentage mortality x absolute increase in PMS

Days 1 to 4	r = 0.80
Days 1 to 6	r = 0.98

Percentage mortality x percentage increase in PMS

Days 1 to 4	r = 0.85
Days 1 to 6	r = 0.96

Although all correlations were significant, the larger coefficents for the longer time intervals indicate that predictions of mortality from PMS 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 became more stressed over time than seedlings that lived, although they initially had lower PMS. An initial reduction, also found by Bixby and Brown (1974) and Timmis (1976), 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 outlined--measuring seedlings once soon after planting and once 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 seedling 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

Bixby, J. A.; Brown, G. N. Rapid determination of cold hardiness in black locust seedlings using a pressure chamber. Abstract No. 12. Boulder, CO: North American Forest Biology Workshop; 1974: 354.

Hocking, Drake; Nyland, Ralph D. Cold storage of coniferous seedlings. Research Report No. 6. Syracuse, NY: Applied Forest Research Institute, State University College of Forestry; 1971. 70 p.

Timmis, Roger. Methods of screening tree seedlings for frost hardiness. In: Connell, M. G. R., Last, F. T., eds. Tree physiology for yield improvement. New York, NY: Academic Press; 1976: 421-435.

In: Murphy, Patrick M., compiler. The challenge of producing native plants for the Intermountain area: proceedings: Intermountain Nurseryman's Association 1983 conference; 1983 August 8-11; Las Vegas, NV. General Technical Report INT-168. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 96 p.

ASEXUAL VS. SEXUAL PROPAGATION OF QUAKING ASPEN

Robert B. Campbell, Jr.

ABSTRACT: 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 revegetation 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, suggestions for root and seed collection and storage, propagation techniques, and the advantages of both sexual and asexual propagation are discussed.

INTRODUCTION

Quaking aspen (*Populus tremuloides* Michx.) has the widest distribution of any native tree species in North America (Fowells 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 advantages. However, seed propagation is less labor intensive and is used by some nurseries to produce large quantities of planting stock.

I will present various factors that nurserymen should consider before selecting between sexual and asexual methods of propagating aspen.

ASEXUAL PROPAGATION

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

Many amateur and professional landscapers transplant these natural suckers, or wildlings, for ornamental purposes. When the wildlings 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 wildlings usually grow slowly at first and develop small leaves. Generally they have few, if any, branch roots at the time they are removed from the parent clone, and the existing root system is inadequate; consequently many wildlings do not survive after transplanting (Schier 1982).

A few commercial landscapers 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 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 McFarland of Landscaper's Service, Steamboat Springs, Colo.)

Another nurseryman substantially improves the survival and vigor of transplanted wildlings as follows: (1) Wildlings are selected from undisturbed clones where the regeneration varies in size and age. (Failure apparently is common when wildlings 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 trees are first wiggled 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 complete foliar fertilizer and one hydraulic injection of the fertilizer into the root system. (4) The trees are sprayed with Benomyl (a systemic fungicide) to reduce the incidence of fungal pathogens common to aspen. (Personal communication with Jerry Morris of Rocky Mountain Tree Experts, Lakewood, Colo.)

Methods have been developed to artificially propagate aspen vegetatively (Schier 1978b). Though labor intensive, these methods offer a way to produce rooted aspen suckers capable of vigorous growth. I want to dispel the myth that vegetatively propagated aspen inherently have slow growth. Aspen trees propagated vegetatively 14 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 Canyon. Schier and Campbell (1980) describe the site and suckering characteristics for these 20 clones. The two groups of clones differed appreciably with respect to aspen density, basal area, and mortality.

The rooted sucker cuttings were planted in tubes, 2.5 inches in diameter by 10 inches long, filled with peat moss:vermiculite (1:1) and placed in the greenhouse. The next spring the suckers were transplanted to peat moss:sand (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 at the Green Canyon Nursery 3 miles northeast of Utah State University.

A total of 439 aspen were planted randomly in 15 rows of up to 30 individuals per row with a 6.6-ft spacing. Soil amendments and fertilizers were not used at the nursery. Rainbird sprinklers provided regular but moderate irrigation. After 2 years at the nursery, the trees had substantial variation in height growth. In an attempt to standardize subsequent vegetative growth, all stems were cut off at ground level in the spring of 1980. 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 lateral branches, the length of the longest three laterals, and stem form. Preliminary results indicate that substantial variation in these morphological traits occurs between clones. Also, clonal variation is obvious for the time of leaf flush, leaf size and shape, and the angle of branching between the main stem and lateral branches. This common-garden planting illustrates well the genetic control of these characteristics in aspen.

The survival rate in the common garden is an impressive 99 percent. Of the 439 aspen planted, only three died; two others 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 asexual propagation. Do the trees in the clone have a desired shape and appearance? Is the soil type desirable for root collection? Are there abundant (or sufficient) lateral roots near the soil surface? Will the roots collected have a high capacity to sucker, and will the sucker cuttings develop roots? (Preliminary trials are suggested to determine the clone's suckering and 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 would expect trees vegetatively propagated from a clone with tall trees to grow reasonably tall; however, I have seen suckers propagated from clones with short trees on a poor site grow unusually fast and tall in a better environment.

Harniss and Nelson (in press) indicate that aspen clones vary in susceptibility to *Marssonina*, a fungal leaf blight. They surveyed about 1,000 acres of aspen in northern Utah during a recent epidemic year for *Marssonina*. Resistant 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 ornamental and revegetation purposes, would be to select for highly resistant clones.

Numerous desirable traits of specific aspen clones can be perpetuated by vegetative propagation. Barnes (1966) suggests that the following characteristics are generally uniform among the ramets of the same clone: leaf size, shape, and color (both spring and fall); phenology; stem form and branching habit (for example, excurrent growth or wide spreading crown and degree of self-pruning); sex; bark color and texture; and tendency for disease and insect attack. These traits may be important to consider when a clone is selected.

Root Collection and Storage

Schier (1978b) explains in detail the root collection process. He mentions specific advantages for using a spade, an anvil-type pruner, and a moist cloth bag for collecting lateral roots that range from 0.4 to 1.0 inch in diameter.

The season of root collection can significantly alter the number of suckers produced. During the spring flush and early shoot growth, the roots of aspen clones have high levels of auxin, which reduces sucker formation (Schier 1973). Schier (1978b) explains that roots collected during the clone's dormant stage (early spring, later 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.

Perala (1978) and Schier (1978a) report that the number of aspen suckers produced is not related to the length of the root cuttings. Because the length is not a critical factor, roots can be cut 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 before planting the roots to begin the suckering process. For example, nurserymen could have the flexibility to collect

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roots from clones at different times, hold them in cold storage, and then plant the roots at the same time. In addition, the first growing season for the new suckers could be lengthened if the roots were collected in the fall, stored, and then planted in the greenhouse during late winter. Schier and Campbell (1978) treated root segments with Benomyl, wrapped them in moist paper towels, placed them in plastic bags, and stored them in the dark at 36° F for up to 25 weeks. In most cases 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 from three clones for 12 months in a cold room, I found that some suckers still arose from the roots. When the remaining roots from the same lot were tested next 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, cut 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 sucker for 6 weeks. (4) Cut the new suckers from the root segments, treat the suckers' bases with indolebutyric acid (IBA), and plant the sucker cuttings in moist vermiculite:perlite (1:1). (5) Put these cuttings on a misting bench for 2 to 3 weeks to root. (6) Transplant the rooted cuttings to containers with peat moss:vermiculite (1:1) and apply a complete fertilizer. Use supplemental light during short days and maintain the temperature between 59° and 77° F. Aspen have winter chilling requirements that are satisfied at 36° to 50° F.

SEXUAL PROPAGATION

Female aspen clones produce highly viable seed in the spring (Fowells 1965; McDonough 1979). Growing aspen from seed is less labor intensive than the asexual methods discussed above. Some nurserymen are growing seedling aspen on a production scale. Native Plants, Inc. presently has in its nursery several hundred thousand aspen seedlings of various sizes, 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 items 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 the same sex. Reports in the literature suggest that the male to female ratio of aspen clones varies in some areas in favor of the male (Fowells 1965, Grant and Mitton 1979). From my general observations, I believe that only 20 to 25 percent of the clones in the West will set seed in any one year. Thus, finding female 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 scaly bract. The female catkins have a single, green, top-shaped capsule at each bract. Although catkins disintegrate rapidly after shedding pollen or seed, enough fragments to identify the clone's sex usually will remain on the duff layer throughout most of the summer. Emphasis should be placed on finding female clones with desirable attributes for the proposed use of the new seedlings. Nevertheless, because of genetic recombination the seedlings will not be exactly like the trees in the female clone. The odds for desirable offspring, however, should be better if the female clone has the preferred characteristics.

Seed Collection

Aspen flowering is controlled in part by temperature. Because of this, the same clone may vary up to 3 weeks in date of flowering from year to year. Temperature also affects flowering phenology along elevational gradients, with earliest flowering beginning at the lower elevations. In northern Utah male and female catkins usually begin to emerge in mid- to late April. The male catkins soon elongate and the clusters of purple anther sacs begin to shed pollen. Following pollination, some 4 weeks later as the leaves begin to flush out, the female catkins elongate as the seeds mature and the green capsules swell. One to 2 weeks later the capsules open and shed the seed in a fluff of cottonlike hairs.

