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Guidelines for Handling Seeds and Seedlings to Ensure Vigorous Stock

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Contents

Introduction

Selecting the appropriate species, matching seed source to planting site, using genetically improved seedlings, and planting a stock type that has the best chance of surviving site conditions created by logging and site preparation are all important factors in achieving reforestation success. However, it is the quality (physiological status) of the stock that determines whether a seedling can express its full potential after planting. All too frequently, the time, labor, and money spent on producing the ideal seedling for a given site are lost because of problems created by poor quality control between cone collection and planting.

The purpose of this publication is to provide guidelines for optimizing quality control during the reforestation process. The guidelines are not meant to tell professionals how to manage their operations, only to remind technicians of practices that need to be considered, and to enhance their awareness of handling precautions; they are intended to apply to all reforestation disciplines concerned with production or establishment of quality stock. The guidelines are grouped sequentially by occupational activities and have some specific objectives:

- Improve individual handler's awareness of all the steps that should be followed by various personnel to produce seeds or seedlings of high vigor.
- Provide checklists that handlers can use directly or after modification by managers to enhance quality control.
- Establish a conceptual framework for care and handling that focuses first on biological needs of seedlings and subsequently on economic and production goals of the operation.
- Promote constructive communications among seed-processing, nursery, and forestry professionals.

The guidelines are not a defense against negligence. On the contrary, the practices outlined in each section are presented to help prevent mistakes caused by inexperience or misinformation. Recognition of undesirable conditions and activities, and then planning ahead to correct them, are essential to reforestation success. Seedling status must be assessed and recorded methodically if causes of failure are to be identified and corrective measures taken.

The guidelines should not be used inflexibly; their application should be tempered with the judgment needed to fit each situation. Furthermore, recommendations can only be based on the concepts and facts with which we are currently familiar; specific points may change, just as they have in the last 10 years. If kept up-to-date and used with discretion, the guidelines can be a valuable tool. Research continues to demonstrate the fragile nature of seeds and seedlings and to warn us that current logging and site preparation practices create micro-environments that can be quite different from those to which the species has adapted over time. Consequently, the margin for error in achieving plantation success can be very small; all practices relevant to the production of vigorous stock must be identified and addressed.

Stress and Vigor Reduction

People often forget that seeds and seedlings are sensitive, living organisms. A seed is a casing for the seedling embryo, not unlike the womb surrounding a developing infant. Rough treatment will cause damage. For example, seed germination is reduced by 20% if a nickel is dropped on a seed from a height of only 3 inches. Dropping the nickel on the seed three more times will kill the embryo. A young seedling is just as sensitive to stress as is a young child. And exposing a seedling's roots to warm, dry conditions after lifting imposes a stress on the seedling.

Stress is often as subtle to a seedling as it is to a human infant. Low seedling vigor, like a child's cold, may not be visible but will have an impact on how well the seedling performs. More important, stress is cumulative. Once a seedling is weakened, its resistance to subsequent stress events and its ability to recover are reduced.

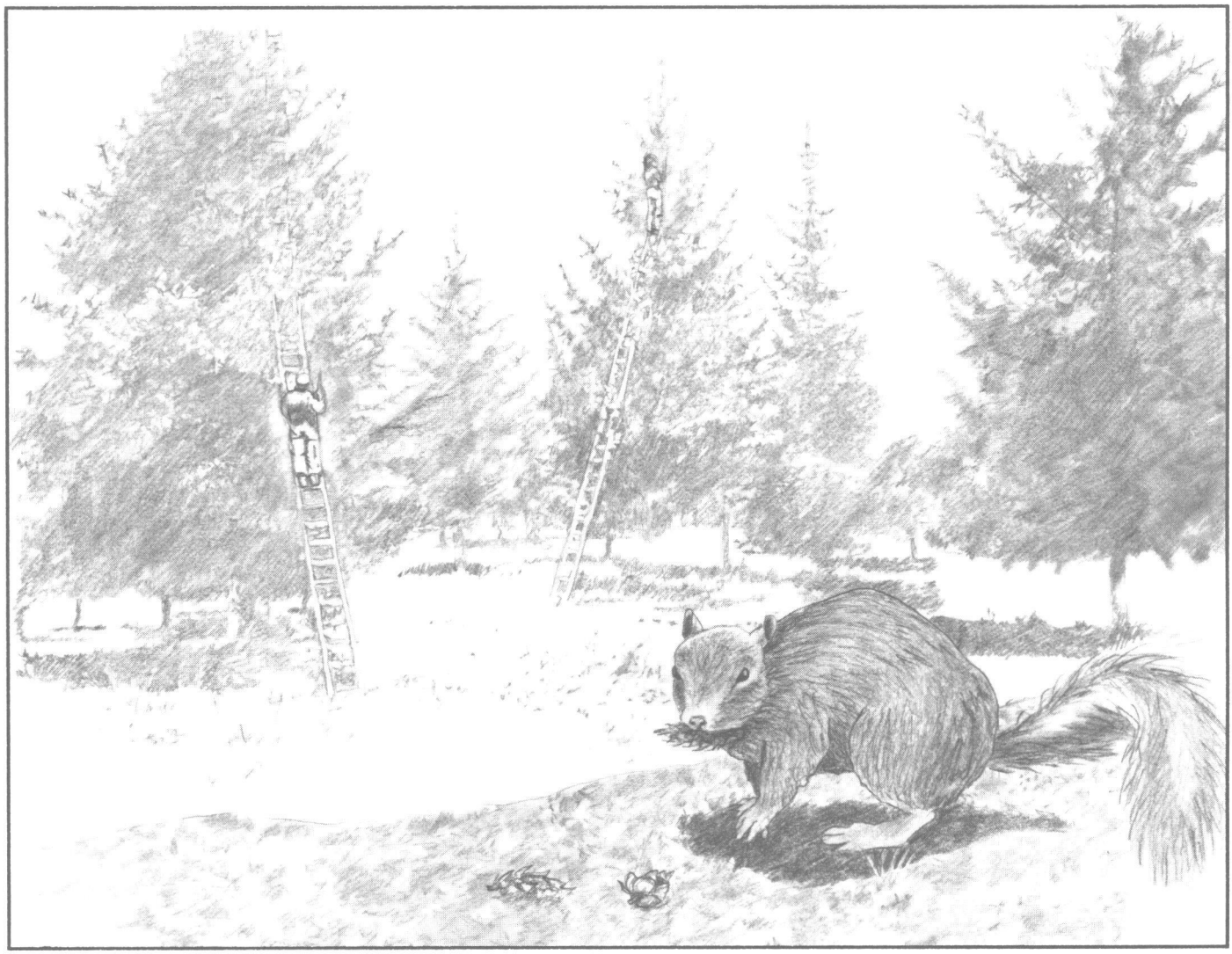
Seedlings respond to stress events such as dehydration, rapid heating, wounding, jarring, and low oxygen levels by shifting their priorities for food and nutrient allocation from growth to survival, adjustment, and repair. If the seed or seedling encounters only a few minor stresses during handling, its response may be too subtle to reduce growth, particularly on sites rich in available resources. However, as the number of stresses increases, so does the likelihood of reduced growth, especially if recovery from prior stresses has not been completed. If their vigor has been reduced by poor handling practices,

seedlings planted on harsh or poorly prepared sites frequently die in the first season. When seedlings have been abused because of poor handling, they may be dying or dead at the time of planting, in which case mortality becomes apparent after the first period of mild, warm weather in spring.

