Chapter 3. Growing Plants From Seeds

You can grow your seedlings two ways: in the ground or in containers. Naturally, both have advantages and disadvantages. In general, seedlings in the ground (called bareroot seedlings) grow slower than seedlings grown in containers, especially when containers are in a greenhouse or sheltered growing area. For the novice, the choice boils down to personal preference, space availability, whether or not you have a greenhouse, and soil quality.

3.1 The Importance of Quality Water

Water is the most important biological factor controlling plant growth, so the quantity and especially the quality of irrigation water are critical to growing native plants. For irrigation purposes, water quality is determined by two factors: 1) the concentration and composition of dissolved minerals often referred to as "soluble salts" or "dissolved salts," and 2) the presence of harmful fungi, weed seeds, algae, and possible pesticide contamination. Groundwater and surface water are the two sources of irrigation water, although surface water from streams, reservoirs, or lakes is more likely to be contaminated with fungal pathogens or weed seeds. Dissolved salts are a more serious problem because there is no inexpensive way to remove them (Figure 3.1). For our purposes, we define a salt as a chemical compound that dissolves in water into positively and negatively charged particles called ions. Using this definition, fertilizer is also a salt. Therefore, salts in the proper concentrations can be beneficial, but too much of any salt can also be harmful. We recommend you have your water tested by a laboratory; water tests are relatively inexpensive and can identify problems before you start growing plants, which can save money in the long run.

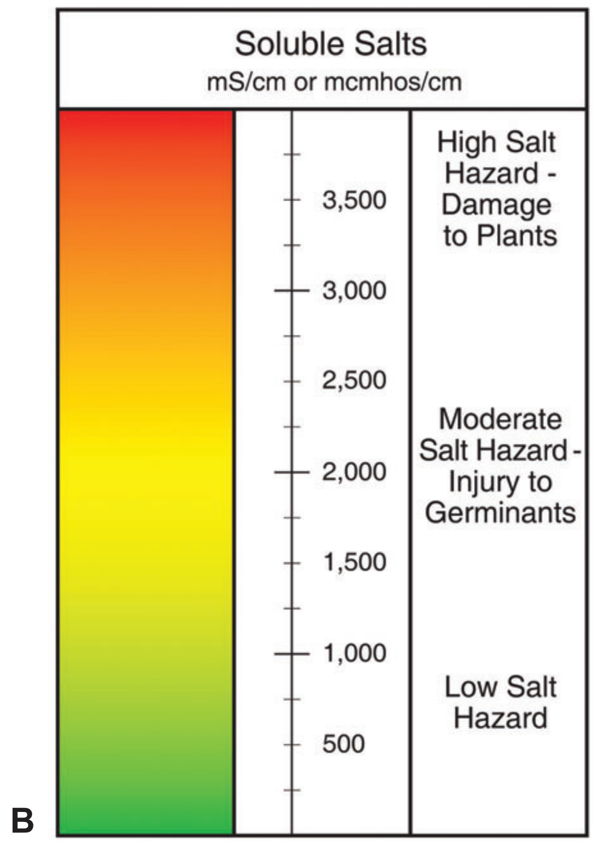


Figure 3.1—Good quality water is critical for growing native plants (A), and the concentration and composition of dissolved minerals, often referred to as "soluble salts," are the major concern (B). Young plants can be damaged by moderate salt levels, so get your water tested.

3.2 Growing Bareroot Seedlings

3.2.1 Nursery Site Selection

One of the most important factors in selecting a nursery site is soil texture, which refers to the fineness or coarseness of a soil (Figure 3.2). "Light" or "coarse" soils are predominately sandy, with some finer particles of silt and clay. Light soils have fast water infiltration, drain well, and are easy to work. "Heavy" or "fine" soils are predominately comprised of silts and clays, with just a few coarser sand particles. Heavy soils have slow water infiltration, drain slowly, and get very hard and crack when dry. A good

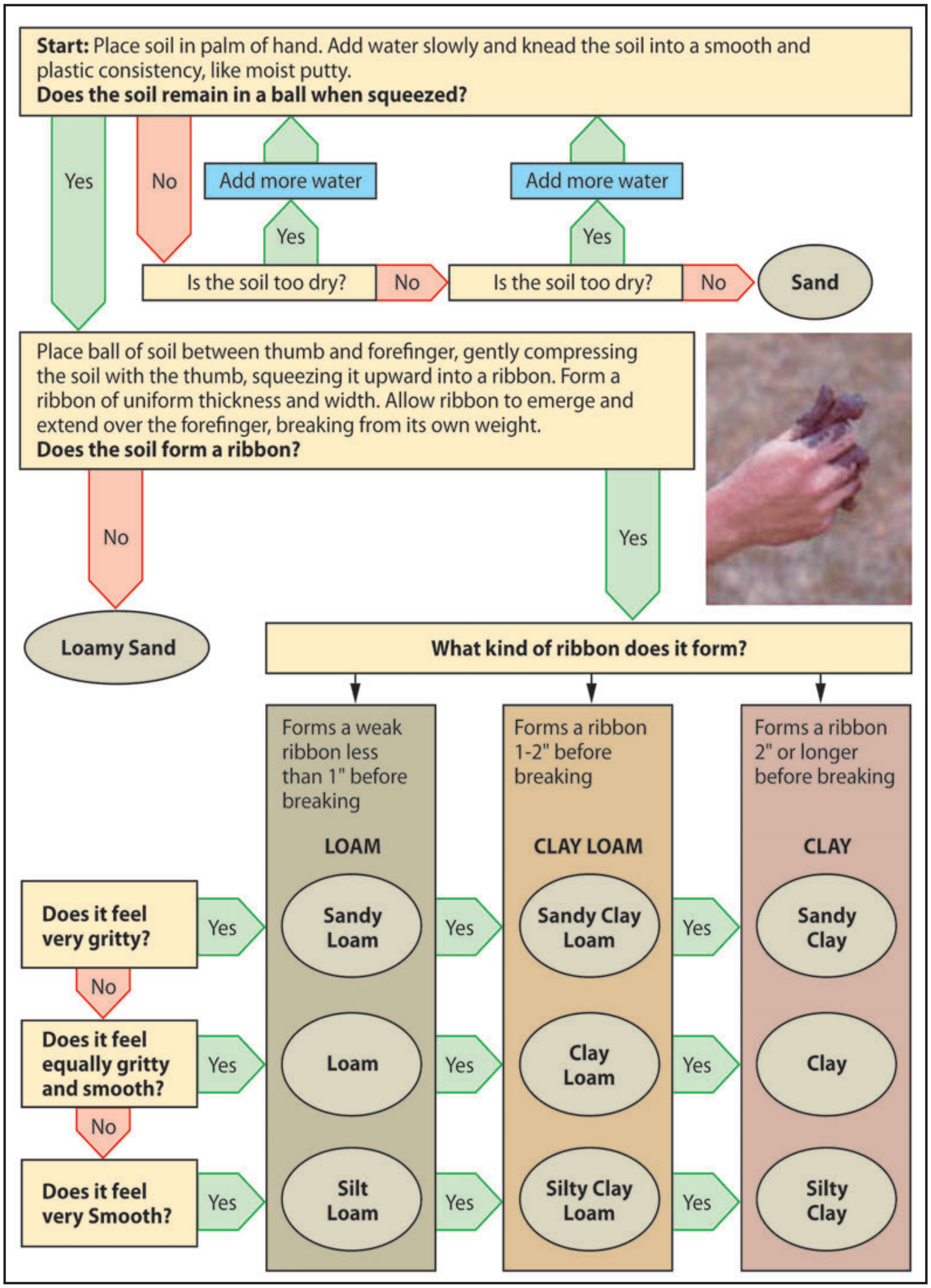


Figure 3.2—*How to determine soil texture by the feel method. Adapted from Colorado State University Extension Publication (GardenNotes #214 at http://www.ext.colostate.edu/mg/gardennotes/214.html (accessed 23 Jan 2012).*

nursery soil for bareroot seedling production has at least 40% sand particles, and no more than 40% silt particles or 25% clay particles (see Figures 3.2 and 3.3A for determining your soil texture). The best soil for growing seedlings is a deep, crumbly, loamy sand, or sandy loam that drains well and maintains a loose structure during prolonged wet weather (Figure 3.3B). Bareroot seedlings must be harvested during winter when they are dormant and soils are wet; removing seedlings from sandy soils causes less damage to fine roots than removing them from heavier soils. Farmers and gardeners use the term "tilth" in describing good soils. Although tilth is hard to describe in words, you can feel it when you are working with a shovel. You should be able to spade a good nursery soil, one with good tilth, and it should break into crumbs, not clods, and be at least a foot deep. Avoid soils with a claypan, hardpan, numerous rocks or bedrock within 18 inches of the surface. The soil should have a pH between 5.0 and 6.0. We'll discuss below what to do with marginal soils on otherwise good sites.

Try to find a gently sloping (1 to 4%) bench, long slope, or ridge top where late spring or early fall frosts are unlikely. In general, a northwestern aspect is better because seedling growth begins later and is less subject to frost damage, and the soil surface dries more slowly, but at high elevations with sufficient water, a southerly aspect is better.

Unfortunately, sandy loam soils are usually associated with river bottoms or other flat areas. Freezing air flows like water from higher slopes down to flat lands at lower elevations, and such areas are known as "frost pockets." Even on sloping ground, a physical obstruction such as the edge of a timber stand or topographical barrier may form an "air dam" and cause a frost pocket effect. Seedlings growing in frost pockets can experience shoot die-back, and may frost heave during winter (the lifting action caused by repeated freezing and thawing of the surface layer of soil).

Low-lying flat areas may also accumulate standing water during prolonged rainy seasons. Waterlogged soil is damaging or fatal to seedlings because of oxygen depletion in the soil or buildup of toxic gases. Poorly drained soils are conducive to several fungi that weaken or kill seedlings. You may be able to correct drainage problems with tile or careful leveling, but the best long-term solution is choosing a well-drained site.

Good nursery sites require full sun, otherwise most seedlings grow weak and spindly. Avoid root zones of adjacent, large trees because they invade seedbeds and deplete soil moisture and nutrients. If you must sow near larger trees, root competition can be controlled by trenching 3-feet deep between the trees and your nursery.

Windbreak trees planted near your nursery should be a different species than crop seedlings because older trees may harbor insects and diseases harmful to nursery seedlings. For example, cottonwoods and aspens are alternate hosts for Douglas-fir needle rusts, and gooseberries (*Ribes* species) should not be grown near white pine because they are an alternate host of a serious disease.

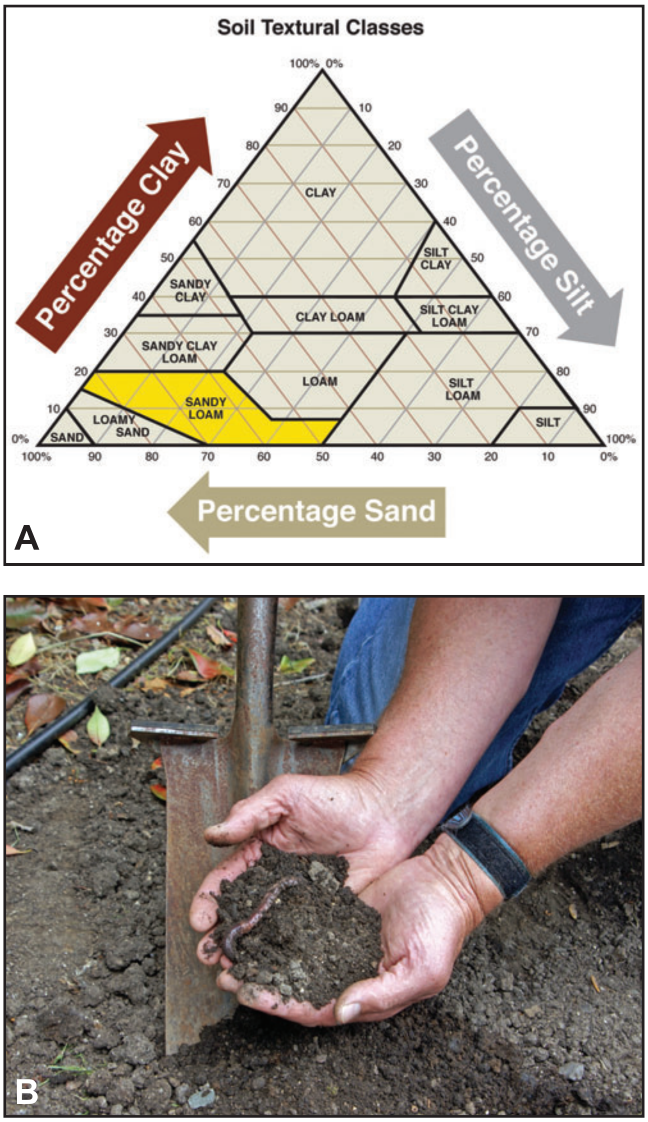


Figure 3.3—Good nursery soils are "light" in texture and sandy loam soils are ideal with high percentages of sand and lower percentages of silt and clay (A). Healthy soils contain earthworms and other beneficial organisms (B).