Rather than collecting the cottony fluff in the field, use a long pruner to cut branches from trees with female catkins about a week before the seed would ordinarily be shed. The catkins can then be forced in a greenhouse or laboratory.

A method commonly used in Europe for seed harvest from European aspen (Populus tremula) will also work for quaking aspen. The cut ends of the catkin-bearing branches are placed in containers filled with water. Water is added as needed and kept at a temperature of 46° to 50° F. High air temperatures (68° to 104° F), low relative humidity, and gentle ventilation quicken the ripening process. The catkins should not be exposed to full sunlight. When the capsules open, a suction device is used to remove the cotton and seed. The seed will separate from the cotton as the air current passes through a series of three cylinders connected by small tubes. The viable seed accumulates in the first two cylinders (FAO 1979).

Aspen seed need not be removed from the cotton for germination, but cleaned seed is easier to handle. The mature seed is tan, plump, and small; Schreiner (1974) indicates there are about 3 million cleaned seeds per pound.

Seed Viability and Storage

McDonough (1979) stresses that aspen in the West produce ample amounts of nondormant, germinable seed. However, inadequate soil moisture during germination and early seedling growth usually prevents establishment under field conditions. He found germination capacities of 90 to 100 percent at temperatures from 36° to 86° F. Germination began within 8 to 12 h when temperatures were 68° to 95° F. Also, seeds air dried for 2 days at 68° F and then stored in vapor-tight bottles at 28° F for 48 weeks retained 90 percent or better germinability.

McDonough (1979) shows that the depth of planting greatly affects seedling emergence, which decreases significantly if the seed is placed deeper than 0.15 inch below the surface. Greenhouse seedbeds and standard potting soils are suitable for germination and seedling establishment when watered gently.

Poplar seed can be stored for several years with only a slight decline in the germination rate if stored in a cool, closed container with low humidity (FAO 1979). Fowells (1965) explains that good seed crops for aspen occur every 4 to 5 years, with only light seed production in the other years. Nurserymen could collect seed during the years of abundant seed and store it for a few years without appreciable declines in germination potential.

We collected seed in May 1979 from one clone in northern Utah, air dried the seed for 2 days, and then stored it in a sealed plastic envelope at 36° F. Initially the germination rate was 94 percent. I tested the seed lot in April 1982 and observed a 92 percent germination capacity. In April 1983, after 4 years of cold storage, the seeds still had 82 percent germinability.

DISCUSSION

The propagation of aspen from seed requires less equipment, labor, time, and space than intensive vegetative methods of propagation. In addition a large outplanting of seedling stock tends to maximize 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. These uses normally require large numbers of planting stock that are more feasible to grow from seed.

In contrast, vegetative propagation yields new ramets genetically identical to the parent. Nurserymen can select for the superior clonal traits preferred by their clientele. The future for asexual propagation of aspen is promising with many possibilities for new advances. In fact, tissue culture, another form of vegetative propagation, is currently being used by Native Plants, Inc. to grow tens of thousands of aspen plantlets from a single seedling tree that has superior traits (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 macro- and micronutrients.

Aspen can be readily propagated by either sexual or asexual methods, both of which have unique advantages. Nurserymen are challenged to capitalize on these advantages to produce aspen stock tailored for specific uses.

PUBLICATIONS CITED

Barnes, Burton V. The clonal growth habit of American aspens. Ecology. 47(3): 439-447; 1966.

Food and Agriculture Organization of the United Nations. FAO Forestry Series No. 10: Poplars and willows in wood production and land use. Rome: Food and Agriculture Organization of the United Nations; 1979. 328 p.

Fowells, H. A. Quaking aspen (Populus tremuloides Michx.). In: Silvics of forest trees of the United States. Agric. Handb. 271. Washington, DC: U.S. Department of Agriculture, Forest Service; 1965: 523-534.

Grant, Michael C.; Mitton, Jeffry B. Elevational gradients in adult sex ratios and sexual differentiation in vegetative growth rates of Populus tremuloides Michx. Evolution. 33(3): 914-918; 1979.

Harniss, Roy O.; Nelson, David L. A severe epidemic of Marssonina leaf blight on quaking aspen in northern Utah. Res. Pap. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; (In press).

McDonough, Walter T. Quaking aspen--seed germination and early seedling growth. Res. Pap. INT-234. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1979. 13 p.

Perala, Donald A. Aspen sucker production and growth from outplanted root cuttings. Res. Note NC-241. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station; 1978. 4 p.

Schier, George A. Seasonal variation in sucker production from excised roots of Populus tremuloides and the role of endogenous auxin. Can. J. For. Res. 3(3): 459-461; 1973.

Schier, George A. Variation in suckering capacity among and within lateral roots of an aspen clone. Res. Note INT-241. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1978a. 7 p.

Schier, George A. Vegetative propagation of Rocky Mountain aspen. Gen. Tech. Rep. INT-44. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1978b. 13 p.

Schier, George A. Sucker regeneration in some deteriorating Utah aspen stands: development of independent root systems. Can. J. For. Res. 12(4): 1032-1035; 1982.

Schier, George A.; Campbell, Robert B. Effect of cold storage on development of suckers on aspen root cuttings. Res. Note INT-248. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1978. 8 p.

Schier, George A.; Campbell, Robert B. Variation among healthy and deteriorating aspen clones. Res. Pap. INT-264. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1980. 12 p.

Schreiner, Ernst J. Populus L. poplar. In: Schopmeyer, C. S., tech. coord. Seeds of woody plants in the United States. Agric. Handb. 450. Washington, DC: U.S. Department of Agriculture, Forest Service; 1974: 645-655.

In: Murphy, Patrick M., compiler. The challenge of producing native plants for the Intermountain area: proceedings: Intermountain Nurseryman's Association 1983 conference; 1983 August 8-11; Las Vegas, NV. General Technical Report INT-168. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 96 p.

seed viability (Benson and Harder 1972). Seed germination was above 90 percent when tested two weeks prior to nursery bed showing.

Installation of experimental nursery beds followed procedures developed by Benson and Einsphar (1962) and modified by Benson and Dubey (1972). Within a 2.44 m x 15.9 m area, five 1.19 m x 2.41 m areas were excavated to a depth of 92 cm for each to accomodate a 1.22 m x 2.44m x 2.44 m wood frame supporting a hinged frame covered with standard window screen. Plywood boards divided each frame into equal quadrants to a depth of 92 cm. Polyethylene plastic lined the main frame soil side walls to the same depth.

The excavated soil was combined with horticulture-grade peat moss to establish four nursery bed growing media: (1) soil; (2) 1/4 peat, 3/4 soil; (3) 1/2 peat, 1/2 soil; and (4) 3/4 peat, 1/4 soil (by volume). In addition, elemental sulfur was added at the rate of 852 kg/ha (750 lb/ac) to each treatment. Physical and chemical properties of media were determined by 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 bromide. The following day, frame tops were lifted and the beds were aerated for 48 hours.

Aspen seeds were sown at the spacing recommended by IPC (Benson and Dubey 1972) to produce 110-160 seedlings per m^2. Following emergence, excess seedlings were thinned. Beds were irrigated daily by 1.8 cm bi-wall perforated drip tubing. Fertilizer was applied via irrigation water at the rate of 113 kg/ha N, 45 kg/ha P and 79.5 kg/ha K.

Treatments were randomized within frames. Within a 30 cm x 91 cm area centered within each quadrant, 12 seedings were labeled in order to record leaf number and height measurements, repeated at two-week intervals. Seedling density for each of three 30 cm x 30 cm subplots was recorded just prior to harvest.

Seventeen weeks from sowing, seedlings were lifted with a spade and enclosed in plastic bags. Ten trees were harvested from each subplot. Height, caliper, and fresh and oven dry weights were recorded for each seedling. A portable leaf area meter (Li-Cor, Inc.) was used to determine leaf area for 12 of the 30 seedlings harvested from each treatment. Analysis of variance, Duncan's mean separation test, and multiple linear regression were employed in data analyses.

RESULTS

Peat additions progressively improved physical and chemical properties of nursery bed media (Table 1). Most notable are improvements in soil reaction, pore space, hydraulic conductivity, and cation exchange capacity. Organic matter increased considerably but approached the recommended level (3 percent) prior to any addition. In the field, soil peat moss reduced surface crusting and puddling compaction caused by irrigation.

Table 1. Chemical and Physical Properties of Nursery Bed Media

	SOIL	1/4 PEAT (v/v)	1/2 PEAT	3/4 PEAT
Hydraulic Conductivity (ml/cm^2 - hr)	14.6	30.6	93.3	245.2
Bulk Density (g/cc)	1.23	1.07	0.79	0.44
Pore Space (% By Vol.)	50.8	56.1	68.4	82.4
pH	7.4	6.8	6.0	4.8
% Organic Matter	2.5	4.0	7.9	15.6
C.E.C. (meq/100g)	14.1	15.5	21.0	39.0
Salts (% Sol.)	1.0	1.5	0.9	0.8
N-Total (PPM) (Kjeldahl)	894	1075	1160	2195
NO_3 (PPM)	13.5	22.6	29.9	42.9
P(PPM)	4.4	4.4	5.0	7.6
K(PPM)	11.6	18.5	19.6	29.8

* Before Addition of Sulfur.

