Seedling Storage, Part 3: Packaging, Monitoring and Handling

The first part of this series in the January, 1996 issue examined the different types of storage and how they must be designed to fit the needs of the outplanting season. In January, 1997, we looked at storage terminology and how to schedule harvesting. In this final installment in the series, we'll discuss pre-storage treatments, types of packaging, the physiological effects of storage, and post-storage handling.

Pre-storage treatments

Just prior to packing the seedlings, some nurseries treat the foliage with fungicides to retard mold development, or dip the roots to protect against molds or desiccation. Foliar fungicides were commonly applied in the past but this practice is under review because of concerns about worker safety. Both nursery workers and tree planters have complained about skin rashes and other allergic symptoms after handling fungicide-treated stock. Also, the very need for pre-storage fungicide treatments of bareroot seedlings is coming under scrutiny because if the stock is clean and diseased seedlings are rigorously culled during packing, then storage molds are much less of a concern. The situation is slightly different for container seedlings because *Botrytis* spp. often can be found on the lower senescent foliage of conifers. These minor infections do not justify culling the seedlings because the fungus will not survive after outplanting. However, *Botrytis* can turn into a serious storage mold if conditions warrant, and so growers often use foliar fungicides to stop the spread of the fungus during storage.

Root dips of bareroot seedlings have been a common pre-storage treatment for the past 50 years. In the Southern States, pine seedlings traditionally were dipped in a kaolinite clay slurry during packing to protect the roots, but these treatments have been replaced by hydrophilic gels in recent years. Root dips are thought to prevent fine root desiccation during handling and storage and therefore increase outplanting performance. However, a recent review of the literature does not support this concept. Research studies found that root dips of conifer seedlings often are detrimental during storage and provide no consistent benefit after outplanting. Nevertheless, many nurseries and tree planters still consider them a necessary pre-planting treatment.

Packaging

The type of storage package and when the seedlings are packaged depends on the type of stock. Conifer seedlings need some sort of protective packaging to retard moisture loss and prevent injury during the storage period, and so typically are packaged immediately after harvesting and grading. On the other hand. some nurseries prefer not to package hardwood seedlings before storage because of concern about molding. The traditional storage method is to store bareroot hardwood seedlings on open racks in coolers or in heeling-in beds in the field **(Figure 1),** and then package them just prior to shipment. However, research has shown that bagged hardwood seedlings or those with just their roots enclosed in bags suffer much less stress.

Figure 1. Some nurseries still store bareroot hardwood seedlings in traditional "heeling-out" beds because of concerns over storage molds.

Enclosing seedlings in some sort of packaging protects them from several different stresses during the storage and handling period **(Table 1).** A good storage container should have the following attributes:

- *Lightweight—Packages* must be handled several times from the nursery to the outplanting site and so must be light enough for workers to handle them without injury.

- *Moisture* proof—Seedlings must be protected against desiccation during storage and handling, yet be permeable enough to allow enough oxygen exchange for respiration.

Table 1. Seedlings can be injured by several **types of stresses during storage and shipping**

Type of Damage	High Risk Conditions	Preventative Measures
Drought injury	Plant moisture stress > 0.5 Mpa	Hardy, fully-turgid seedlings; proper packaging
Drought injury (Winter desiccation)	Exposure to weather, or freezer storage	Proper packaging: refrigerated storage, but no bales in freezers
Cold injury	Temperatures below seedling cold hardiness level roots are much more susceptible than shoots.	Hardy seedlings; refrigerated storage
Heat injury	Temperatures above 5 °C (40 cF); consider exposure time vs. temperature	Hardy seedlings: refrigerated storage
Loss of dormancy	Warm temperatures: consider exposure time vs. temperature	Hardy seedlings: refrigerated storage
Mechanical injury	Compression; physical shock	Hardy seedlings; use boxes for containers: proper handling

- Durable—Packages are stored under high humidity and so must be physically strong. Also, some bareroot hardwood seedlings have very rigid roots which can easily puncture the walls of storage containers.

- *Conducive to bulk handling—Storage* containers should fit easily on racks or pallets for handling with forklifts or other equipment.

Depending on the species and the type of storage, seedlings are packaged in bales, bags, or boxes. The standard storage container should weigh no more than 40 to 50 lbs and will hold from 500 to 2,000 seedlings, depending on the species and stock type.

