The Container Tree Nursery Manual

Volume Seven

Chapter 5
Handling and Shipping

Contents

7.5.1 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. Good guidelines for proper care during this critical time have been published for bareroot nursery stock (DeYoe 1986; USDA Forest Service 1989), and the same guidelines apply to container plants. During handling and shipping, nursery stock may be exposed to many damaging stresses, including extreme temperatures, desiccation, mechanical injuries, and storage molds (table 7.5.1). This is also the period of greatest financial risk, because nursery plants have reached their maximum value right before shipping (Paterson and others 2001). Adams and Patterson (2004) concluded that improper handling of nursery stock was a more important factor than the type of outplanting tool.

One reason for the increasing preference of container stock is that it tolerates the abuses of storage, shipping, and handling better than bareroot plants. This is particularly true with many broadleaved trees and other native plants; for example, oak (*Quercus* spp.) and beech (*Fagus* spp.) seedlings grown in a variety of containers tolerated rough handling better than bareroot stock (fig. 7.5.1). In a hardwood restoration outplanting, even the highest quality nursery plants did not survive and grow well if they were not handled properly (Self and others 2006).

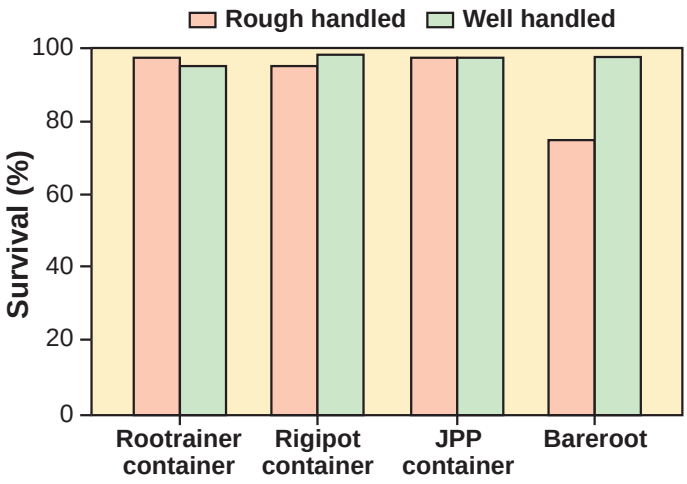


Figure 7.5.1—*Oak and beech container plants tolerated rough handling much better than did bareroot stock (Kerr 1994).*

Table 7.5.1—*Nursery plants are subjected to a series of potential stresses, from harvest through outplanting*

Process	Types of stress			
	Temperature extremes	Desiccation	Mechanical injuries	Storage molds
Nursery storage	High	Low	None	Medium
Handling	Medium	Medium	High	None
Shipping	Medium	Low	High	None
Onsite storage	High	High	None	High
Outplanting	High	High	High	None

Potential levels of stress None Low Medium High

7.5.2 Minimizing Stresses During Handling

It is important to emphasize that nursery plants are alive and perishable, and so should be treated with utmost care at all times. Stressful injuries incurred between lifting from the nursery and outplanting, however, are often not evident until several weeks 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 (fig. 7.5.2A). 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. As emphasized in Chapter 7.2, plants are best able to tolerate stress when they are not actively growing. Nonhardened, succulent plant tissue is much more vulnerable to stresses (fig. 7.5.2B). Regular monitoring of plant condition, close supervision of nursery and field personnel, periodic testing of plant quality, and maintenance of detailed records are essential to document conditions during shipping and handling.

A

B

Figure 7.5.2—*It is often difficult to determine exactly which stresses lead to "transplant shock" or "check" (A). Nonhardy and nondormant nursery stock (B) is much more susceptible to all types of stresses during handling and shipping.*

Three stresses are most common after stock leaves the nursery: moisture, temperature, and physical.

7.5.2.1 Moisture stress

Desiccation is the most common stress encountered during handling, shipping, and storage at the field site (onsite storage) 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 a greater moisture content than woody roots and are 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 minutes, bareroot conifer seedlings exhibited increasing moisture loss with increasing air temperature and wind speed (fig. 7.5.3). This shows the critical importance of keeping nursery plants cool, out of direct sunlight, and protected from drying winds.