3.2.2 Site Preparation

How big a nursery site will you need? Well, it depends on how many seedlings you plan to grow. Plan on growing about 25 seedlings per square foot using beds 4 feet wide (so you can reach the centers). Therefore, each lineal foot of nursery bed will yield 100 seedlings. For example, if you want to grow 1,000 seedlings, the length of bed required would be 1,000 divided by 100 = 10 feet. So a 4 x 10 foot bed would be sufficient. Plan on adding about 50% more space for walkways between beds.

Your soil should be thoroughly worked at least 12 inches deep the year before sowing. If your site was recently cultivated and is free of heavy sod and weeds, one plowing in fall is sufficient. That plowing should be followed in spring by fine disking and harrowing, rototilling, or spading and raking just before laying out your beds. Just a note about rototilling—do it sparingly and at a low RPM. Rototilling enhances the breakdown of soil organic matter and soil structure, two characteristics of soil beneficial to seedling growth.

If your site hasn't been recently cultivated, deeply plow and grade the soil a full year before establishing beds. Heavy debris like roots, rocks, wood chunks, and other foreign matter should be removed. This should be followed by summer fallowing (repeated cultivation) to break down heavy organic matter and control new growth of grass and weeds. Persistent, deep-rooted plants like blackberries, thistles, bindweed, and quack grasses should be eradicated with herbicides during the early summer growing season (please consult your university extension agent or Natural Resources Conservation Service [NRCS] representative for proper chemicals and application rates; use them only with a great deal of caution for the crop, yourself, and the environment—always read and follow label directions).

If you have an otherwise good site but only marginal soil, you'll have to modify the soil with large quantities of amendments. Either incorporate sandy loam soil or organic matter. We recommend organic material, including peat moss, garden compost, ground and composted leaves, and well-composted manure. Adding organic amendments and/or coarse sand to heavy clay loams will improve drainage, texture, tilth, and fertility. Put the amendment about 6 inches deep on top of the soil (about 2 cubic yards of amendment per 100 square feet of soil to be treated), and then work it into the soil to a depth of 12 inches. Sawdust, a readily available source of organic matter, can be used as an amendment with caution (see Section 3.2.6, Soil Management).

Test your soil for pH, soil acidity, with kits available at garden centers or through gardening catalogs. Soils with pH below 7.0 are considered "acid" while those above 7.0 are considered "basic" (Figure 3.4). A good nursery soil for native plants should have a pH between 5.5 and 6.5. If your soil pH is too high (more than 6.0), add sulfur to bring it down. Conversely, if the soil is too acidic (less than 5.0), add lime to increase pH. The actual amounts of sulfur or lime needed to achieve the desired change in pH vary with the amounts of sand, silt, and clay in your soil. You'll need a more complete soil test and some expert advice in order to apply the correct amounts. Soils can usually be tested at universities or other testing laboratories and test results often include sulfur and lime recommendations. Ask your university extension agent or NRCS representative for nearby laboratories.

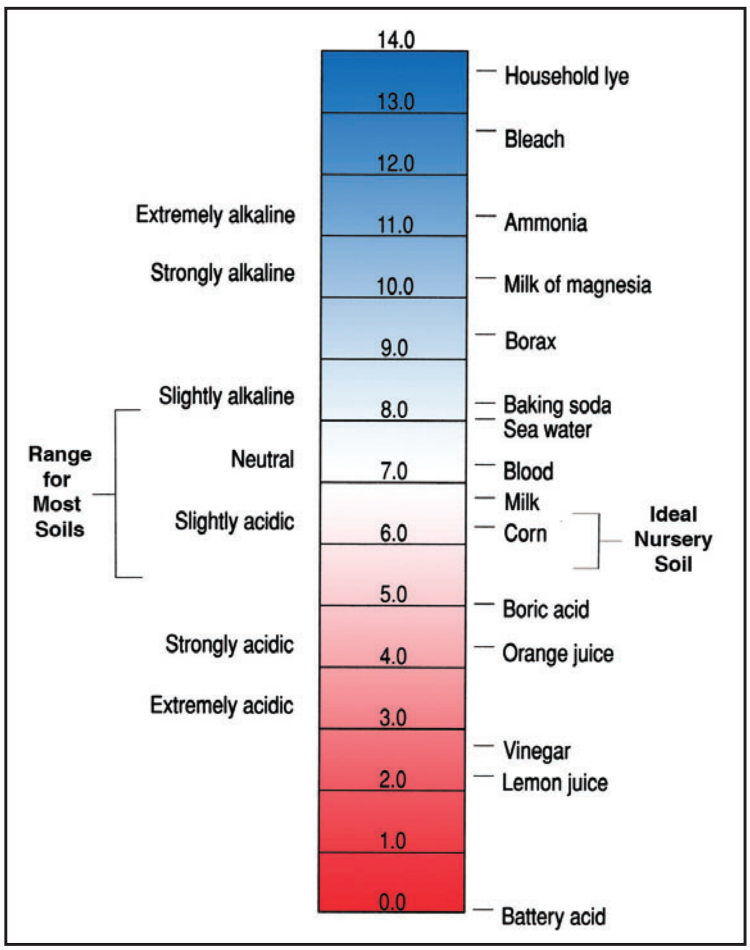


Figure 3.4*—The ideal nursery soil has a pH of from 5.5 to 6.5, so have your soil tested.*

3.2.3 How to Grow Seedlings

Generally, it takes 1 to 2 years to grow bareroot, woody, native plant seedlings large enough for planting, but some slow-growing species like bristlecone pine may take 3 or 4 years. Most conifer seedlings are grown 2 years in the same nursery bed, and professional nursery managers call them 2+0 seedlings (2 years in the same bed without any years in a transplant bed). Huskier seedlings can be grown by transplanting 2+0s into another bed for an additional year. These would be called 2+1s. Many eastern deciduous trees and shrubs and conifers of the southeastern U.S. can be grown in a single year, whereas conifer seedlings at more northerly latitudes and in the western U.S. require 2 years. For the sake of discussion, let's assume you'll be growing 2+0 seedlings.

3.2.3.1 Fertilizers: Organic vs. Synthetic—Plants require 13 nutrients to sustain healthy growth (Figure 3.5); sometimes these are referred to as minerals or elements. Six of these nutrients are called macronutrients because the plant requires them in greater amounts than the other seven, called micronutrients, which are required only in very small amounts. Of the six macronutrients, three are considered the primary, or most important, nutrients for healthy plant growth and are commonly supplied through fertilizers: nitrogen (N), phosphorus (P), and potassium (K). Nitrogen is critical for aboveground plant growth, especially new shoots, needles, and buds. Plants lacking sufficient N grow slowly or are stunted and have pale green or yellow needles. In young seedlings, P is important for root growth and bud development. Potassium is necessary for root growth, efficient water use by the plant, and improved disease resistance. The secondary macronutrients and micronutrients are normally present in fertile soil or supplied through irrigation water. Soil tests are necessary to diagnose nutrient deficiencies.

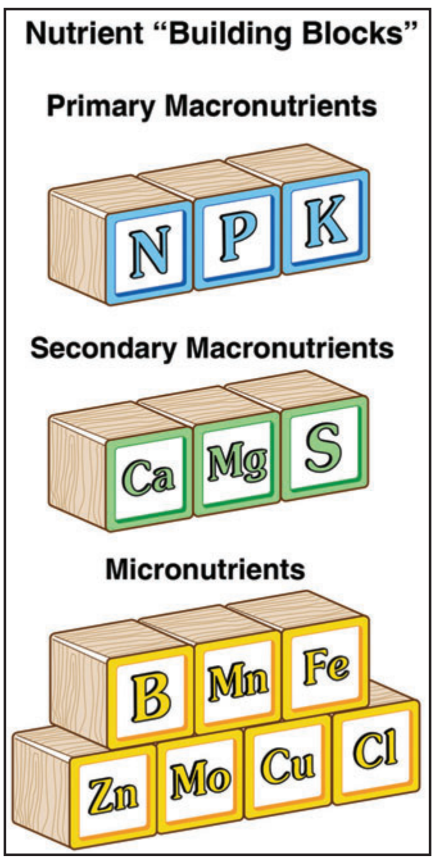


***Figure 3.5**—Plants need 13 nutrients for healthy growth, especially the three primary macronutrients found in most fertilizers: nitrogen, phosphorus, and potassium.*

Nutrients can be supplied to your plants through either organic fertilizers (for example: manure, compost, kelp) or synthetic fertilizers that are available at garden centers or farm chemical suppliers. To a native plant seedling, a molecule of nitrate nitrogen is the same whether it comes out of a cow or out of a bag purchased at a garden center. In general, organic fertilizers have low percentages of N:P:K; N ranges from 0.5 to 1.5% in manure and 2 to 4% in composts, whereas synthetic fertilizers have much higher concentrations of N, ranging up to 33% or more. Because organic fertilizers like manure and compost are associated with lots of decomposing organic matter and microorganisms (bacteria and fungi), and organic matter is important to healthy soil, one benefit of using organic fertilizers is the organic matter and microorganism additions. Because synthetic fertilizers don't supply it, organic material should be added to nursery soil.

Fertilizer can be applied to seedlings two ways: incorporated into the soil or applied over the crop (top-dressing). The application technique depends on the solubility of the fertilizer. Nitrogen and K fertilizers are soluble so they can be top dressed and your irrigation water will carry them down to the roots. However, P is not soluble so it must be incorporated into the root zone before sowing the crop.

How much fertilizer should you apply? Too much fertilizer is a common mistake. It's better to put slightly less fertilizer on a crop rather than too much. Remember that the label on any fertilizer always shows the percentages of N, P, and K, and always in this order: N:P:K. (Well, that's not completely true, and this can be made really complicated, which we show in Appendix 6.2.) Here's the easiest approach that should work for most situations. Using a whirlybird type spreader or a drop-type spreader, apply fertilizer evenly across the bed. Before sowing, incorporate 2.5 pounds of 0:20:0 (calcium superphosphate) into every 100 square feet of nursery bed. Use a spade or rototiller to work the fertilizer into the ground.

Once seedlings are growing, top dress seedlings (apply fertilizer over the tops of seedlings) at a rate of 7 ounces of 10:10:10 (N:P:K) per 100 square feet of nursery bed three times during summer (mid-June, early July, mid-July) and again in mid to late September. The mid-June application should be avoided if damping-off is a problem. Water immediately after applying the fertilizer to wash it off foliage and move it into the ground where it's available to roots.

If you care to be more intense with your fertilization program, the result being larger seedlings in less time, check the appendices for necessary formulas for determining the amounts of different fertilizers to apply. Some examples are provided for fertilizers to use on acidic soils with pH under 6.0 (Appendix 6.2.1), basic soils with pH more than 6.0 (Appendix 6.2.2), or if you want to use a strict organic fertilization program (Appendix 6.2.3).

3.2.3.2 Sowing and Germination—After incorporating fertilizer and/or adjusting soil pH, make sure your nursery bed is smooth and level. Professionals usually make beds that are 4 feet wide and raised 3 to 6 inches, but you can make raised beds of any size using redwood or cedar boards for siding. Raising the beds promotes drainage and soil-warming, which encourages faster germination and root growth; saturated soil stays cooler and promotes damping-off and root diseases.

You may sow either in rows or by broadcasting. Either way, the idea is to get enough seedlings per square foot to achieve good seedling growth without causing too much competition between seedlings. If you broadcast sow (Figure 3.6A), spread three-fourths of the seeds evenly over the nursery bed. Mixing a little baby powder (talc) on the seeds, especially when they are small, makes them easier to handle and easier to see on the ground. Use remaining seeds to fill any "holes." Gently press seeds into the soil with a board and cover with a light layer of mulch. When properly done, broadcast sowing results in even-spaced seedlings that have room to grow (Figure 3.6B).

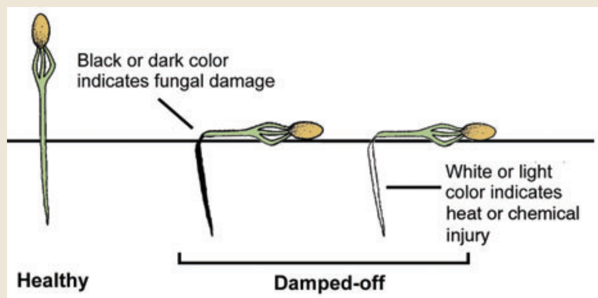
Sowing seedlings in rows or "drills" (Figure 3.6C) may take more time, especially if you manage the within-row distance between seeds, but it's worth it —you'll spend less time weeding, root pruning, and harvesting, and you'll grow more uniform, nicer-looking, healthier seedlings. Rows are typically about 6 inches apart for most species. Probably the easiest way to sow in rows is by using a marking board (Figure 3.6C). Based on your germination percentage, sow enough seeds so you'll have about 25 seedlings per square foot after germination is complete (Table 3.1). If you plan to transplant the seedlings after the first growing season, you may use densities up to 50 seedlings per square foot. A handy tool, especially for smaller seeds, is a vibrating hand seeder, available in garden centers and through mail-order nursery catalogs. If you are sowing a lot of seeds, you should consider a walk-behind precision garden seeder like the Cole Planet Junior (Figure 3.6D), which can handle many sizes of seeds.

