Care and Handling of Container Plants From Storage to Outplanting©

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INTRODUCTION

Nursery plants are in a period of high risk from the time they leave the protected environment of the nursery to when they are outplanted. During handling and shipping, nursery stock may be exposed to many damaging stresses, including extreme temperatures, desiccation, mechanical injuries, and storage molds. This is also the period of greatest financial risk, because nursery plants have reached their maximum value right before shipping (Paterson et al., 2001). Adams and Patterson (2004) concluded that improper handling of nursery stock had more impact on plant quality than the type of outplanting tool.

All the information in this paper is included in The Container Tree Nursery Manual Vol. 7: Seedling Processing, Storage, and Outplanting. It was published as Agriculture Handbook 674 by the USDA Forest Service (Landis et al., 2010) (Fig. 1).

Growers go to extremes to produce the highest quality plants and strive to have them at their best when they are sold or shipped to the customer. As plant people, we all know that nursery stock is alive and perishable and so should be treated with utmost care at all times. Unfortunately, customers or people who handle plants after they leave the nursery often don't appreciate this fact. Stressful injuries incurred between lifting from the nursery and outplanting, however, are often not evident until several weeks or even years after planting. Symptoms include browning, chlorosis, poor survival, or decreased growth and are commonly known as "transplant shock" or "check." It can be extremely difficult to pinpoint the exact stress that leads to these symptoms. It is a waste of time and money to produce or purchase high-quality plants only to have them die or grow poorly after outplanting as a result of these unnecessary stresses.

THE CHAIN OF PLANT QUALITY

Nursery plants are at their maximum quality immediately before they are harvested at the nursery, but they then must pass through many hands before being outplanted. Outplanting success is dependent on maintaining plant quality by minimizing stress at each phase of the operation. It is useful to think of plant quality as a chain in which each link represents one of the sequences of events from harvesting and storage at the nursery until planting at the outplanting site (Fig. 2). The cumulative effect of the various stresses can be much greater than any one individual stress. As stress increases, the plant shifts energy from growth to damage repair. Physiological functions are damaged and survival and growth are reduced. These effects are exacerbated further when plants are outplanted on harsh sites.

Each stage in the process represents a link in a chain, and overall plant quality is only as good as the weakest link. It is useful to think of nursery plant quality as a checking account in which all types of abuse or stress are withdrawals. Note that all stresses are cumulative and no deposits can be made — it is impossible to

