Containers

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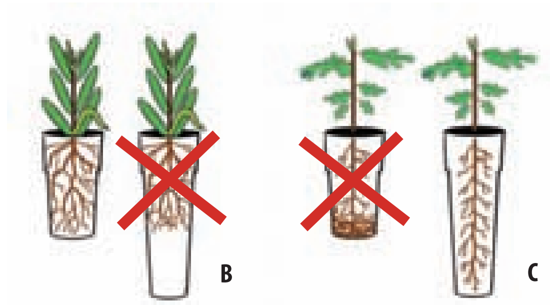
The choice of container is one of the most important considerations in developing a new nursery or growing a new species. Not only does the container control the amount of water and mineral nutrients that are available for plant growth, a container's type and dimensions also affect many operational aspects of the nursery such as bench size and type of filling and harvesting equipment. After a container is selected, it can be very expensive and time consuming to change to another type.

Many terms have been used to describe containers in nurseries and some are used interchangeably. In the ornamental trade, large individual containers are called "pots" or "cans" but they are simply called "containers" in native plant nurseries. Restoration seedlings, typically grown in small-volume containers, are often referred to as "plugs." Plug seedlings are usually grown in individual containers called "cells" or "cavities" that are aggregated into "blocks," "trays," or "racks." In general, individual cavities are permanently aggregated into blocks, and cells are independent containers that can be inserted in or removed from trays or racks.

Most nurseries will grow a wide variety of species and therefore several different containers will be required (figure 6.1A). The choice of container for a particular native plant species depends on root system morphology, target plant criteria (see Chapter 2, *The Target Plant Concept*), and economics. These factors are interrelated, which makes discussing them difficult, but, fortunately, some generalizations, hold true:

Alex Gladstone of the Blackfeet Nation in Montana by Tara Luna.



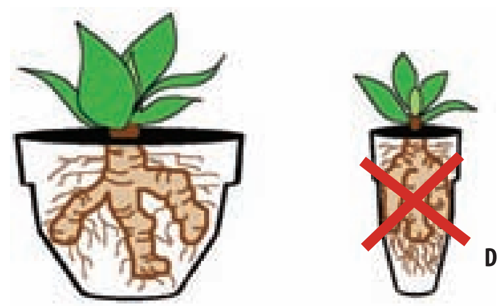


Figure 6.1—*(A) Native plant nurseries use a variety of containers to produce different species and stocktypes. (B) Some plants, including most forbs, grow best in shorter containers (C) whereas taprooted species such as oaks do better in taller ones. (D) Fleshy-rooted plants should be grown in short wide containers.* Photo by Tara Luna, illustrations by Steve Morrison.

- Plants that develop shallow, fibrous root systems, as most forbs do, grow better in shorter containers (figure 6.1B).
- Plants with long taproots, such as oaks or some pines, grow better in taller containers (figure 6.1C).
- Plants with multiple, thick, fleshy roots, such as arrowleaf balsamroot and prairie turnip, and species with thick, fleshy rhizomes grow better in wide containers (figure 6.1D).

Because choosing the type of container is such a critical step, a discussion of some of the biological and operational considerations is very important.

CONSIDERATIONS IN CHOOSING CONTAINERS

Size

Container size can be described in many ways, but volume, height, diameter, and shape are most important.

Volume

The volume of a container dictates how large a plant can be grown in it. Optimum container size is related to the species, target plant size, growing density, length of the growing season, and growing medium used. For example, to grow large woody plants for an outplanting site with vegetative competition, a nursery would choose large-volume containers with low densities. These plants would be taller, with larger root-collar diameters, and have been shown to survive and grow better under these conditions.

In all nurseries, container size is an economic decision because production costs are a function of how many plants can be grown per area of bench space in a given time. Larger containers occupy more growing space and take longer to produce a firm root plug. Therefore, plants in larger containers are more expensive to produce, and they are also more expensive to store, ship to the project site, and outplant. The benefits, however, may outweigh the costs if the outplanting objectives are more successfully satisfied.

Height

Container height is important because it determines the depth of the root plug, which may be a consideration on dry outplanting sites. Many clients want the plants to have a deep root system that can stay in contact with soil moisture throughout the growing season. Height is also important because it determines the proportion of freely draining growing medium within the container. When water is applied to a container filled with growing medium, it percolates downward under the influence of gravity until it reaches the bottom. There, it stops due to its attraction for the growing medium, creating a saturated zone that always exists at the bottom of any container. Two things control the depth of this saturated layer—container height and the type of growing medium. With the same growing medium, the depth of the saturation zone is always proportionally greater in shorter containers (figure 6.2). For example, a 4-in- (10-cm-) tall container will have the same depth of saturation as a 10-in- (25-cm-) tall container, but the 4-in-tall container will have a smaller percentage of freely drained medium.

Diameter

Container diameter is important in relation to the type of species being grown. Broad-leaved trees, shrubs, and herbaceous plants need a larger container diameter so that irrigation water can penetrate the dense foliage and reach the medium.

Shape

Containers are available in a variety of shapes and most are tapered from top to bottom. Container shape is important as it relates to the type of outplanting tools used and the type of root system of the species grown.

Plant Density

In containers with multiple cells or cavities, the distance between plants is another important factor to consider. Spacing affects the amount of light, water, and nutrients that are available to individual plants (figure 6.3A). In general, plants grown at closer spacing grow taller and have smaller root-collar diameters than those grown farther apart (figure 6.3B). Plant leaf size greatly affects growing density. Broad-leaved species should be grown only at fairly low densities, whereas smaller-leaved and needle-leaved species can be grown at higher densities. Container spacing will affect height, stem straightness, root-collar diameter, and bushiness. Container spacing also affects nursery cultural practices, especially irrigation. Some of the other effects of plant growing densities are shown in table 6.1.

Root Quality

Container plant quality is greatly dependent on the plant's root system. Most native plants have very aggressive roots that quickly reach the bottom of the container and may spiral or become rootbound. Several container design features have been developed specifically to control root growth and development.

Drainage Holes

Containers must have a bottom hole large enough to promote good drainage and encourage "air pruning."

Figure 6.2—*A saturated layer of growing medium always exists in the bottom of containers. With the same growing medium, the proportion of saturated media is higher for shorter containers.* Modified from Landis and others (1989).