Regardless of when or how seeds were sown, most species should be covered by a thin (1⁄8- to 1⁄4-inch-thick) mulch of pine needles, sawdust, fine-screened bark (1⁄8-inch diameter), sand, very fine gravel, or screened garden compost (only use the fines). Mulch should be no more than twice the thickness of the seed, and will keep seeds from drying out. Sowing seeds too deep is a common and serious mistake (Figure 3.7). Seeds that should not be covered include those that are very small (for example, sagebrush) or require light for germination (for example, birch).

Seeds may also be sown in fall, allowing them to stratify under natural conditions. Fall sowing can be particularly advantageous for species that required some warm, moist treatment before stratification (see Appendix 6.1). Fall-sown seeds must be protected from predators, especially mice (see below), and from drastic variations in temperature. To

Damping-off

Germinating seeds and young seedlings are very susceptible to diseases, which are collectively known as "damping-off." Several factors including fungi, chemicals, or high-temperatures can cause the stem tissue to collapse at the ground surface. When fungi cause damping-off, the roots are dark and decayed, discolored roots; however, when seedlings damp-off because of chemical damage or heat injury, the root remains white. Damping-off is most serious on seeds with low germination percentages, seeds germinating during periods of cold and wet weather, and when seedbeds are watered too much. Damping-off can be minimized by using clean seeds and well-drained soil. If damping-off is particularly bad, refrain from using any nitrogen fertilizer because this worsens the disease. Remove and discard dead and dying seedlings immediately to help prevent infection of other seedlings.



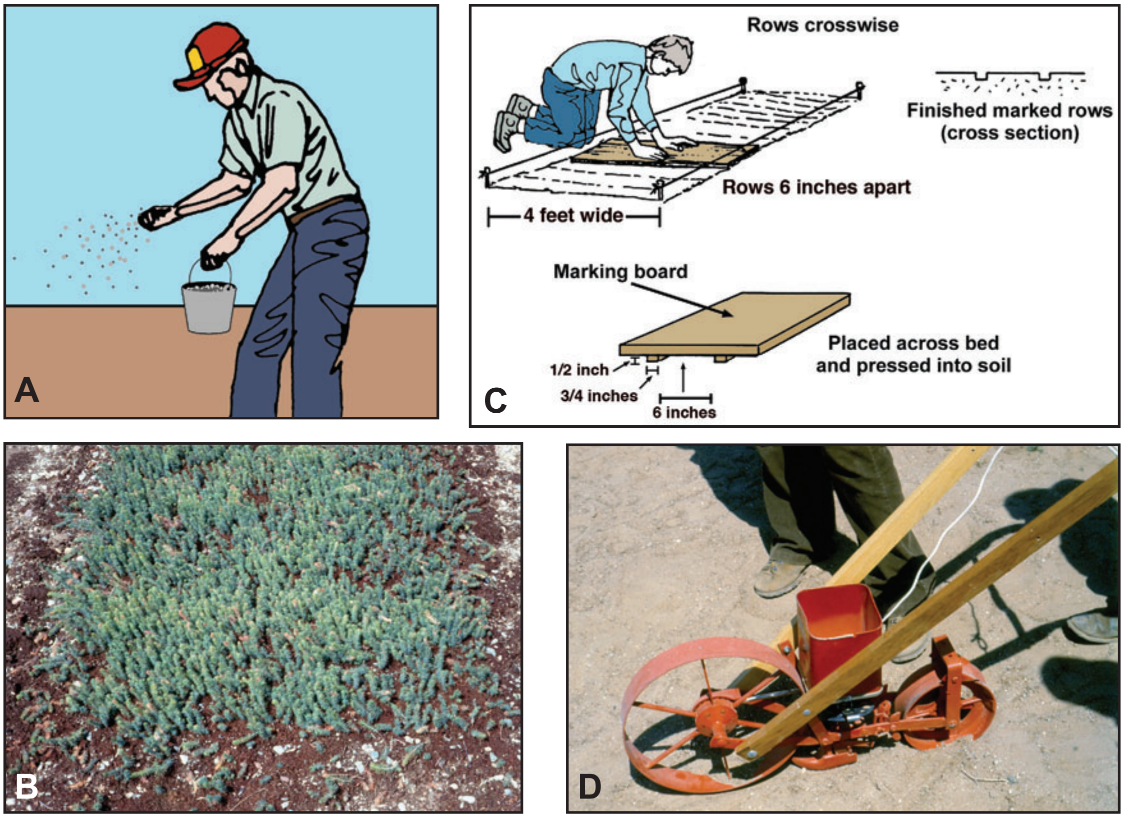


Figure 3.6—*Broadcast sowing can be done by hand (A) or with a whirly bird seeder. The biggest problem with broadcast sowing is controlling plant density – these seedlings are much too dense (B). Row or "drill" sowing can be done by hand using a marking board (C) or a walk-behind seeder like the Cole Planet Junior (D) adapted from Raising Forest Tree Seedlings at Home, Pacific Northwest Cooperative Extension Publication PNW 96, 1981. 11 p..*

Table 3.1—For the germination percentage of your seedlot, and assuming you'll sow 10% extra for losses and that your rows are 6 inches apart, this table provides an estimate of how many seeds to sow per square foot and how far apart those seeds should be in each row.

Germination percentage	Seeds to sow per square foot	Seeds to sow assuming a 10% loss during the first year	Inches between seeds in rows
80 to 100	32 to 25	35 to 27	1 to 1¼
60 to 80	42 to 32	46 to 35	¾ to 1
40 to 60	62 to 42	68 to 46	½ to ¾
20 to 40	125 to 62	138 to 68	¼ to ½

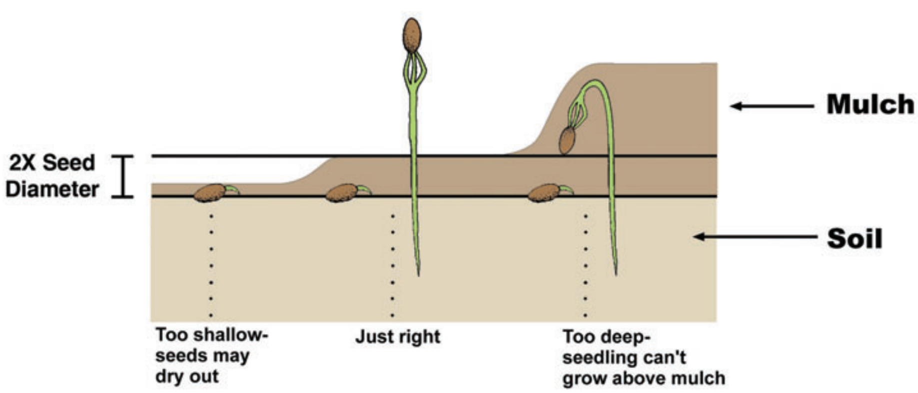


Figure 3.7—*Sowing at the proper depth is critical and varies with seed size. Seeds that are sown too shallow will dry out or be eaten by birds or rodents, but seeds sown too deep will not have the energy to push to the surface.*

protect seeds from drying and frost heaving, fall sowings will need to be covered with a thick mulch. A 2-inch-thick layer of straw works well, but it must be removed in early spring to allow germination.

Newly sown seeds should be protected from pests, especially mice and birds. Covering seedbeds with mesh, elevated 6 to 12 inches above the soil but extending to the soil around the edges, will minimize losses to birds. If the mesh is small enough, this will also exclude mice and help prevent wind and water erosion. Keep the area near your seedbeds free of weeds and debris to eliminate hiding places for mice and other pests.

Water sparingly during germination and emergence—“moist, but not wet” is a good rule of thumb. A few light mistings on sunny days are better than one thorough watering. Remember, sprouting seeds are very susceptible to damping-off, which is a serious problem when seedbeds are overwatered.

3.2.3.3 Young Seedlings: Establishing Your Crop—About a month after germination, check your seedling densities. If you have more than 40 seedlings per square foot and don’t want to transplant after the first growing season, consider thinning seedlings to 25 to 30 per square foot to ensure healthy growth. Discard thinned seedlings the same way you discard diseased seedlings—burn or bury them.

Remove weeds diligently by pulling or apply herbicides before they grow large and interfere with growth of your seedlings (Figure 3.8A). Use herbicides with a great deal of caution for the crop, yourself, and the environment—always read the label. Make sure you control weeds in and around your nursery beds, too. Good weed control efforts on the rest of your property will diminish the number of weed seeds sprouting in your nursery.

As seedlings grow, maintain a good mulch layer (¼- to ½-inch thick). Mulch reduces watering needs, keeps soil cool, prevents soil from splashing onto your seedlings, and helps retard weed growth (Figures 3.8B). Young seedlings can be damaged by high soil surface temperatures so, on very warm days, you may need to water to cool the seedbeds. As the stems of your plants grow thicker, they can tolerate higher temperature so this type of watering won’t be needed.

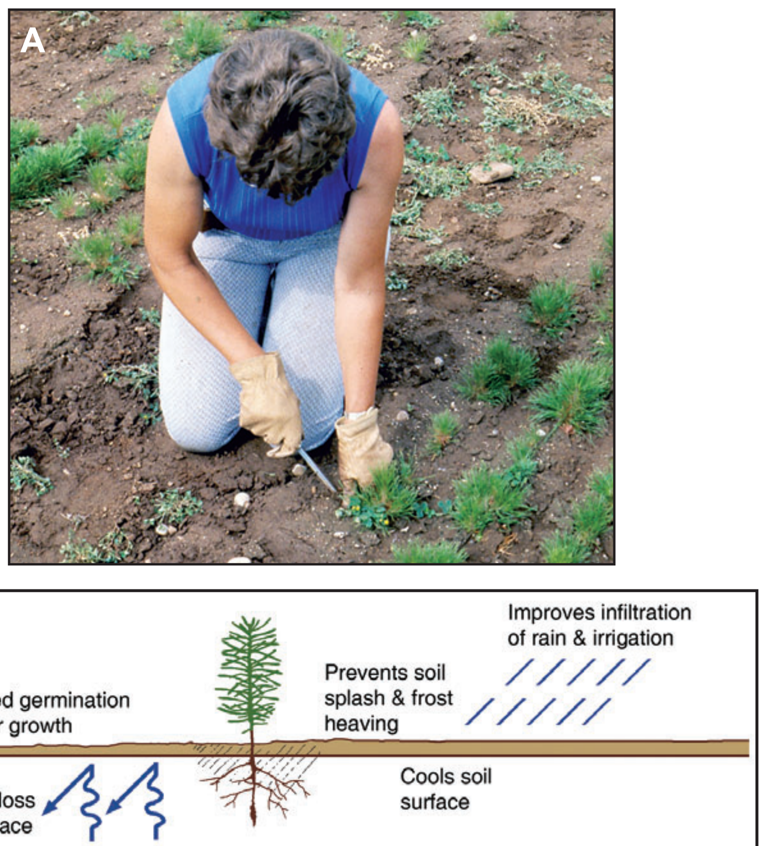


Figure 3.8—*Weeds should be controlled by hand (A) or with herbicides, and it’s much easier when they are small. Maintaining a good seedbed mulch has many benefits (B).*

Some native plants will grow much better if inoculated with beneficial microorganisms, such as mycorrhizal fungi (Figure 3.9A) or *Rhizobium* bacteria (Figure 3.9B). You can inoculate with soil or duff that you collect from beneath the same plant species in the field, or buy commercial inoculum. Many beneficial microorganisms are specific to one type of plant so do some research online before purchasing any product.