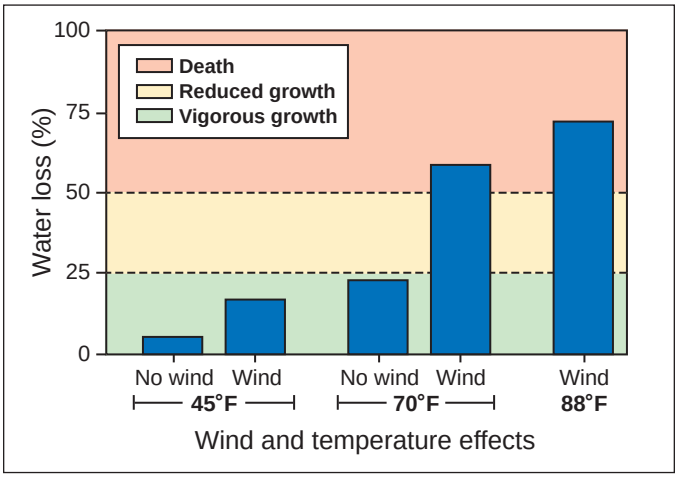


Figure 7.5.3—*When bareroot conifer nursery stock was exposed for 5 minutes, plant moisture loss increased with higher temperatures and wind until plant survival and growth were adversely affected (modified from Fancher and others 1986).*

Fortunately, roots of container plants are protected somewhat by the growing medium, which serves as a reservoir of water and nutrients. If the plug is allowed to get too dry, however, desiccation damage can be severe. Once roots have dried, subsequent growth reductions are inevitable, even when shoot water potential recovers (Balneaves and Menzies 1988). Dormant conifer plants are more vulnerable to damage from root exposure than are dormant hardwood plants.

Moisture stress can be avoided by making sure plugs are kept moist (but not saturated) throughout their journey from nursery to outplanting. Container stock should be irrigated 1 to 2 days before harvesting, depending on weather conditions (Fancher and others 1986). This allows the plugs to drain to field capacity; saturated media is unhealthy for roots, increases shipping and handling weight, and increases the potential for storage molds.

7.5.2.2 Temperature stress

Either hot or cold temperature extremes can quickly reduce the quality of nursery plants during handling and shipping.

Exposure to warm temperatures can damage stock in several ways.

Increased hazard from storage molds. Pathogenic fungi, such as Botrytis mold, can survive in all types of storage and may grow rapidly during shipping in the humid environment of a storage bag or box if the temperatures are too warm. Increased carbon dioxide from plant respiration in storage and shipping containers is also thought to stimulate fungal development. There have been anecdotal reports of storage mold "blowups" in boxes of freezer stored nursery stock after only a few days exposure to ambient conditions. Storage molds are discussed in detail in Volume Five.

Accelerated resumption of growth. Nursery plants that are stored during the winter are harvested at peak hardiness, which is ideal for storage, shipping, and handling. When ready for outplanting, properly stored plants have had their chilling requirements fully satisfied, however, and cold temperature is the only environmental factor that prevents resumption of growth. After their chilling requirement has been met, stored nursery stock exposed to even a short period of warm temperatures will rapidly initiate shoot growth (fig. 7.5.4).