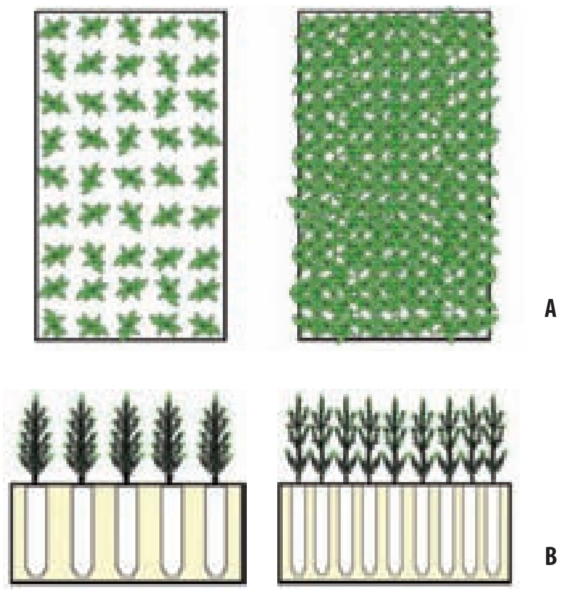


Figure 6.3—*(A) Next to volume, spacing is the most important characteristic in multi-celled containers. (B) Plants grown too close together become tall and spindly and have less root-collar diameter.* Illustration by Steve Morrison.

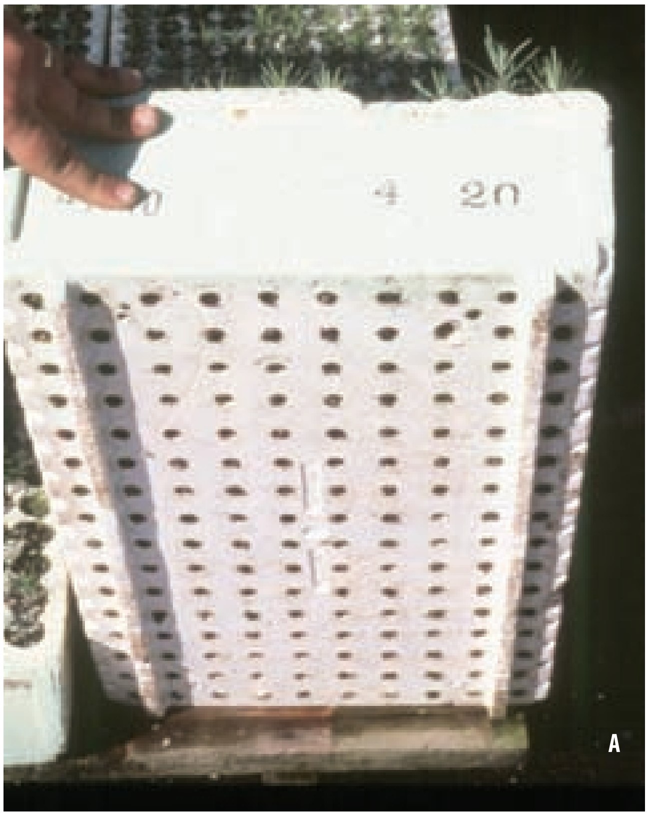
As mentioned previously, roots quit growing when they reach an air layer under the container. Some containers feature a bottom rail to create this air layer (figure 6.4A), whereas flat-bottomed containers must be placed on specially designed benches (figures 6.4B and C). On the other hand, the drainage hole must be small enough to prevent excessive loss of growing medium during the container-filling process.

Root Pruning

Spiraling and other types of root deformation have been one of the biggest challenges for container growers, and nursery customers have concerns about potential problems with root-binding after outplanting

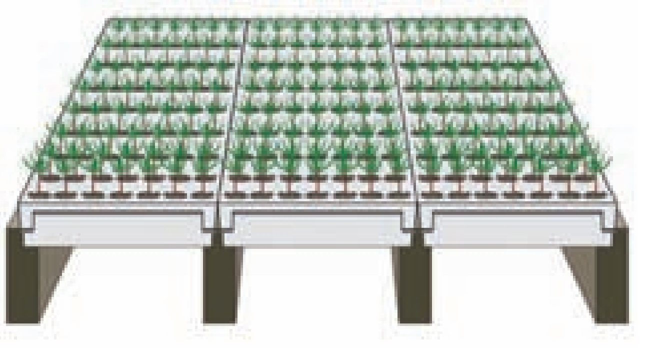
Table 6.1—Effects of container density on plant growth in nurseries

High Density	Low Density
Plants will be taller and have smaller root-collar diameters	Plants will be shorter and have larger root-collar diameters
Difficult to irrigate and fertilize with overhead sprinklers because water and liquid fertilizers need to penetrate dense patches of foliage	Easier to irrigate and fertilize with overhead sprinklers
Greater likelihood of foliar diseases due to poor air circulation between plants	Better air circulation between seedlings; less disease problems
Cooler medium temperature	Warmer medium temperature
Foliage in lower crown will die because of shading	Plants have fuller crowns because more light reaches lower foliage



A

B



C

Figure 6.4—*(A) Some block containers are designed to promote air pruning. (B) Other containers must be placed on mesh-topped benches or (C) be supported to create an effective air space underneath.* Photos by Thomas D. Landis, illustration by Jim Marin.

(figure 6.5A). The research, most of which has been done with forest trees such as lodgepole pine, showed that rootbound seedlings were more likely to blow over after outplanting. The aggressive roots of native plants, however, can be culturally controlled by chemical or air pruning. Although both pruning methods have been used in forest nurseries, they are uncommon in native plant nurseries.

Chemical pruning involves coating the interior container walls with chemicals that inhibit root growth (figure 6.5B), such as cupric carbonate or copper oxychloride. Copper-coated containers are available commercially (for example, the Copperblock™) and some nurseries apply the chemical by spraying or dipping. Copper toxicity has not been shown to be a problem for most native species, and the leaching of copper into the environment has been shown to be minimal.

Several companies have developed containers that featured air slits on their sides to control spiraling and other root deformation by air pruning (figure 6.5C). The basic principle behind the "sideslit" container is simple. Just as when plant roots air prune when they reach the bottom drainage hole, they stop growing and form suberized tips when they reach the lateral slits in sideslit containers. Forest nurseries found that sideslit containers had two drawbacks: (1) roots sometimes bridged between containers, and (2) seedlings in sideslit containers dried out much faster than those in containers with solid walls.

Soft versus Hard Plugs

Better outplanting performance is usually achieved with container plants whose roots form a firm root plug, but the amount of root deformation increases with the amount of time that plants are kept in a given container. A hard or firm plug is achieved when plant roots bind the growing medium just enough to facilitate extraction from the container without the medium falling off the roots. Some customers prefer soft plugs, however, that have looser roots around the plug after extraction because they grow new roots more quickly following outplanting and better resist frost heaving or other mechanical disturbances.

Root Temperature

Color and insulating properties of the container affect medium temperature, which directly affects root growth. Black containers can quickly reach lethal temperatures in full-sun whereas white ones are more reflective and less likely to have heat buildup. In hot, sunny climates, a grower should use containers in white or other light-reflecting colors to protect against root injury (figure 6.6). Another option is to use white plastic, Styrofoam™, or other insulating material around the outside perimeter of the containers.