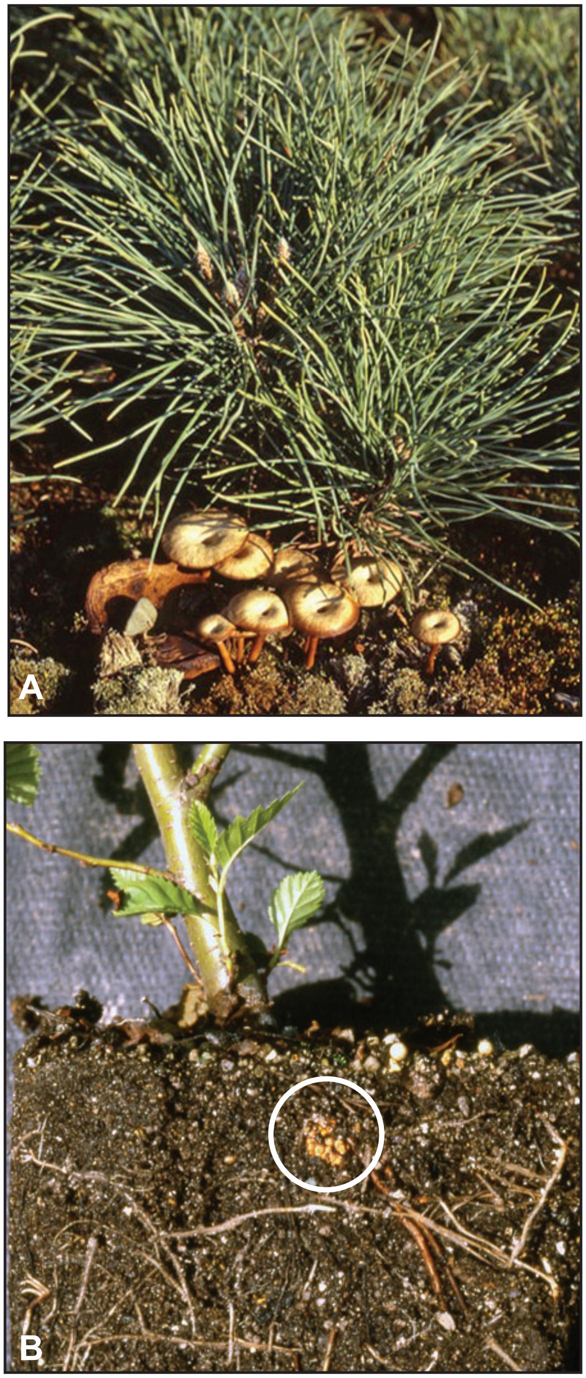


Figure 3.9*—Beneficial microorganisms such as mycorrhizal fungi (A) and* Rhizobium *bacteria (B) can improve the growth of some native plants.*

3.2.3.4 Watering—Once seeds germinate, the basic philosophy for watering seedlings is to water deeply but infrequently (Figure 3.10A). Be sure to wet the entire root zone during each watering. How long you need to water will depend on how much water is going through your irrigation system, your soil, outside temperature and wind, and whether or not you are using a mulch. Keep your nursery soil evenly moist—use a small hand trowel to see if the soil is dry or moist. Irrigate early in the day to allow seedling foliage to dry.

You have a variety of options for watering seedlings, from low-tech to high-tech. The easiest technique is using a watering can or a garden hose with a soft-spray nozzle. This option is fine if you have a small area. Larger areas will probably require a less labor-intensive watering system. An oscillating yard sprinkler hooked up to a garden hose works well, provided you check its output over the entire nursery bed, making sure all portions receive adequate amounts of water. For larger nursery areas, the next level of sophistication would be a fixed irrigation line with systematically spaced nozzles. Such a system will provide a more even irrigation, resulting in more uniform seedlings and probably less wasted water. Fixed-line systems can be placed in exact locations and put on timers to use water most efficiently.

Check the output from any sprinkler system by systematically placing small jars, plastic cups, or cans throughout your bed (Figure 3.10B). Run the sprinkler system for a known time, and then measure how much water is in each collection vessel. Once you know how long the sprinkler must run to achieve adequate watering, you can put the system on a timer. Some variability across the nursery bed is inevitable, but make sure the minimum amount of water delivered entirely wets the root zone. Unfortunately, sprinklers "waste" a lot of water due to evaporation from plants and runoff so water early in the morning before it gets too hot and windy.

Drip irrigation lines can be laid along rows of seedlings in small seedbeds (Figure 3.10C), or individual emitters or drip rings around large transplants. Drip systems are very efficient as little water is lost to evaporation (especially if covered with mulch), but you'll have to water for a longer period of time due to the slower water application rates.

3.2.3.5 Root Pruning—Root pruning promotes a fibrous root system and makes harvesting seedlings easier on you and the seedlings. Remember, you can only root prune efficiently if you sowed in rows—it's nearly impossible to root prune broadcast sown seedlings. If you're growing 2+0 seedlings, they need to be undercut at a depth of 5 to 6 inches during fall of the first growing season. The easiest way to do this is to use a sharp tile spade or shovel

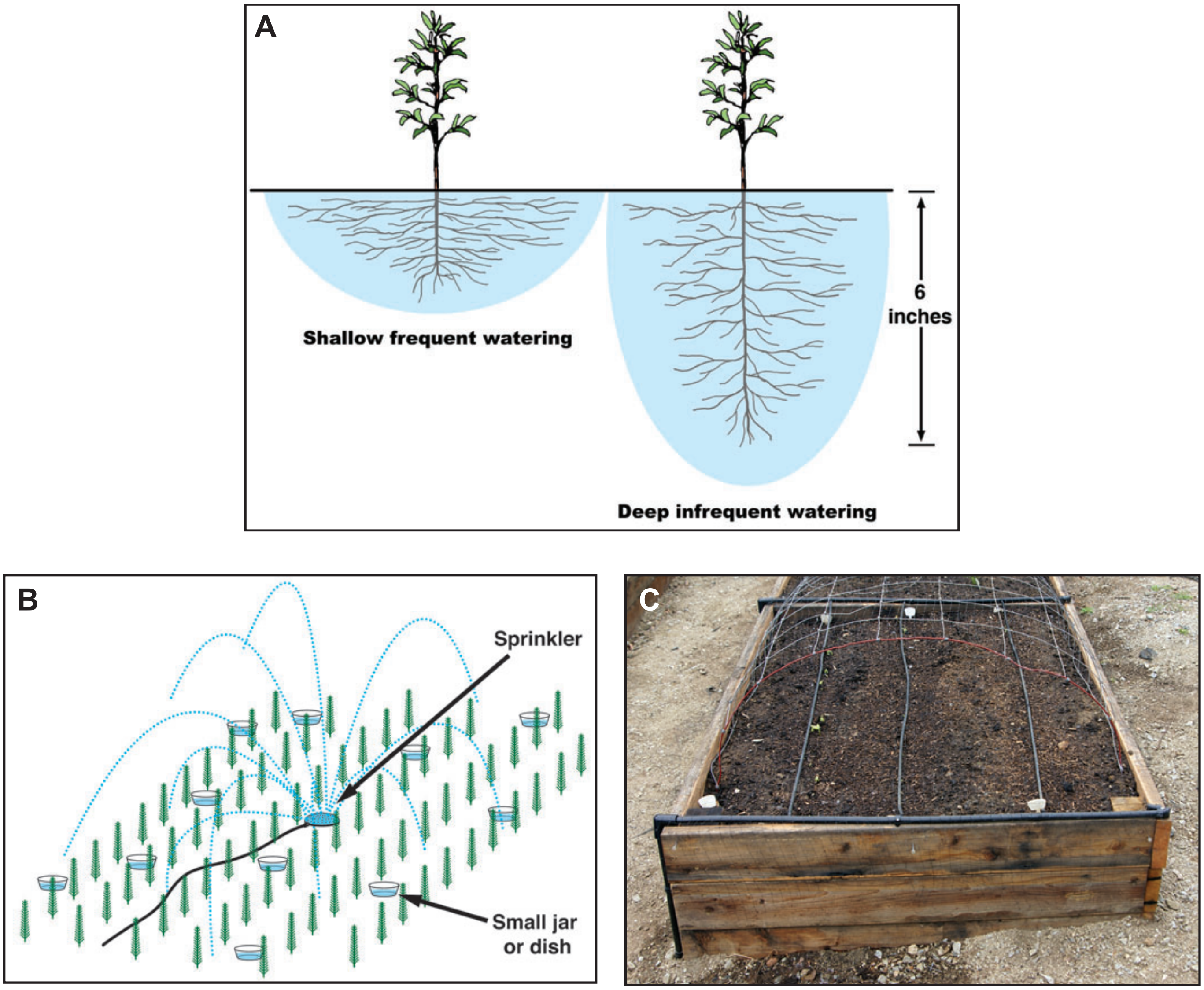


***Figure 3.10**—Water is the most important chemical for growing native plants. Deep, infrequent irrigations promotes a strong, well-developed root system (A). Check your soil to determine when irrigation is necessary and, if using a sprinkler system, check water distribution with a grid of small cans or jars (B). Drip irrigation lines are an efficient way to irrigate bareroot seedbeds (C).*

and slice in on an angle under the rows of seedlings (Figure 3.11A). You may have to make angle cuts from both directions to ensure seedlings are fully undercut. During the second growing season, you'll want to prune the lateral roots 2 or 3 times, first in late spring and the last time in late summer (Figure 3.11B). This cutting procedure keeps roots of seedlings in one row from intertwining with roots of seedlings in another row—a real nightmare to untangle when you dig seedlings for planting. Use your sharp tile spade or shovel and slice vertically halfway between rows, and an equal distance outside the outer row. Schedule root pruning so seedlings are watered and fertilized after the treatment. Transplants should be root-pruned with the same timing and frequency of 2+0s.

3.2.4 Lifting, Handling, and Storage

Nursery managers call the process of digging seedlings out of nursery beds "lifting" or "harvesting." Harvesting should be done when seedlings are dormant, either late fall, winter, or very early spring before new growth starts. Dormant seedlings handle stresses of lifting, storage, and planting better than non-dormant stock—the result being

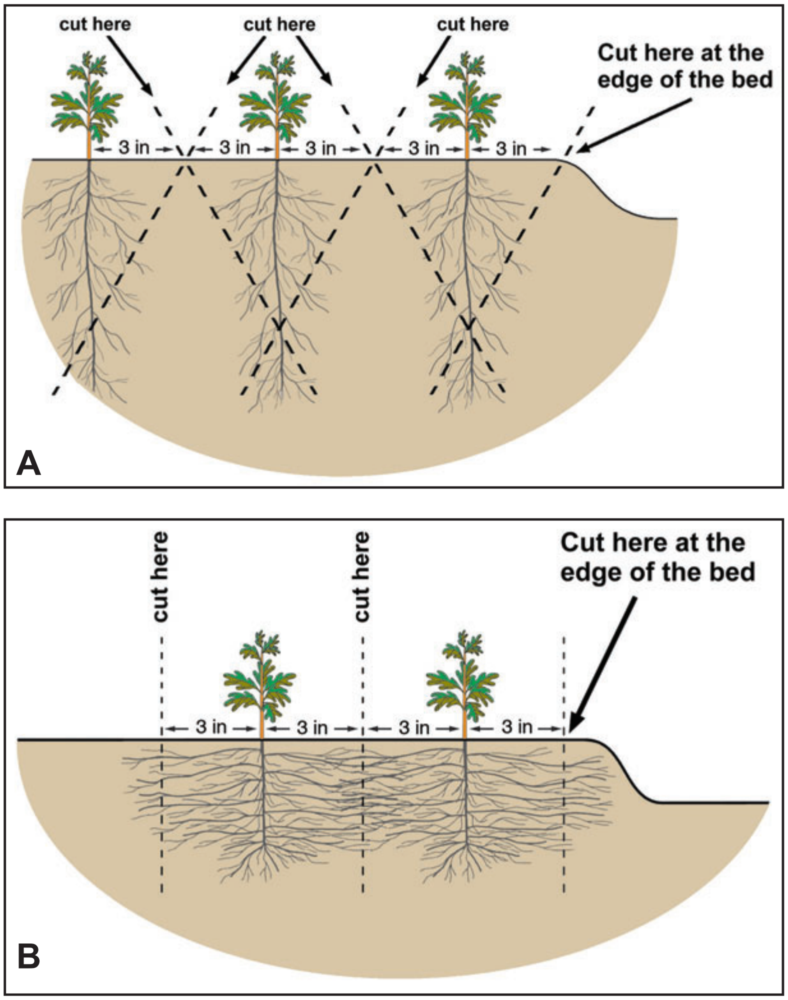


Figure 3.11*—Root pruning with a sharp spade or tile shovel during the first growing season helps develop a more fibrous root system (A). Vertical pruning of larger plants (B) creates moisture stress, which slows height growth.*

better outplanting survival and growth. Using a garden fork, seedlings should be gently dug from the ground, the soil gently removed from their roots while preserving the fine roots (Figure 3.12A), and seedlings gently put into boxes, plastic tubs, or buckets (Figure 3.12B). Gentle handling is the key. Always keep the root system moist by wrapping roots in wet burlap or covering them with moistened wood shavings or chips. Keep harvested seedlings out of the sun and wind. If you harvest in the fall for spring planting, wrap seedling roots to keep them moist, enclose seedlings in plastic bags to prevent desiccation, and keep them cool (32 to 36 °F). Check often for mold. Storage molds usually begin developing on dead foliage. Therefore, be diligent when you put seedlings into storage and remove as much dead foliage as possible. Storing seedlings in an upright position also seems to help reduce mold problems. Remove moldy seedlings as soon as they are evident.

3.2.5 Transplanting

Typically, plant density in a transplant bed is much less than in a seedbed, about 10 seedlings per square foot (spaced 6 inches by 6 inches apart). Because they are planted at wider spacing (Figure 3.13A), transplants grow faster and develop better stem diameter (Figure 3.13B) and roots. When transplanting seedlings, be sure to place the roots in a vertical plane without any twisting or kinking (Figure 3.13C). The roots of improperly transplanted seedlings become deformed, which seriously decreases plant quality. Although plants can be transplanted almost any time except when they are actively growing, transplanting during the fall or early spring is recommended. This reduces transplant shock because plants are more hardy and weather conditions more favorable. Transplants are cultured much the same way as seedlings but increased growth rates will require more irrigation and fertilizer.