Many cultural practices imposed at the nursery are interpreted as stress by the seedling. Root pruning (undercutting) triggers a stress response that shifts growth from stem to roots; this increases root fibrosity and the chances of survival after planting on the site. Although this practice is an important tool for the nursery, the seedling is being wounded. Like any surgical technique, it must be done carefully and properly to gain the maximum benefit. Height growth stops because the injury severs the supply of water that was being used to drive enlargement of stem and needle tissues. The stress of dehydration and wounding triggers metabolic changes that induce reallocation of growth substrates to sites of repair; thus, there is a proliferation of roots. Pruning at lifting and during processing elicits a similar stress response. However, because the seedling has been removed from its natural environment, food production no longer occurs, so the substrates for wound repair must come from a limited supply of reserves. Additional stresses prior to planting will make similar demands on this reserve supply. Food reserves used in repair cannot be replenished until after planting, a time when the need to recover may detract from the quick, extensive root development needed for establishment.

Because potential stresses are unavoidable, those induced during handling need to be minimized by strict quality control measures. The following guidelines are designed to enable seed-processing, nursery, and forestry professionals to recognize and prevent potential problems before they jeopardize the success of new plantations.

Guideline Set 1:
From Cone Collection through Seed Processing



Cone Collection

1. Frequently survey the cones in the area from which you wish to collect; begin survey by June 1 for low elevations and southerly latitudes or by July 1 for high elevations and northerly latitudes.

2. Make sure cones are mature when picked. To evaluate maturity accurately, sample cones from a variety of trees and slice seeds open. Look for embryo (premature seedling) enlargement and thickening (from milky to pasty) of the starchy female gametophyte. Color change[1] in cones can be a useful indicator of when to begin sampling more intensively for maturity.

   a. Douglas-fir--The seedcoat is dark brown with a light brown seedwing at maturity. Green cones develop a brownish tint before the scales flare.

   b. True firs--The seedcoat and wing achieve a light brown color after changing from green or bluish-purple, depending on the species.

   c. Spruce--The seedcoat color proceeds from pink to purple or dark red to nearly black at maturity.

   d. Pine--The seedcoat and wing of ponderosa pine change from greenish-yellow to brown with a faint tinge of yellow or green. Sugar pine is similar, but rarely yellowish. Lodgepole and Jeffrey pine change from greenish-purple to yellowish-brown, and dark purple to light purplish-brown, respectively.

3. Use a sharp knife to sample the cones for mature seeds. The embryo must fill 90% or more of the embryo cavity, and the starchy surroundings should be firm and whitish. Use a hand lens to magnify smaller seeds. If cones are picked when the seeds are not quite fully mature (embryo fills 75 to 90% of the cavity and the starchy surroundings are spongy), then the cones will need to be after-ripened by keeping them under well-aerated, cool (shaded) and moist conditions for 2 to 6 weeks; check frequently for maturity.

   a. For Douglas-fir, spruce, pine, and hemlock, cut lengthwise down the center from stem to tip.

   b. For true fir, cut lengthwise from stem to tip but off-center about 1/3 of the distance to the edge of the cone (3/8 to 5/8 inch, depending on the size of the cone).

   c. For incense-cedar and western red cedar, cut widthwise slightly below the center of the cone.

4. The economics of collecting in a given year vary with the organization and the circumstance. However, to maximize economic return, evaluate seed soundness and the occurrence of insect damage before you decide to collect.

   a. General guidelines for identifying the economic practicality of collecting cones of different species are as follows:

      (1.) Douglas-fir--5 or more sound seeds per cut face.

      (2.) Spruce--10 or more sound seeds per cut face.

      (3.) True fir--more than 50% of the seeds filled on a cut face.

   b. Look carefully for insect damage, which may reduce yields significantly (see Table 1).

5. When cones are ready to be picked, employ a qualified tree climber. Instruct the climber to:

   a. Pick cones in the upper third of the canopy, if possible, to maximize vigor and viability of the seeds. Note: Many commercial seed companies collect from squirrels' seed caches.[2] Squirrels sample cones early in the season to test food quality. What you find in caches between August and October, depending on elevation or latitude, should represent pickable cones. Check maturity carefully before you collect. Caution: Seeds collected from squirrel caches may be in-

[1] Color changes occur gradually during ripening and may be difficult to interpret; therefore, color should only be used as a guide to, not an absolute statement of, seed maturity.

[2] These seeds can only be certified as Audit or Source Identified B seeds, which have a reduced sale value. Seeds classified as Audit are purported to originate from a designated zone and elevational band, but there is no guarantee of this. The collection location for Source Identified B seeds has been verified [see DeYoe (1983)].

TABLE 1.
INSECT DAMAGE TO CONES AND SEED OF PACIFIC NORTHWEST CONIFERS.

Insect type and species	Host conifers[1] DF	GF	NF	WH	SS	PP	LP	Damage
Cone moths								Burrows within cone. External frass and pitch sometimes visible. Three or more larvae can deform cone and damage 75% of the seeds.
Barbara colfaxiana	‡	‡	‡					
Eucosma bobana						‡		
Eucosma rescissoriana							‡	
Cone worms								Larvae bore through the cone scale and the seeds, leaving a round hole. Frass may be visible externally. Can destroy up to 50% of the seed crop.
Dioryctria abietella	‡						‡	
Dioryctria spp.						‡		
Cone midges								Cone tissue deformed, but seeds not damaged. Seed extraction may be hindered or prevented.
Contarinia washingtonensis	‡							
Dasineura spp.					‡			
Seed chalcids								Larvae consume all tissue inside the seedcoat. No external evidence can be seen on cone or seeds.
Megastigmus spermotrophus	‡							
Megastigmus spp.		‡	‡					
Megastigmus tsugae				‡				
Megastigmus piceae					‡			
Seed (gall) midges								Larvae feed inside the cone. Each larva destroys only a single seed.
Dasineura abiesemia		‡	‡					
Mayetiola carpophaga						‡		
Seed moths								Larvae bore through the cone pith into the seeds. Seed destruction usually is 20 to 30%.
Laspeyresia spp.							‡	
Hedulia injectiva							‡	
Seed maggot								Larvae move from seed to seed, feeding in the cone. Damage may include up to 25% of the seeds in a cone, but less than 5% of the cone crop.
Earomyia abietus		‡						
Western conifer seedbug								Insect feeds by piercing through cone scales and seedcoat and injecting enzymes that dissolve contents, which are then removed by suction. Immature seeds collapse; mature seeds are left empty with a minute hole in the seedcoat.
Leptoglossus occidentalis	‡	‡					‡	

[1] DF--Douglas-fir; GF--grand fir; NF--noble fir; WH--western hemlock; SS--Sitka spruce; PP--ponderosa pine; LP--lodgepole pine.

fested with cold fungus (Calocypha spp.). Check with a pathologist if you are suspicious.

b. Avoid contaminating the cones with debris (needles, branches, dirt, etc.) that can stimulate mold, inhibit drying, and damage seeds during processing.

c. Lower bags of cones from the tree on a rope. Never drop them to the ground.

d. Use the proper type of bag. The potato sack made of burlap is good because its weave is not tight enough to induce mold or heating and not loose enough to shred easily. Nylon screen sacks are best. The mesh size should be small enough to prevent seed loss. Repair any tears or holes.

e. Tag the cone sacks inside and outside with moisture-resistant tags. Use a water-proof pen to identify your cones (location, species, age, etc.). If you wish to keep cone lots separate, consider color coding your bags by weaving colored yarn through the mesh. Tie bags securely closed with wire or twine, leaving ample space for cones to flare.

f. Never fill sacks more than half full, because overfilling increases the risk of mold and overheating. Mats of mold hyphae can restrict seed release by preventing full flaring of cones. A general rule is 1 bushel of cones per 2-bushel bag.

g. Store bags on racks that permit good exposure to air circulation, whether in the field or during transportation to the extractory.