Economic and Operational Factors

Cost and Availability

Although the biological aspects of a specific container are important, cost and availability are often the controlling factors in container selection. Associated expenses, such as shipping and storage costs, must be considered in addition to purchase price. Many containers are produced at only one location and their shipping costs increase as a direct function of distance from the manufacturer; others, such as Styrofoam™

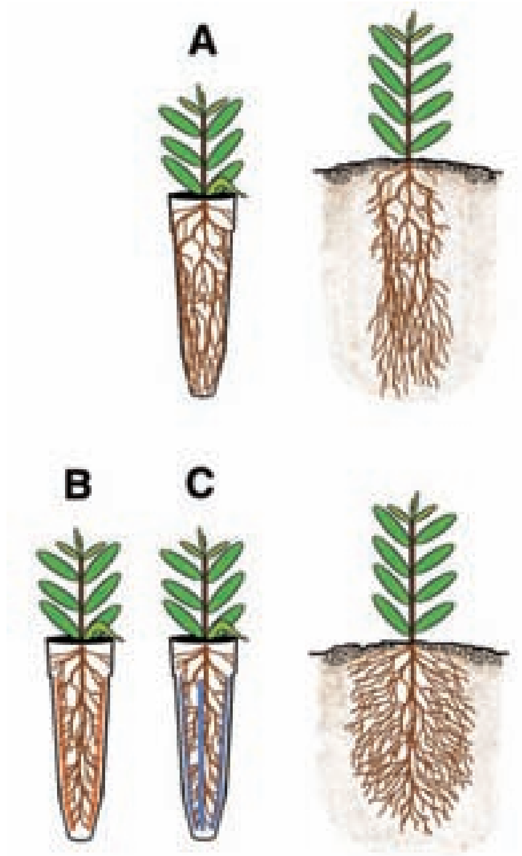


Figure 6.5—*(A) Native plants with aggressive roots often exhibit spiraling and other deformities after outplanting. New roots often retain the shape of the original plug . (B) Containers coated with copper will chemically prune roots, and (C) other containers are available with lateral slits to encourage air pruning on the side of the plug.* Illustration by Steve Morrison.

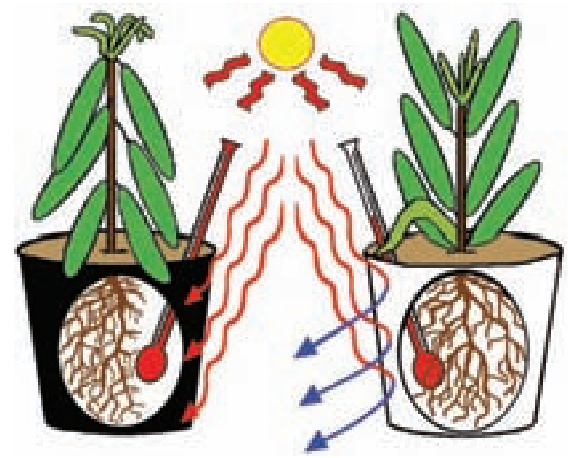


Figure 6.6—*Container color is a consideration, especially when containers are exposed to direct sunlight. Roots in white containers stay cooler than those in black ones.* Illustration by Steve Morrison.

blocks, are produced or distributed from various locations around the continent and are therefore widely available. Long-term availability must also be considered to ensure that ample supplies of the container can be secured in the foreseeable future.

Durability and Reusability

Containers must be durable enough to maintain structural integrity and contain root growth during the nursery period. The intense heat and ultraviolet rays in container nurseries can cause some types of plastics to become brittle, although many container plastics now contain ultraviolet (UV) inhibitors. Some containers are designed to be used only once whereas others can be reused for 10 or more crop rotations. Reusability must be considered in the container cost analysis because the cost of reusable containers can be amortized over their life span after adjusting for the cost of handling, cleaning, and sterilizing of the containers between crops (discussed later in this chapter).

Handling

Containers must be moved several times during crop production, so handling can be a major concern from logistic and safety standpoints. Collapsible or stackable containers, such as Zipset™ Plant Bands or Spencer-Lemaire Rootrainers™, have lower shipping and storage costs; they must, however, be assembled before filling and sowing and thus require additional handling. The size and filled weight of a container will affect ease of handling. Containers must be sturdy enough to withstand repeated handling.

As mentioned earlier, large containers are increasing in popularity, but they become very heavy when saturated with water and may require special pallets for handling by forklift (figure 6.7). Some block containers are easier to handle than others. Styroblock™ containers are rectangular with a smooth bottom, which makes them much easier to handle by conveyor. Containers with exchangeable cells are more difficult to handle, especially if they will be shipped to the outplanting site and must be returned. Ray Leach Cone-tainers™ are popular for growing native plants, but the plastic trays often crack after several uses and their sharp edges make conveyor handling difficult. Automated handling systems also place mechanical stress on containers. If containers will be shipped to the outplanting site, then the type of shipping and storage system must be considered during container selection. If seedlings are to remain in the container, then some sort of shipping box must be used to protect them.

Figure 6.7—*Handling containers through the entire nursery cycle is a major consideration, especially when plants become large and heavy.* Photo by Thomas D. Landis.

Ability to Check Roots

Although it is easy to observe shoot growth and phenology, the condition of the growing medium and the degree of root activity are hidden by the container. For most containers, it is impossible to monitor root growth without disturbing the plant. Late in the growth cycle, however, the plant's roots have formed a firm root plug and can be removed from the container. Book-type containers, such as Spencer-Lemaire Rootrainers™, however, are hinged along the bottom of the containers so that they can be opened and the growing medium and roots examined during the entire growing season.

Ability to Cull and Consolidate

One advantage of tray containers with interchangeable cells, such as Ray Leach Cone-tainers™ and Deepots™, is that cells can be removed from the tray and replaced. This advantage is particularly useful during thinning, when empty cells can be replaced with cells containing a germinant, and during roguing, when diseased or otherwise undesirable plants can be replaced with cells containing healthy ones. This consolidation can save a considerable amount of growing space in the nursery. This practice is particularly valuable with seeds that germinate slowly or unevenly, and so exchangeable cells are very popular in native plant nurseries.

Holdover Stock

Some nurseries will hold onto their stock without transplanting in an effort to reduce costs and save growing space, hoping that the stock will be outplanted next year. This practice, however, is a bad idea. The shoots of holdover stock may look just fine, but, in fact, the root system is probably too rootbound to grow well after outplanting (figure 6.8). Nursery stock that has been held in containers for too long a period is much more prone to root diseases. If nursery stock must be held over, then it must be transplanted to a larger container size to keep the root systems healthy and to maintain good shoot-to-root balance.