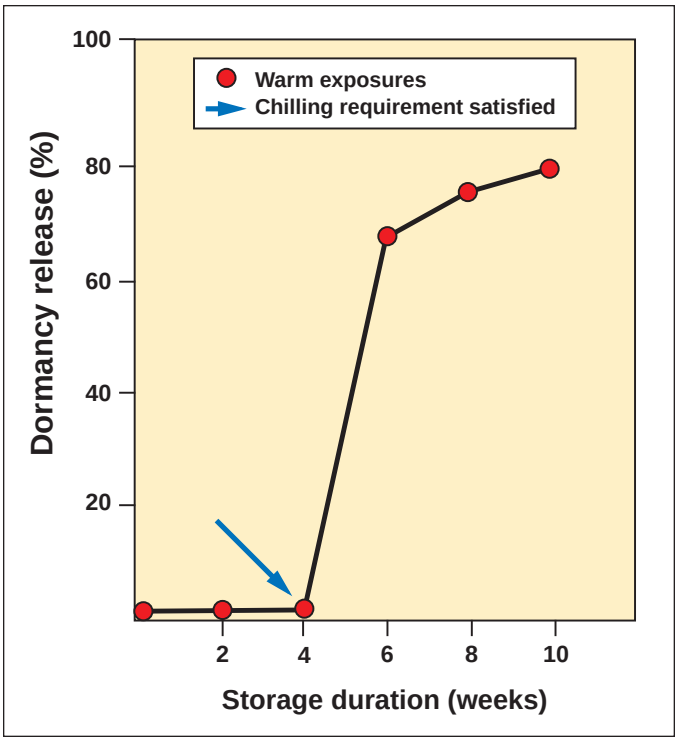


Figure 7.5.4—*Cold-stored Norway spruce (*Picea abies*) seedlings exposed to short periods of warm temperatures (17 °C [63 °F]) rapidly broke dormancy after the chilling requirement had been met (modified from Hanninen and Pelkonen 1989).*

Moisture stress. Stagnant air within the storage or shipping bag or box is a poor heat conductor, but direct sunlight and wind can rapidly increase plant temperatures and cause serious moisture stress (fig. 7.5.3).

Heat stress. Stored nursery plants are alive and respiring. This means, when plants are exposed to warm temperatures, their respiration adds heat to their environment; this is particularly serious in closed environments such as storage or shipping bags or boxes. Maintaining good air circulation in storage areas, especially in nonrefrigerated storage, will minimize heat buildup due to plant respiration.

Freezing damage. Freezing temperatures can damage nursery stock. Because they are much less cold-hardy, roots are much more susceptible than shoots to freeze

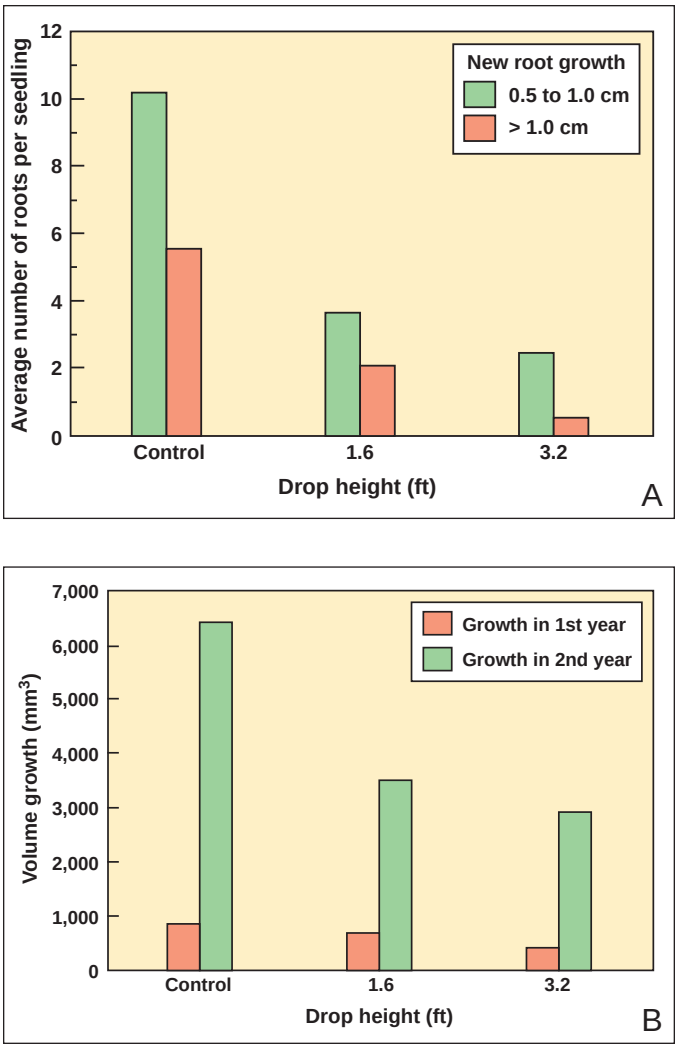


Figure 7.5.5—*When bags of conifer seedlings were dropped from different heights, their ability to produce new roots (root growth potential) was significantly reduced (A). This mechanical injury still affected plant growth 2 years after outplanting (B) (modified from Stjernberg 1996).*