Seedlings grown with peat amendments were considerably taller and supported more leaves than those grown in soil alone (figs. 1 and 2). Seedling density averaged 132 per square meter across all treatments and density differences among treatments were not statistically significant at the .05 level. Table 2 compares harvested seedlings across treatments. Most significant is the failure of soil or soil and 1/4 peat to produce a minimum caliper of 0.3 cm (1/8"). Only 3/4 peat produced a 30-cm shoot. Reading across treatments in Table 2, differences for any paired numbers are statistically significant at the .01 level except leaf areas for 1/2 and 3/4 peat.

Multiple regression analysis of the pooled data provided an opportunity for examining growth relations of aspen seedlings. The correlation matrix found in Table 3 shows several parameters to be closely related. Specifically, height is closely related to caliper, leaf number, and shoot weight. All of the values shown are statistically significant (.0001 level).

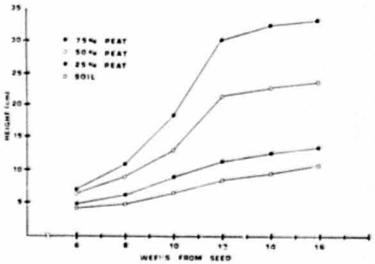

Figure 1. Cumulative Height Growth for Quaking Aspen Seedlings Under Nursery Bed Conditions

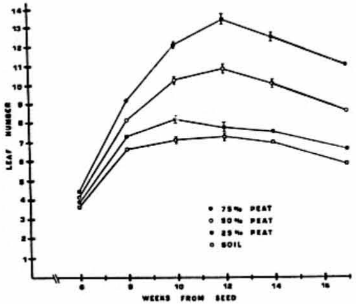

Figure 2. Cumulative Leaf Number for Quaking Aspen Seedlings Under Nursery bed conditions

Table 2. Seedling Growth Responses at 16 Weeks

	SOIL	¼ PEAT	½ PEAT	¾ PEAT
Height (cm)	10.92	13.60	24.11	33.73
Caliper (mm)	1.94	2.26	3.18	3.95
Leaf Number	5.77	6.73	8.52	11.00
Leaf Area (cm^2)	21.88	30.29	49.32	50.16
Shoot DWT (g)	0.24	0.37	0.98	1.88
Root DWT (g)	0.11	0.22	0.57	0.99

Table 3. Correlation Matrix (R^2)

	Height	Caliper	Leaf No.	Shoot DWT	Root DWT	Leaf Area
Height	--	.86	.74	.81	.67	.22
Caliper		--	.68	.76	.71	.15
Leaf No.			--	.63	.52	.23
Shoot DWT				--	.78	.12
Root DWT					--	.12
Leaf Area						--

DISCUSSION AND CONCLUSIONS

The study demonstrated that plantable aspen seedlings can be successfully grown at the Mora Valley nursery site if the soil is amended with peat and sulphur. If the desired caliper is 0.3 to 0.9 cm (1/8" to 3/8"), 1/2 to 3/4 of the nursery medium must be peat if seedlings are grown and harvested in less than 110 days. In the Mora Valley, it would be possible to plant earlier, however, and this would result in larger seedlings. Allowed an additional three weeks, seedlings grown in 1/2 peat may reach desired dimensions.

The relative importance of physical and chemical conditions derived from peat were not determined. However, seedlings grown in peat-amended media were subjected to conditions more favorable than soil for nutrient exchange and uptake, and less favorable for build up of soil pathogens.

Applied over an extensive area, peat amendments would be costly and a local substitute might be sought. In northern New Mexico old composted sawdust can be obtained and may provide a satisfactory substitute (Montano and others 1977). The disadvantages of fresh sawdust and farm yard manure were discussed by Armson and Sadreika (1974), who also recommended peat application rates and procedures.

PUBLICATIONS CITED

Armson, K. A. and V. Sadreika. 1974. Forest tree nursery soil management and related practices. Can. Ministry of Natural Resources. 177 p.

Benson, M. K. and D. Dubey. 1972. Aspen seedling production in a commercial nursery. Inst. Pap. Chem. Genet. and Physiol. Notes No. 12, 7 p.

Benson, M. K. and Einsphar. 1962. Improved method for nursery production of quaking aspen seedlings. Tree Planters' Notes No. 53:11-14.

Benson, M. K. and M. L. Harder. 1972. Storage of aspen seed. Inst. Pap. Chem. Genet. and Physiol. Notes No. 11,4 p.

Cryer, D. H. 1980. Soil analysis: A method to determine Christmas tree productivity in the mountain valleys of Mora County. M.S. Thesis, New Mexico State Univ., Las Cruces. 110 p.

Harder, M. L. 1970. Procedures for collection and extraction of Populus seed. Inst. Paper Chem. Genet. and Physiol. Notes No. 9:3 p.

Jones, J. R. and D. P. Trujillo. 1975. Development of some young aspen stands in Arizona. USDA For. Serv. Res. Pap. RM-151,11 p.

Montano, J. M. J. T. Fisher and D. J. Cotter. 1977. Sawdust for growing containerized forest tree seedlings. Tree Planters' Notes 28:6-9.

Myers, J. F. and G. H. Fechner. 1980. Seed hairs and seed germination in Populus. Tree Planters' Notes 31:3-4.

In: Murphy, Patrick M., compiler. The challenge of producing native plants for the Intermountain area: proceedings: Intermountain Nurseryman's Association 1983 conference; 1983 August 8-11; Las Vegas, NV. General Technical Report INT-168. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 96 p.

GROWTH OF AUSTRIAN PINE AND NORWAY SPRUCE

SEEDLINGS IN MINI-CONTAINERS

Houchang Khatamian and Fahed A. Al-Mana

ABSTRACT: Austrian pine (*Pinus nigra* Arnold) and Norway spruce (*Picea abies* (L.) Karst.) 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 Book Tinus; intermediate in Book Hillson, Square Container and Tar Paper; smallest in Leach Tube, Styroblock 8 and Styroblock 7. The shoot and root dry weight of spruce were greater in smaller containers. Pine seedlings grew equally well in all containers. The ratio of the root dry weight/container volume (mg/cm^3) of both species was higher in the smaller containers.

INTRODUCTION

In recent years, there has been a gradual shift from field-grown, bare-root nursery stock to container production. The increased use of containerized seedlings in nursery 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 workers (Arnott 1974; Barnett 1982; Johnson 1975). Generally, there are three categories of containers used in forestry and ornametal plant production: tube, block, and plug (Barnett 1982). A containerized seedling has a root system which holds the growing medium when removed from the container, and when planted the roots make immediate contact with the soil (Mann 1977). Easy plug extraction depends upon the proper development of the root system, media, moisture content of the plug and the construction of the container walls and ridges (Tinus 1978). Usually, four to five months is needed to produce gro-plug seedlings with root systems suitable for transplanting into larger containers or the field, or for sale (Mann 1977; Thomas 1980).

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 circling of roots (Dickenson and Whitcomb 1978; Tinus and McDonald 1979).

Research has shown that container volume and diameter influence plant growth, and there is a minimum volume below which growth is limited (Wall and Whitcomb 1980). In one study (Venator and Rodriguez 1977), the shoot and root growth of *Pinus caribaea* var. hondurensis was influenced by the cavity sizes of Styroblock 4 and 8. Similar results were noted for lodgepole pine and white spruce (Carlson and Endean 1976; Endean and Carlson 1975).

Seedlings produced in uniform size mini-containers are adaptable to mechanized planting. The production cost of the containerized seedlings may be higher than field-grown ones, but compensations include faster and superior growth, higher production, longer planting periods and lower labor and land costs. The purpose of this research was to evaluate the effectiveness of selected mini-containers on the rate of seedling growth.

MATERIALS AND METHODS

Austrian pine (*Pinus nigra* Arnold) and Norway spruce (*Picea abies* (L.) Karst.) were grown in selected mini-containers to evaluate their effects on seedling growth (table 1). All containers were filled with Jiffy-Mix (commercially available peat-vermiculite 1:1 mix) and placed on wire benches in a glass greenhouse. Four seeds were placed in each cavity. At two weeks after germination seedlings were thinned to one per cavity and at three weeks seedlings were fertilized with liquid 20 N -8.6 P -16.6 K (100 ppm N) once a week and watered every two to three days as needed. The pH of the water was maintained between 5.0-5.5 using phosphoric acid (Tinus and McDonald 1979). The pH and Electrical Conductivity (EC) of the growing medium were monitored before and throughout the trial. Plants were grown for 18 weeks from March to August, 1981, with average day and night temperatures of 30° and 18°C, respectively.

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Table 1. Container/cavity dimensions

Container Type[1]	Composition	Top Diam. (cm)	Length (cm)	Width (cm)	Depth (cm)	Volume (cm^3)
Styroblock 7[2]	Styrofoam	3.0	--	--	22.5	121.3
Styroblock 8	Styrofoam	3.8	--	--	15.0	131.1
Leach Tube[3]	Polyethylene	3.8	--	--	13.5	131.1
Book Hillson[4]	Polyethylene	--	3.8	3.8	12.5	172.1
Book Tinus	Polyethylene	--	5	3.8	18.1	352.4
Square Bottomless	Unknown plastic	--	4	4	18.9	302.4
Cylinder Tar Paper	Asphalt	6.2	--	--	18.9	570.8

[1] Containers referred to in text as small are, Styroblock 7, Styrobloc, 8, and Leach Tube. Containers referred to in text as large are, Book Hillson, Book Tinus, Square Bottomless and Cylinder Tar Paper.