TYPES OF CONTAINERS

Many types of containers are available and each has its advantages and disadvantages, so side-by-side comparisons are difficult. It is a good idea to try new containers for each species on a small scale before buying large quantities.

Six main types of containers are used in native plant nurseries. These containers, identified in the following list, range in volume from 0.5 cubic in (8 ml) to 25 gal (95 L) (table 6.2):

- One-time-use containers.
- Single, free-standing containers.
- Exchangeable cell containers held in a tray or rack.
- Book or sleeve containers.
- Block containers made up of many cavities or cells.

Figure 6.8—*Many native plants have aggressive roots and cannot be held over from one growing season to the next or they will become dangerously rootbound.* Photo by Thomas D. Landis.

One-Time-Use Containers

The first major distinction in container types is whether they will be used once or whether they can be cleaned and used again. The idea of growing a plant in a container that can be transplanted or outplanted directly into the field is attractive and many designs have been tried. Unfortunately, most of these early attempts failed because the material broke down in the nursery or failed to decompose after outplanting. Jiffy® containers are the only one-time system in use in native plant nurseries and are discussed in a later section.

Single, Free-Standing Containers

Several types of single-cell containers are being used to grow native plants for specific conditions.

RootMaker® Containers

These unique containers have staggered walls and a staggered bottom that prevent root circling and direct roots toward the holes in the walls and the bottom of the container. The containers were among the first to use side "air slits" to air prune plant roots (figure 6.9) and are available in many sizes of single containers that are either square or round. Smaller volume RootMaker® cavities are joined together in blocks.

Polybags

Bags made of black polyethylene (poly) plastic sheeting are the most commonly used nursery containers in the world because they are inexpensive and

Table 6.2—Volumes and dimensions of containers used in native plant nurseries

Type	Volume (in³ [ml])	Height (in [cm])	Top Diameter (in [cm])
SINGLE FREE-STANDING CONTAINERS			
RootMaker® singles	180–930 (15,240–29,500)	6–12 (15–30)	6–10 (15–25) [a]
Polybags	90–930 (1,474–15,240)	4–8 (10–20)	6–8 (15–20)
Treepots™	101–1,848 (1,655–30,280)	9.5–24.0 (24–60)	3.8–11.0 (10–28) [a]
Round pots	90–4,500 (1,474–73,740)	6–18 (15–45)	6–14 (15–35)
CONTAINERS WITH EXCHANGEABLE CELLS HELD IN A TRAY OR RACK			
Ray Leach Cone-tainers™	3–10 (49–172)	4.75–8.25 (12–21)	1.0–1.5 (2.5–3.8)
Deepots™	16–60 (262–983)	10–14 (25–36)	10–14 (25–36)
Jiffy® pellets	0.6–21.4 (10–350)	1.2–5.9 (3–15)	0.8–2.2 (2.0–5.6)
Zipset™ Plant Bands	126–144 (2,065–2,365)	10–14 (25–36)	3.0–3.8 (7.5–10.0) [a]
BOOK CONTAINERS			
Spencer-Lemaire Rootrainers™	3.8–21.5 (62–352)	4.25–6.00 (10–15)	1.0–2.0 (2.5–5.0) [a]
BLOCKS MADE UP OF MANY CAVITIES OR CELLS			
Styroblock™ and Copperblock™	0.5–61.0 (8–1,000)	2.0–5.9 (5–15)	0.6–4.0 (1.5–10.0)
Ropak® Multi-Pots	3.5–6.0 (57–98)	3.50–4.75 (9–12)	1.2–1.5 (3.0–3.8)
IPL® Rigi-Pots™	0.3–21.3 (5–349)	1.7–5.5 (4–14)	0.6–2.3 (1.5–5.8)
Hiko™ Tray System	0.8–32.0 (13–530)	1.9–7.9 (4.9–20.0)	0.8–2.6 (2.1–6.7)
RootMaker®	11–25 (180–410)	3–4 (7.5–10.0)	1.5–3.0 (3.8–7.5) [a]
"Groove Tube" Growing System™	1.7–11.7 (28–192)	2.50–5.25 (6–13)	1.3–2.3 (3.3–5.8)

[a] Containers have square tops.

easy to ship and store (figure 6.10A). Unfortunately, polybags generally produce seedlings with poorly formed root systems that spiral around the sides and the bottoms of the smooth-walled containers. This problem becomes much worse when seedlings are not outplanted at the proper time and are held over in the containers. Copper-coated polybags are available and, compared with regular polybags, plants grown in copper polybags produce a much finer, fibrous root system that is well distributed throughout the containers (figure 6.10B).

Individual Natural Fiber Containers

Containers made of fiber or compressed peat come in a variety of sizes (figure 6.11) and are preferred by some native plant nurseries because they are ecologically friendly. The roots develop without the potential deformity problems of solid-walled containers, and peat pots can be transplanted or outplanted with minimal root disturbance or transplant shock.

Treepots™

These large-volume containers are constructed of flexible hard plastic and are good for growing trees and woody shrubs. Many sizes are available that are either square or round (figure 6.12A); square shapes increase space and irrigation efficiency in the growing area. Treepots™ feature vertical ribs on the inside wall to prevent root spiraling, are reusable, and store easily because they can be nested when empty. The depth of their root plug helps plants access soil water on dry sites and, for riparian restoration, provides stability against water erosion. Because of their large height-to-diameter ratios, Treepots™ require a support rack for growing and shipping (figure 6.12B).

Round Pots

Round black plastic pots or cans are the standard for ornamental nursery stock. They are available in many large sizes from numerous manufacturers; one encouraging feature is that some brands are recyclable (figure 6.13A). Round pots are used in some native plant nurs-

Figure 6.9—*The RootMaker®, which was the first to feature sideslit air pruning, is available as a single, free-standing container or in aggregate blocks.* Photo by Tara Luna.

Figure 6.10—*(A) Polybags are inexpensive containers that can produce good plants. (B) Root spiraling is often serious, but copper-coating has solved that problem.* Photo A by Thomas D. Landis, B by R. Kasten Dumroese.

Figure 6.11—*Fiber or peat pots are popular in some native plant nurseries because they are ecologically friendly.* Photo by Tara Luna.

eries, especially for landscaping applications (figure 6.13B). Round pots are very durable and so can be reused for many years; because they can be nested when empty, they use little storage space. Most designs have a ridged lip that makes the pots easier to move and handle when they are wet. Root deformation has been a serious problem with these containers, however, some are now available with internal ribs or copper coating to prevent root spiraling.