Field Storage of Cones

1. Try to deliver cones daily to some central storage location.

2. If cones must be stored in the field for more than a day, use the following precautions:

   a. Always store bags of cones in a cool, sheltered environment. Natural air drying is the best way to store cones. An open-sided shed with racks provides good air circulation for drying cones before delivery to the processing plant.

   b. Hang cone bags in the shade, draped over racks or branches of trees, or lay them flat on screens that are at least 3 feet above the ground.

   c. Do not allow sacks to touch one another.

   d. Gently turn bags every day or two to facilitate water release and prevent case hardening.

   e. Cover cone bags if it begins to rain.

Transportation of Cones

1. Handle cones gently during loading and unloading; they are very susceptible to bruising.

2. If cones are still green and have had little or no air drying, ship them in refrigerated vans with good air circulation.

3. If cones have been air dried, ship them in a vehicle that will provide good air circulation and protection from rain. Hang bags over racks. If racks are not available, stack cone bags no more than two deep on top of pallets placed on the bed of the vehicle.

4. Avoid any layovers or delays during transit. Park in the shade if you stop.

5. Travel when weather is cool (early morning or evening for short trips and at night for long trips).

6. Provide an inventory of your cone shipment upon delivery and double check sacks to make sure tags are secured and properly marked.

7. Place cones in suitable storage (warm, well ventilated, and dry) immediately upon arrival.

Seed Processing—Good Communication

1. Establish an open-door policy with the seed processor. Make an appointment to tour the plant and learn the processing sequence and purpose of each machine. Better yet, form a group tour; such tours allow better interaction and more efficient use of the proprietor's time.

2. Review contracts with the processor and discuss specifications for purity, filled seed levels, moisture levels, packaging, seed testing, and other services. In processing, emphasis can be put on either quantity of seeds (maximum pounds per bushel) or quality of seeds (uniformity and high germination); let the processor know which you prefer.

3. Discuss payment agreements, insurance, and liability. Get a written agreement on lots to be processed in time for stratification and sowing during the current year. Determine what is included in pricing and what is extra. Do not assume anything; follow up verbal discussions with written documentation.

Seed Processing—Inspection Points

1. Establish check points at locations where empty cones and empty seeds are discarded. Do not hesitate to have the processor assist you in checking performance.

   a. Shake processed cones. If several filled seeds fall out of most of the cones you sample, the processing may have been incomplete.

   b. Check in the reject pile for damp or moldy cones that have not flared.

   c. A standard cut test or an X-ray test will disclose whether good and rejected seeds have been mixed. A cut test evaluates the percentage of sound, non-insect-infested seeds. Slice open a sample of 100 seeds and inspect the embryos and the degree to which they fill the embryo cavities. An X-ray test performs the same analysis more quickly and provides a photograph of the results for future reference.

2. Check to see that humidity in storage areas remains under 70% and sustained temperature does not rise above 100°F (prior to freezer storage).

3. Ensure that seeds to be freeze-stored are maintained at moisture levels between 6% and 9% of their oven-dry weight. Keeping seed moisture levels low is <u>essential</u> for maintaining viability during storage.

4. Check to see if at least one original tag remains with cones or seeds at each processing step.

5. Guard against contamination of subsequent lots.

   a. Inspect seed tumblers, dewingers, scalpers, and separators for stray seeds just before a new lot is started.

   b. Check floors and tables for the same purpose.

   c. Check in equipment crevices and on the floor for spilling of good seeds.

6. Inspect the rubber paddles of dewingers (or any component that contacts seeds) for wear. Seed damage often occurs at these points.

7. Inspect samples of cleaned seeds with a hand lens.

   a. Look for broken or denuded seeds.

   b. For most species, brittle, dull seedcoats are indicators of poor seeds. (Wet, sticky seeds with a strong odor of pitch signify poor seeds in true fir.)

   c. X-ray samples of suspect seeds.

Freeze Storage of Seeds

1. Seeds to be freeze-stored should have a low moisture content (between 6% and 9%).

2. Seeds from small lots should be stored in 4- to 6-mil plastic bags tagged on both the inside and the outside. These bags can then be bulked together in padded, rigid containers for storage and transport.

3. Seeds from larger lots can be placed directly into padded, rigid containers. The total weight should not exceed 40 to 50 pounds if damage is to be minimized during handling and shipping. If future testing of seed quality is intended, several hundred seeds can be kept in a 4- to 6-mil bag resting atop the bulk seeds. This arrangement prevents damage that would be caused by sampling frozen seeds with a seed probe.

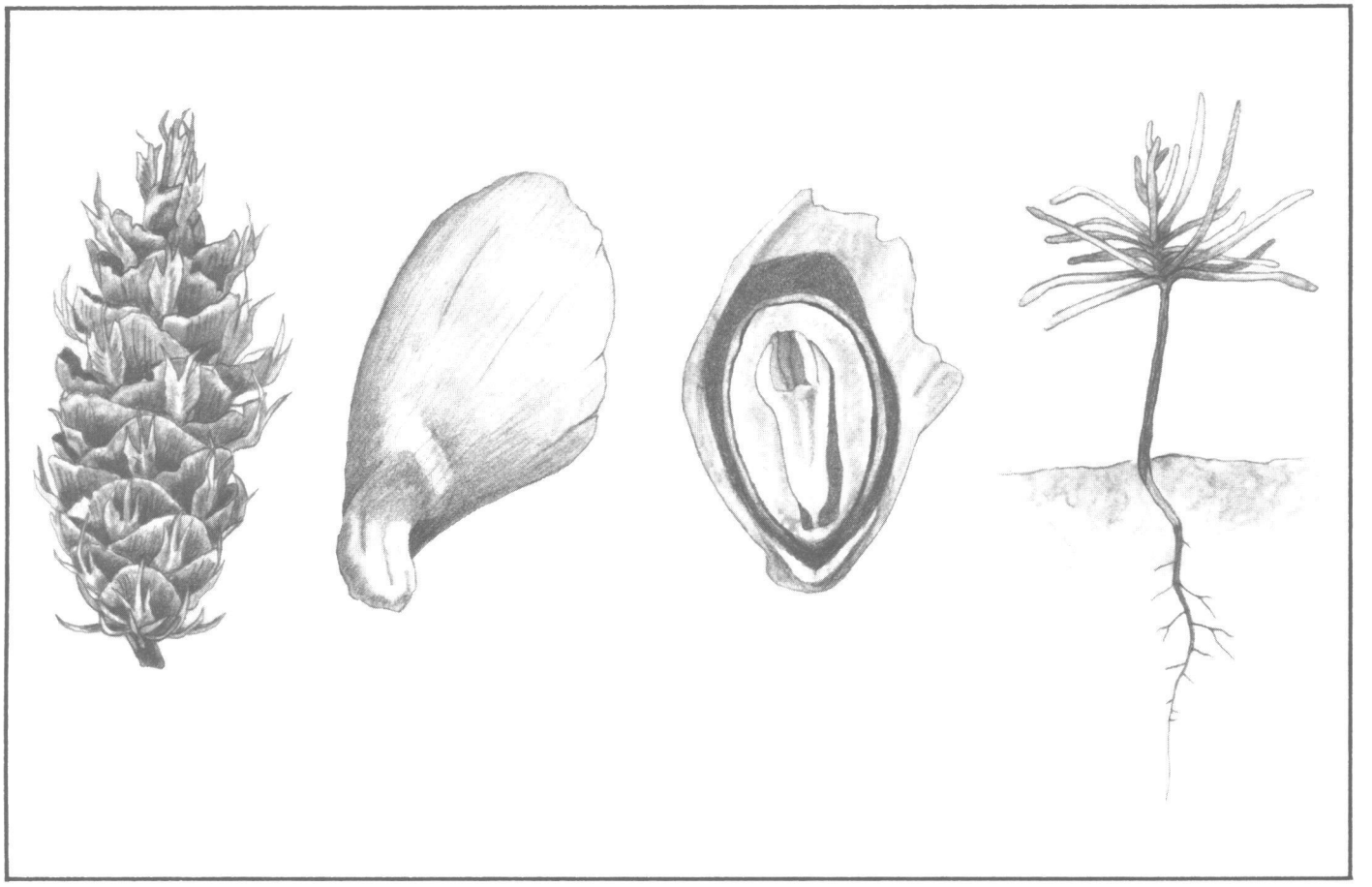
4. Storage temperatures of -10° to -15°F are satisfactory. Temperatures as high as -1° to