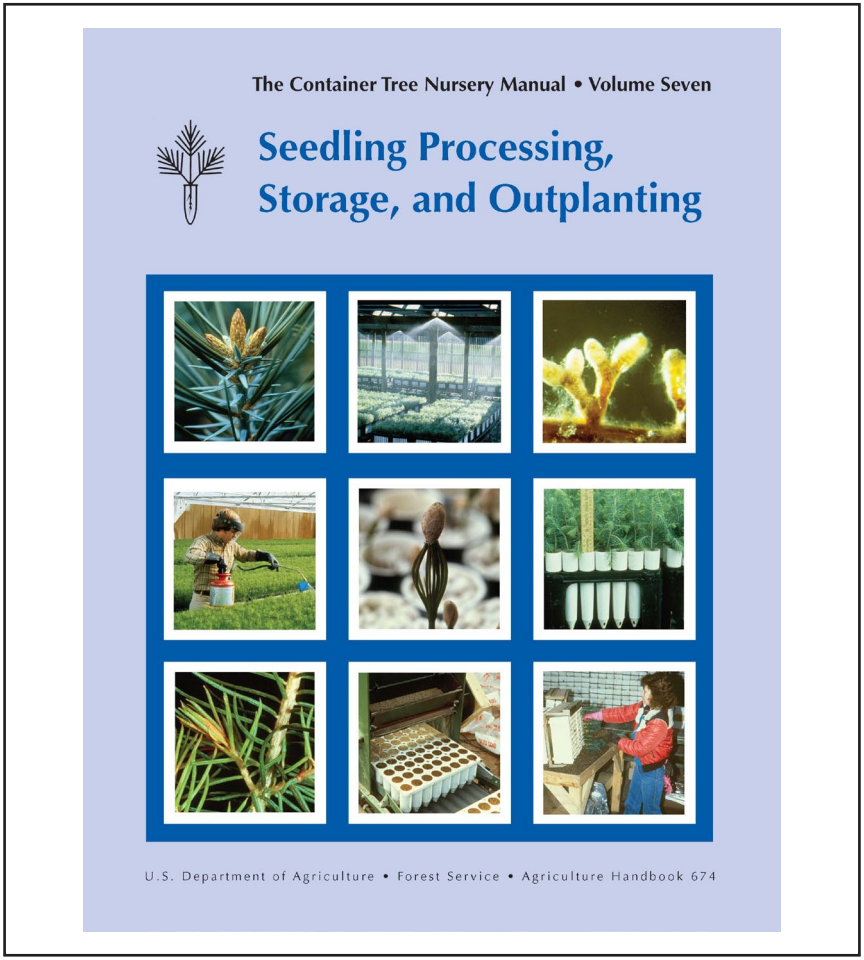

Figure 1. Container Tree Nursery Manual, Vol. 7 (covers from harvesting and grading at the nursery to out planting in the field). Softbound copies can be purchased from the U.S.A. Government bookstore <website: www.bookstore.gpo.gov>.

increase plant quality after nursery harvest (Fig. 3). Because all types of abuse or exposure are cumulative, it is helpful to think of nursery plant quality as a checking account. Immediately before harvesting, plants should be at 100% quality, but all subsequent stresses are withdrawals from the account. It is impossible to make a deposit — nothing can be done to increase plant quality after plants leave the nursery.

STORAGE

The first link in the plant quality chain is when nursery stock is harvested and stored. It is important to realize that plant storage is an operational necessity, not a physiological requirement (Landis, 2000), because of the following four reasons.

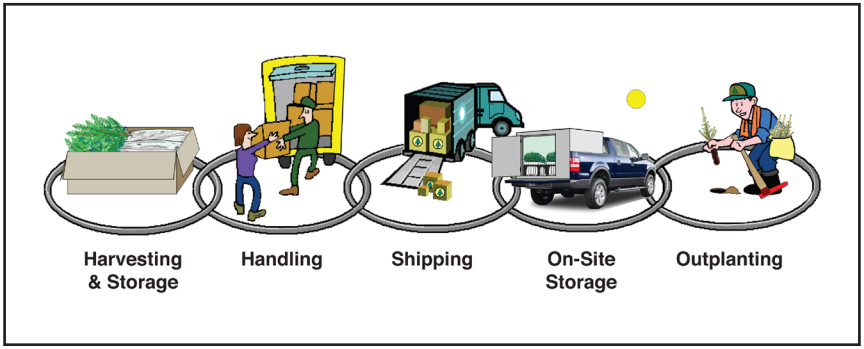

Figure 2. Nursery plant quality can be visualized as an interconnected chain of events from harvest to outplanting.