Pot-in-Pot System

This technique is popular for producing very large container plants and involves growing plants in one container that is placed inside another larger in-ground container (figure 6.14A). The plant container is suspended off the bottom of the in-ground pot by the shoulder lip and is supplied with trickle or drip irrigation. The pot-in-pot system is advantageous because plants are more stable and less susceptible to being blown over by the wind. Because the container is below ground, its root system is insulated against excessive cold or heat (figure 6.14B). Disadvantages include higher costs for materials and labor, and plants with aggressive root systems may grow through the drain holes of the in-ground pot into the surrounding soil.

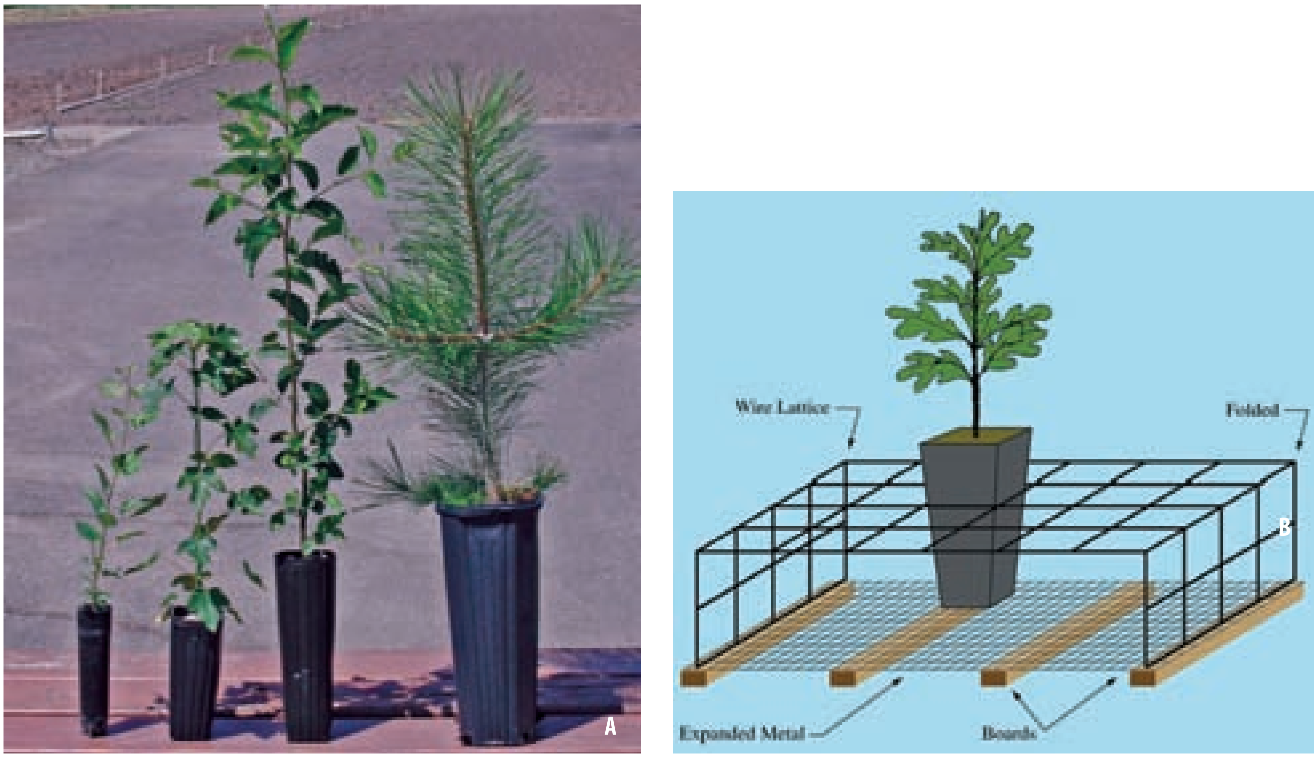


Figure 6.12—*(A) Treepots™ are popular native plant containers because of their deep root systems, but (B) they need to be held in a rack system.* Photo by Thomas D. Landis, illustration by Jim Marin.

Figure 6.13—*(A) Some standard round plastic containers or "cans" are now recyclable, and (B) are sometimes used to grow native plants for ornamental landscaping.* Photo A by Thomas D. Landis; B by Tara Luna.

Figure 6.14—*(A) The pot-in-pot system is a popular method for growing very large container stock because it provides stability and (B) insulation against heat or freezing injury .*
Photos by Thomas D. Landis.

Exchangeable Cells Held in a Tray or Rack

In this category, individual cell containers are supported in a hard plastic rack or tray. The major advantage of this container system is that the individual cells are interchangeable. Following germination, empty cells can be removed and their spaces in the rack filled with cells with plants. This process is known as consolidation and makes efficient use of nursery space. For native plants that germinate over a long period, plants of the same size can be consolidated and grown under separate irrigation or fertilizer programs. Another unique advantage is that cells can be spaced farther apart by leaving empty slots; this practice is ideal for larger-leaved plants and also for promoting good air circulation later in the season when foliar diseases can become a problem. Racks are designed to create enough air space underneath to promote good air pruning. Plastic cells can be reused for several growing seasons.

Ray Leach Cone-tainers™

This is one of the oldest container designs on the market and is still popular with native plant growers. In this system, individual soft, flexible plastic cells are supported in a durable hard plastic tray (figure 6.15). Trays are partially vented to encourage air circulation between cells, and have a life expectancy of 8 to 10 years. Cells come in three types of plastic: recycled, low density, and low density with UV stabilizers. All have antispiral ribs and a center bottom drainage hole with three or four side-drain holes on the tapered end.

Deepots™

These single cells are constructed of thick plastic and held together by hard plastic racks (figure 6.16). Available in several sizes, they have internal vertical ribs for root control and supports on the bottom of each container provide stability. Racks hold the containers together but do not create an air space underneath, so Deepots™ must be grown on wire mesh to facilitate air pruning of the roots. Due to their large volume and depth, Deepots™ are popular with native plant nurseries growing woody shrubs and trees.

Figure 6.15—*Ray Leach Cone-tainers™ are one of the most popular container types for growing native plants because they can be consolidated in the racks.* Photo by Tara Luna.

Figure 6.16—*Deepots™ come in large sizes and are popular for growing woody shrubs and trees.* Photo by Tara Luna.

Figure 6.17—*(A) Jiffy® pellets are composed of dry compressed peat surrounded by mesh and expand when watered . (B) Smaller pellets are being used to start germinants can be transplanted into larger Jiffy® containers or other containers.* Photo A by Thomas D. Landis; B by Stuewe & Sons, Inc.