3.2.6 Soil Management

Between crops, add amendments to maintain healthy soil and good tilth. Additions of organic matter improve tilth, reduce puddling, increase water infiltration, insulate soil, improve soil structure, promote better root growth, improve soil aeration, make working the soil easier, and help suppress root diseases. Adding organic matter is necessary because soil microorganisms are constantly decomposing it as a food source. Good green cover crops include canola, kale, ryegrass, and buckwheat. Avoid clovers or be prepared to do a lot of weeding of these overzealous seed producers. Clovers also tend to promote root disease. Cover crops should be cut and worked in while green. Other good organic amendments include compost (Figure 3.14), manure, straw, fine-screened bark, shredded leaves, and peat. Use 1 to 1.5 cubic yards of amendment per 100 square feet of nursery bed (a layer about 3 to 4 inches deep), and work it in to a depth of 6 to 8 inches. With amendments like fresh sawdust, straw, leaves, bark, and fresh manure, you should add extra N at a rate of 5 to 10 pounds per ton of amendment. Otherwise, soil microorganisms that decompose the amendments will use all available nitrogen in the soil, leaving little available for your seedlings. Soil amendments and cover cropping are just good farming practices, and a wealth of good information can be found online.

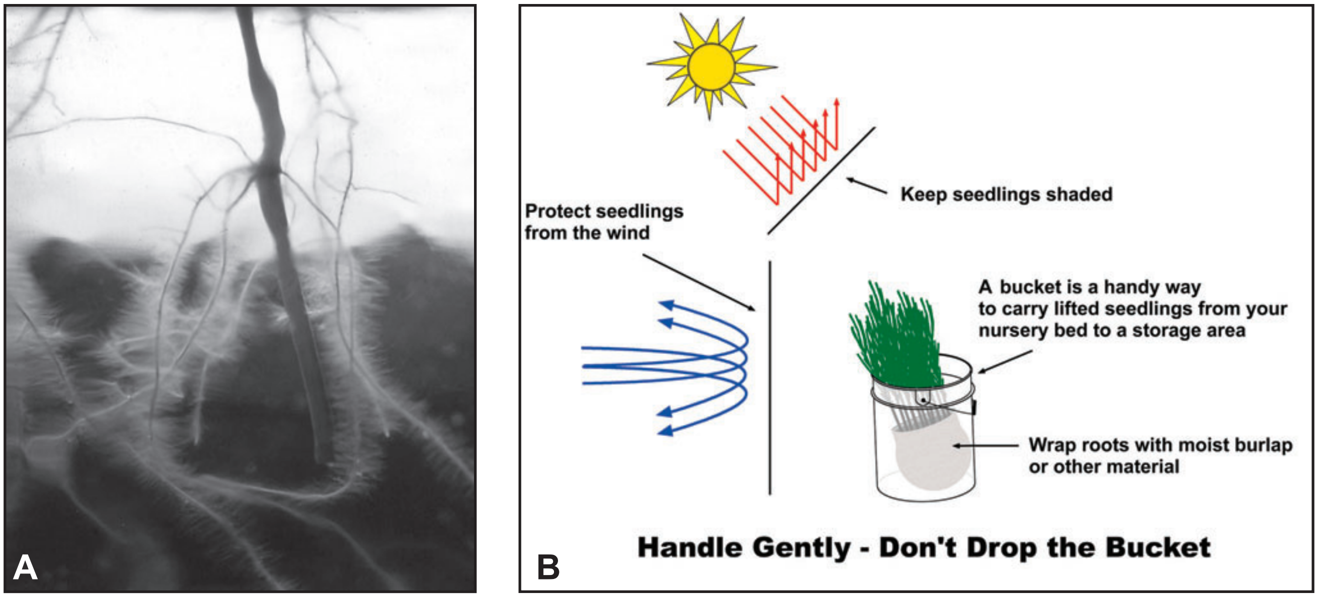


Figure 3.12—*Harvesting, or "lifting" nursery stock, must be done carefully to minimize injury to fine roots (A). After removing them from the seedbed, wrap roots in wet burlap and place bundles of plants in a bucket out of the sun and protected from wind (B).*

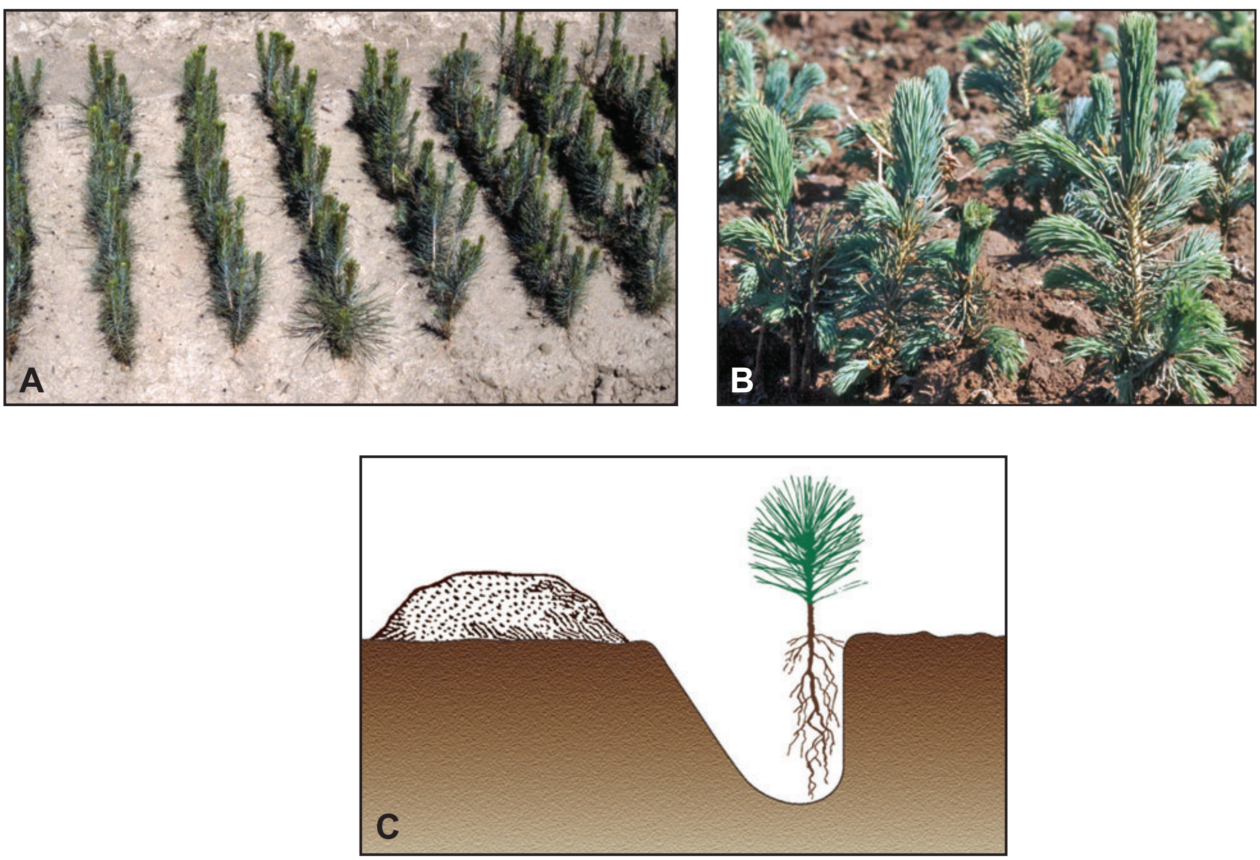


Figure 3.13—*Transplanting seedlings increases their growing space (A), which produces plants with larger stem diameter and more fibrous roots (B). When transplanting, it is critically important to orient the roots vertically (C) to prevent deformation.*

Figure 3.14—*Organic matter, like this mushroom compost, is the ideal amendment to improve the productivity of nursery soils.*

3.3 Growing Container Seedlings

Seedlings can be grown in containers in a variety of propagation environments where growth limiting factors, such as temperature, water, and fertilizer, are controlled. One big advantage of container plants is that you can grow them larger in less time than bareroot stock. However, because container plants have much less moisture reserves, you can kill them a lot faster too!

3.3.1 The Propagation Environment

The basic concept is to create an environment where as many of the environmental factors that control plant growth can be modified (see Section 1.1, Factors That Limit Growth). Professional growers constantly adjust temperature, moisture, fertilizer, humidity, and sometimes even sunlight to keep their crops growing in particular ways to produce seedlings of the highest quality. Environmental conditions and cultural procedures in your set-up will probably be less sophisticated than commercial nurseries, and that's okay. Growing native plants is always a balance between ideal conditions and what you can actually afford.

The simplest propagation environment is an open compound where container seedlings are grown outside in an area with plenty of sunlight but protected from the wind (Figure 3.15A). It's possible to grow a few seedlings in a sunny window or under grow lights (Figure 3.15B), but, as we'll discuss later, native plants need to acclimatized to the outside environment. Plastic-covered cold-frames (Figure 3.15C), hobby-sized greenhouses (Figure 3.15D), and similar structures work well. A good structure will allow air circulation on sunny days, block precipitation, and provide good light transmission. One problem with greenhouses is that they heat-up rapidly so adequate cooling requires an investment into controllers and constant monitoring.

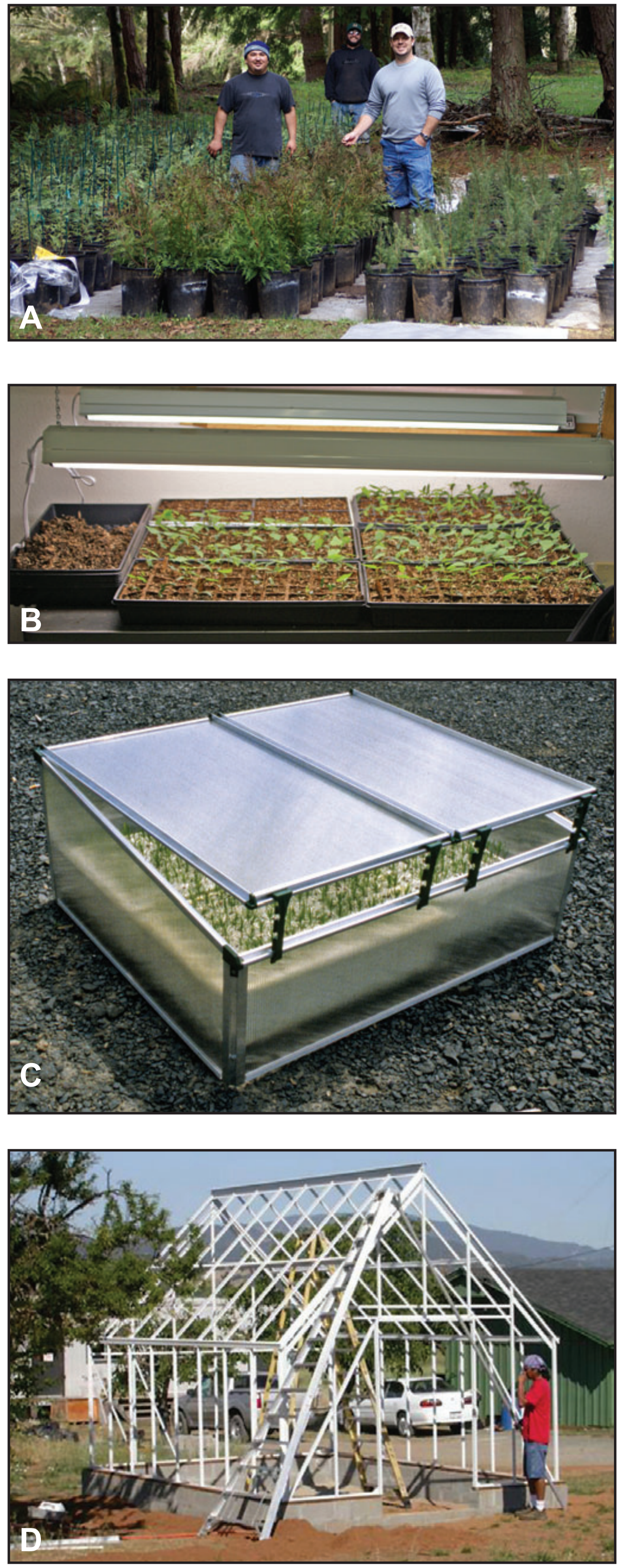


Figure 3.15—*Propagation environments can vary from open compound (A) to grow lights (B), to cold frames (C), or hobby greenhouses (D).*

3.3.1.1 Growing Media—Garden soils are generally too heavy and lack sufficient pore space to grow a good container seedling, which is why professional nursery managers use soilless potting mixes ("growing media"). Many popular growing media use Sphagnum peat moss as the major component because of its high water-holding capacity and ability to hold nutrients. Because peat moss holds a lot of water, however, it is often mixed with other components, such as perlite, pumice, or vermiculite to increase aeration within the container. Be careful of off-the-shelf mixes often sold in garden centers or chain stores; sometimes these mixes are just floor sweepings after companies package their "professional" grade mixes and contain too many "fine" particles that reduce aeration and hamper seedling growth.