–5°F are also adequate; with such temperatures, however, little margin for error is left in case of freezer breakdown. Even though seeds maintained at the proper moisture content can withstand higher temperatures for short periods (days to weeks), it is best to keep seeds cold.

5. Seeds to be transported to the nursery should be maintained in the same well–marked plastic bags and shipped in cushioned containers. It is not necessary that seeds be frozen during transport, but they must be kept cool (between 35° and 40°F).

6. Seeds remaining at the extractory should be freeze–stored according to standards designated in Guideline Set 2.

Guideline Set 2:
From Certification through Storage of Seeds



Seed Identity

1. All seeds should be certified. Check with the appropriate agency for seed certification standards in your state.

2. Source Identified A or Select B seeds, if available, are recommended. Avoid use of Audit stock.

3. When purchasing seeds (or seedlings), ask to review records pertaining to:

   a. Seed lots and sublots.

   b. Seed source (tree seed zone, elevation, township/range, description of locality).

   c. Collection date.

Seed Testing

1. Have a reputable seed laboratory or nursery conduct the following tests:

   a. Seed purity (quantity of debris, soil, foreign seeds, etc.).

   b. Seed weight (seeds per pound). Note: The number of seeds per pound increases with decreasing seed moisture content; therefore, you get more for your money if measurements are made on dried seeds.

2. Have the testing facility explain to you how the data are interpreted.

3. The moisture content of seeds should be tested by processors before (and after) storage. Seed moisture content should be between 6% and 9% (varies with species).

Seed Storage

1. Seeds should be stored under the following conditions: cool, dry, clean, free of insects and rodents, and well aerated.

2. Moisture content of seeds should be between 6% and 9% (varies with species) at the beginning of storage.

3. Stored seeds must be clearly labelled both inside and outside the plastic packets or sacks.

4. Storage containers must be tightly sealed and rigid to prevent moisture exchange and physical damage.

5. Seeds should be freeze-stored at -10° to -15°F; temperatures should fluctuate no more than ± 1°F. Note: Seeds properly packaged and stored at these temperatures have no opportunity to take on moisture and should not require periodic moisture checks.

6. The freezer should have a malfunction alarm that is lockable.

7. Personnel must be on hand (or on call) to solve problems quickly.

8. When seed containers are removed from the freezer, allow them to come to room temperature before they are opened. This process will prevent moisture condensation.

9. Periodically check seeds visually or by X-ray (annually or at 2- to 5-year intervals). This can be done safely and effectively by initially placing small samples of seeds from a given lot in sealed baggies; these can be placed on top of the bulk seeds in the storage container for future sampling. Such an arrangement avoids damage caused by plunging a sampling probe into an entire lot of frozen seeds.

10. Make sure the nursery has adequate seed-drying facilities (warm, circulating air) in case arriving seeds have not previously been stored and processed and are, for whatever reason, too moist for safe storage. Note: If seeds have become too moist during a brief, earlier storage, any resulting damage cannot be repaired by subsequent redrying.

11. Because viability after storage may vary among species or even families and is influenced by seed condition at the time of storage, check seed germination periodically (5- to 7-year intervals).

Guideline Set 3:
From Seed Stratification through Nursery Culturing

Seed Transportation

1. Seeds should be transported in rigid, air–tight containers and labelled inside and outside.

2. Keep non–stratified seeds cool and dry, handle them gently, and deliver them rapidly. Note: Weekend arrivals should be avoided.

3. Stratified seeds should be kept refrigerated during transit and delivered very quickly.

Preparing Seeds for Sowing

When seeds are prepared for sowing, treatment is required to release them from dormancy. The seeds are first soaked to leach out any germination inhibitors. Then the water is drained off and the environment's "dormancy release signals" are mimicked by subjecting seeds to stratification (pre–chilling) for 14 to 90 days at low positive temperature. Optimum stratification for tree seeds varies with species, seed origin, history of the seed lot, and temperature of the stratifying medium. Most seeds require a stratification regime to facilitate rapid, uniform germination.

1. Check with the seed processor to see if the seeds require stratification.

2. Seeds should be soaked for 20 to 40 hours at 40° to 65°F in an appropriate container. The water should be changed every 2 to 5 hours during this period to optimize extraction of inhibitors.

3. Good aeration is essential to seed vigor; therefore, a simple air pump attached to the soaking/stratifying container is necessary.

4. After soaking, the water must be drained and the moist seeds placed in cold storage (33° to 40°F) for the number of days required to maximize germination of the particular species and seed source.

5. Keep seed temperature constant during stratification, and prevent freezing by continuously circulating air with fans.

6. Make sure the nursery has a temperature alarm system and trained personnel on call for repair.

7. Separate seeds into small batches so that they do not accumulate heat from their own respiration.

8. Periodically check seeds and stir gently as needed. Note: Good aeration should reduce or eliminate the need for this potentially detrimental practice.

9. Minimize mold development on seeds during stratification by maintaining sterile conditions. Fungicides may be needed to prevent molding.

10. Time the stratification to end as close as possible to anticipated sowing dates.

11. The surface of the seeds should be dried prior to calibration of the seed drill so that seeds will flow freely through the drill. Note: Recent work with Douglas–fir revealed that re–drying of seeds to 25% moisture content before sowing (fully soaked seeds have about 55%) improved vigor.

12. The period of seed stratification should be determined by results of seed tests.

One Method of Stratification

1. Weigh the seeds and place them in a clear plastic bag (5 pounds or less of seeds per bag).

2. Gather the open end of the bag around a breather tube (short piece of plastic pipe).

3. Fasten the bag to the tube with a wire tie.

4. Make a loop at the end of the wire tie and attach an identification tag.

5. Add cold tapwater to the bag so that the seeds are completely immersed and able to absorb water freely.

6. Hang the bag from a metal hook during soaking and stratification. Soak the seeds for 20–48 hours at 40°–65°F (may vary with species and seed source) and aerate them by using a small air compressor, such as from a fish tank.

7. Change the water frequently (every 2–5 hours) to eliminate leached substances that inhibit seed dormancy.

8. Poke holes in the bottom of the bag to drain the seed leachate (water plus germination inhibitors leached out of the seed). Do not leave standing water in the bag.

9. Hang the bag with moist, drained, and rinsed seeds in a cooler at 33° to 40°F, and check periodically for signs of mold or premature germination. The temperature and duration of stratification vary with the species and seed source; stratification normally lasts between 20 and 50 days.

10. Dry the seeds on towels with a fan after stratification, and gently stir occasionally to insure even drying.

11. Place the seeds in clean cloth bags and return them to the cooler after they are dry enough to be handled safely.

12. Keep the seeds refrigerated until they are sown. (Seeds can be stored in cloth bags for several months but should be checked for mold frequently.)