Bales/Crates — Bareroot seedlings are sometimes packaged in open-ended bales or wrap-around crates when seedlings will be stored for only a few months. Because seedlings continue to lose moisture during storage, baled stock must be kept moist by misting or periodic light irrigation. Bales are popular in the South and in the Midwest, some nurseries prefer bales for their hardwood stock. In the West, bales are only used when the seedlings will be stored in snow caches. However, they are not suitable for freezer storage because seedling foliage is exposed to freeze drying.

The haling process consists of orienting the seedlings with their roots in the middle and then alternating with layers of wet sphagnum moss or other moisture-retentive material like shingletow. One or two slats are included to provide rigidity and then the entire bundle is baled with a waterproof wrapper.

Bags — Specially-constructed kraft paper/polyethylene ("K-P" or "Poly") packing bags feature gusset construction and a waxed and sown bottom. The typical poly bag consists of three layers with a 50 lb (110 kg) wet strength. and the inner ply is coated with a thin layer of plastic on the inside to retard moisture loss. Poly bags are most commonly-used for bareroot seedlings although they have occasionally been used for container stock. Bundles of seedlings are oriented on their sides with their roots overlapping in the middle and mixed with layers of sphagnum moss or singletow to prevent desiccation. Some nurseries sew the tops of their polybags whereas others just fold them over and then strap them with a banding machine. During storage and shipping, bags must be stored on shelves or pallet racks to allow good circulation.

Boxes — The typical storage box is made of corrugated cardboard that has been treated with plastic or wax to make it waterproof. Some nurseries use corrugated plastic boxes that, although they are more expensive, are reusable. Container nurseries who ship their stock to the outplanting site in the growth container often put

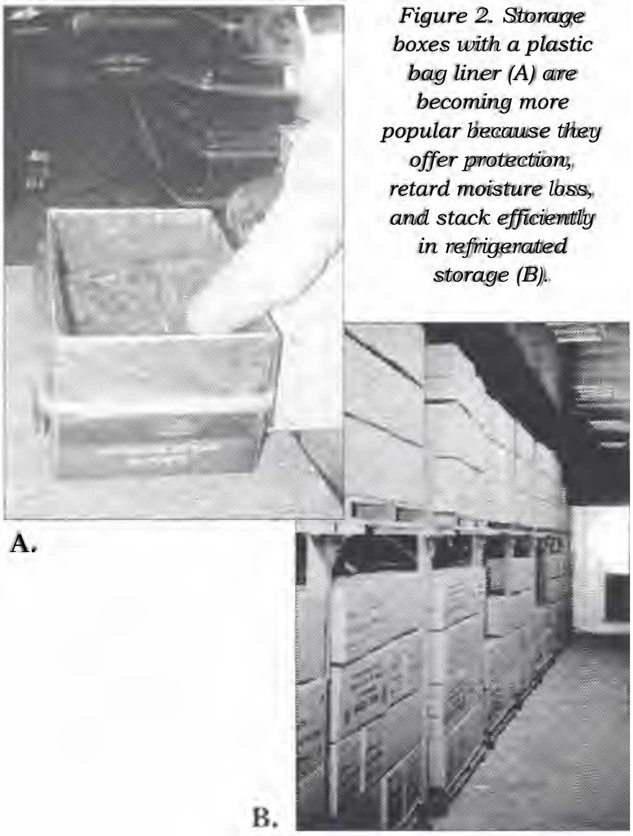

Figure 2. Storage boxes with a plastic bag liner (A) are becoming more popular because they offer protection, retard moisture loss, and stack efficiently in refrigerated storage (B).

them in boxes for additional protection against mechanical injury. Boxes are the standard for freezer storage of pull-and-wrap container stock but, because they are not moisture-proof, a thin (1-2 mil) plastic bag liner is needed **(Figure 2a).** Because of their square shape, boxes can be stacked more easily and safely than bags or bales, but should still be placed on pallet racks or shelves during long-term storage to allow good movement of the refrigerated air (Figure 2b).

Monitoring stock quality in storage

The physiology of dormant seedlings during storage can best be visualized as "suspended animation" - the seedlings are alive but their physiological functions have slowed to a minimum. The critical limiting factor that maintains dormancy during storage is temperature **(Table 1).** Therefore, temperature should be rigorously monitored throughout storage and shipping operations. It is important to measure temperature within the containers as well as in the storage building because the two locations tell you different things. Because stored seedlings are still respiring, they generate a small amount of heat which means that the in-bag or in-box temperature will always be a couple of degrees warmer than the ambient environment **(Figure 3).** For this reason, the setpoint temperature for the storage environment should always be 1 to 2 degrees cooler that the desired temperature in the container. For example, you may have to operate with a setpoint of 28 °F (-2 °C) to obtain a temperature of 30 °F (-1 °C) in-box temperature. The temperature in the storage facility should be monitored as well because it tells you whether the compressors are working properly and whether you arc getting good distribution of the cold air.