damage. Ambient and in-box temperatures should be monitored regularly; temperature monitoring equipment is now inexpensive and readily available (See Section 7.4.6). Freezing damage has even occurred in cooler storage during shipping because of equipment failure. This is common, because refrigeration units on shipping vans are notoriously fickle and air circulation is restricted. Boxes in the front of the van near the refrigeration units will necessarily be colder than those in the back. Resist the temptation to overpack trucks; leave adequate space for good air circulation (Rose and Haase 2006). Stock that has been cooler stored should be shipped at these same temperatures (0.5 to 1 °C [33 to 34 °F]), whereas frozen stock can be shipped under warmer temperatures to begin the thawing process.

When nursery stock reaches the outplanting site, the plants should be kept as cool as possible. Onsite storage is discussed in Chapter 7.6.

7.5.2.3 Physical stress

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 hand-ling and shipping of nursery stock should receive training on how to minimize physical 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 (McKay and others 1993; Sharpe and others 1990; Tabbush 1986). 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. Root growth potential tests on boxes of cooler-stored white spruce seedlings showed fewer new roots were produced as the distance the box was dropped increased (fig. 7.5.5A). Interestingly enough, volume growth of these seedlings still showed growth depression 2 years after outplanting (fig. 7.5.5B).

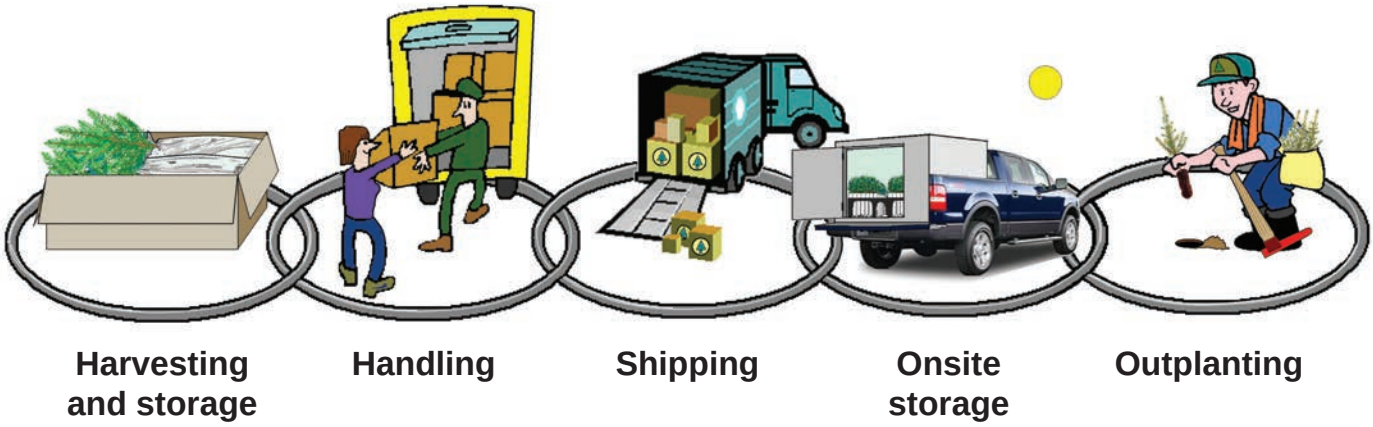


Figure 7.5.6—*Nursery plants are subjected to a series of stresses from the time they are harvested to when they are outplanted. Each stage in the process represents a link in a chain, and overall plant quality is only as good as the weakest link.*

7.5.2.4 Accumulated stress

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. 7.5.6). 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.