3.3.1.2 Containers—Professional growers use a variety of specialized containers. Common, suitable containers have drainage holes in the bottom and vertical ribs on the sides to prevent root spiraling (Figure 3.16), which is a serious problem with most woody plants. Current nursery jargon for containers can be somewhat confusing. For the scope of this booklet, an individual container in which the seedling grows will be called a "container" and the aggregation of "containers" (what holds the containers together) will be called a "block."

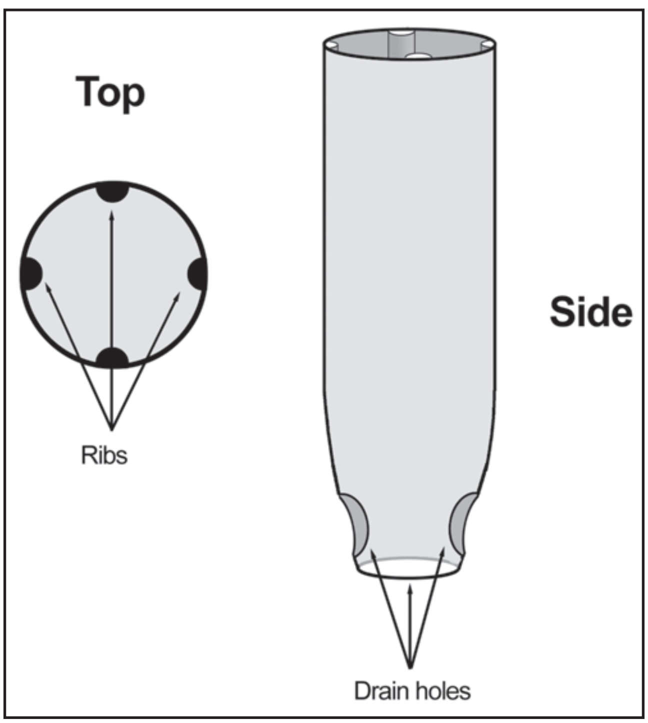


Figure 3.16—Good containers for growing native plants have ribs or slits in the sides to keep roots from spiraling, and drain holes in the bottom.

Hard-sided plastic containers come in a variety of sizes and shapes, and any of them will work well, provided they have adequate drainage holes at the bottom, and ribs or angular construction (not round in cross section) to keep roots from spiraling. This requirement rules out using nearly all containers used to grow annual flowers or vegetables and found at most garden centers, including pre-formed peat pots. Some of the newer containers have slits cut in the sides or copper coatings to prevent root spiraling. When seedling roots touch the copper, the growing tip is stunted, causing the root to branch. The result is a more fibrous root system and better root growth all along the sides of the root plug.

Two good container types for beginners are flexible plastic cells held in hard plastic racks such as the Ray Leach Cone-tainer™ (Figure 3.17A) or the Deepot™ (Figure 3.17B). Both containers come in several sizes. The main advantage of these single cell containers is that cells can be moved around and consolidated—empty containers can be removed and replaced with containers with seedlings, which saves space. This feature can be especially important when growing species with poor or slow germination, like many native woody plants. Blank containers provide breeding places for nuisance insects like fungus gnats, that when present in sufficient quantities, can damage seedlings. Also, seedlings will generally grow more uniformly if empty containers are removed. If you only plan to grow a few crops, these containers are a good choice.

Another good option for beginning growers is peat pellets, such as Jiffy pellets. Peat pellets are shipped and stored as hard, flat disks of peat moss covered by plastic mesh. When watered, the discs expand vertically (Figure 3.17C). These also come in a variety of sizes and have blocks to hold individual pellets (Figure 3.17D). Don't confuse them with peat pots, which are smooth-sided and will allow roots to circle. Like single cell containers, peat pellets can be consolidated. One advantage is that when you get ready to plant your seedlings, you plant the whole peat-pellet as well, without the bother of empty containers to clean before the next crop. Also, roots will grow out the sides of peat pellets, so when outplanted, the root system often takes on a more natural looking shape than seedlings grown in hard-sided containers that lack a copper coating. Another advantage is that the containers need not be cleaned between crops, and they are very economical if you plan on growing only a few crops. The downside of this feature, however, is that you may have to prune the roots between peat pellets every month or so to keep the seedling roots from intertwining, although the newer style blocks that hold the pellets are designed to reduce this problem, and they can dry out rapidly in arid conditions.

Figure 3.17*—It's best to use specialized containers for growing native plants such as the Ray Leach Cone-tainer™ (A), the Deepot™ (B), or Jiffy™ pellets that expand when irrigated (C & D).*

3.3.1.2.1 Filling Containers—When filling, it's important to put a uniform amount of growing medium in each container and tamp it down firmly—don't compact it. If containers are filled with varying amounts or density of growing medium, seedlings will also vary in size. Overcompacted growing medium restricts root growth, reduces shoot growth, and disrupts water drainage, all of which increase the susceptibility of your seedlings to root diseases.

Spread growing medium evenly over the tops of containers, and gently tap the block a time or two on the table or ground to allow settling. Gently dropping it from a height of 6 inches onto a concrete floor works well. Then, topdress growing medium over the containers and tap the block once again. Next, take a hand brush and sweep extra medium out of the containers until the surface is about ¼ inch below the top of the container (deeper for larger seeds). This space will be needed to sow your seeds and add some mulch.

If you are going to sow seeds in the same spot as you plan to grow the seedlings, go ahead and water your medium until water is dripping out the bottoms of the containers. If you need to carry containers from where you plan to sow them to where you plan to grow them, it will be easier to water after sowing.

3.3.2 Sowing and Germination

Depending on your local climate, your propagation environment, and the temperatures you can maintain around your seedlings, plan on sowing in early spring. If you can't control temperatures well, you may wish to hold off sowing until late spring to avoid problems with frost. Good air temperatures during the germination period range from 65 to 80 °F. If you have access to bottom heat, use it! Warm growing media will help promote faster germination and decrease the possibility of disease.

Prepare seeds as described in Section 2.8 (Seed Treatments). Three different techniques are used for sowing native plants based on seed size, shape, and ease of germination (Table 3.4).

3.3.2.1 Direct Sowing (20% of Species)—This method is best for seeds large enough to handle easily, and for species that germinate with few problems. Although it is less commonly used than the other techniques, direct sowing is the standard for most tree species. For less than a few thousand seedlings, it's easiest and quickest to sow by hand. Coating seeds with a little baby powder makes them easier to sow and easier to see on top of the medium. The number of seeds to put into each container will depend on the germination expected from the seeds. Use Table 3.2 for an approximate number of seeds to sow per container to end up with 90% or more of your containers with one seedling. Ideally, you'd like to minimize the number of empty containers, but, as you can see in the example in Table 3.3, you reach a point when adding another seed fails to result in appreciably more filled containers. You'll have to decide whether seed economy (saving seeds for next time) is more important than a few empty cells. Using more seeds than is necessary will also require you to do more thinning after germination. If you'd like to be more precise and don't mind a little math, the direct calculations for determining seeds per container to sow are relatively simple and are provided in Appendix 6.3.

Seeds of most species should be barely covered with a thin mulch of perlite or coarse grit, with mulch depth being no more than twice the thickness of the seeds (see Figure 3.7). Make sure the covering material doesn't have too many fine particles that can cause crusting. A good mulch keeps seeds from splashing out during watering, helps retard algae and moss growth, keeps the surface of the medium cool and moist but not wet, and keeps the zone around the young stems drier, thus reducing disease problems. Seeds that should not be covered include those that are very small (for example, sagebrush) or require light for germination (for example, birch).

3.3.2.2 Sowing Germinants (15% of Species)—This method is recommended for large seeds with deep, complex, or unknown dormancy requirements (Table 3.4). Sowing germinants is particularly useful for seeds of variable or unknown germination. It is a good technique for beginning growers because it ensures that a live seed is placed in every container and that the crops will grow uniformly. To sow germinants, soak your seeds and place them in stratification (if necessary) like you would for a germination test (see Section 2.10, Germination Testing). Very large seeds (for example, acorns) are mixed with a moist medium such as *Sphagnum* moss, whereas smaller seeds are scattered between layers of moist paper towels. Place the seeds in a plastic ziplock-type bag, label, and keep in the refrigerator. Check the seeds at least weekly and, as soon as the seed begins to germinate (Figure 3.18A), place that germinant on top of moistened growing medium in the container and gently cover with mulch (Figure 3.18B).

Table 3.2—Based on germination of your seedlot, sow the appropriate number of seeds so 90% or more of your containers will have at least one seedling.

Seed germination percentage	Seeds to sow per container	Percentage of containers with at least one seedling
90+	1 to 2	90 to 100
80 to 89	2	96 to 99
70 to 79	2	91 to 96
60 to 69	3	94 to 97
50 to 59	4	94 to 97
40 to 49	5	92 to 97

Table 3.3—A sowing example for a seedlot of common milkweed having 65% germination. Assuming 1,000 seedlings are desired, notice that adding more than 3 seeds per container really doesn't improve the number of containers with seedlings but does waste many seeds. Refer to Appendix 6.3.

Seeds sown per container	Empty containers	Containers with at least one seedling	Seeds sown	Seedlings produced	Additional seedlings produced per additional 1,000 seeds sown
1	35%	65%	1,000	650	—
2	12%	88%	2,000	880	230
3	4%	96%	3,000	960	80
4	1%	99%	4,000	990	30
5	0%	100%	5,000	1,000	0

Table 3.4—Characteristics of the main seed propagation methods for forest trees and other native plants.

Planting method	Best method for:	Advantages	Disadvantages
Direct seeding: Seeds are sown into growth containers with or without treatment	• Seeds of medium to large size • Uniformly shaped seeds with smooth seed coats • Seeds of high quality with viability test information	• Quick • Minimizes seed handling • Mechanical (automated) seeding possible • Less labor required • Planting occurs all at once	• Requires seeds of known high quality • Dormant seeds must be treated (or sown containers must be placed into conditions to meet dormancy requirements) • Requires thinning and/or consolidation for difficult-to-germinate seeds
Planting germinants: Seeds germinating (no leaves visible) in stratification trays or bags are planted into growth containers ("sowing sprouts")	• Very large or irregularly shaped seeds • Seeds of unknown quality or low purity • Valuable or scarce seed lots • Seeds requiring warm moist treatments or stratification	• Good growing space utilization • Efficient use of seeds • Can adjust for unknown seed quality	• Slower and more labor intensive than direct seeding • Sowing can take weeks or months to complete • Crop development will not be uniform because of staggered sowing • Sowing date depends on seed treatment requirements • Root deformation possible if poorly transplanted
Transplanting emergents: Seeds are sown into trays or pots filled with medium; a few days or weeks after germination and when leaves are present, seedlings are transplanted into growth containers ("pricking out")	• Small or fragile seeds • Seeds of unknown quality or low purity • Valuable or scarce seed lots	• Good growing space utilization • Efficient use of seeds • Can adjust for unknown seed quality • More uniform crop development	• Transplanting requires skill and is labor intensive • Difficult to control density in seed trays so disease potential can be high • Root deformation possible if poorly transplanted

3.3.2.3 Transplanting Emergents (65% of Species)—This technique, commonly called "pricking out," is better for small or fragile seeds that would be difficult to direct sow or sow as germinants (Table 3.4). The process begins with sowing seeds in shallow germination trays or small pots filled with a standard peat growing medium that is lightly tamped until it is firm, but not compacted (Figure 3.18C). Larger seeds are scattered over the surface of the medium by hand, or smaller seeds can be sown with a salt shaker with the holes in the top enlarged. The sown seeds are covered with a light application of fine-textured mulch (unless they are very tiny or need light for germination), irrigated, placed into a greenhouse, and misted lightly. Transplanting should be completed as soon after germination as possible, especially before the new root sends out lateral roots (Figure 3.18C, D, and E). Gently pull the germinant from the medium, make a dibble hole in the growing medium of an empty container, gently place the plant in the hole, firm the medium around the stem, and water thoroughly. This procedure sometimes produces a "J-root" or kink in the seedling stem; while not as important for grasses or many herbaceous plants, this may, for species that produce a strong taproot and/or woody species, reduce growth in the nursery and/or cause mechanical weakness or mortality after outplanting (Figure 3.18F). If the root has grown too long to easily transplant, you may reduce its length before transplanting, but don't remove more than half of the root. Transplanting germinated seeds or young seedlings requires some degree of skill but can be easily mastered with a little practice.

Figure 3.18*—Many native plants should be propagated by sowing germinating seeds (A & B), or transplanting young emerging seedlings (C & D). Herbaceous species with strong taproots (for example, arrowleaf balsamroot) and woody species (for example, longleaf pine) are best transplanted before lateral root development (E), and these transplants should have their roots oriented vertically without kinking to avoid root deformation (F).*

3.3.3 Irrigation and Fertilization

Once your plants are established in their containers, it's time to start watering and fertilizing on a regular basis.