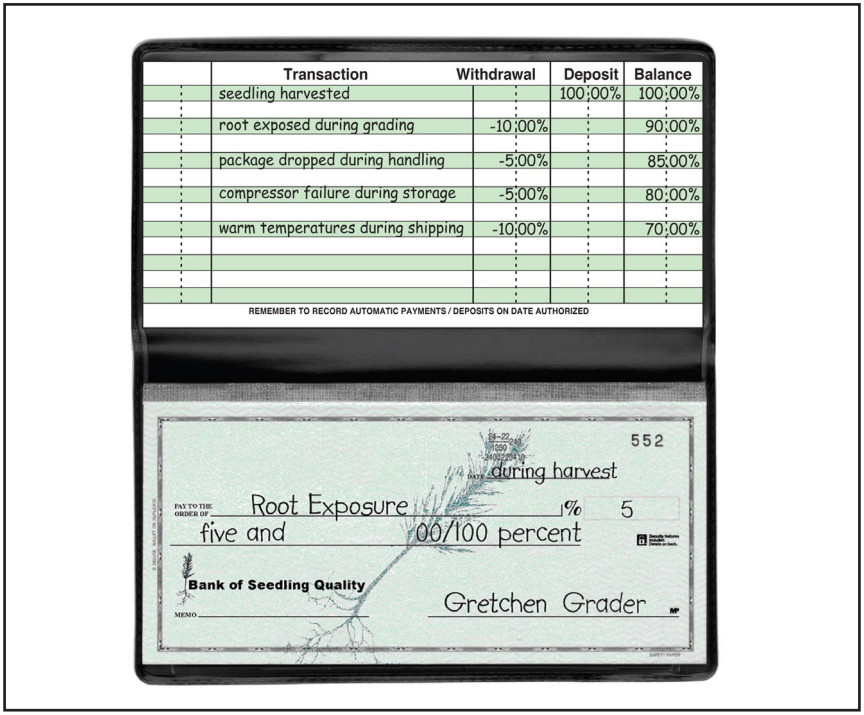

Figure 3. A checking account in which every stress is a withdrawal is a useful analogy for the stresses incurred after plants leave the nursery.

Distance Between Nursery and Outplanting Site. Today, most native plant nurseries are located at great distances, often hundreds or even thousands of miles, from the outplanting sites of their customers. This is particularly true of container nurseries because, as long as the proper seed source is used, high-quality plants can be grown in greenhouses in ideal growing environments located far away. The farther the distance from the nursery to the outplanting site, however, the greater the need for storage.

Differences Between the Lifting Window at the Nursery and Outplanting Windows. As mentioned in the previous section, container nurseries are often located in climates different from those of their customers. In mountainous areas, this is especially true, because nurseries are typically located in valleys at low elevation that have much different climates than outplanting sites at higher elevations. Differences between lifting and outplanting windows will also depend on the season of outplanting. If customers desire summer or fall outplanting, then short-term storage is all that is necessary. Often, however, the best conditions for outplanting occur the following spring, so it is necessary to protect plants throughout winter.

Facilitating Harvesting and Shipping. The large numbers of plants being produced at today's nurseries means that it is physically impossible to lift, grade, process, and ship stock in a short time. Therefore, one primary benefit of storage facilities is that they help to spread out the scheduling and processing during harvesting and shipping.

Refrigerated Storage Can Be a Cultural Tool. Many growers do not appreciate the fact that refrigerated storage can be used to manipulate plant physiology. Cold storage temperatures can partially satisfy the chilling requirement of dormant stock, and refrigerated storage has even been shown to improve plant quality (Ritchie, 1989). On the other hand, plants with atypical dormancy patterns may not benefit from refrigerated storage. Cold storing water oak (*Quercus nigra*) seedlings did not appear to prolong dormancy, increase stress resistance, or increase outplanting performance (Goodman et al., 2009).

While some nurseries use open or sheltered storage, most forest nurseries in the Pacific Northwest use one of the two types of refrigerated storage (cooler storage and freezer storage), which can be differentiated by their temperatures (Fig. 4) and the recommended duration of storage. Both nursery research and operational experience has shown that cooler storage is best for periods of 2 months or less, whereas freezer storage is recommended for longer storage periods. Cooler storage is preferred when nursery stock is outplanted throughout the winter, whereas freezer storage is recommended for periods longer than 2 months, especially for high-elevation sites when outplanting may not occur until June or even later.