13. Pack the seeds on blue ice and ship within 24 hours.

Seed Sowing

1. Make sure the nursery has an accurate system for tracking lots through sowing, cultivating, lifting, and grading, and finally to sales.

2. To maximize precision of sowing density, calibrate the seed drill for each seed lot before sowing begins.

3. Make sure the seed drill is well-maintained and properly adjusted.

4. Before seeding, ensure that seedbeds have been well-worked and are uniformly smooth and weed-free and that problem areas have been avoided (those with poor drainage, frost pockets, disease spots, etc.).

5. Check sowing density during sowing and adjust as necessary. Make sure an inspector is assigned to follow along behind the seeder and monitor sowing depth and evenness.

6. Consider the option of encouraging mycorrhizal fungi. Note: Mycorrhizae are fungi that have been shown to be very beneficial to the development of most tree species. Many nurseries will inoculate seedbeds with mycorrhizae spores prior to sowing to help ensure that the beneficial union between seedling and fungus is established as early as possible.

7. Irrigate seeds immediately after sowing.

8. When possible, complete sowing by April 15 at low-elevation nurseries and by May 15 at mid-elevation or eastside nurseries.

9. Weed control is critical for germination and seedling survival. Manual or mechanical weeding can cause damage. Pre-emergent herbicides give the best results. Note: Precautions should be taken when using any herbicide; follow label specifications and test new herbicides thoroughly before applying operationally.

10. Sow seeds uniformly so that eventual growing density for 2-0 stock will fall between 17 and 25 per square foot. (The optimum sowing density appears to vary slightly among species; normally, it ranges from 15 to 30 seeds per square foot. A safe standard to follow is 20 to 25 seeds per square foot of bed.)

11. Make sure locations of seed lots are prominently marked in the field and accurately mapped.

12. Monitor germination and mortality in the beds so that future sowing of the same seed lot can be adjusted if necessary.

Nursery Cultural Practices

1. Monitor germinants closely for insect and disease problems and administer treatment quickly, if necessary.

2. Monitor the water status of seedlings closely to facilitate irrigation scheduling.

   a. Growth in spring should be rapid and "stress needles" (short, stubby needles) absent.

   b. Dormancy should be induced by mid-July. Reducing irrigation helps stop shoot elongation so that buds can set. Budset is essential for development of cold hardiness and of resistance to winter stresses

(low temperatures and freeze–induced drying).

c. Conditions conducive to the deepening of dormancy should be maintained in late summer and fall so that diameter development and root extension are not impaired.

3. Evaluate soil moisture or plant moisture stress to refine irrigation schedules.

4. Analyze foliage and soil nutrients to refine fertilization regimes.

5. Continue weeding (manually, mechanically, or with herbicides) around seedlings to minimize growth loss without damaging seedlings.

6. Seedlings may be undercut[3] or wrenched[4] periodically as a cultural treatment to promote development of a fully fibrous root system and discourage height growth. Note: If seedlings are top pruned, mowing should be done before significant lignification (stem rigidification) commences on new growth; such early mowing will minimize damage to the terminal bud and delays in normal bud development.

7. Spring transplanting should be completed by May 15.

8. Initiate fall transplanting by mid–August and complete before rains begin.

9. Apply fertilizers in a timely manner to maximize seedling development, to provide stored minerals to outplanted seedlings, and to enhance color. Note: Fertilization in late summer or early fall has been associated with reductions in frost hardiness.

10. For protection of seedlings and germinants, make sure contingency plans are established that permit rapid response to extreme temperatures (spring frosts and summer hot spells).

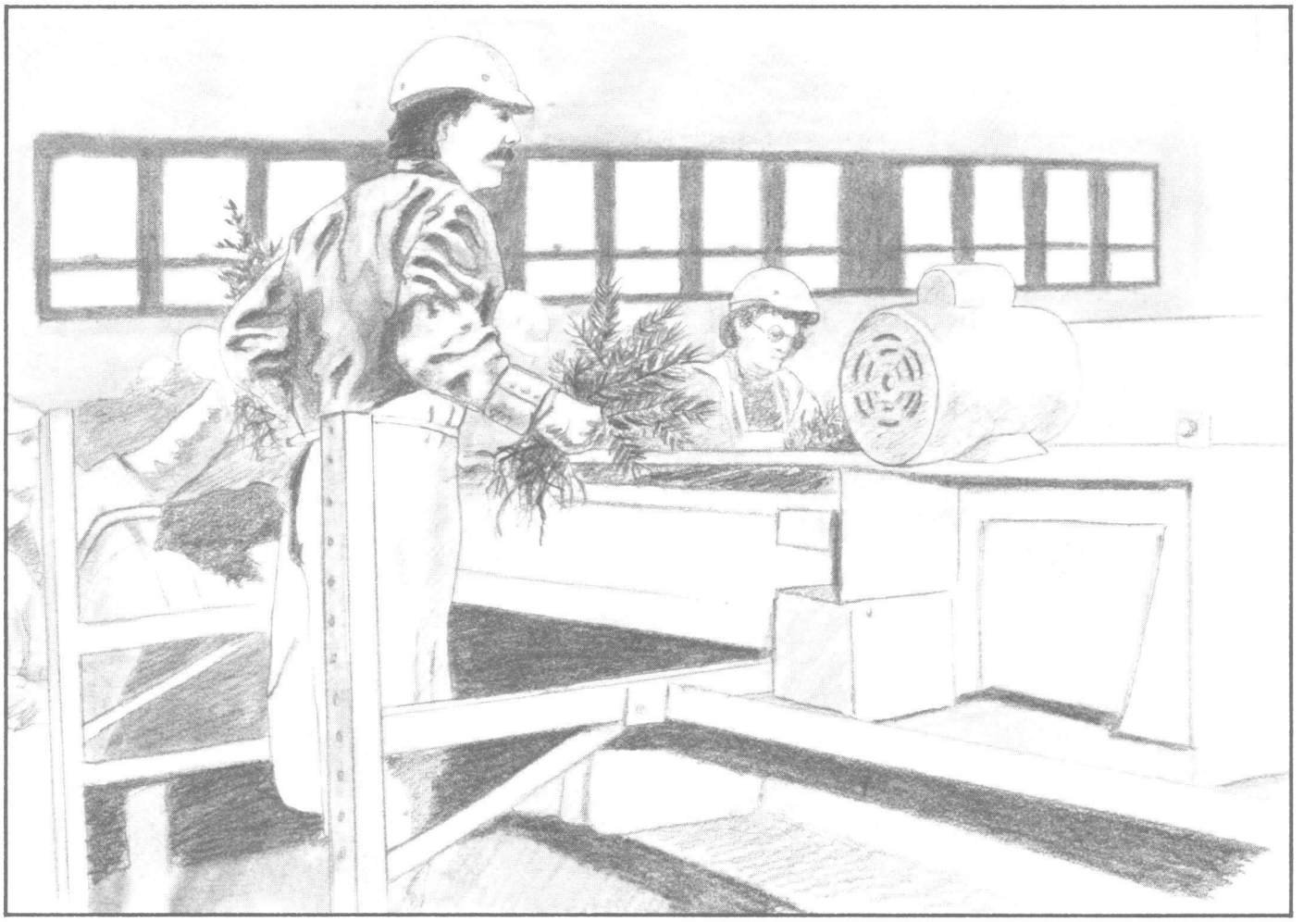
11. Periodically check seedlings for root and foliage disease.

12. Do not allow water to accumulate in nursery beds. Drain all standing water quickly.

[3] A thin, sharp blade is pulled parallel to the surface at a depth of 5 to 6 inches in the fall of the first growing season or spring of the second growing season.