With hardy, dormant seedlings, desiccation has been shown to be serious concern during long-term storage. Container seedlings stored outside overwinter can suffer unacceptable root injury even when covered with a protective snow cover **(Figure** 4). To miminize desiccation in seedlings stored under refrigeration, high humidity be maintained around the seedlings and they should not be subjected to excessive air movement. This best method of accomplishing this objective depends on the type of packaging. For baled conifers and open-stored hardwood seedlings, the floors of the storage building are wet down periodically with a hose so that the ambient relative humidity is always near 100%. When seedling arc packed in poly bags or in boxes with plastic bag liners, the humidity in cold storage facilities is less of a concern because essentially no moisture is lost after the seedlings are packed. Still, well-designed cold storage rooms are equipped with mist jets and humidity sensors that maintain high humidity. With freezer storage, humidity control is strictly an in-package concern because all free moisture in the storage room turns to ice crystals.

Several pieces of equipment can be used to monitor seedling condition during storage. In-bag thermometers have already been mentioned but the advent of data loggers have revolutionized the technology. Data loggers are self-contained recording devices that monitor temperature, humidity and other weather

Figure 3. Although ambient temperature readings indicate how the refrigeration equipment is functioning, the true indication of storage temperature can only be obtained with in-bag monitoring.

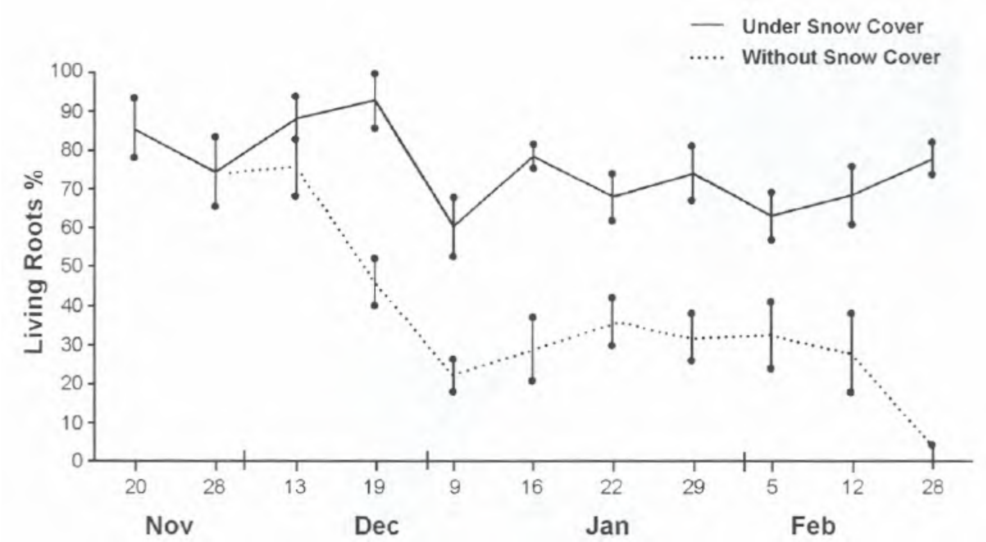

Figure 4. Roots are always less hardy than shoots, and roots of these container Scots pine were seriously damaged when exposed during outside storage. Snow cover provided some protection but significant damage still occurred (Sutinen and others 1996).

variables that contribute to seedling stress. New models are small enough to place in storage packages where they detect both incidence and duration of exposure. Many nurseries measure plant moisture stress with a pressure chamber prior to and during harvesting, and this equipment also affords a quick and accurate way of monitoring the degree of seedling desiccation during storage.

Handling During Storage Period

Seedlings must necessarily be handled many times during harvesting, packing, storage, shipping, and outplanting.

Defrosting frozen stock — Frozen seedlings should be defrosted before excessive handling or exposure to sunlight or drying winds. Cell membranes may be ruptured by intercellular ice crystals, and conifer seedlings can develop damaging moisture stress while their roots are still frozen. The current operational practice has been to thaw frozen seedlings slowly at ambient temperatures in dark rooms or under shade, but this can take several days or even weeks. Recent research, however, has shown that frozen seedlin gs can be fully thawed in as little as 3 to 4 hours at room temperature.