Extremely careless handling of planting stock usually manifests itself immediately after outplanting—plants die within days or weeks. Unfortunately, the ramifications of poor handling are usually more insidious and are not immediately apparent because it causes a degree of sublethal injury that only will be reflected in decreased survival and growth weeks or months after outplanting. A good example is root injury. Roots that have been damaged by exposure or freezing may not look any different, but they have lost the ability to function properly. This condition is particularly serious with container stock because these injuries primarily affect roots on the outside of the root plug. Because the roots on the inside still function, damaged plants are able to remain turgid and so appear normal. After outplanting, however, the damaged roots cannot grow out into the surrounding soil, so plants struggle for a while and may eventually die. On moist sites with low evaporative demand, this can take weeks or months.

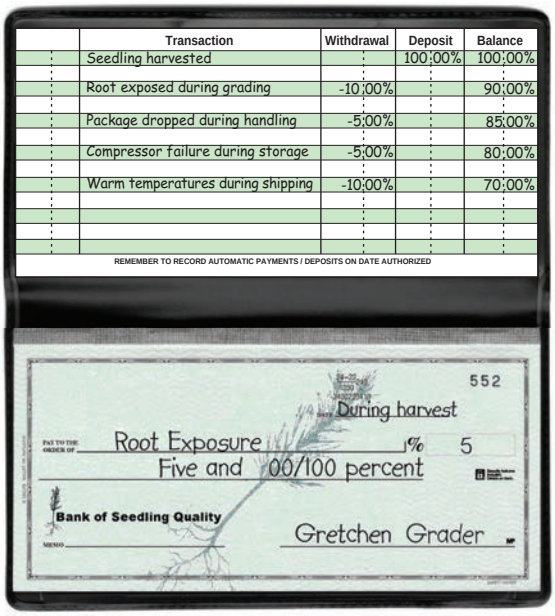


Figure 7.5.7—*It is useful to think of nursery plant quality as a checking account in which all types of abuse or stress are withdrawals. Note that all stresses are cumulative and no deposits can be made—it is impossible to increase plant quality after nursery harvest.*

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 percent quality, but all subsequent stresses are withdrawals from the account (fig. 7.5.7). It is impossible to make a deposit—nothing can be done to increase plant quality after plants leave the nursery.

7.5.3 Handling and Shipping Systems

When nursery stock is ready to outplant, it must be moved from nursery storage to the outplanting site. Nursery employees usually use the same handling system to move plants in and out of storage, and the equipment is generally conveyors, handcarts, forklifts, and other motorized handling equipment that was discussed in Volume One. Shipment to the customer or outplanting site, however, often requires specialized handling and equipment. The best handling system for shipment will depend on plant physiological condition, container type and size, and whether the plants will be shipped in their containers.

7.5.3.1 Shipping in the growth container

When container nursery stock was first produced back in the 1970s, most nurseries shipped plants to their customers in the growth container. Some nurseries still use this practice and usually stack containers on metal or wooden racks inside the delivery van (fig. 7.5.8A). This method works best when shipping distances are relatively short and the roads are not overly rough. Some nurseries place their containers inside cardboard boxes for shipping. Unfortunately, used containers need to be returned to the nursery, requiring a second trip, and often the containers are damaged during transit (fig. 7.5.8B).

Shipping in containers has worked well for forest industry nurseries that grow stock for their own lands. For example, J.D. Irving, Limited, a reforestation company in New Brunswick, Canada, has developed a sophisticated pallet handling system for moving containers about the nursery and to the outplanting site (figs 7.5.8 C&D). Their system allows efficient handling of container plants while providing excellent protection against mishandling. After the stock is outplanted, the same pallets are used to transport empty containers back to the nursery without damage (Brown 2007).

One primary advantage of this system is that plant roots are protected by the container and, if plants must be held in temporary storage before planting, they can be irrigated (fig. 7.5.8E). Nursery stock that will be hot-planted is not fully hardy and endures less stress when left in the growth container. The major disadvantage of shipping in containers is that a given number of plants occupies considerably more volume and weighs more compared with stock that has been extracted for storage. In addition, stock shipped in the containers, especially those that cannot be consolidated, is not necessarily graded, so cull plants may also be handled and shipped.