[4] A thick, broad blade is pulled at a 25° angle at a depth of 8 to 10 inches in the spring or summer of the second growing season.

Guideline Set 4:
From Lifting through Delivery of Seedlings



Lifting, Pulling, and Preparing for Processing

Lifting involves use of a wrenching blade to break the root system from the soil at a depth of 8 to 12 inches so that pulling is facilitated. Pulling is extraction of the seedlings from the soil and placement in field containers.

1. The timing of lifting may vary, depending on the nursery environment, the species and provenance, the cultural regime used to condition stock for lifting, and the availability and type of storage facilities. For coastal and Cascade stock from elevations below 3,000 feet, seedlings are normally lifted between mid-December and mid-February and then planted or placed briefly in cold storage (less than 2 months at 33° to 34°F). Seedlings from higher elevations, high latitudes, or intermountain regions can be lifted as early as mid-November. These seedlings can be stored for up to 8 months. Freeze storage (29° to 31°F) is preferred over cold storage (33° to 34°F).

2. Lifting should not proceed if soils are frozen at or below the surface or if they are so moist or mucky that there is a risk of root damage.

3. Make sure that personnel know to keep seedlings moist and cool and to handle seedlings, field containers, and packing bags and boxes carefully.

4. Lifting should be stopped and irrigation initiated if moisture stress exceeds a predetermined level established by the nursery. The likelihood of moisture stress occurring can be assessed by monitoring factors associated with drying (air temperature, humidity, wind velocity, and time of day).

5. Lifting should not begin until all essential items (field containers, moistened burlap, extra water, radiation shields, monitoring equipment, pallets, and a vehicle for hauling) are assembled and the pulling crew is aligned and ready.

6. A multiple checking system should be in use to help ensure integrity of lots and sources.

7. Make sure drivers carefully maneuver their machinery.

8. Make sure seedlings are removed from the beds immediately after they have been loosened with the lifting machine.

9. Seedlings should be pulled from the bed gently and in groups to minimize root disturbance. Note: Moisten seedling roots (and tops) immediately after pulling to minimize risk of moisture stress even though the seedlings may be covered with damp burlap and a radiation shield.

10. Excess soil should be gently removed from seedlings, particularly from the tops.

11. Make sure field containers are sturdy and big enough to hold large seedlings so that the tips of stems and roots are not damaged during packing, loading, and transit.

12. Place seedlings in field containers quickly.

    a. Moisten seedlings to minimize stress.

    b. Place a moistened cover over the seedlings to reduce moisture loss and help prevent warming.

    c. On lightly overcast to sunny days, use a white or silver radiation shield to protect seedlings against warming.

    d. Monitor moisture stress. Keep it below 8 bars.

13. Stack field containers quickly and gently on pallets after lifting.

14. Prevent bouncing or jerking of seedling containers during transport to the loading dock.

15. Unload containers gently and store in a cool, damp environment with little or no light until seedlings are ready for processing.

    a. Pre-coolers equipped with humidifiers and maintained at 40°F provide excellent temporary storage.

    b. Do not keep seedlings in pre-processing facilities for more than a few days. The seedlings first placed in pre-storage should leave first, and container movement should be minimized.

Seedling Processing

1. Maintain temperature in the processing room below 55°F.

2. Use fluorescent lighting because it radiates less heat than do other types of lighting.

3. Minimize radiation from outside (windows, skylights) and inside (heat lamp sources).

4. Handle seedlings gently during processing.

   a. Pull seedlings apart gently to avoid root stripping.

   b. Rinse excess soil from roots and stems to prevent mold development.

   c. Avoid bending or compressing branches or stems during bundling.

   d. Facilities should be available for moistening seedlings during processing if their roots appear to be drying.

   e. Bundle seedlings with a material that will not injure their stems (wide strips of cellophane wrap as opposed to twine or string).

5. Assign a quality control person to monitor seedlings.

   a. Make sure seedlings are graded for color, insect and disease damage, root form, caliper, mechanical damage, stressed appearance, etc. according to minimum acceptable standards established in the contract.

   b. Make sure a sharp blade is being used to trim roots to the proper length so that pinching or stripping is prevented.

   c. Ask if shoot/root ratios of individual seedlings in bundles are comparable to the shoot/root ratio measured for the bundle as a whole. This practice is simply a check on the uniformity of seedling balance in a bundle and is not performed routinely.

   d. Make sure roots are cleaned of excess soil and debris.

6. Make sure bags or boxes are coated with wax or polyethylene and well-sealed to prevent moisture loss.

7. Repair holes in bags or boxes prior to cold storage.

8. Make sure seedlings are packed gently in bags or boxes and that they spend only a short time in the processing room before going to cold storage.

9. If bags are used, make sure they are folded to provide a good moisture seal without crushing the seedlings.

10. Make sure packing containers are well marked as to buyer, lot, and source.

11. If packing materials are used at the nursery, make sure that they are non-toxic to seedlings (moss, not cedar bark shavings or shingle-tow).

12. Pack seedlings in bags or boxes so that the stems and needles cannot be easily contaminated by any remaining soil on the roots of adjacent seedlings (root-to-root packing instead of root-to-shoot packing).

13. Keep bag or box weights below about 40 to 50 pounds to minimize rough handling that arises from being unable to manipulate heavier containers easily.

14. Make sure seedlings processed first are moved into cold storage first.

15. Group seedlings by seed lot so that movement of stored containers is minimized and the desired seedlings are readily accessible to customers.

Seedling Storage

1. Gently move and stack bagged or boxed seedlings on pallets.

2. Ensure that each seedling container is off the floor on pallets, away from the walls, and open to the air on at least one side.

3. After processing, cool seedlings for at least 3 full days before delivery is permitted.

4. The temperature of seedlings in bags or boxes must be kept near 33°F in cold storage and between 28° and 30°F in freeze storage.

5. Seedlings must be kept moist and the bags or boxes sealed so that humidity inside remains high. Note: Trying to maintain high humidity at cold or subfreezing temperatures promotes icing and frequent cooler breakdown unless some type of frost-free system is used.