Minimizing exposure — Obviously, seedlings should be handled with care and exposed as little as possible but research has shown that desiccation is more of a concern than warm temperatures. A comprehensive evaluation of the various types of stresses affecting seedlings during storage, handling, and outplanting revealed that desiccation of the root system was the most damaging factor and that direct sunlight and high temperatures were significant only as they increased moisture stress. The true impact of careless exposure i5 not immediately apparent, however, because it causes a degree of sublethal injury that only will be reflected in suboptimal performance after outplanting.

Physical shock — Several studies have shown that seedlings are relatively tolerant to vibration and dropping. Although research has shown that rough handling and shocks during have relatively minor effects on seedling quality. they are accumulative and so should be avoided **(Figure 5a).** This is one of those cases where common sense should prevail over the need for validation through research.

A.

Figure 5. Although research studies have shown that physical shocks and mishandling do not cause major injury (A), all types of abuse are cumulative and can only decrease seedling quality (B—see figure on following page).

Conclusions and Recommendations—
Accumulated Stresses

Storage must be viewed as a holding action which strives to maintain stock quality until the seedlings can be outplanted. Harvesting itself is a tremendous stress, especially with bareroot stock, and then the seedlings are subjected to a series of additional stresses as they are graded, packed, stored, shipped. and outplanted. Because of the variability involved and our lack of sensitive monitoring equipment, it is difficult to quantify or predict the degree of these individual stresses. However, it is very important to emphasize that *stresses are cumulative, and that there is no way to increase quality after the seedlings are harvested.* A useful concept is to think of seedling quality as a checking account. Each seedling has a given quality "balance" when it is harvested, and each stress only subtracts from that initial quality just like writing a check **(Figure 5b).** Unfortunately, there is no way to make deposits to this account - there is nothing we can do to improve seedling quality after it leaves the nursery. So, nursery managers must pay close attention to details during the storage period so that their seedlings reach their customers at their peak of quality.

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B. Bank of Seedling Quality

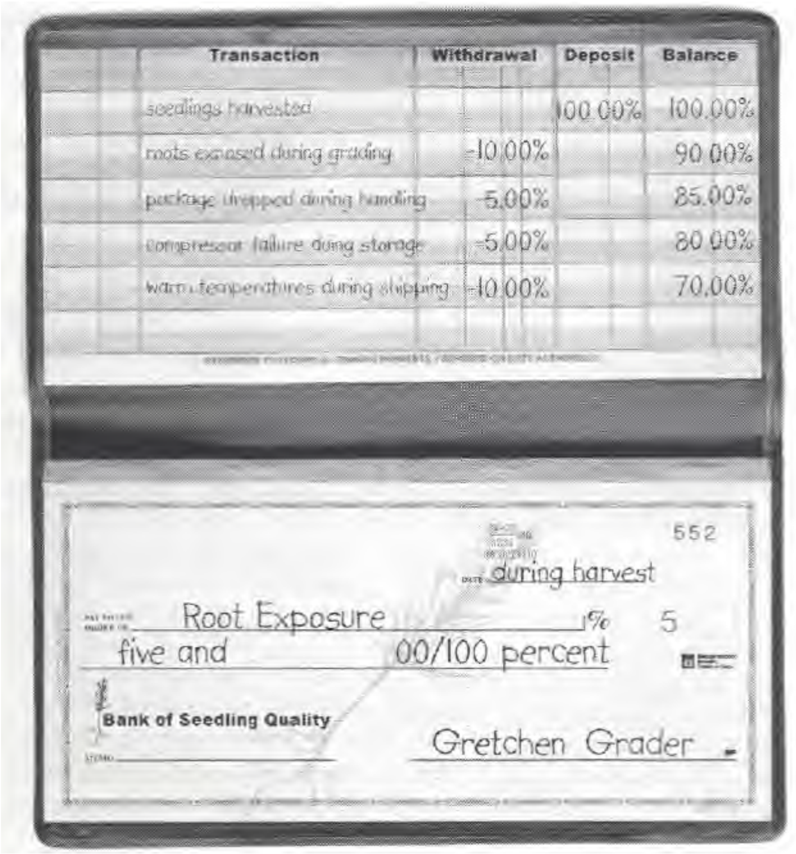

Figure 5h. Each abuse to seedlings is like a check drawn on a bank account of seedling quality.

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