Large container stock (> 500 ml [> 1 qt]) is always shipped in its growth container because it is too large and heavy to be handled any other way. The Forest Service J.H. Stone Nursery in Central Point, Oregon, grows native plants in containers up to 55 L (15 gal) in volume (fig. 7.5.9A). These plants are grown in special racks at the nursery; these same racks are used to transport the plants to the outplanting site (fig. 7.5.9B).

7.5.3.2 Shipping in boxes or bags

Nursery stock extracted from growth containers and stored in cardboard boxes requires much less storage space and weighs less when shipped as compared with stock shipped in their containers. In addition, the box provides physical protection during storage, shipping, and handling (fig. 7.5 10A). Boxes stack efficiently (fig. 7.5.10B) and pallets of boxes can be easily moved by hand, pallet jack, or forklift and loaded quickly and readily into delivery vans (fig. 7.5.10C). Delivery vans should be equipped with racks; otherwise, the weight of boxes stacked too high could mechanically damage the stock (fig. 7.5.10D).

A

B

D

C

E

Figure 7.5.8—*Shipping plants in their growth containers requires a rack system to support and protect the stock (A). One drawback of this system is that containers must be returned to the nursery and can be damaged in transit (B). Some large forest nurseries have developed sophisticated rack handling systems for shipping plants to the outplanting site and returning the used containers to the nursery (C&D). One advantage of shipping in the growth container is that plants can be irrigated prior to outplanting (E) (C&D, courtesy of J.D. Irving, Limited).*

A

B

Figure 7.5.9—*Large container stock is always shipped in the growth container and transported to the field in the same nursery racks (A&B).*

A

B

C

D

Figure 7.5.10—*Cardboard boxes provide protection to plants during storage, shipping, and handling (A). Because they can be stacked, boxes make efficient use of space in storage units and delivery vans (B). Pallets of boxes can be easily moved by hand or forklift (C). Delivery vans should use racks to prevent shipping boxes from being crushed (D).*

7.5.4 Nursery Stock Delivery

Many different methods have been used to deliver plants from the nursery to the outplanting site. The most appropriate method will depend on the distance involved, the number of plants, and the dormancy and hardiness of the stock. Although rail and even commercial airlines have been used, most nursery stock is delivered by truck because most outplanting sites are in remote locations. Nursery plants can be subjected to severe mechanical shocks during transport, especially on gravel or dirt roads, and reducing speed will minimize potential injury (Stjernberg 1997).

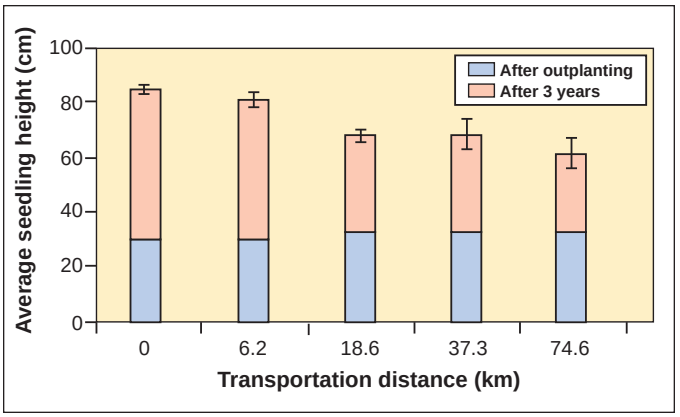
7.5.4.1 Delivery in refrigerated trailers

Nursery stock, whether shipped in the container or extracted and packed into boxes or bags, is typically shipped by truck. For large quantities of plants, typical of forest companies, and when the trip will take more than a few hours, shipping is usually done by trucks with refrigerated trailers ("reefers") (fig. 7.5.11A). Because high temperature is the major risk factor during nursery stock transport, the use of refrigerated vans has had a significant effect on enhanced plant quality and outplanting success. In a review of the success of southern pine plantations, the use of refrigerated vans was named as the single most important factor in making sure that plants arrived at the outplanting site in good condition (Fox and others 2007).