HANDLING AND SHIPPING

During handling and shipping, nursery stock may be exposed to many damaging stresses, including extreme temperatures, desiccation, mechanical injuries, and storage molds (Table 1). By far, desiccation is the most common stress encountered during harvesting, handling, and shipping, and can have a profound effect on survival and growth. Plant water potential influences every physiological process, and at stressful levels, can greatly reduce growth, even if survival is unaffected. These damaging effects can persist for several seasons after outplanting. Roots are the most vulnerable to desiccation because, unlike leaves and needles, they have no waxy coating or stomata to protect them from water loss. Fine root tips have greater moisture content than woody roots and are therefore most susceptible to desiccation. If fine roots appear dry, then they are probably already damaged although it is difficult to quantify the amount of injury in the field. When exposed for just 5 min, bareroot conifer seedlings exhibited increasing moisture loss with increasing air temperature and wind speed (Fancher et al., 1986). This shows the critical importance of keeping nursery plants cool, out of direct sunlight, and protected from drying winds.

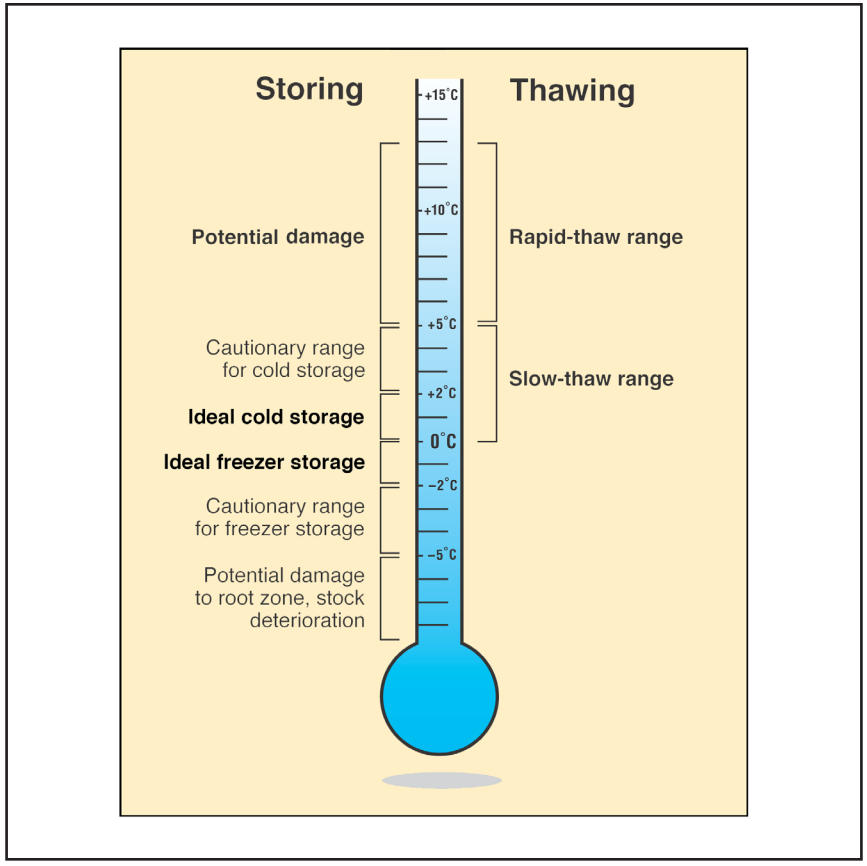

Figure 4. The actual temperature difference between cooler and freezer storage is minimal but those few degrees cooler make a tremendous difference in storage duration. Warmer temperatures are recommended for thawing frozen stock.

Because temperature affects all aspects of plant physiology, either hot or cold temperature extremes can quickly reduce the quality of nursery plants during handling and shipping. Besides increasing the risk of desiccation, high temperature exposure can increase the risk of storage molds such as *Botrytis cinerea*. Freezing temperatures can damage nursery stock. Because they are much less cold-hardy, roots are much more susceptible than shoots to freeze damage. Ambient and in-box temperatures should be monitored regularly; temperature monitoring equipment is now inexpensive and readily available. Freezing damage has even occurred in cooler storage during shipping because of equipment failure; unfortunately, this is relatively common, because refrigeration units on shipping vans are notoriously fickle and air circulation is restricted.