Jiffy® Pellets

Jiffy® products consist of dry, compressed peat growing media inside a soft-walled, meshed bag and come in a variety of sizes (figure 6.17A). When sown and irrigated, the pellet expands into a cylindrical plug surrounded by mesh that encourages air pruning all around the plug. Pellets are supported in hard plastic trays, so individual pellets can be consolidated to ensure full occupancy. Irrigation schedules must be adjusted due to greater permeability of the container wall. Some root growth occurs between the pellets, so they must be vertically pruned prior to harvesting. Jiffy® Forestry Pellets are popular in forest nurseries in the Northeastern United States and Eastern Canada, where they are outplanted directly into the field. Smaller Jiffy® pellets are used for starting plants that are then transplanted into larger Jiffy® sizes or other containers (figure 6.17B). This system is ideal for species that germinate very slowly or over a long period of time.

Zipset™ Plant Bands

Zipset™ Plant Bands are square, one-use containers composed of high, internal-sized, bleached cardboard that are assembled in a hard plastic tray (figure 6.18). Zipset™ Plant Bands maintain their integrity in the nursery but biodegrade after 9 to 18 months. Some native plant nurseries prefer Zipset™ Plant Bands because they protect the root plug during storage and shipping.

Figure 6.18—*Zipset™ Plant Bands are inexpensive containers that can be shipped directly to the field.* Photo by Stuewe & Sons, Inc.

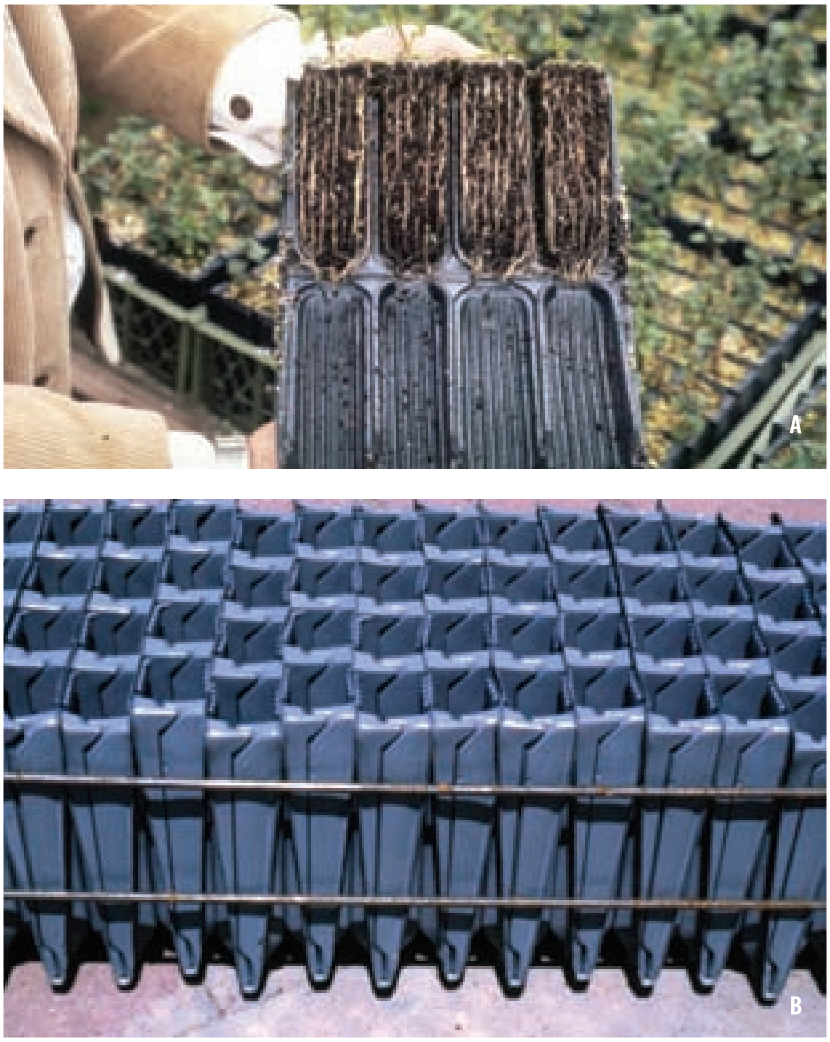


Figure 6.19—*(A) Spencer-Lemaire Rootrainers™ are designed to allow easy inspection of growing media and the root plug. (B) The hinged soft plastic sheets are assembled and placed into hard plastic trays or wire "baskets" to form blocks.* Photos by Thomas D. Landis.

Book or Sleeve Containers: Spencer-Lemaire Rootrainers™

These unique "book" containers are composed of flexible plastic cells that are hinged at the bottom, allowing the growing media and root system to be examined when the books are open (figure 6.19A). The books are held together in plastic or wire trays or "baskets" to form blocks of cells (figure 6.19B). As the name implies, Rootrainers™ have an excellent internal rib system to guide plant roots to the drainage hole and to prevent spiraling. One real advantage of using the books is that they nest easily and can be shipped inexpensively; the nesting feature also makes for efficient storage. The plastic is less durable than other container types, but the books can be reused if handled properly. Rootrainers™ have been used to grow conifers and other native plants in tribal nurseries in the Southwestern United States for many years.

Blocks Made up of Many Cavities or Cells

Multicelled containers are popular for growing native plants and range in size from very small "miniplugs" to some around 1 gal (4 L) in volume (table 6.2).

Styroblock™ and Copperblock™

Styroblock™ containers are the most popular type of container used in forest nurseries in the Western United States and are available in a wide range of cavity sizes and spacings (figure 6.20A) although outside block dimensions are standard to conform to equipment handling. This container has also been used for grow-