[2] Styroblock 7 and 8-Silvaseed Company, P. O. Box 118, Roy, Washington 98580.

[3] Leach Tube--Ray Leach Cone-Tainer, 15--N. Maple Street, Canby, Oregon 97013.

[4] Book Hillson adn Book Tinus--Spencer--Lemaire Industries LTD., 11413-120 Street, Edmonton, Alberta, Canada T5G 2Y3.

At the eighteeenth 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 65°C 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.

RESULTS AND DISCUSSION

Stem Length

Larger containers such as Book Tinus and Tar Paper produced greater stem length for Austrian pine and Norway spruce when compared with the small size cavities of Styroblock 7 (table 2). Possibly the larger diameter of these containers influenced the plant stem length. Similar results were reported for the lodgepole pine and white spruce (Carlson and Endean 1976; Endean and Carlson 1975). Wall and Whitcomb (1980) also reported an increase in seedling height of Lacebark Elm, Atlas Cedar and Japanese Black Pine.

Shoot and Root Dry Weight

With the exception of root dry weight in Tar Paper, the shoot and root dry weights of pine were similar in all containers tested (table 2). Whereas the greatest shoot dry weight of Norway spruce was obtained in the small and tapered containers. According to Endean and Carlson (1975), container configuration (height or diameter) had no effect on shoot dry weight or the shoot length of lodgepole pine seedlings, but it did on white spruce seedling growth. It appears that lodgepole pine and white spruce respond differently to containerized conditions (Carlson and Endean 1976). Spruce is a more shallowly rooted species than pine and therefore had a greater number of roots in the top quarter of the container. In contrast, pine had more roots in the bottom of the container. Austrian pine grew equally well in all containers tested regardless of container configuration and volume. However, Norway spruce seems to grow better in the smaller and tapered containers such as Styroblock 7, Styroblock 8, and Leach Tube, possibly because of its shallow root system.

Shoot/Root Ratio

The shoot/root dry weight ratio of pine seedlings was greatest in Tar Paper which gave the smallest root system (table 2). The Tar Paper was formed as a cylinder which had smooth walls and no ribs. Circulating and spiralling primary lateral roots about the tap root is common in cylindrical containers (Tinus 1978 and Agnew 1981). The main disadvantage observed with the Tar Paper container was the root penetration through the tar paper wall into the adjacent tar paper pots. This makes pot removal difficult, damages the root system and results in loss of roots. This is likely the reason for lower root dry weight of both species grown in Tar Paper containers. Such problems with Tar Paper containers also were noted by Strachan (1974). Norway spruce had a greater shoot/root dry weight ratio in the larger volume containers: Tar Paper, Book Tinus and Book Hillson (table 2).

Root Quality

The extensity,fibrousness, and uniformity of the root system were taken into consideration when visual evaluations on root quality were made. Austrian pine produced a very good root system in all containers tested except for Tar Paper. The root system of spruce was good in Leach Tube, Styroblock 8 and Styroblock 7 (table 2). The plugs of both species indicated a more fibrous and dense root system in Leach Tube and Styroblock containers (fig. 1). The Book planters produced plugs 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/cm^3) of Austrian pine and Norway spruce seedlings.

Container	Stem Length (cm)	Dry Weight (g)			Root Quality[x]	Root Dry Weight/ Container Volume Ratio (mg/cm)
		Shoot	Root	Ratio		
			Austrian Pine			
Styroblock 7	4.3c[y]	0.92a	0.36ab	2.55c	4.2ab	3.0a
Styroblock 8	4.6bc	1.19a	0.44a	2.70c	4.5a	3.3a
Leach Tube	4.5bc	1.05a	0.39ab	2.69c	4.3a	3.0a
Book Hillson	5.0ab	1.11a	0.34ab	3.26b	4.0ab	2.0b
Book Tinus	5.2a	1.21a	0.41a	2.95bc	3.9ab	1.2c
Square Bottomless	4.7abc	1.24a	0.41a	3.02bc	4.4a	1.4c
Cylinder Tar Paper	4.8ab	1.23a	0.27b	4.55a	3.4b	0.5d
			Norway Spruce			
Styroblock 7	2.8c	0.30ab	0.18ab	1.66bc	3.4ab	1.5a
Styroblock 8	3.0bc	0.32a	0.20a	1.60bc	3.7a	1.5a
Leach Tube	3.0bc	0.27abc	0.19a	1.42c	3.7c	1.5a
Book Hillson	3.1b	0.22cd	0.09c	2.44a	2.1c	0.5b
Book Tinus	3.5a	0.19d	0.09c	2.11ab	2.0c	0.3b
Square Bottomless	3.0bc	0.23bcd	0.14abc	1.64bc	2.8abc	0.5b
Cylinder Tar Paper	3.4a	0.25abcd	0.12bc	2.08ab	2.5bc	0.2b

[z] Means of 24 seedlings from 4 replicates.
[y] Mean separation in columns by Ducan's multiple range test, 5% level.
[x] Visual rating of root system; 1 = poor, 2 = fair, 3 = good, 4 = very good, 5 = excellent.

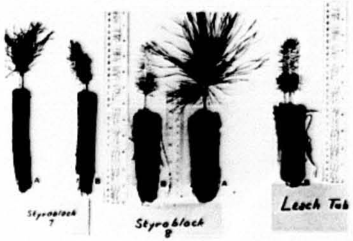

Figure 1. Austrian pine (A) and Norway spruce (B) plugs extracted from Styroblock 7, Styroblock 8, and Leach Tube.

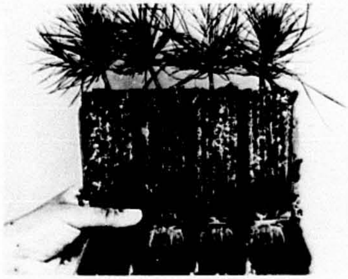

Figure 2. Austrian pine seedlings grown in Book Hillson which can be easily opened to observe the root system.

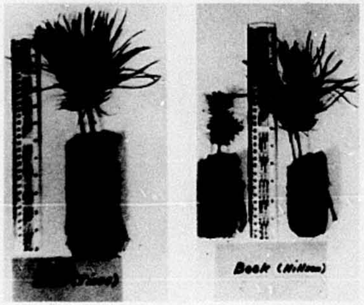

Figure 3. Austrian pine plugs extracted from Book Tinus and Book Hillson. Norway spruce plug of Book Hillson.

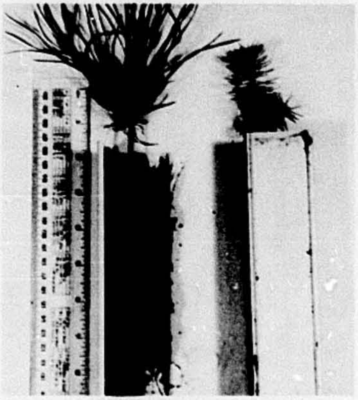

Figure 4. Austrian pine and Norway spruce grown in square bottomless container.

The square containers were effective for the production of a good root system in both species (fig. 4).

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 Sjoberg 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 of various types of mini-containers on the seedling performance after transplanting need further research.

PUBLICATIONS CITED

Agnew, M. L. Influence of plexiglass inserts on prevention of root spiraling of container grown tree species. Master's Thesis, Department of Horticulture, Kansas State University, Manhattan, Kansas. 1981.

Allison, C. J. Jr. Design consideration for the RL single cell system. Proc. N. Amer. Containerized For. Tree Seedling Symp., Great Plains Agric. Counc. Publ. 68:233-236; 1974.

Arnott, J. T. Performance in British Columbia. Proc. N. Amer. Containerized For. Tree Seedling Symp., Great Plains Agric. Counc. Publ. 68:283-290; 1974.

Barnett, J. P. Growing containerized Southern pines. Proc. N. Amer. Containerized For. Tree Seedling Symp., Great Plains Agric. Counc. Publ. 68:124-128; 1974.

Barnett, J. P. Selecting containers for southern pine seedling production. P. 15-24. In R. W. Guldin and J. P. Barnett (eds.) Proceedings of the Southern Containerized Forest Tree Conference. Savannah, Georgia; 1982.

Carlson, L. W., and F. Endean. The effect of rooting volume and container configuration on the early growth of white spruce seedlings. Can. J. For. Res. 6:221-224; 1976.

Dickenson, S. and C. E. Whitcomb. Effect of container design on root quality. Res. Rpt., P-777, Agric. Exp. Sta., O.S.U. P. 35-36; 1978.

Endean, F. and L. W. Carlson. The effect of rooting volume on the early growth of lodgepole pine seedlings. Can. J. For. Res. 5:55-60;1975.

Johnson, H. J. Canadian forestry service container planting trials in Alberta, Saskatchewan, and Manitoba. Proc. N. Amer. Containerized For. Tree Seedling Symp., Great Plains Agric. Counc. Publ. 68:298-305; 1974.

Mann, W. F., Jr. Status and outlook of containerization in the South. J. For. 75:579-581; 1977.

Sjoberg, N. E. The Styroblock container system. Proc. N. Amer. Containerized For. Tree Seedling Symp., Great Plains Agric. Counc. Publ. 68:217-228; 1974.