Boxes of nursery plants are handled many times from when they leave the nursery until the plants are finally outplanted. Rough handling can result in reduced plant performance after outplanting. Each person involved in the handling and shipping of nursery stock should receive training on how to minimize physical

Table 1. Nursery plants are subjected to a series of potential stresses from harvest to outplanting.

Process	Potential Levels of Stress			
	Temperature Extremes	Desiccation	Mechanical Injuries	Storage Molds
Nursery Storage				
Handling				
Shipping				
On-Site Storage				
Outplanting				

Levels of Stress	Low	Medium	High

stresses. The potential for physical damage to nursery stock can come from dropping, crushing, vibrating, or just rough handling. It is easy to forget that nursery plants are alive when they are in boxes. Studies have shown that the stress of dropping boxes of seedlings reduced root growth potential, decreased height growth, increased mortality, and increased fine-root electrolyte leakage. Stjernberg (1996) did a comprehensive evaluation of the physical stresses that nursery stock is subjected to during transport from the nursery to the outplanting site.

Shipping stock in refrigerated trucks is recommended whenever possible to maintain plant quality until outplanting. However, if open pickups must be used, then boxes of plants should be covered with a reflective tarp. Specially constructed Mylar® tarps with white outer and silver inner surfaces are available from reforestation supply companies (Fig. 5). In operational trials, plants under such tarps were as cool as those stored in the shade (Fig. 6). Dark-colored tarps, such as army-green canvas, allow plants to heat to damaging levels and should never be used (DeYoe et al., 1986).

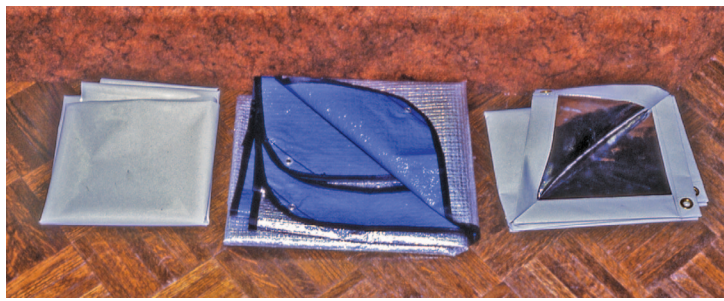

Figure 5. Special reflective tarps for covering nursery plants during delivery or during on-site storage are commercially available.

On-Site Storage. Nursery stock should be outplanted as soon as it arrives on the project site, but that is often operationally impossible. Weather delays, worker scheduling, and poor communication are just a few of the reasons why onsite storage may be necessary. The duration of onsite storage should last for only a few days, although, under unanticipated weather, such as heavy snow, it can reach a week or more. Therefore, it is always wise to plan ahead. Ideally, project managers should bring only as much stock as can be planted on a given day to avoid the need for onsite storage. Distance and other logistical factors, however, may make this difficult.

Overheating and desiccation are the major stresses that can occur during onsite storage. Because of significant differences in dormancy stage and hardiness, however, nursery stock for hot-planting must be treated differently from stock that comes from refrigerated storage. It is a good idea to conduct a thorough inspection of nursery stock when it arrives at the outplanting site. All boxes should be opened and checked for the following (Mitchell et al., 1990):

- In-box temperatures of refrigerated stock should be checked upon delivery and should be cool, no warmer than 2 to 4 °C (36 to 39 °F). Stock delivered in containers or hot-plant stock should be kept as cool as possible and out of direct sunlight.