The risk of injury to nursery stock increases with the shipping distance. This is most critical for hot-planted stock for summer or fall outplanting because the plants are not fully dormant or at their peak of hardiness. When the outplanting performance of hot-planted silver birch (*Betula pendula*) seedlings was monitored, height growth measured after the first year was not affected by transportation distance (Luoranen and others 2004). When the same plants were measured after 3 years, however, shoot height decreased with shipping distance (fig. 7.5.11B).

The temperature inside the trailer should be monitored during transit because truck refrigeration units are prone to failure. Both high- and low-temperature injury has occurred when refrigerated units have malfunctioned. The ideal temperature in a delivery truck depends on whether the plants are going to be hot-planted or are coming from cooler or freezer storage, especially if frozen stock needs to thaw. In an operational trial, temperatures in boxes of

A



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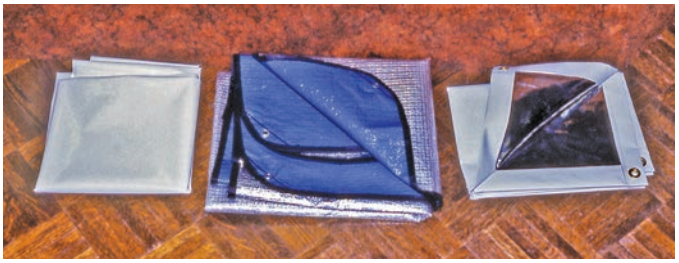
C

Figure 7.5.11—*Refrigerated vans ("reefers") are used to ship nursery stock for long distances (A). The risk of injury to nursery stock increases with the shipping distance (B). Dropoff reefer units can provide ideal long-term, onsite storage (C) (B, modified from Luoranen and others 2004).*

A

B



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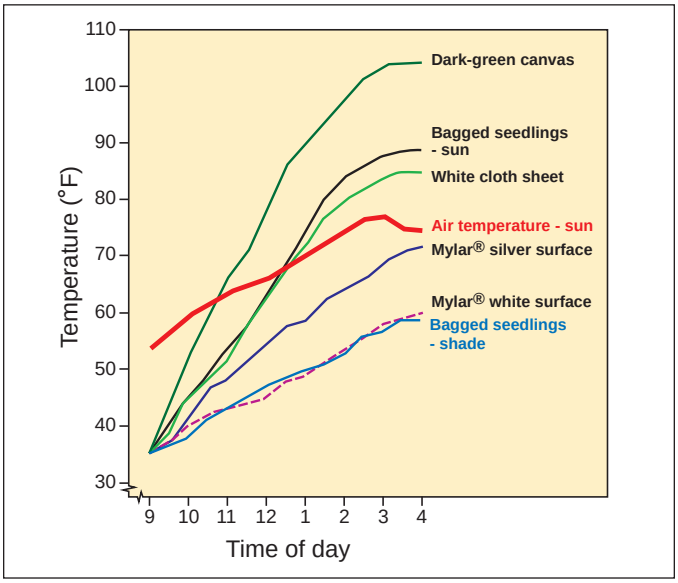

D

Figure 7.5.12—*Nonrefrigerated nursery delivery vehicles should be painted white and insulated to keep inside temperatures low (A). In open pickups, nursery stock should be covered with tarps (B); special reflective tarps (C) are commercially available. Research has shown that reflective Mylar® tarps provide much better insulation than standard green canvas ones (D) (D, modified from DeYoe and others 1986).*

refrigerated nursery stock ranged from 2 to 10 °C (36 to 50 °F) in refrigerated vehicles compared with 10 to 22 °C (50 to 72 °F) in nonrefrigerated vehicles (Stjernberg 1996). If boxes are loaded by hand, place spacers (such as wooden boards or foam blocks) between boxes or bags to allow air circulation and to prevent the load from shifting.

The Mt. Sopris Nursery in Colorado had specially designed reefer units developed that could be dropped off on the outplanting site to provide longer term, onsite storage (Figure 7.5.11C).