3.3.3.1 Irrigation—You'll need to water 1 to 3 or more times per week, depending on the size of the container, media, seedling size, conditions in your propagation environment, and ambient weather. Always water early in the morning so that foliage will dry completely during the day, reducing disease problems and incidence of fertilizer burn.

An easy and repeatable way to determine when to water is by using an ordinary bathroom scale. Right before sowing, and about an hour after you've saturated the medium in your containers, weigh the block on a scale. Let's say it weighs 26 pounds. This is your "field capacity" block weight; it reflects how much water is held in your containers. When the weight drops to a certain percentage of field capacity weight, it's time to water your seedlings (Table 3.5). We call this target block weight and it changes somewhat with the age of your crop. When seedlings are small, it may take several days, or even a week, depending on weather to dry from saturated to target block weight. Once seedlings are larger, however, and depending on your climate, the change in block weight from field capacity to target can happen often, perhaps every other day or even daily! About once every 6 weeks or so, obtain a new field capacity weight to compensate for the weight of the seedlings. Note: This works well if you have plants in nearly all of the containers. If your block of seedlings has many blanks, those will lose water more slowly making this technique less useful.

The simplest way to water your seedlings is with a watering can (Figure 3.19A), or a hose-end nozzle (Figure 3.19B). Make sure you apply an even amount of water across all the containers, and that you apply enough water so that some drips out the bottom of the containers. Often containers around the edges of the crop will dry down more than those in the center and may require additional water. A hose with a fine spray nozzle, or even a lawn sprinkler, will also work well. If you plan on growing many seedlings, you may wish to construct a permanent irrigation system. For any type of sprinkler system, check the output to make sure all the seedlings receive about the same, and adequate, moisture.

An innovative way to irrigate container plants is known as subirrigation, which involves holding plants in a structure where they can be watered from below (Figure 3.19C). The water is absorbed into the growing media and moves upward by capillarity. Subirrigation is particularly useful when broadleaved plants get larger and it's almost impossible to water each container from above because the leaves shed the water. It also works very well for growing wetland native plants, such as sedges and rushes (Figure 3.19D).

3.3.3.2 Fertilization—Please refer to the fertilizer discussion in Section 3.2.3.1 (Fertilizers: Organic vs. Synthetic) because much of that is relevant to growing seedlings in containers. For container seedlings, the two options for keeping your plants well supplied with nutrients are:

1. Incorporating controlled-release fertilizers into the growing media prior to sowing, or top dressing.
2. Liquid feeding or "fertigating" throughout the growing season.

For beginners, the best plan may be to use a combination of both.

The three nutrients, nitrogen (N), phosphorus (P), and potassium (K), are the most important, in terms of amounts needed, for healthy shoot and root growth, and are commonly added via fertilizers (Figure 3.20A). N is critical for aboveground seedling growth, especially new shoots, needles, and buds. Plants lacking sufficient N grow slowly or are stunted and have pale green or yellow needles near their bases. P is important for root growth and bud development, and K is important for root growth, efficient water use by the plant, and improving disease resistance.

Because container seedlings do not have the benefit of basic soil fertility and are grown in an artificial media, fertilizer application is more critical than with bareroot seedlings. On the other hand, this also makes it much easier to apply too much fertilizer, resulting in tall, spindly seedlings. Many factors influence how much fertilizer should be applied, including the species being grown, container size, seedling age, weather, type of medium, and so on.

Table 3.5—An example weekly record of block weights assuming a field capacity block weight of 26 lbs., and that seedlings will be watered when target block weight reaches 85% of the field capacity weight (26 lbs. x 0.85 = 22 lbs.)

	July 22	July 23	July 24	July 25	July 26	July 27
Field capacity weight	26.0	26.0	26.0	26.0	26.0	26.0
Actual weight	22.0	25.0	23.5	20.8	24.5	21.5
Percentage difference	85%	96%	90%	80%	94%	83%
Need to water?	Yes	No	No	Yes	No	Yes

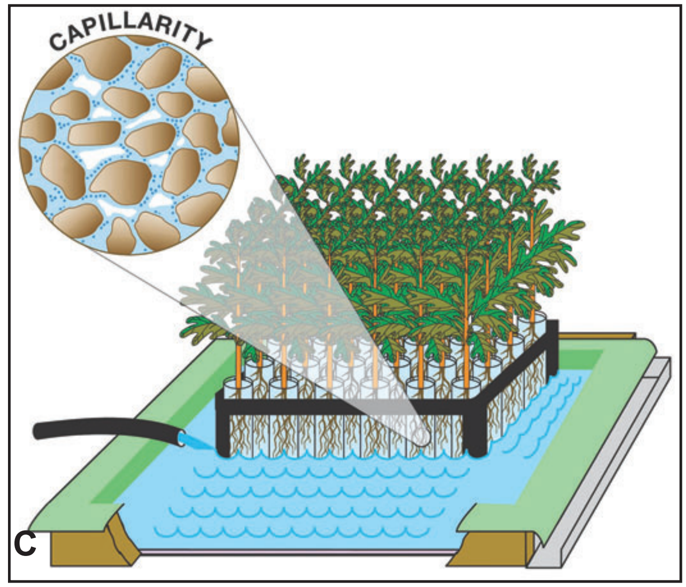


Figure 3.19*—Using a watering can (A) or hose-end nozzle (B) is the easiest way to water container seedlings. Watering from below ("subirrigation") is effective on larger broadleaved plants when it's ineffective to sprinkle irrigate (C); this method is very useful for growing wetland native plants (D).*

3.3.3.2.1 Controlled-Release Fertilizers—These fertilizers generally contain all the macro and micronutrients. The fertilizer is encapsulated by a thin, plastic shell that forms a round "prill." The composition and thickness of the shell, along with water availability and temperatures, control the rate of release of the fertilizer from the prill (Figure 3.20B). Typical release rates range from 3 to 18 months. The most effective way to apply controlled-release fertilizers is to incorporate the prills into the growing medium at label rates when you are filling the containers. Keep in mind that if you store that medium for a length of time before using it, conditions may be sufficient for the fertilizer to be released. Prills can also be "top-dressed" to individual containers during the growing season (Figure 3.20C). Although controlled release fertilizers are easy to use, they suffer the drawback of not being able to completely control when the nutrients become available. This can cause problems, particularly when you want to stop height growth and begin dormancy.

3.3.3.2.2 Fertigation—Soluble fertilizers are easily and uniformly applied with water. The type and amount of fertilizer is discussed in the next section. You can apply liquid fertilizers dissolved in water by hand with a watering can (Figure 3.19A). A more accurate way to apply liquid fertilizers is to use a siphon injector such as the Hozon™ (Figure 3.20D). The flow of water through the hose causes a suction that pulls the fertilizer stock solution up and mixes it with the water in the hose at a 1:16 ratio (Figure 3.20E).

You should check the injection ratio of your siphon occasionally. Put a known amount of water into a container (this is your "stock solution"), put the siphon hose in it, and then measure how much water comes through the hose (use a 5-gallon bucket or some other container of known volume to measure out flow) until the stock solution container is empty. For example, if you had 1 quart of stock solution, and collected 4 gallons (16 quarts) of water while waiting for the stock solution to be used up, your siphon has an injection ratio of 1:16. In Section 3.3.3.2.4 (Sample Fertigation Schedule) you'll see why this is important. Note: Laws require anti-siphon devices on any irrigation system connected to a domestic water source. Hozon™ injectors are designed to prevent contaminated water from siphoning back into your drinking water supply.

3.3.3.2.3 Seedling Growth Phases—It's really difficult to give a "recipe" for fertilizing container seedlings because different species require immensely different amounts of fertilizer, different seed sources for a species may have different requirements, and a species requires different amounts of fertilizer as it goes through the growing season. Therefore, use the following methods for a conifer seedling as a general guide. Be prepared to modify it as your seedlings develop.

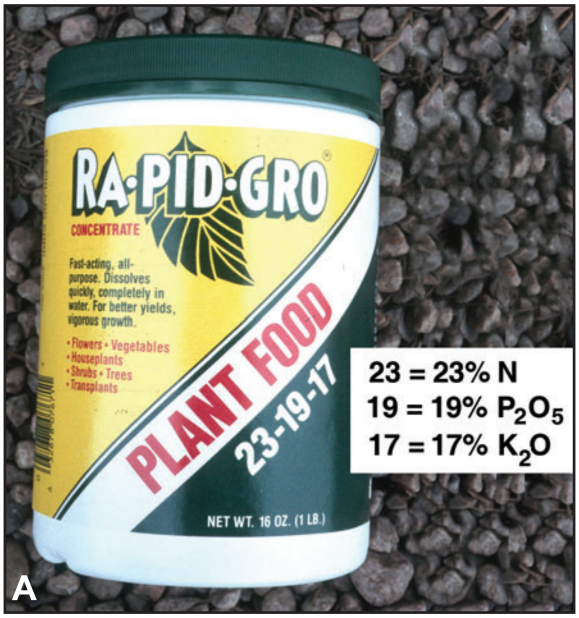
Use Table 3.6 as a guide to determine how much and how often to fertilize. All seedlings have three distinct growth phases: establishment, rapid growth, and hardening. During each phase, you manipulate fertilizer and water to control seedling growth. During the establishment phase, seedlings should be well watered (80 to 85% block weights) and receive daytime temperatures between 65 to 80 °F and nighttime temperatures above 60 °F. This phase lasts about a month and helps get seedling root systems started. During the rapid growth phase, seedlings receive their highest doses of N to encourage height growth. Target block weights are still 80 to 85% and temperatures are similar to the initial growth phase. Depending on species, the rapid growth phase may last from 3 to 15 weeks. When seedlings are about as tall as desired, the rapid growth phase ends and hardening begins.

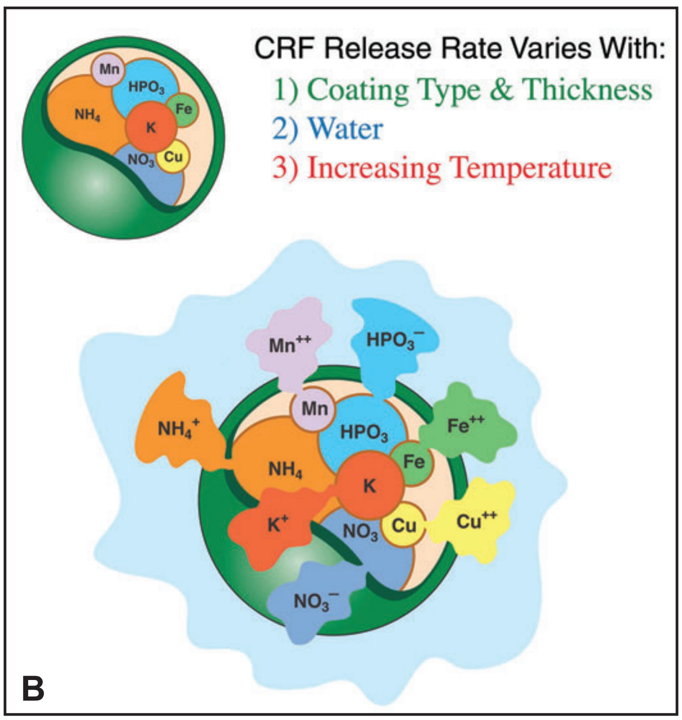
Hardening is the most important part of growing container seedlings. During the first stage of hardening, levels of N in the applied fertilizer solution are greatly reduced and target block weights are gradually lowered to 60 to 70%. This stage encourages seedlings to decrease shoot growth and for some species, stop shoot growth and form terminal buds. The appearance of brown buds at the tip of the shoot usually takes a few weeks to a month or so. Sometimes pines, which usually form terminal buds, will form a rosette of dense needles at the tip of the shoot. This is okay. Some native plants don't form buds, so your objective is to slow shoot growth and keep seedlings stocky.

After a month or so, the objective is to increase seedling stress resistance, especially to cold temperatures. Levels of N can be slowly increased, but target block weights are usually still low (60 to 70%). Increasing N in the applied fertilizer helps the seedling increase in stem diameter, form a big bud, and continue to develop roots. Temperatures are allowed to go to ambient, especially at night, and along with the low target block weights help condition the seedling for life on the planting site.

So, the general guideline for fertilizing and watering low, medium, or fast growing seedlings can be approximated by using Table 3.7. A more advanced guideline can be found in Appendix 6.4.

3.3.3.2.4 Sample Fertigation Schedule—Let's assume you're growing ponderosa pine seedlings. Table 3.7 shows ponderosa pine is a "medium" grower. Let's also assume the crop is in the accelerated growth phase; Table 3.7 indicates seedlings with a "medium" growth rate should get 130 ppm N. Using Miracle-Gro, Table 3.8 shows that we need 1 teaspoon of fertilizer per gallon of water to get 130 ppm N. Now let's assume a few thousand seedlings are watered with a hose. Use a siphon injector (1:16) to apply 32 gallons of fertilizer solution containing 130 ppm N. That means you'll need 2 gallons of concentrated fertilizer stock solution to run through the siphon (32 gallons/16 [the injection ratio] = 2 gallons stock solution). To make the concentrated fertilizer solution, mix 32 teaspoons (1 teaspoon for every gallon) of fertilizer into 2 gallons of water.