6. To minimize handling, organize bags or boxes of seedlings according to how they will be picked up.

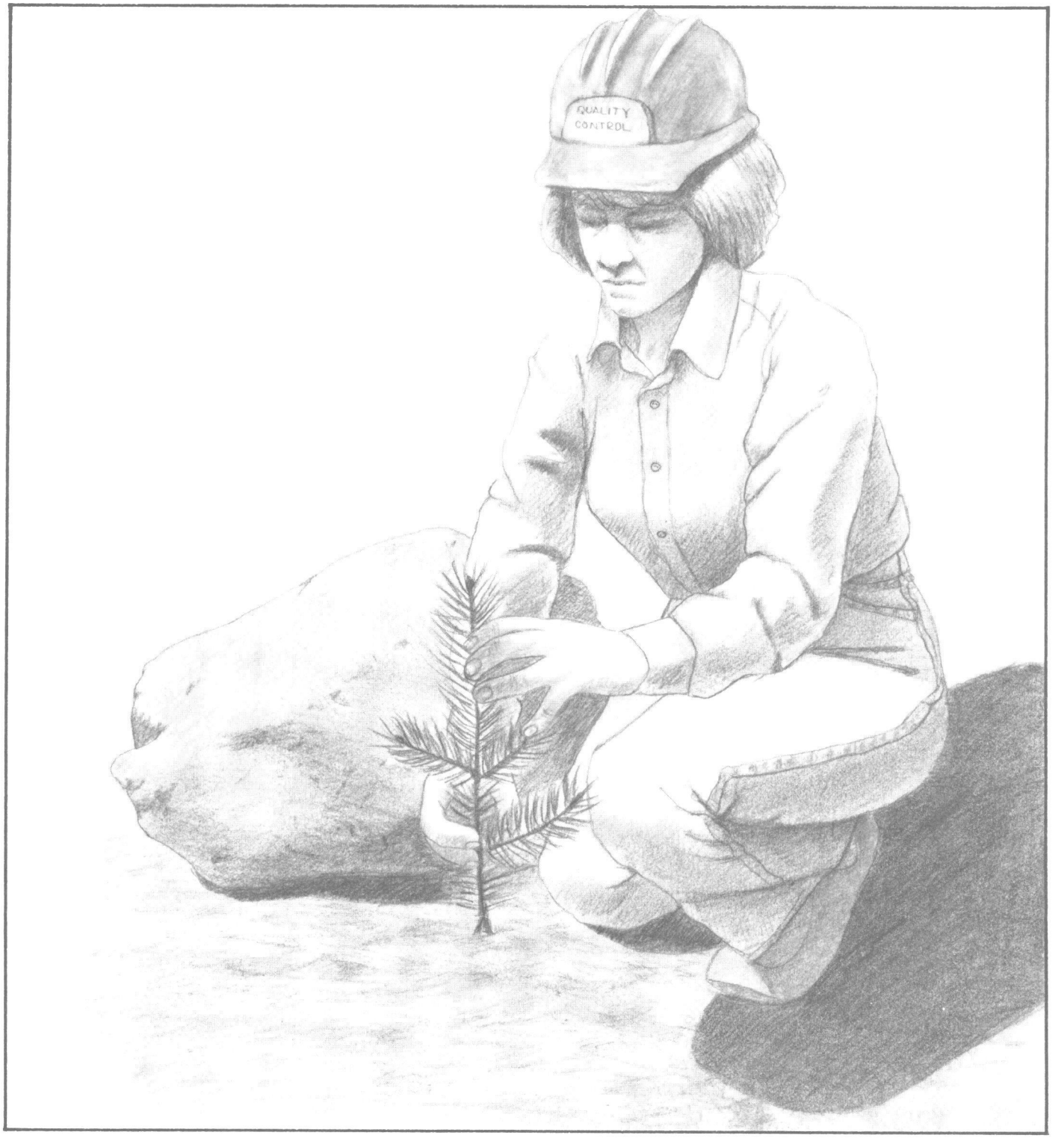
7. If seedlings are to be stored for long periods (2 to 8 months), periodically sample a few containers from different locations within the cooler to ensure that seedling roots are moist. If tissues, particularly roots, appear dry, sprinkle water on seedlings. Note: Re-seal sampled containers tightly after seedlings have been moistened.

8. Periodically check bags and boxes for holes or tears and make repairs.

9. If possible, seedlings of low-elevation maritime species should be stored for as short a period as possible; vigor can be reduced by prolonged storage. However, prolonged storage (lifting in late fall plus storing for 6 to 8 months) appears to be a feasible treatment for species that thrive at high elevations, high latitudes, or in intermountain regions. Freezer storage can minimize vigor reduction in both cases if freezing and thawing rates are slow.

10. Make sure coolers are equipped with alarm systems to notify nursery personnel, both during and after working hours, of unfavorable temperatures (high or low) in the cooler or in the seedling containers.

Guideline Set 5:
From Acceptance through Planting of Seedlings



Acceptance at the Nursery

1. Seedlings from an appropriate seed source should be ordered early enough to ensure acquisition of the desired quantity and stock type by September 1. Purchasers wishing to request stock grown to certain specifications should sign a contract with the nursery prior to seed sowing (2– to 3–year lead time).

2. Coordinate with the nursery to minimize storage time between lifting and pickup. Note: Storage over the winter (mid–November until May or June) may be a better approach for nurseries located in cold climates, particularly if there is a high probability of frozen or soggy soils near the end of the lifting window in March.

3. Pick up seedlings as close to planting time as possible. Note: If seedlings have been stored in a freezer, make arrangements for them to be thawed slowly, preferably under cold storage at the nursery.

4. Pick up seedlings when weather is cool and moist: for a short trip, travel in the early morning or evening; for a long trip, travel at night.

5. Do not remove seedlings from the cooler until you are ready to leave.

6. Check before you sign for acceptance. Look for the following signs of poor quality:

   a. Dry roots.

   b. White root tips (elongation has begun). [5]

   c. Swelled or burst buds.

   d. Presence of mold on needles or stems.

   e. Physical damage (stem girdling, root stripping, lesions, stem swelling near groundline, etc.).

   f. Seedlings frozen in a solid block of ice.[6]

   g. Ripped or crushed bags or boxes exposed to circulating air.

Transportation from the Nursery to Local Storage

Several types of vehicles may be used for seedling transport; some of the most common, in order of preference, are a refrigerated van (BEST), a truck with canopy (OK), a truck with no canopy (AVOID). No matter which one is used, temperature of the bags or boxes should be monitored to ensure that seedlings remain cool. Comply with the following specifications:

1. Maintain seedling temperature at 35°F in refrigerated vans. If the vehicle is regularly used for seedling transport, install a temperature–monitoring system in the cargo space and an alarm or meter in the cab.

2. Use racks or loading pallets for good air circulation.

3. Make sure at least one side of every box or bag is exposed to circulating air.

4. Allow air space between all interior surfaces of the cargo space and the bags or boxes.

5. If the cargo space is unrefrigerated, install styrofoam insulation on all interior sides, including the cargo bed.

6. Paint the canopy bright white on the exterior surface and metallic silver on the interior surface; use a tarp of the same colors if there is no canopy.

7. Park the vehicle in shaded areas.

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[5] The presence of white root tips on seedlings indicates that temperatures inside boxes became warm enough to trigger root initiation for that species or family. The temperature at which growth can occur varies with species and, in general, decreases from 40° to 36°F for mild–climate species to 32°F for cold–climate species. Good freezer storage should prevent root growth (or premature budburst) of cold–climate species, but such prevention may be difficult in cold storage. For mild–climate species, growth in storage should not be a problem if temperatures are maintained below 34°F. The danger in premature root development arises from the extreme sensitivity of new root tips to damage (breakage and desiccation) during handling and planting. The seedling must repair the damage before it can devote significant effort to generating new roots. Consequently, the rapid development of roots after planting is slowed and the risk of mortality increased, particularly on harsher sites.

[6] A critical component of successful freezer storage is slow, controlled thawing. Ideally, seedlings should be removed from the freezer and placed in cold storage (10–day maximum) or a pre–cooler (5–day maximum) to ensure that ice blocks are melted and seedlings properly thawed before delivery. Considerable damage can occur to roots if frozen stock is handled on the site.

8. If ice is used, place it above the seedlings to optimize mixing of cool and warm air. Construct a platform so that bags or boxes are not crushed.

9. If using an unrefrigerated (but insulated) vehicle and travelling longer than 6 hours, be sure to travel only during damp and cool days or in the evening (overnight).

10. Secure the bags or boxes in the cargo space to prevent shifting or bouncing when travelling on bumpy roads. Handle carefully at all times; physical abuse causes respiratory heat and subsequent decline in seedling vigor.

Local Storage

1. Unload the vehicle quickly and carefully.

2. Plant the seedlings as soon as possible. Keep temporary storage time at a minimum.

3. Use a cooler, if available. Cooler space (possibly for lease) might be found at an industrial or governmental facility, landscape nursery, florist shop, or meat packing house. Note: Avoid storage in coolers being used for fruit storage. The fruit ripening process produces large amounts of ethylene, a gaseous plant hormone that by diffusion can come in contact with seedlings and jeopardize their development after planting.

    a. Keep seedling temperature as close to 33°F as possible and provide continuous monitoring.

    b. Avoid using facilities without devices that warn of high and low temperatures.

    c. Make sure seedlings are moist and bags or boxes are well-sealed before storage, especially if humidifiers are unavailable.

    d. Store bags or boxes on pallets so that each container has at least one surface exposed to circulating air.