7.5.4.2 Delivery in nonrefrigerated trucks

For shorter trips, nonrefrigerated trucks are often used. Delivery vans should be aluminum or painted white to reflect sunlight and should be parked in the shade during stops and when they reach the outplanting site (fig. 7.5.12A). Plant ProTek is a new insulated truck liner that has been successfully tested with ornamental stock shipments and should have application for native plant nursery stock (Anonymous 2006). Adding "blue ice" in the boxes of small shipments would help keep temperatures down, although it could increase delivery costs.

Small pickup trucks. If open pickups must be used, then boxes of plants should be covered with a reflective tarp (fig. 7.5.12B). Specially constructed Mylar® tarps with white outer and silver inner surfaces are available from reforestation supply companies (fig. 7.5.12C). In operational trials, plants under such tarps were as cool as those stored in the shade (fig. 7.5.12D). Dark-colored tarps,

such as army-green canvas, laid directly on boxes, however, allow plants to heat to damaging levels and should never be used (DeYoe and others 1986).

Commercial parcel trucks. Many State and private nurseries often ship small quantities of an assortment of native plants to a variety of customers. For example, the University of Idaho Frank Pitkin Nursery, which serves as the State nursery for Idaho, routinely ships an average of 120 seedlings at a time to each of its 1,500 customers throughout the state. To facilitate this, plants are extracted from containers and placed into plastic bags. Bags of plants are then bulked into stackable plastic tubs for cooler storage (fig. 7.5.13A). These tubs provide maximum flexibility in the cooler, allowing the configuration of the storage facility to be adjusted from year to year as production numbers vary. As the shipping season progresses, empty tubs can be removed from the cooler, thus creating additional workspace to process orders. As orders need to be shipped, employees move from tub to tub, gathering the appropriate species and quantities (fig. 7.5.13B). Completed orders are placed into cardboard boxes, weighed (Figure 7.5.13C), labeled (fig. 7.5.13D), and prepared for shipping by commercial delivery companies, such as United Parcel Service (UPS) or FedEx (fig. 7.5.13E). Because these packages will not always be handled by trained personnel, boxes must be heavy duty to protect nursery stock (fig. 7.5.13F). Within Idaho, all orders are usually delivered within 2 days. Customers are advised automatically by e-mail when their order leaves the nursery, and they receive tracking numbers to monitor the delivery process.


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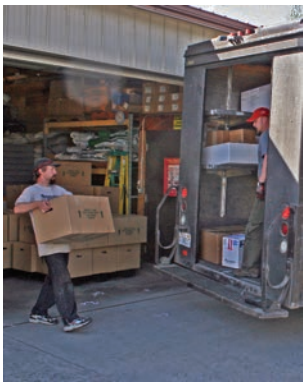
E

F

Figure 7.5.13—*Bundles of plants are taken from bulk bins in cooler storage (A), individual orders are assembled in cardboard shipping boxes (B), boxes are weighed (C), and shipping labels with bar codes are printed (D). Boxes are shipped to customers by package delivery early each week to ensure delivery before the weekend (E). The value of proper packaging becomes especially apparent with nursery stock delivered by commercial parcel services (F).*

7.5.5 Summary and Recommendations

After a crop begins the process of leaving the growing or storage area for the outplanting site, the financial and plant-quality risks peak—plants have reached their full economic value and should be at their highest quality level. 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.

The key to successful handling and shipping is to minimize stresses. Special equipment is often used to move plants that remain in their original containers throughout storage and shipping, thus reducing physical stress. Many nurseries, however, extract stock from containers and store and ship them in boxes or bags to reduce storage volume and shipping weight and to avoid the logistics of having containers returned to the nursery. In general, large numbers of plants, such as those shipped by reforestation, forest product, or Federal nurseries, are routinely shipped in large refrigerated trailers to reduce temperature stress and to maintain stock quality. For smaller nurseries, such as private native plant operations and State facilities, and for small quantities of stock that are being sent to locations near the nursery, stock is often shipped without refrigeration—such shipments are successful if care is taken to minimize extremes of temperature and physical stress.

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