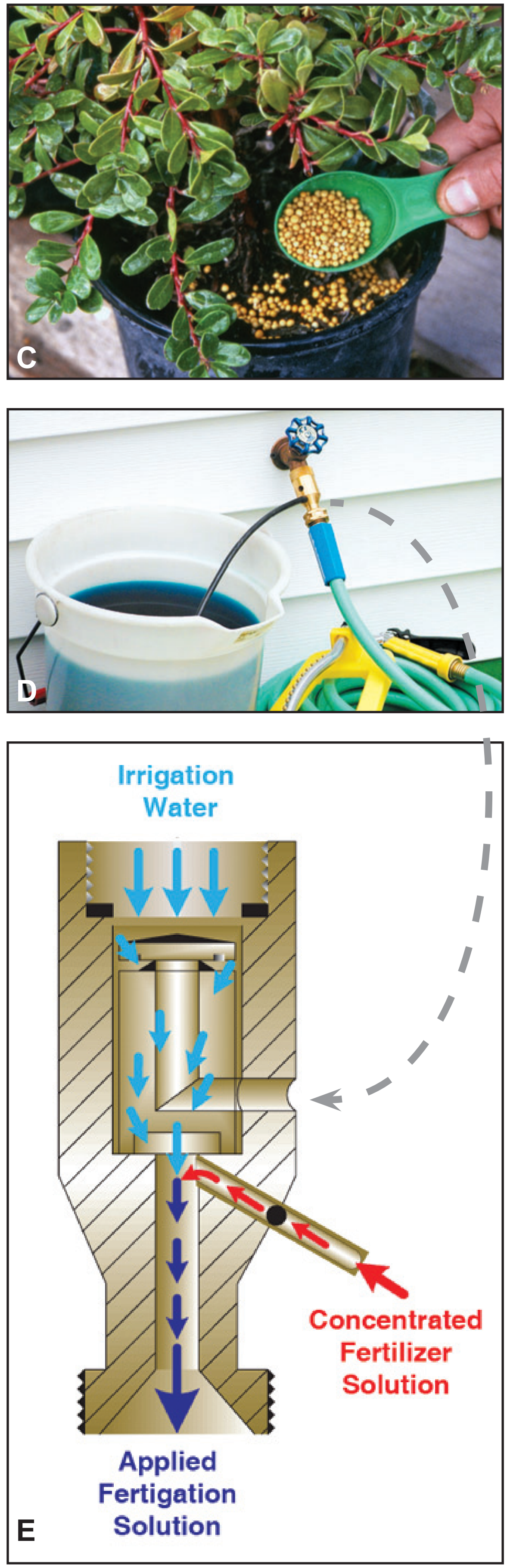


Figure 3.20—*All fertilizers are required by law to show their composition of nitrogen (N), phosphorus (P), and potassium (K). Controlled-release fertilizer particles ("prills") consist of soluble fertilizers inside thin plastic shells; after water penetrates the prills, soluble nutrient ions move outward into the growing medium (B). Controlled-release prills can be top-dressed on larger container plants (C). The Hozon™ (D & E) is a simple fertilizer injector that attaches to a garden hose and sucks concentrated fertilizer solution and mixes it with water at an approximate ratio of 1 part fertilizer to 16 parts water (D & E courtesy of Hummert™ International).*

Table 3.6—An approximate amount of N in parts per million (ppm) to apply to seedlings for each growth phase and an approximate target block weight. See Table 3.8 for converting ppm.

	Plant Growth Phases			
			Hardening	
Fertilizer levels (Table 3.7)	**Establishment**	**Rapid growth**	**Bud formation period**	**Remainder ofhardening period**
	ppm Nitrogen			
Low	33	65	0	33
Medium	65	130	0	65
High	65	200	33	65
Target block weights	80%	80%	60 to 70%	75%

Table 3.7—Fertilizer application guidelines for some native plants.

Low	Medium	High
Grasses and sedges	Cow parsnip	Huckleberry
Lupine [1]	Monarda	Whitebark pine
Salvia	Chokecherry	Pinyon pine
Buffaloberry [1]	Cottonwood	Interior Douglas-fir [2]
Ceanothus [1]	Elderberry	
Hawthorn	Red-oiser dogwood	
Sagebrush	Serviceberry	
Coastal Douglas-fir [2]	Jack pine	
Quaking aspen	Ponderosa pine	

[1] = Nitrogen-fixing species inoculated with appropriate beneficial microorganism
[2] = Ecotype differences

Table 3.8—Teaspoons of Miracid® or Miracle-Gro® to add per gallon to achieve desire parts per million (ppm) of nitrogen (N) for container seedlings. If you use any other type of fertilizer, you'll need to calculate ppm using directions found in Appendix 6.4.

	ppm Nitrogen	
Teaspoons per gallon of water	**Miracid 30:10:10 (N:P:K)**	**Miracle-Gro 15:30:15 (N:P:K)**
¼	65	33
½	130	65
¾	195	98
1	260	130
1½	195	
2	260	

Having said all of this, remember that the amount of fertilizer you'll have to apply will depend on the type of container, growing medium, and other environmental factors. If seedlings seem to be growing too fast (they're too spindly or flop over when not supported), then reduce the rate of fertilizer (less N), or reduce how often you fertilize (every other watering or less). Conversely, if they're growing too slowly, you may increase the rate of fertilizer (more N) to encourage growth. It's extremely important to keep detailed records of what you do to your crop and how the seedlings grow. Measuring seedling height every 2 to 3 weeks and matching that to the amount of fertilizer applied will help you adjust your fertilizer schedule to grow even better seedlings.

3.3.4 Light

As mentioned earlier, most species require full intensity sunlight for proper growth and development. That means they can't be grown on a windowsill and it's not economical to raise them with only grow lights. Many species are, however, very sensitive to slight changes in daylength. A species like interior Douglas-fir grown under normal daylight conditions will form buds before they are as tall as desired. It's fairly easy to "fool" seedlings, however, into "thinking" the day is longer by providing some periods of light to break up the night. A single 300-watt bulb suspended 4 to 5 feet above the crop for every 60 to 80 square feet of containers is sufficient light. The easiest way to "fool" your seedlings is to put the light on a timer set to come on before sundown and to extend the length of day to 18 or 20 hours. Once your seedlings are as tall as you'd like them, turn off the light. The abrupt change in daylength, along with changes in target block weight and fertilization rate, will encourage your crop to cease shoot growth and form buds.

3.3.5 Hardening

Once your plants have reached the desired height, it's time to harden your crop. Hardening means slowing their growth rate and getting them ready for the cooler temperatures of fall and winter. The first step in hardening is to reduce irrigation to stress the plants slightly. If you have your plants in a greenhouse or cold frame, the next step to induce hardiness is to expose your plants to full sunlight (the exception being shade-loving plants), wind, and ambient temperatures. Induce a mild nutrient stress by first leaching the growing medium with water, and then reducing the amount of fertilizer you are applying, especially nitrogen. You should be able to see some color changes in the foliage and the leaves or needles should feel tougher to the touch. The leaves of deciduous plants will become yellow and eventually drop. These changes are desirable and mean that your crop is ready for outplanting or overwintering.

3.3.6 Pest Management

Disease can occur rapidly in a crop of container seedlings because the nursery environment is also conducive to diseases. Sanitation is key to minimizing disease problems. Always remove diseased material immediately and either burn it, bury it, or send it away in the trash.

The first disease you may encounter is damping-off (see text box on page 32). It affects germinating seeds and very young seedlings. Damped-off seedlings tip over at the ground line and shrivel up. You can help prevent it by watering sparingly when seedlings are small, and by quick removal of dead and dying seedlings. The second important disease is root rot, and it usually becomes a problem when seedlings are larger. Seedlings turn brown, often from the top of the stem. Generally, once you see symptoms, it's too late to do much about it. Root rot can be prevented by using clean containers, proper watering, and keeping seedlings and their roots from getting too hot. Use a 1 inch by 6 inch piece of wood laid on end to shade the edges of blocks exposed to direct sunlight.

At the end of the growing season Botrytis disease is often a problem. The fungus *Botrytis* forms a gray web-like growth on needles, eventually infecting seedling stems and causing death. Botrytis generally becomes a problem when foliage from one seedling touches foliage from another seedling. The fungus gets its start on dead foliage and disease is favored by cool temperatures and high humidity. Botrytis disease can be controlled by proper watering, removing dead and dying seedlings as you see them, and brushing foliage after watering. A piece of PVC pipe works well as a brush, but be gentle so shoots aren't damaged. During hardening, you can also spread seedlings out to encourage air movement between them, thus reducing disease. If you're using Ray Leach cells or peat pellets, you can rearrange them to have an empty row between rows of seedlings.

One last problem with container seedlings is fungus gnats. These small, dark flies are more nuisance than problem, although in large enough quantities their larvae will feed on seedling root systems and can kill seedlings. They're usually more troublesome when seedlings are watered too often, and their populations soar if you have a lot of moss and algae, especially in blank cells. Fungus gnats are best controlled through proper irrigation. Yellow sticky cards, which are available through garden catalogs, trap the insects and make you aware of a potential problem. Place the cards at or near the surface of the containers and when the flies land on it, they become entangled. The cards work best when laid flat.

3.3.7 Beneficial Microorganisms

Because container plants are growing in an artificial growing medium, some native plants will benefit from inoculation with mycorrhizal fungi or nitrogen-fixing bacteria (see Section 3.2.3.3, Young Seedlings: Establishing Your Crop). Inoculation should not be seen as a "magic bullet" but as a way to make good plants better. Because large amounts of fertilizer generally inhibit mycorrhizal formation, it's usually best to wait to inoculate until the hardening period. Inoculation with beneficial microorganisms is a complicated subject and the benefits vary from species to species, so do some research online or check with a native plant nursery for advice.

3.3.8 Harvesting, Handling, and Storage

The outplanting season, or "window," will determine when seedlings are harvested ("lifted"), handled, and stored. Properly hardened seedlings can be planted whenever adequate site conditions exist (good soil moisture and warm soil temperatures). In the southeastern U.S., seedlings can be outplanted from late fall through early spring. At more northerly latitudes or at higher elevations in the western U.S., seedlings can be planted during fall if good soil moisture and warm soil temperatures are present (see Section 5.2, Outplanting Windows). If the end of seedling production coincides with a good outplanting window (for example, seedlings are hardened in fall and the outplanting site has good soil moisture), then seedlings can be pulled directly from containers and immediately outplanted without storage.

If, however, properly hardened seedlings must be held during the winter until the outplanting site is ready, then seedlings will need to be stored. Plants growing in an enclosed structure can be kept in their containers until about mid-November through mid-December. Keep the plants as cold as possible, but try not to let the root plugs freeze by placing the containers close together on the ground, and insulating around the roots with sawdust or Styrofoam™ panels. A few gentle freezes of 28 °F or higher are probably okay, especially if you've exposed seedlings to cold temperatures before freezing. However, seedlings suddenly exposed to a drastic drop in temperature can be damaged or even killed. Then, if you have access to refrigeration, seedlings should be removed from their containers in mid-December to mid-January, enclosed in plastic bags, and kept at 28 to 34 °F until you are ready to plant them. Seedlings can be stored in this manner for up to 6 months. Thaw frozen seedlings slowly, at low temperatures, and out of direct sunlight before planting. If you don't have access to refrigerated storage, keep your plants in a cool, shady, protected location, such as a shade-frame or lath house. In open storage, plants may need to be irrigated during warm or windy periods in the late winter and early spring.

Regardless of storage method, check seedlings often for molds. Storage molds usually begin growing on dead foliage. Therefore, when you put seedlings into storage, remove any dead foliage. Storing seedlings in an upright position also helps reduce mold problems. Remove moldy seedlings immediately.

3.3.9 Holding Seedlings Over

If your seedlings have sufficient roots to be pulled from the containers but are too small to plant, you have two options: transplanting into larger containers or growing them as bareroot transplants. Seedlings at this stage cannot be held over in the same container for a second growing season because they become rootbound. Unless transplanted, seedlings will have too many roots for the container and won't grow well after outplanting. Seedlings can be transplanted into larger containers anytime from fall to spring.

3.3.10 Cleaning Containers Between Crops

In between crops, containers should be thoroughly cleaned of old growing medium, algae, and other debris. Fungal spores can still remain after vigorous cleaning, however, waiting to infect your next crop. Dipping containers in very hot water (160 to 180 °F degrees) for 15 seconds to 2 minutes (depending on the temperature and type of container) will kill nearly all the fungal spores. Soaking containers in a 10% bleach solution and then rinsing with fresh water is also effective.

3.4. Additional Reading.

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