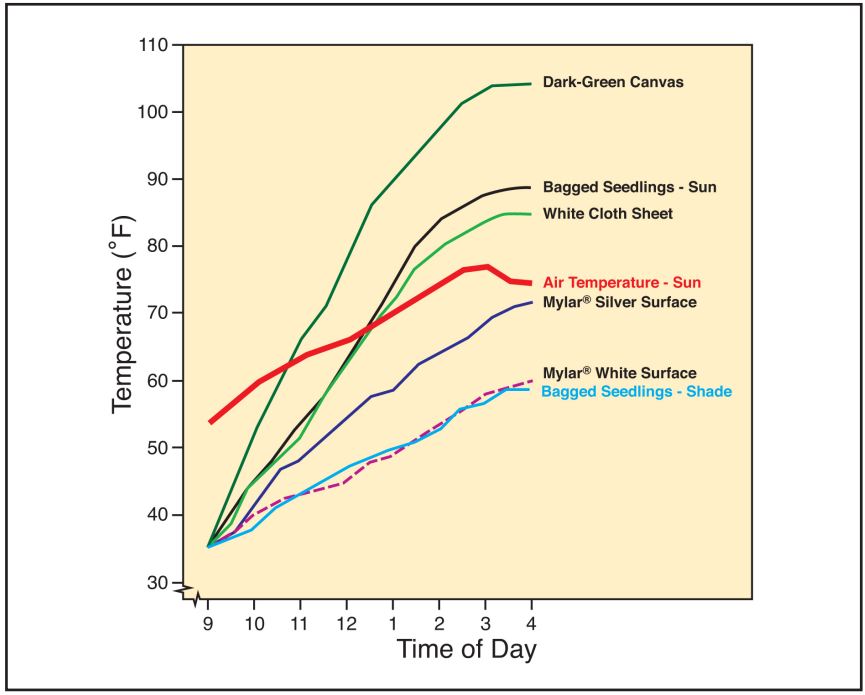

Figure 6. Research has shown that reflective Mylar® tarps provide much better insulation than standard green canvas ones (modified from (DeYoe et al., 1986).

- If possible, use a pressure chamber to check plant moisture stress of a sample of plants.
- Nursery stock should not smell sour or sweet, which is evidence that the stock has been too warm or excessively wet.
- Root plugs should be moist. If the plants have foliage, most often it should be a healthy green. For species with terminal buds, those buds should still be firm.
- Check the firmness of the bark around the root collar. The bark should not easily slough off and the tissue underneath should be creamy, not brown or black, which indicates frost injury.
- Spread the foliage to check for white or gray mycelia, which is evidence of storage molds, such as *Botrytis cinerea*. In particular, check foliage at the base of the crown. If mold is present, check the firmness of the tissue underneath. Soggy or water-soaked tissue indicates serious decay and those plants should be culled. Plants with superficial mycelia without corresponding decay should be planted immediately. Fungal molds will not survive after exposure to ambient conditions on the site.

SUMMARY

Overwinter storage should be developed to meet local climate, nursery stock type, and production factors. Storage of nursery stock becomes more important as the distance from the nursery to the outplanting sites increases, differences between climates at the nursery and field sites are great, and nurseries produce large quantities of plants requiring months to process. After a crop begins the process of leaving the storage area for the outplanting site, the financial and plant-quality risks peak because plants have reached their full economic value. Plants are living, perishable organisms and it is paramount to minimize stresses that can reduce their quality. The three primary types of stress that seedlings may encounter are moisture loss (desiccation), temperature extremes, and physical damage. Stock should be regularly monitored and handled gently to avoid exposure to stress. The effects of stress are cumulative — plants exposed to excessive stress may be dead at the time of outplanting or die shortly afterward. Unfortunately, the more common scenario is that the accumulation of stress causes a gradual and cumulative reduction in survival and growth that may or may not become apparent until weeks or months after outplanting.

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QUESTIONS AND ANSWERS

Todd Jones: I'm wondering about deciduous plants in plugs. How long can you hold them in a frozen state.

Tom Landis: It depends on the packaging. If they're in a moisture-proof polybag you can store them almost indefinitely. We store them 4–6 months in the freezer, but I wouldn't go any longer than that.

Steve Hottovy: Could you comment on how quickly you freeze the seedlings?

Tom Landis: It all depends on the plant's hardiness. The hardier the plant, the lower you can take it without damage. It's not so much the rate of freezing as it is the ultimate low temperature that's used.

Mark Krautmann: I probably speak for everyone here by thanking you for your lifetime of service.

Tom Landis: Thank you. It's nice to know it's appreciated.