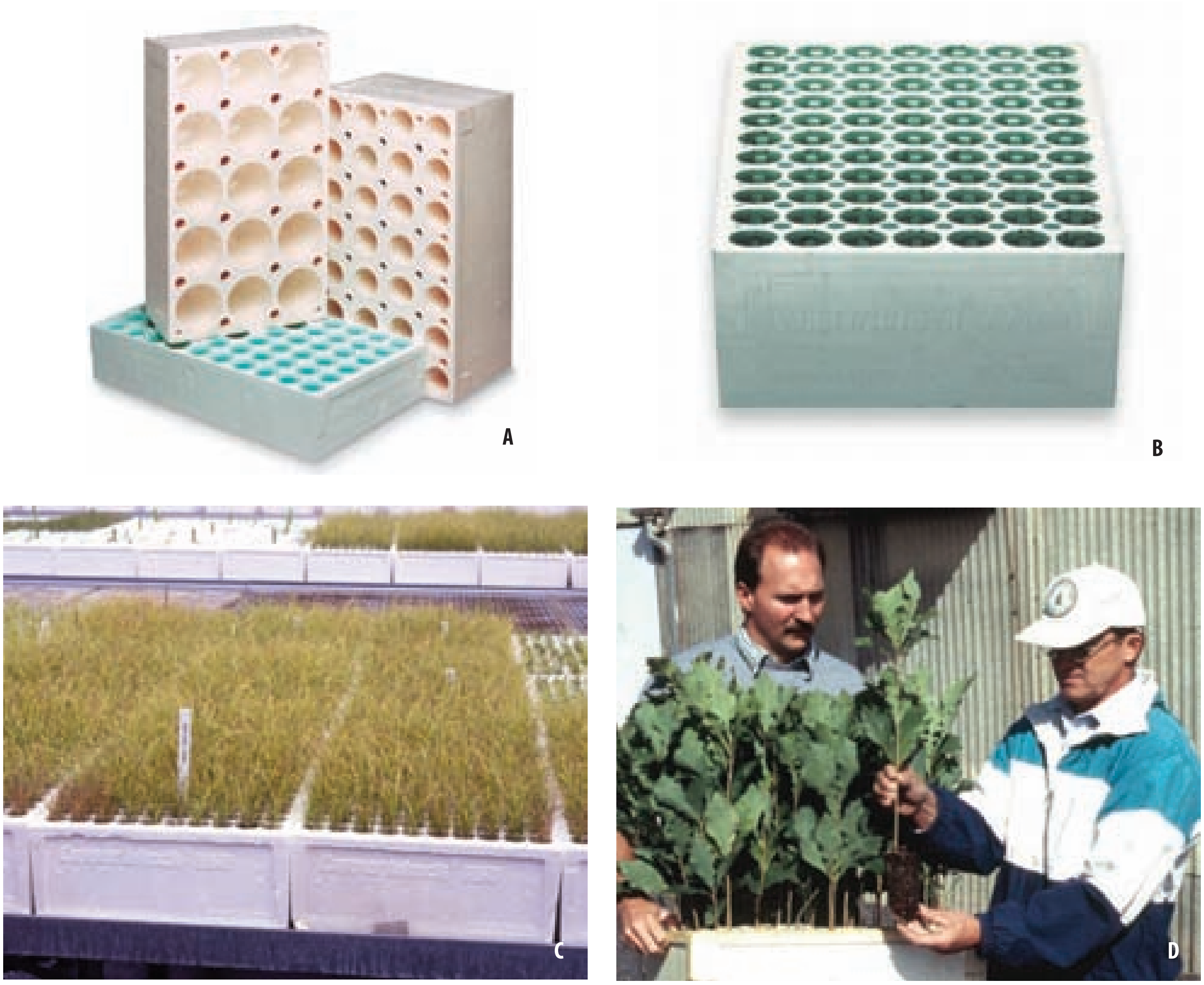


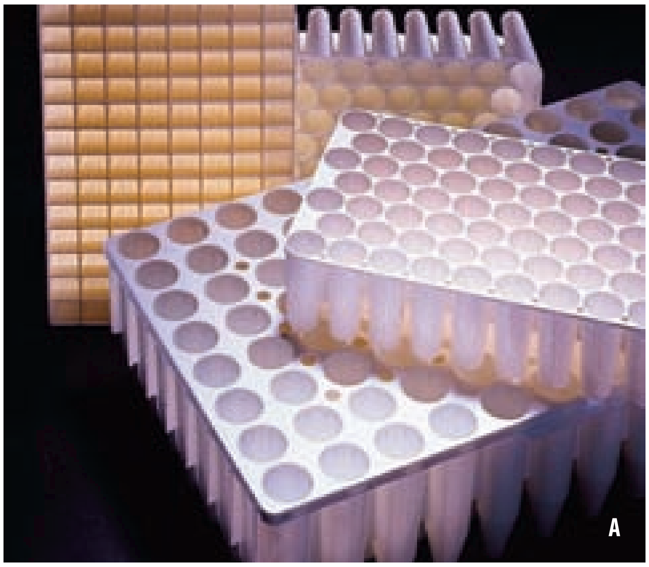
Figure 6.20—*(A) A wide assortment of Styroblock™ containers is available. (B) The cavity walls of Copperblock™ containers are coated with copper, which causes chemical root pruning of species with aggressive roots systems. Styroblock™ and Copperblock™ containers have been used to grow a variety of native plants from (C) grasses to (D) oaks.*
Photo A by Stuewe & Sons, Inc, B and D by Thomas D. Landis, C by Tara Luna.

ing native grasses (figure 6.20B), woody shrubs, and trees (figure 6.20C). The insulation value of Styrofoam™ protects tender roots from cold injury and the white color reflects sunlight, keeping the growing medium cool. Styroblock™ containers are relatively lightweight yet durable, tolerate handling, and can be reused for 3 to 5 years or more. One major drawback is that plants cannot be separated and consolidated and so empty cavities and cull seedlings reduce space use efficiency. Species with aggressive roots may penetrate the inside walls of the cavities (especially in older containers reused for several crops), making the plugs difficult to remove. The Copperblock™ container is identical to the Styroblock™ except that it is one of the few commercially available containers with copper-lined cavity walls to promote root pruning (figure 6.20D).

Hardwall Plastic Blocks

Hardwall plastic blocks are available in a variety of cavity sizes and shapes and outside block dimensions (table 6.2). Extremely durable, these containers have a life expectancy of more than 10 years. The thick plastic is impervious to root growth.

Ropak® Multi-Pots are white in color, available in square and round cavity shapes, and have been used to grow a wide variety of species (figure 6.21A). Because they are so durable, they are popular in mechanized nurseries and have been used to grow herbaceous and



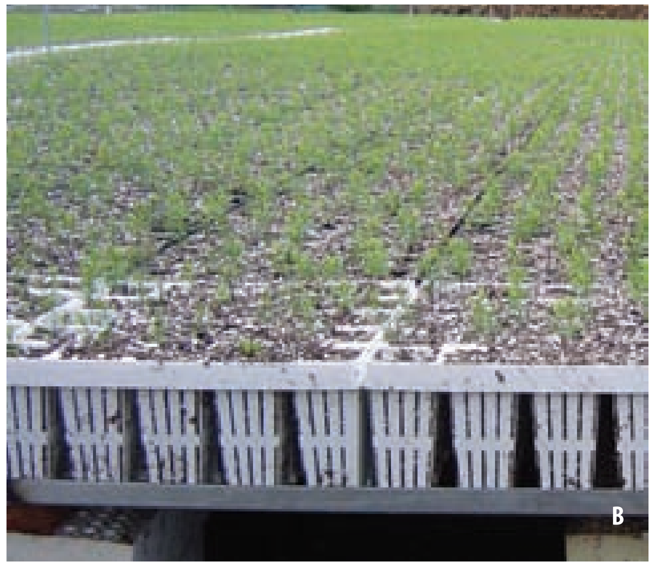


Figure 6.21—*Hardwall plastic blocks are extremely durable containers made by several manufacturers. (A) Ropak® Multi-Pots, (B) IPL® Rigi-Pots, and (C) the Hiko™ Tray System.* Photos A and C by Stuewe & Sons, Inc., B by Thomas D. Landis.

woody species. Cavity walls have vertical ribs to prevent root spiraling. **IPL® Rigi-Pots™** are usually black but other colors can be obtained in large orders. They are available in a variety of block dimensions and cavity sizes and shapes including sideslit models to encourage air pruning of roots (figure 6.21B). The **Hiko™ Tray System** features a variety of block and cavity sizes and shapes (table 6.2). All cavities have vertical root training ribs and/or sideslits (figure 6.21C). The **"Groove Tube" Growing System™** features grooves in the side walls and large drainage holes to promote root development.