Strachan, M. D. Tar paper container. Proc. N. Amer. Containerized For. Tree Seedling Symp., Great Plains Agric. Counc. Publ. 68:209-210; 1974.

Thomas, S. P., Jr. Gro-plug systems and their practical application in growing ornamentals. Proc. Int. Plant. Prop. Soc. 30:312-318; 1980.

Tinus, R. W. Root system configuration is important to long tree life. Proc. Int. Plant. Prop. Soc. 28:58-64; 1978.

Tinus, R. W. and S. E. McDonald. How to grow tree seedlings in containers in greenhouses. Rocky Mountain Forest and Range Experiment Station, USDA Forest Service, Bottineau, N. Dak., 256 p.; 1979.

Venator, C. R. and A. Rodriguez. Using styroblock containers to grow *Pinus caribeau* var. *hondurensis* Borr. of golf. nursery seedlings. Turrialba 27(4):393-396; 1977.

Wall, S. and C. E. Whitcomb. A comparison of commercial containers for growing tree seedlings. Res. Rpt. P-803, Agric. Exp. Sta., O.S.U., P. 72-75; 1980.

In: Murphy, Patrick M., compiler. The challenge of producing native plants for the Intermountain area: proceedings: Intermountain Nurseryman's Association 1983 conference; 1983 August 8-11; Las Vegas, NV. General Technical Report INT-168. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 96 p.

EQUIPMENT FOR REVEGETATING DISTURBED LANDS

Richard G. Hallman

ABSTRACT: Federal land managers find themselves caught between new mining laws that require complete restoration and the difficulty of establishing plant growth in the arid area where mining is occurring. The Bureau of Land Management funded the Forest Service Missoula Equipment Development Center to develop equipment for revegetation. Six equipment systems were developed.

INTRODUCTION

When surface mining for coal in the West began in earnest, about 10 years ago, it became apparent that many techniques developed over the years for improving range habitat were unsuited to revegetate mined land. Surface mining mixes soil profiles, alters surface and ground hydrology, and removes all vegetation. Clearly, new equipment and techniques were needed to restore this land.

The Bureau of Land Management (BLM) of the Department of the Interior (USDI) was the logical Government agency to tackle the problem. About 80 percent of strippable coal in the West is Federally owned, and the BLM manages most of the land where the coal is found. The BLM, along with the Office of Surface Mining, another USDI agency, is responsible for determining the revegetation potential of these lands.

Federal and State mining laws require that restored vegetation equal what existed before mining. Fortunately, coal seams in the West often are thick; seams of 20 feet and more are not unusual. So revenue from mining deposits of that magnitude makes it economically feasible for operators to do the revegetation job that is required.

As part of its effort to develop new revegetation techniques, the BLM turned to the USDA Forest Service Missoula Equipment Development Center (MEDC). MEDC and its sister Center at San Dimas, Calif., were the only equipment development organizations involved in rangeland improvement activities.

In 1975 MEDC personnel began working with the BLM to develop equipment and techniques to revegetate lands under arid and semiarid conditions where establishing vegetation is difficult and expensive. Six pieces of equipment were eventually built to accomplish six specific revegetation tasks. Each piece of equipment is described in the following text. The six equipment systems currently are being evaluated in various locations in the West to perfect the techniques and to establish cost data. For additional information, write USDA Forest Service, Missoula Equipment Development Center, Fort Missoula, Missoula, MT 59801.

DRYLAND PLUG PLANTER

Function

The dryland plug planter (fig. 1) is designed to automatically plant containerized trees and shrub stock on surface-mined reclaimed sites. To insure survival on semiarid sites, the root systems must stay in contact with soil moisture. To help accomplish this, the planter is able to plant containerized stock seedlings that are up to 61 cm long.

Figure 1.--Dryland plug planter plants large container stock; large stock improves survival chances.

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Description

The dryland planter is designed to be mounted on the rear of a tractor. It features hydraulic leveling devices, hydraulic auger with a scarifier, rotating carousel mounted on a movable carriage and two packing spades. The machine plants containerized shrubs or trees quickly and effectively. The leveling devices and high clearance enable operations on rough ground or moderate slopes, while insuring adequate placement. The containerized root system and auger holes allow sufficient moisture uptake and unrestricted root growth for better survival.

The planting is automatic and controlled from the tractor. When the planter is positioned, the platform is leveled with hydraulic cylinders. The auger digs a hole; the scarifier auger then removes any competing vegetation from around the hole. The carousel containing the seedlings rotates and the carriage moves forward on the platform, dropping a seedling into the hole. The packing spades firm the soil around the seedling. Planting rate is estimated at more than one per minute.

Specifications

Carousel capacity: 24 seedlings
Auger diameter: 7.6 to 12.7 cm
46 cm scarifier
Depth: 61 to 76 cm
Power requirements (drawbar): 52 to 75 kW

TREE TRANSPLANTER

Function

The tree transplanter system (fig. 2) 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 transport 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 TS-44A Tree Spade mounted on an Owatonna 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 digs the trees or plugs, places them in the trailer pods, and tows the trailer between the transplant site and transplant supply area.

Specifications--Trailer

Overall width: 2.4 m with walkway removed
Height: 2.1 m
Weight: 2,722 kg
Capacity: 8 trees or plugs or 3,922 kg
Cone size: 112 cm diameter, 109 cm deep
Power requirements: 60 kW recommended

Specifications--Tree Transplanter

Ball (cone) depth: 46 to 152 cm
Tree size: to 25 cm diameter (maximum tree size may vary with the type of root structure)
Mounting: tractors, trailers, truck or front-end loaders

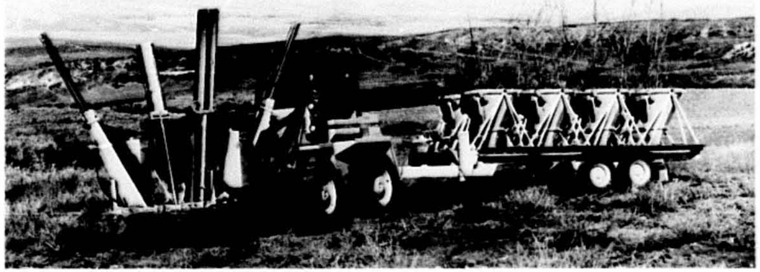

Figure 2.--Tree transplanter revegetates reclaimed mine sites with trees and shrubs.

DRYLAND SODDER

Function

The dryland sodder (fig. 3) transfers native topsoil from the mine area to the reclamation area with its structure, profile, and vegetation intact. Reclamation is greatly enhanced because the soil horizons are not mixed, so soil development does not have to be repeated.

The dryland sodder strips the top layer of soil and vegetation (sod, forbs, shrubs, and small trees) from areas to be surface mined and places it intact over reshaped areas. The soil layer is scooped into the sodder and transported to the reclamation area. It is removed by tilting and shaking the bucket while slowly moving the loader backward. The conveyer system will feature hydraulic control of the conveyor rollers, allowing the sod to be removed without tilting the bucket.

Description

The dryland sodder is a modified front-end loader bucket. The side walls and back wall are vertical to minimize damage to shrubs and tree seedlings that are stripped along with the soil and sod. The wide, flat bottom of this bucket is sprayed with plastic to reduce friction. A conveyor system is being developed for the bottom of the dryland sodder to aid loading and unloading of the sod strips and to prevent excess soil separation during the transfer.

Specifications

Width: 4.3 m
Length: 2.4 m
Depth: to 30 cm
Power requirements (flywheel) 80 to 391 kW

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

SPRIGGER

Function

The sprigger (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 sprigger is a modified potato harvester. It consists of an undercutting blade and a pair of wide, inclined conveyors. The conveyors are long rods attached between two chains and spaced 3.8 cm 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 sprigger is towed and powered by a tractor.

After the shrubs are mowed, the sprigger is pulled through the stand, cutting the roots well below the ground 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 bareroot rhizomatous shrubs, or sprigs, are gathered and carefully planted on the reclamation area.

Specifications

Width: 1.5 m
Depth: 30 cm
Power requirements (drawbar): 60 to 75 kW

Figure 4.--Sprigger digs up rhizomatous material for planting on reclaimed areas.

BASIN BLADE

Function

The basin blade (fig. 5) scoops out large basins or depressions along slopes. Moisture accumulates in these basins to provide a favorable microsite for plant growth. 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 scarifying teeth 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 multiple-ripper shank. It is raised, lowered, and tilted hydraulically. Several replaceable scarifying teeth are located along 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: to 91 cm
Power requirements (flywheel) 216 to 276 kW

Figure 5.--Basin blade makes depressions in soil that trap moisture, creating favorable conditions for plant growth.

HODDER GOUGER

Function

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

The gouger is towed behind a tractor. The hydraulically powered automatic cycling system moves the frame up and down in relation to the wheels to create depressions. The depth of the depressions, cycle rate, and blade configuration can be varied to suit the site conditions. Average production rates have varied from 1 to 1.1 ha per hour.

The gouger creates more and larger depressions than similar equipment. The automatic cycling and hydraulic depth control make it easier to operate and the adjustable cycle rate and variable blade configurations contribute to its versatility. The spring-loaded blade arms enable it to operate in fairly rocky ground.