4. If a cooler is not available, plant quickly!

    a. Place bags or boxes on north side of a large structure that receives no direct radiation, or under the canopy of a very dense grove of evergreen trees (you should see no ground vegetation).

    b. Keep surface of boxes damp by spraying with water during the day.

    c. Cover bags or boxes with a reflective tarp set up as a lean-to. Such a tarp will protect against radiation, provide shade, and allow air to circulate.

    d. Check bags or boxes for rodent damage frequently and repair rips or tears immediately. Check seedlings to make sure they are still moist and reseal bags or boxes tightly.

    e. Monitor temperature (leave dial thermometer in place) and check frequently. Spray bags or boxes with water if warming above 40°F is noted.

Transportation to the Planting Site

1. Make sure the site has been prepared in a manner that will favor survival and maximize growth (burning, herbicides, scarification, or some appropriate combination).

2. Double check the seed lot and planting specifications of seedlings designated for planting.

3. Take only as many seedlings to the field as you intend to plant that day.

4. Handle bags or boxes gently and take precautions to minimize bouncing and sliding around on the bed.

5. Check temperature before you start your trip and leave the dial thermometer in place so you can monitor temperature throughout the day.

6. If weather is sunny, windy, dry, or warm, make sure you have everything you need to keep seedlings protected (water, reflective tarp, damp moss) and pressure chamber to measure seedling moisture status, thermometer to measure air temperature, and sling psychrometer to measure humidity.

Seedling Protection at the Planting Site

1. Never allow planters to sit on bags or boxes.
2. Never place anything heavy on bags or boxes. (For example, never use spare tires to keep the protective tarp secure while driving.)
3. If possible, park in the shade, regardless of the type of vehicle being driven.
4. Keep seedling containers tightly sealed and in the refrigerated van or under the insulated pickup canopy until the planter is returning for another load.
5. If a pickup with a protective tarp is used and no shade is available, remove the bags or boxes of seedlings from the bed, place them in the shade of the pickup, and cover them with the protective tarp.
6. Open one seedling container at a time, and close partially filled containers tightly to prevent moisture loss.
7. Make sure you carefully separate roots in seedling bundles so that root damage (breakage and stripping) will be minimized during planting.
8. Return partially empty bags or boxes to a cool, damp location until you see a planter returning for a new batch of seedlings.
9. While you are waiting, monitor seedling temperature (maintain below 40°F) and moisture status (pressure chamber should be kept below –5 bars).

Planting

1. Assign inspectors to planting crews and check that there is consistency among inspectors with regard to planting criteria.
2. Seedlings must be placed in bags so roots are well-protected from dry, circulating air.
3. Do not pack seedlings too tightly; keep them loose for easy removal and minimal damage to stems and small roots.
4. Use good judgment in distributing seedlings to planters. Unless you have provided a way to keep seedling roots moist (water dip, jelly rolls,[7] water-absorbant slurry, wet moss, etc.) and temperatures inside bags fairly cool (insulated bags), do not provide planters with more seedlings than can be planted in 1 hour (warm, windy, dry day) to 2 hours (warm, calm, humid day).
5. If roots appear dry, dip them in water or a vermiculite slurry for one minute before placing them in the planting bag.
6. If conditions are warm, dry, windy, or sunny, gently place dampened sphagnum moss over seedling roots. Be prepared to stop planting if conditions become unfavorable.
7. Jelly rolling can help minimize potential stresses of the environment when planting must be done in late spring after snowmelt.
8. Keep planting bag collapsed at the top to minimize drying.
9. If roots appear flooded, pour out excess water in the bottom of the planting bag to prevent asphyxiation (low oxygen) damage to any covered roots.
10. Use bags that are white on the outside and silver on the inside and insulated, particularly if planting is to be done on days when it is sunny, warm, windy, or dry.
11. Use a planting tool that is best suited to the seedling roots and the site.
12. Do not allow planters to field-prune roots.
13. Do not allow planters to hit or vigorously shake seedlings in an effort to dislodge excess soil.
14. Seedlings should be pulled gently from planting bags to avoid root stripping.
15. Plant in favorable microsites (no vegetation, moist mineral soil, free of duff or debris in the planting hole, and in partial shade of stumps, logs, debris, dead brush, etc.).
16. Remove trees from the planting bag one at a time and only after hole is prepared.

[7] Jelly rolling is an expensive process that has been shown to be no more effective than dipping roots in water or a vermiculite slurry, if seedling quality is good.

17. Roots should fall straight down in the planting hole. Do not allow J– or L–rooting.

18. Make sure that soil is gently packed around the root system as the hole is filled. Planters must not stomp the ground at the base of the seedling with their boot heels; rather, they should tap firmly with their toes (the aim is better).

19. The root collar should be level with or slightly below the packed soil surface but no deeper than the lowest living branch junction.

20. All seedlings in a planting bag should be planted before taking coffee or lunch breaks.

21. If moderate to high browse damage is anticipated, install protective devices as soon after planting as possible.

22. Protect seedlings from mice or mountain beavers (boomers) by a combination of habitat manipulation (elimination of food and protective cover by broadcast burning, herbicides, and scarification) and baiting, trapping, or installing physical barriers.

23. Protect seedlings from gophers by a combination of habitat manipulation and baiting or trapping.

24. After planting, perform a late–spring survey after the seedlings have undergone mild stresses. Early mortality strongly suggests that stock was dead or low in vigor at planting. It should also prompt early assessment of animal or vegetation problems.

25. Mid–summer surveys may also provide information on stock quality, particularly if seedlings have not encountered severe heat or moisture stress. Development of short, stubby "stress needles" is a good indicator of root damage at or before planting. If mortality is occurring in the absence of environmental extremes (and despite good site preparation), then quality is most assuredly a factor.

26. Keep vegetative competition at a minimum during establishment (first 3 to 5 years). Recent research has suggested the following: (1) 2 to 4 years of continuous vegetation control (greater than 80% kill) can more than double volume production of seedlings on good sites (Sites I and II) and more than triple volume production on fair (Site III) to poorer (Site IV) sites during the establishment years; (2) 4 years of continuous vegetation control on Site III land can reduce time to sapling closure by 7 to 10 years when seedlings are planted at 8– by 8–foot spacing; (3) growth reduction of seedlings is similar with brush or grass and herb competition on moist sites; and (4) seedling growth is reduced to a greater extent by competition from grass and herbs than by brush on drier sites.

Conclusion

These guidelines were developed to help seed–processing, nursery, and forestry professionals maintain seedling vigor through the use of sound handling practices. They were designed to clarify the operational constraints with which professionals must contend while trying to maintain high seedling quality. Each stage of the process is important, for one weak link in the chain can destroy everyone's investments in time, labor, and money. Trying to reduce reforestation costs by forgoing sound quality control is poor economics: the costs of replanting a plantation that failed because of low–vigor seedlings can be devastating. Reforestation is not a simple endeavor; success requires careful planning, cooperation, and commitment from all concerned. These guidelines are simply a tool to help maximize that success.

Additional Reading

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Guidelines are provided for optimizing quality control during the reforestation process. The guidelines are grouped sequentially by occupational activity and can be used as convenient checklists by workers and supervisors. The importance of minimizing stresses to seeds and seedlings is emphasized.

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