Miniplug Trays

Miniplug containers are used to start young seedlings that are transplanted into larger containers after establishment (figure 6.22). They are particularly useful for species with very small seeds that make precise seeding difficult. Multiple germinants can be thinned and plugs transplanted to larger containers. In these situations, the use of miniplug trays is much more space and labor efficient than direct seeding into larger cells. They require, however, constant attention because they dry out quickly. If you use miniplug trays, you may need to irrigate them several times a day, construct an automatic mist system, or use subirrigation.

CLEANING REUSABLE CONTAINERS

Reusable containers usually have some residual growing medium or pieces of roots that could contain pathogenic fungi. Seedling roots sometimes grow into the pores of containers with rough-textured walls, such as Styroblock™ containers, and remain after the seedling plug has been extracted (figure 6.23A). Liverworts, moss, and algae also grow on containers and are very difficult to remove from reusable containers. Used containers should be first washed to remove old growing media and other debris; a pressure washer is excellent for this purpose. The containers should then be sterilized with hot water, bleach, or other chemicals. Because many tribal nurseries choose not to use pesticides, how-

Figure 6.22—*Miniplug containers are used to grow small seedlings that are transplanted into larger containers.*
Photo by Tara Luna.

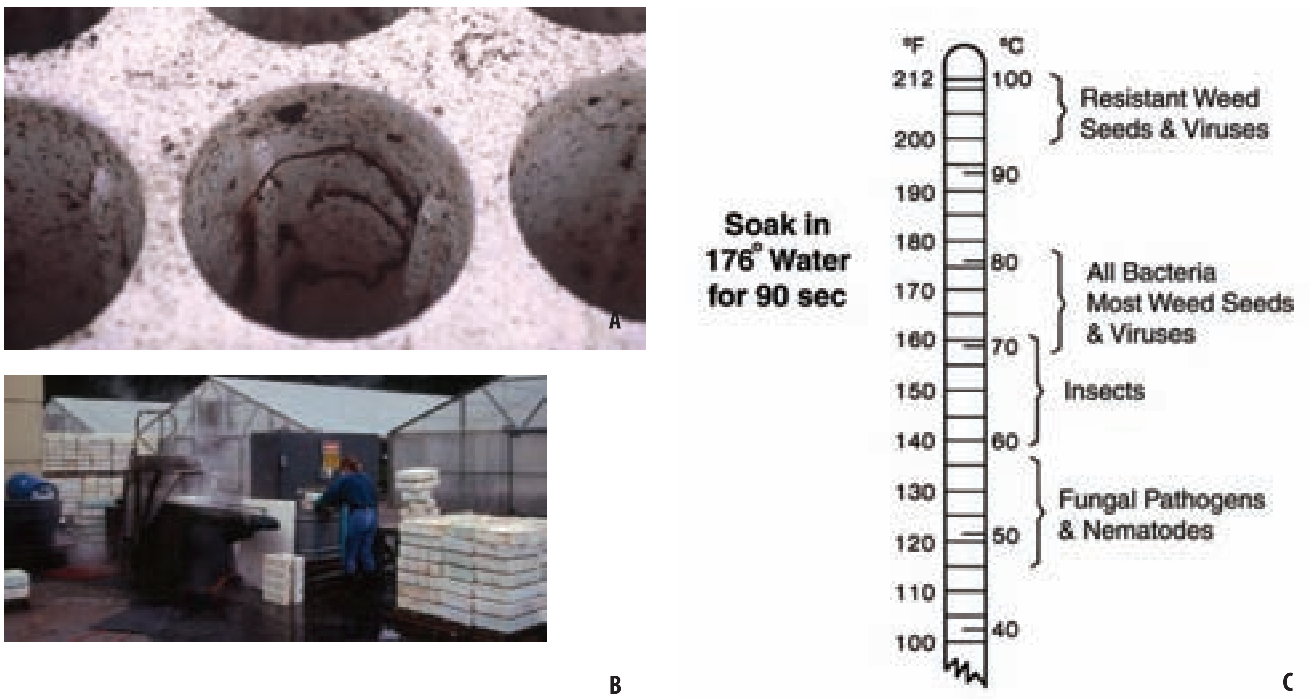


Figure 6.23—*(A) Used containers should be washed and sterilized before resowing, because residual growing media and seedling roots can contain disease organisms. (B) Hot-water dips are an effective treatment; (C) submersion in water of 165 to 185 °F (75 to 85 °C) for 30 to 90 seconds has been shown to be adequate for all types of containers.*
Photos by Thomas D. Landis.

ever, hot-water dips are the most effective way to kill fungi and other pests in used containers (figure 6.23B). Most pathogens and weed seeds are killed when containers are held at 158 to 176 °F (40 to 60 °C) for more than three minutes (figure 6.23C). For containers, a good rule of thumb is to use a soaking temperature of 165 to 185 °F (75 to 85 °C) for 30 to 90 seconds for Styrofoam™ containers; 15 to 30 seconds is probably sufficient for hard plastic containers (Dumroese and others 2002). Soaking Styrofoam™ for longer durations at 185 °F (85 °C) or at hotter temperatures can cause the material to distort. Older Styrofoam™ containers often benefit from a longer soaking duration (up to three minutes). Commercial units are available, but many nurseries have built homemade container dipping systems that hold the containers under hot water in a dip tank.

SUMMARY

The types of containers selected for your nursery will have a great effect on seedling quality and will influence the horticultural practices used in the facility. Different species will require different types of containers based on the types of leaves and root systems they possess; small experiments may be needed to determine which containers are best. In some cases, custom containers may need to be designed to suit the species, outplanting objectives, and site. Container types currently on the market have advantages and disadvantages; however, the newest designs are focused on increasing seedling root quality and outplanting performance. Cost, available space, desired stock size, and the properties and dimensions of the container are among the most important factors to consider. Container selection is a key part of nursery planning.

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ADDITIONAL READINGS

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APPENDIX 6.A. PLANTS MENTIONED IN THIS CHAPTER

arrowleaf balsamroot, *Balsamorhiza sagittata*
lodgepole pine, *Pinus contorta*
oaks, *Quercus* species
pines, *Pinus* species
prairie turnip, *Pediomelum esculentum*