Specifications

Implement width: 3.4 m
Depression width: 38 to 56 cm
Depression length: 0.9 to 1.2 m
Depth: 15 to 25 cm recommended
Power requirements (drawbar): 37 kW minimum

Figure 6.--Hodder gouger makes depressions in soil and simultaneously seeds area to establish plant cover.

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PRELIMINARY TRIALS ON UPGRADING *PLATANUS OCCIDENTALIS* WITH THE HELMUTH ELECTROSTATIC SEED SEPARATOR[1]

Robert P. Karrfalt 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.

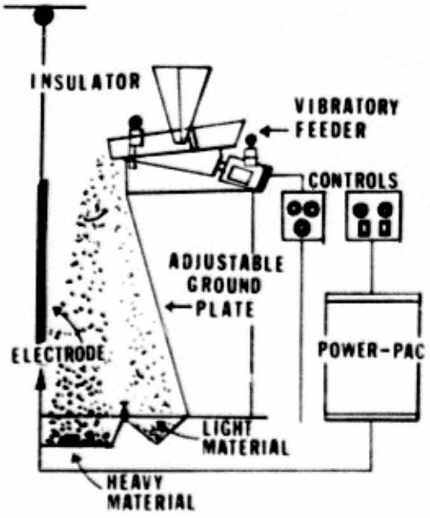

Figure 1.--Diagram of the electrostatic seed separator.

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

[1] Mention 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.

Table 2.--Germination and germination value computed on full seed basis.

FRACTION #	ORIGINAL	1	2	3	4	5	6
GERMINATION	88	92	87	93	93	89	85
GERMINATION VALUE	71.7	82.15	78.66	88.58	100.75	96.46	95.58

According to the data obtained, the electrostatic separator appears to have definite potential to effectively upgrade small tree seed. Other species that might be effectively upgraded would include birch, sweetgum and conifers such as white spruce. In a preliminary trial, redwood purity was visually much improved with the Helmuth separator. There were no laboratory test data. In the nursery, the upgraded seed will give more uniform germination and provide more uniform seedling densities, greater numbers of plantable seedlings per pound of seed, and more efficient use of nursery space.

PUBLICATIONS CITED

Belcher, E. W.; Karrfalt, R. P. The processing of conifer seed. In: Proc. Small Lot Forest Seed Processing Workshop: 1977, Oct. 18-20; Atlanta, GA. USDA Forest Service, Southeastern Area. pp 9-18. 1978.

Bonner, F. New developments in seed processing. In: Proc. Small Lot Forest Seed Processing Workshop: 1977, Oct 18-20; Atlanta, GA. USDA Forest Service, Southeastern Area. pp 19-23. 1978.

Czabator, F. J. Germination value: an index combining speed and completeness of pine seed germination. For. Sci. 8: 386-396; 1962.

In: Murphy, Patrick M., compiler. The challenge of producing native plants for the Intermountain area: proceedings: Intermountain Nurseryman's Association 1983 conference; 1983 August 8-11; Las Vegas, NV. General Technical Report INT-168. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 96 p.

SURVIVAL, GROWTH, AND ROOT FORM OF CONTAINERIZED JEFFREY PINES TEN YEARS AFTER OUTPLANTING

J. D. Budy and E. L. Miller

ABSTRACT: To evaluate the effect of various containers on survival and growth, trials established in 1973 were remeasured 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 planted 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 container planting systems both in Canada and the U.S. resulted in a tremendous need to transmit research findings. Fortunately, much of the information has been made available through conference proceedings. In 1971, the Canadian Forestry Service sponsored a workshop on container planting (Waldron 1972). The first international conference held in Denver brought together much of the knowledge and expertise available on containerized seedlings (Tinus and others 1974). Two symposia held in 1981, the Southern Containerized Forest Tree Seedling Conference (Guldin and Barnett 1982) and the Canadian Containerized Tree Seedling Symposium (Scarratt and others 1982), updated much of the available information on containerized seedling systems.

Although information has rapidly accumulated since the early 1970's, long term studies on growth and development are lacking. The development and evolution 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 container designs. Although a symposium was devoted to the root form of bare-root and containerized seedlings (Van Eerden and Kinghorn 1978), the overall effect of root configuration 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 outplanted on adverse sites.

METHODOLOGY

The materials and methods used in establishing the original trial in 1973 are discussed in the North American Containerized Forest Tree Seedling Symposium (Miller and Budy 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 recover the root system extending 30cm from the container. No attempt was made to recover the entire root system. After excavation, the number of lateral roots extending from the container sidewalls was recorded and the diameter of the tap root at the bottom of the container was measured. The seedling was severed at the root collar, and shoot and root green weights were determined.

Containers

The container types included in the 1973 trial and reevaluated in 1983 are described in Table 1. The Japanese paperpot is designated FH520. The Conwed is an open-mesh, nonbiodegradable polypropylene plastic material. The Conwed designated as 9+3 in this paper contained 9-inches of potting mix with 3-inches of the plastic mesh left exposed above the soil surface when planted. The Zeiset containers are made of a polyethelene coated board stock paper, similar to that used in milk cartons. The polyetheylene coating (.0005 inch) is intended to keep plants divided while in the greenhouse, but not thick enough to girdle plants when outplanted in the field.

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Table 1.--Description of containers evaluated.

Container Type	Dimensions				Material	Rooting	Volume
	Dia. (in)	Depth (in)	Dia. (cm)	Depth (cm)		(in^3)	(cm^3)
8-Paperpot	2.0	7.9	5.0	20.0	Treated paper	25.1	392.7
9+3-Conved	2.0	9.0	5.0	22.9	Plastic mesh	28.3	463.3
12-Conved	2.0	12.0	5.0	30.5	Plastic mesh	37.7	617.8
12-Zeiset	2.5[1]	12.0	6.4[1]	30.5	Polyethylene cover - ed cardboard	75.0	1229.0

[1] Side of square.

RESULTS

Survival and Growth

After 10 years, the survival was very similar to the first year survival (Table 2). Compared to the losses encountered during the first year, subsequent mortality was relatively low. The highest survival and best growth after 10 years were evident with the Conved containers. The results indicated a highly significant difference ($P < .01$) in survival between the Conved containers and the paper and cardboard containers. After nine years the difference in heights was apparent, but not significant. The significant difference ($P < .05$) in height growth was not revealed until after ten years. The seedlings in Zeiset containers showed the lowest height and diameter growth. The poor field performance of the Zeiset seedlings appears to be related to the root form and is discussed in the following section.

Root Form

Excavation of the containerized seedlings revealed that field performance may be largely affected by the design and shape of the container. Representative root systems after excavation are shown for the 12-Conved (Fig. 1), 9+3-Conved (Fig. 2), 12-Zeiset (Fig. 3), and 8-Paperpot (Fig. 4). The most obvious difference between the four container types is the lack of lateral roots penetrating from the Zeiset container.

The only container type which showed any signs of breaking down was the Paperpot. The Zeiset containers were still very much intact and it appeared that the plastic coating was very effective in preventing lateral root development. The Conved containers were not expected to break down; however, as the lateral roots developed they were able to break apart the plastic mesh (Fig. 5). Although the roots showed signs of constriction (Fig. 6), the developing lateral roots can apparently overcome the obstruction.

Table 2.--Mean survival, diameter and height of Jeffrey pine seedlings outplanted in 1973.

Container Type	Survival[1] 1974	Survival[1] 1983	Diameter[2] 1983	Height[1] 1983
	(%)	(%)	(cm)	(cm)
9+3-Conved	80^{a}	63^{a}	3.3	77^{a}
12-Conved	76^{a}	61^{a}	3.1	70^{ab}
12-Zeiset	59^{b}	39^{b}	2.3	51^{b}
8-Paperpot	50^{b}	34^{b}	2.5	57^{ab}

[1] Means with the same superscript are not significantly different.
[2] Diameter at root collar.

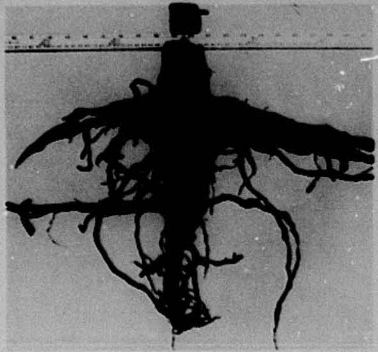


Figure 1.--Root penetration of a Jeffrey pine through a 12-Conved ten years after outplanting.

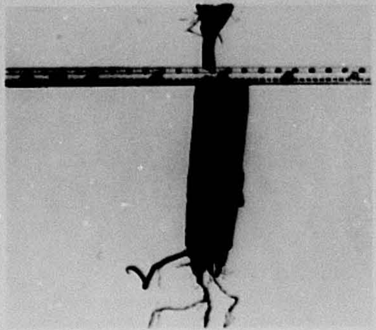


Figure 2.--Root Penetration of a Jeffrey pine through a 9+3-Conved ten years after outplanting.

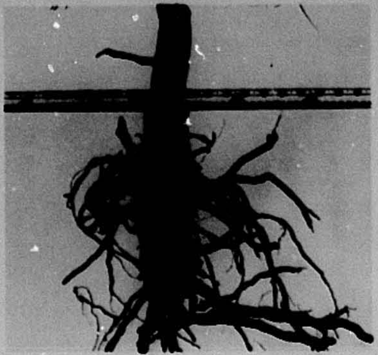


Figure 3.--Root penetration of a Jeffrey pine through a 12-Zeiset ten years after outplanting.

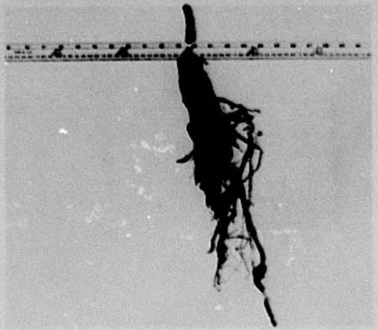


Figure 4.--Root penetration of a Jeffrey pine through a 8-Paperpot ten years after outplanting.

Characteristics of the excavated seedlings are shown in Table 3. The Conved seedlings had a greater number of lateral roots penetrating through the container sidewalls, a larger tap root emerging from the bottom of the container, and a greater biomass than the Zeiset and Paperpot seedlings. There was a highly significant difference ($P < .01$) in the mean number of lateral roots between the Conved and both the Zeiset and Paperpot seedlings (Table 3). Also, the Paperpot seedlings had significantly ($P < .01$) greater root penetration through the sidewalls than the Zeiset seedlings. The lack of lateral root penetration for the Zeiset seedlings may account for the poor field performance. In addition, after the containers were removed from the excavated seedlings (Fig. 7-10), root problems were most evident on the Zeiset seedlings. Although the Zeiset seedlings developed lateral roots (Fig. 11), the laterals were confined within the container and became quite deformed after ten years of restricted growth (Figure 12).

Figure 5.--Close-up view of a lateral root breaking apart the plastic mesh of a Conwed Container.

Figure 6.--Lateral Root of a Jeffrey pine showing constriction resulting from the plastic mesh of a Conwed container ten years after outplanting.

Table 3.--Mean root and shoot characteristics of excavated Jeffrey pines ten years after outplanting in four container types (5 samples per container type).

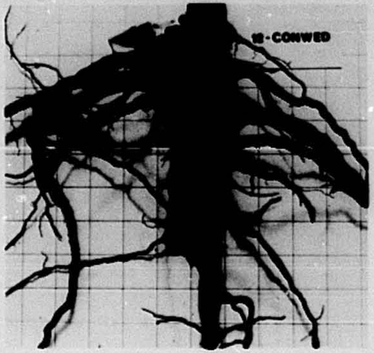
Container Type	Lateral Roots[1]	Tap Root Diameter	Green Weight Root	Green Weight Shoot
	(no.)	(cm)	(kg)	(kg)
9+3-Conwed	19.6^a	2.12	.381	1.39
12-Conwed	19.6^a	2.24	.406	1.60
12-Zeiset	$.6^b$	.99	.227	.73
8-Paperpot	11.0^c	1.26	.112	.42

[1] Means 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 Conwed containers while the poorest survival and growth occurred on the Zeiset and Paperpot containers. The most significant finding was the lack of lateral root penetration through the Zeiset containers. Although the manufacturer's intention with the plastic coating is to keep the plant roots divided during the rearing stages in the greenhouse, the thin coating apparently prevents 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. Owston 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 Conweds than in either milk cartons or cardboard tubes. Tinus (1978) has suggested that holes or slits be incorporated into the upper sides of solid wall containers to increase surface laterals for wind firmness; however, the results of this study indicated that better growth and development resulted where lateral root development was unrestricted.



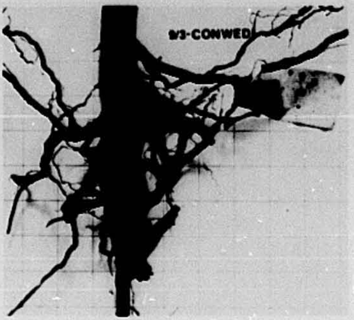
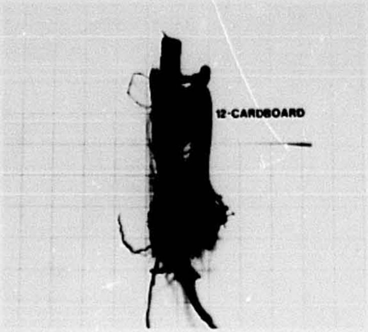


Figure 7.--Root system of a Jeffrey pine with the 12-Conwed container removed ten years after outplanting (grid = 4x4cm).

Figure 9.--Root system of a Jeffrey pine with the 12-Zeiset container removed ten years after outplanting (grid = 4x4cm).



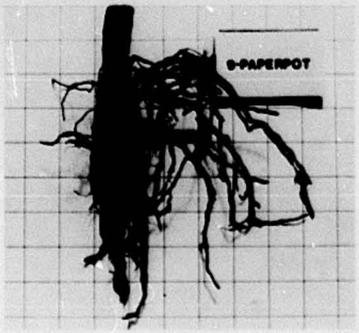


Figure 8.--Root system of a Jeffrey pine with the 9+3-Conwed container removed ten yers after outplating (grid = 4x4cm).

Figure 10.--Root system of a Jeffrey pine with the 8-Paperpot container removed ten years after outplanting (grid = 4x4cm).

The growth and development of seedlings outplanted in Conwed containers also dispel some of the early fears of root constriction problems associated with the plastic mesh type of container. Although Barnett (1982) reported that loblolly pine roots can become severly constricted by the plastic mesh three years after outplanting, the results of this study indicated that the lateral roots can break apart the plastic mesh. The Conwed material has been manufactured in various degrees of flexibility, and the material used in Barnett's study was less flexibie than the material used in this study. Owston and Stein (1978) tested the same Conwed material as used in this study

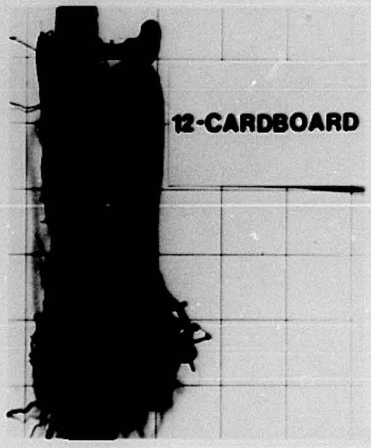


Figure 11.--Jeffrey pine root system showing the restriction of lateral root development after ten years in a 12-Zeiset container (grid = 4x4cm).

Figure 12.--Close-up view of a Jeffrey pine root system showing deformation after ten years in a 12-Zeiset container (grid = 4x4cm).

and reported girdling on the lateral roots. They found that the lateral roots penetrating the plastic mesh were smaller in diameter than those penetrating peat-fiber pots. The root constriction 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 outplanted 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 unrestricted 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 McGilvroy 1981).

PUBLICATIONS CITED

Barnett, J.P. Selecting containers for southern pine seedling production. In: Guldin, R.W.; Barnett, J.P., ed. Proceedings of the Southern Containerized Forest Tree Seedling Conference; 1981 Aug. 25-27; Savannah, Georgia. Gen. Tech. Rep. SO-37:15-24; 1982.

Barnett, J.P.; McGilvray, J.M. Container planting systems for the South. Res. Pap. SO-167. U.S. Dep. Agric., For. Serv., South. For. Exp. Stn., New Orleans, LA; 1981. 18p.

Guldin, R.W.; Barnett, J.P., ed. Proceedings of the Southern Containerized Forest Tree Seedling Conference. 1981 Aug. 25-27; Savannah, Georgia. Gen. Tech. Rep. SO-37. U.S. Dep. Agric., For. Serv., South. For Exp. Stn., New Orleans, LA; 1982. 156p.

Miller, E.L.; Budy, J.D. Field Survival of Container-grown Jeffrey pine seedlings outplanted on adverse sites. In: Tinus, R.W.; Stein, W.I.; Balmer, W.E., ed. Proceedings North American Containerized Forest Tree Seedling Symposium; Great Plains Agric. Counc. Pub. 68:377-383; 1974.

Owston, P.W.; Stein, W.I. Survival, growth, and root form of containerized and bare-root Douglas-firs and noble firs seven years after planting. In: Van Eerden, E.; Kinghorn, J.M., ed. Proceedings of the Root Form of Planted Trees Symposium; 1978 May 16-19; Victoria, B.C. B.C. Min. For./Can. For. Serv. Joint Rep. 8:216-221; 1978.

Scarratt, J.B.; Glerum, C.; Plexman, C.A., ed. Proceedings of the Canadian Containerized Tree Seedling Symposium. 1981 Sept. 14-16; Toronto, Ontario. COJFRC Symposium Proceedings O-P-10; 1982. 460p.

Tinus, R.W. Root system configuration is important to long tree life. In: International Plant Propagators' Society Combined Proceedings. 28:58-62; 1978.

Tinus, R.W.; Stein, W.I.; Balmer, W.E., ed. Proceedings of the North American Containerized Forest Tree Seedling Symposium. 1974 Aug. 26-29; Denver, Colorado. Great Plains Agric. Counc. Publ. No. 68; 1974. 458p.

Van Eerden, E.; Kinghorn, J.M., ed. Proceedings of the Root Form of Planted Trees Symposium. 1978 May 16-19; Victoria, B.C. B.C. Min. For./Can. For. Serv. Joint Rep. No. 8; 1978. 357p.

Waldron, R.M., ed. Proceedings of a Workshop on Container Planting in Canada. 1971 Sept. 28-30; Alberta. Directorate of Program Coordination; Ottawa, Ontario; Info. Rep. DPC-X-2; 1972. 168p.

In: Murphy, Patrick M., compiler. The challenge of producing native plants for the Intermountain area: proceedings: Intermountain Nurseryman's Association 1983 conference; 1983 August 8-11; Las Vegas, NV. General Technical Report INT-168. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1984. 96 p.

GROWING CONTAINERIZED TREE SEEDLINGS IN A SHADEHOUSE

Thomas M. Smith

ABSTRACT: Initial data indicate containerized ponderosa pine (Pinus ponderosa, Rocky Mountain form) tree seedlings germinated 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 in early May rather than early June and may survive a July outplanting at the same location.

INTRODUCTION

On May 2, 1983, three baskets of seed, each containing 13 Spencer-LeMaire, Tinus (21.5 cubic inches) bookplanters, were sown at the Bureau of Indian Affairs (BIA) greenhouse in Albuquerque, N.M. A Zuni, 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 1983, therefore, germination conditions were not optimum. The production greenhouse currently maintains a triple crop schedule producing 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, 1983, 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 1983, and were from a Zuni, 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 30' x 100' double poly nexus style greenhouse with a shadehouse approximately 100' x 100'. The fertilizer used is Peters 20-20-20 for the greenhouse, Peters 9-45-15 for after-stress and in the shadehouse, and Peters STEM for trace element addition in both the greenhouse and shadehouse.

In an attempt to determine if crop production could be increased, two baskets of seed, each containing 13 Spencer-Lemaire Tinus (21.5 cubic inches) bookplanters, were sown on May 2, 1983. These baskets of seeds were then placed with a crop of ponderosa pine containerized tree seedlings that were sown in early February 1983. All seedlings were from a Zuni, N.M., source.

The germinants were watered twice daily with the boom during scheduled waterings and supplemented with hand waterings for two weeks. No watering was done on the weekends.

Table 1 lists the daily temperature extremes in the greenhouse from May 2 to June 7, 1983.

Table 1.-- Greenhouse maximum, minimum, and current temperatures from 5/2/83 to 6/7/83

Date	Time	Max.	Min.	Current
5/2	0733	84	76	78
5/3	0720	80	68	71
5/4	0739	82	69	72
5/5	0727	80	70	72
5/6	0740	83	70	72
5/7	1159	78	69	76
5/8	1200	78	70	78
5/9	0729	84	70	72
5/10	0739	80	70	73
5/11	0735	82	70	73
5/12	0738	81	70	76
5/13	0740	80	70	71
5/14	0800	78	70	78
5/15	0800	79	71	78
5/16	0740	81	70	74
5/17	0735	79	70	72
5/18	0735	78	71	73
5/19	0730	78	71	74
5/20[1]	0740	80	71	72
5/23[2]	0722	78	62	66
5/24	0735	82	63	66
5/25	0740	87	62	65
5/26	0725	84	65	66
5/27	0730	88	63	64
5/28	0800	80	63	68
5/29	0800	85	64	67
5/30	0814	80	64	68
5/31	0745	77	62	64
6/1	0735	78	60	62
6/2	0740	79	60	62
6/3	0734	80	58	60
6/4	0800	77	57	65
6/5	0800	81	58	64
6/6	0730	82	63	64
6/7	0715	78	62	63

[1] Hygrothermograph clock stopped during evening of 5/20/83 and no recordings available until 5/23/83.

[2] May 23, 1983, the greenhouse crop was flushed then stressed: germinants were neither flushed nor stressed.

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The temperatures that were maintained in the greenhouse were within the optimum range for seedlings in the "exponential" stage, but they were not optimum for "germination."

During stressing the germinants were watered Monday, Wednesday, and Friday morning, and were fertilized within one tablespoon/gallon 20-20-20.

The greenhouse crop and germinants were moved to the shadehouse on June 7, 1983.

In the shadehouse the germinants received the following:

A. June 8 - water and fertilize with shadehouse 2 lb. 9-45-15+STEM/6 qt. water.
B. June 10- water from greenhouse lines.
C. June 13 - water and fertilize with shadehouse 2 lb. 9-45-15+STEM/6 qt. water.
D. June 15 - water from greenhouse lines.
E. June 16 - water and fertilize with shadehouse 2 lb. 9-45-15-STEM/6 qt. water.
F. June 17 - water from greenhouse lines, fertilize 1 tablespoon/gal. 20-20-20.
G. June 20 - water and fertilize with shadehouse 2 lb. 9-45-15+STEM/6 qt water.
H. June 22 - water from greenhouse lines, fertilize 1 tablespoon/gal. 20-20-20.
I. June 27 - water and fertilize from greenhouse lines, 1/2 lb. 20-20-20+STEM/4 qt. water.
J. June 29 - water and fertilize from greenhouse lines, 1/2 lb. 20-20-20+STEM/4 qt water.
K. July 1 - water from greenhouse lines.
L. July 4 - water and fertilize from greenhouse lines, 1 lb. 20-20-20+STEM/4 qt. water.
M. July 6 - water and fertilize from greenhouse lines 1 lb. 20-20-20+STEM/4 qt. water.
N. July 7 - water and fertilize from shadehouse lines,2 lb.9-45-15+STEM/6 qt. water.
O. July 11 - water from greenhouse lines, fertilize 3 tsps./gal. 20-20-20.
P. July 13 - water and fertilize from greenhouse lines, 1/2 lb. 20-20-20+STEM 4 qt/ water.
Q. July 15 - water from greenhouse lines.
R. July 18 - begin water and fertilize from greenhouse lines, 2 lb. 20-20-20+STEM.
S. Continue watering schedule of 7/18 on Mondays and Wednesdays, and water only from greenhouse lines on Fridays

Table 2 records the measurements of the germinants as of August 1, 1983.

Table 2.--Measurements of germinants, August 1983

Basket No.	Caliper (Inches)					Height (Inches)				
	Max.	Min.	Mean	Mode	Median	Max.	Min.	Mean	Mode	Median
1	3/32	1/16	0.067	1/16	1/16	4 7/8	1 1/2	3.983	4	4
2	3/32	1/32	0.067	1/16	1/16	4 7/8	1 3/4	3.635	3 1/2	3 5/8
3	3/32	1/16	0.066	1/16	1/16	5 3/8	2 1/2	3.756	3 1/4	3 1/2

Basket number 1 contained 52 seedlings, basket number 2, 51, and basket number 3 contained 50. The maximum possible number of seedlings was 52 per basket.

Containerized tree seedlings are grown for spring and summer outplanting. Seedlings sown in the summer are scheduled for outplanting the following spring. The goal of the summer sowing is to produce a seedling that would successfully overwinter in the shadehouse. Currently the seedlings are actively growing and have good secondary needle development. Chronologically, these seedlings are one month older than those in the greenhouse. They are further developed in all phases of growth than those that have been in a fully controlled greenhouse for two months.

On May 3, 1983, two baskets, each containing 52 ponderosa pine containerized tree seedlings were moved to the shadehouse. These seedlings were sown in early February 1983 from a Zuni, N.M., seed source. The seedlings were not moved to the shadehouse until low temperatures could be assured to be above 32°F.

Table 3 details daily Fahrenheit temperature ranges in the shadehouse.

Table 3.--Daily maximum, minimum, and current shadehouse temperatures from 4/29 to 6/7/83

Date	Time	Max.	Min.	Current
4/29	1553	85	39	85
5/2	1615	87	35	66
5/3	1630	88	33	74
5/4	1558	92	33	87
5/5	1615	90	36	88
5/6	1556	87	40	80
5/9	1617	88	40	80
5/10	1610	83	45	83
5/11	1602	91	40	87
5/13	1605	90	36	80
5/16	1613	88	34	82
5/17	1610	82	32	62
5/18	1618	86	34	84
5/19	1630	82	38	64
5/20	1618	83	46	64
5/23	1610	92	38	87
5/24	1610	92	46	92
5/25	1612	98	47	83
5/26	1609	97	53	86
5/27	1612	100	52	88
6/1	1610	90	45	98
6/2	1620	90	64	88
6/3	1622	93	46	90
6/6	1604	98	42	88
6/7	1616	92	50	90

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.

Basket	Caliper (inches)				
No.	Max.	Min.	Mean	Mode	Median
1	3/8	1/16	0.157	1/8	5/32
2	7/32	3/32	0.144	1/8	1/8

Basket	Height (inches)				
No.	Max.	Min.	Mean	Mode	Median
1	7	2 1/2	4.865	5.25	4.75
2	6 7/8	2	4.03	4	4

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

Basket	Caliper (inches)				
No.	Max.	Min.	Mean	Mode	Median
1	3/32	1/16	0.119	1/8	1/8
2	5/32	3/32	0.124	1/8	1/8

Basket	Height (inches)				
No.	Max.	Min.	Mean	Mode	Median
1	7	3	4.954	4	5 1/4
2	7	2	5.02	4 1/2	5

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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Contains 17 papers describing successful procedures, guidelines, and problems in propagation and production of native plants. Emphasis is on seed or plant production for revegetating disturbed lands.

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

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This publication reports research involving pesticides. It does not contain recommendations for their use, nor does it imply that the uses discussed here have been registered. All uses of pesticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

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Field programs and research work units of the Station are maintained in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)