CHAPTER THREE

# Growing Seedlings

There are two ways to grow your seedlings—in the ground or in containers. Naturally, there are advantages and disadvantages to both. 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 home gardener, it probably boils down to personal preference, space availability, whether or not you have a greenhouse, and conditions of the soil you have to work with.

## 3.1 Growing Bareroot Seedlings

### 3.1.1 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. "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. 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. Avoid heavy soils that become sticky in wet weather or hard, caked, and cracked when dry (Figure 3.1). A good nursery soil for bareroot seedling production has at least 40% sand particles, and no more than 40% silt particles or 25% clay particles (see Figure 3.2 and box for determining your soil texture). Avoid soils with a claypan, hardpan, numerous rocks, or bedrock within 3 to 4 feet of the surface. The soil should have a pH between 5.0 and 6.0. We'll discuss what to do with marginal soils on otherwise good sites below.

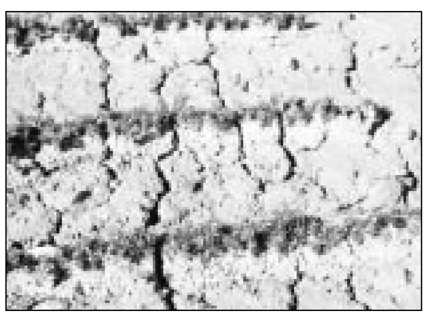

**FIGURE 3.1**
*Heavy clay soils crack and become hard as they dry.*

Try and 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. Basically, you need a good sandy soil because: 1) seedlings must be harvested during winter dormancy, and 2) removing seedlings from sandy soils doesn't damage fine roots.

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

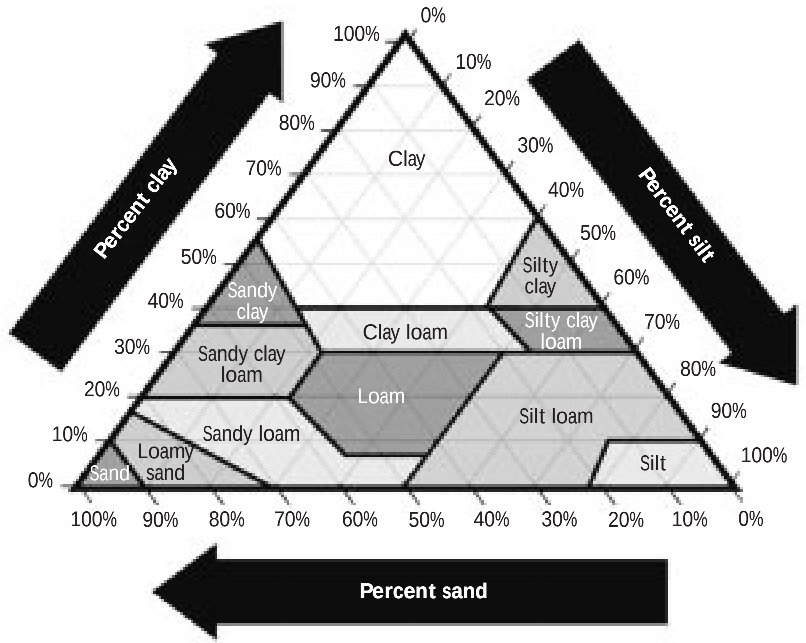


**FIGURE 3.2**

*After using the technique described in the box below, use this soil texture triangle to find the intersection of the amounts of sand, silt, and clay in your soil—your soil texture.*

## *Soil Texture*

*Judge the relative amounts of sand, loam, and clay in your soil through a simple test. Pour 5 inches of dry soil into a 1-quart canning or mayonnaise jar. Fill the jar with water and fasten the top securely. Shake it thoroughly, then let it settle for 24 hours. The soil types will settle out into layers, with sand on the bottom, silt in the middle, and clay on the top. Measure the layers for a rough percentage of soil types in your soil. For example, if you have 5 inches of soil in the jar, with 1 inch of clay and 2 inches each of silt and sand, then the soil contains 20% clay and 40% each silt and sand—a loam soil.*

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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 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. Similarly, grand and concolor fir nursery stock shouldn't be grown near bracken fern, an alternate host of a serious needle rust on fir species.

### 3.1.2 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 ÷ 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 Resource 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).

Correct drainage problems by ditching, leveling, burying tile, and/or raising the beds at least 18 inches above the extreme high water table. If you have to level, remove the good topsoil and stockpile it. Level the subsoil and then replace the topsoil. All of your soil productivity is in the topsoil!

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 organics. We recommend organic material, including peat moss, garden compost, ground and composted leaves, and well-composted manure which improves water retention, tilth, and fertility. Adding organic amendments and/or coarse sand to heavy clay loams will improve drainage, texture, 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 3.1.6, Soil Management).

Test your soil for pH, soil acidity, with kits available at garden centers or through gardening catalogs. Soils with pH under 7.0 are considered "acid" while those over 7.0 are considered "basic." A good nursery soil for conifer seedlings should have a pH between 5.0 and 6.0. If your soil pH is too high (over 6.0), add sulfur to bring it down. Conversely, if the soil is too acidic (under 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 Natural Resource Conservation Service (NRCS) representative for nearby laboratories.

### 3.1.3 How to Grow Seedlings

Generally, it takes 2 years to grow seedlings large enough for planting. Some slow-growing species, like spruce, subalpine fir, or bristlecone pine, may take 3 or 4 years. Most 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+0's into another bed for an additional year. These would be called 2+1's. For most species, let's assume you'll be growing 2+0 seedlings.

#### *3.1.3.1 Fertilizers—"Organic" vs. Man-made*

Plants require mineral nutrients to sustain healthy growth. Usually nitrogen (N), phosphorus (P), and potassium (K) are the most important nutrients for healthy plant growth and are commonly supplied through fertilizers. N is critical for aboveground plant growth, especially in new shoots, needles, and buds. Plants lacking sufficient N grow slowly or are stunted and have pale green or yellow needles. In conifer seedlings, P is important for root growth and bud development. Potassium is necessary for root growth, efficient water use by the plant, and improves disease resistance.

Nutrients can be supplied to your trees through either "organic" fertilizers (manure, compost, kelp) or man-made fertilizers available at garden centers or from farm chemical suppliers. To a tree 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. Organic fertilizers have low percentages of N, P, and K; N ranges from 0.5 to 1.5% in manure and 2 to 4% in composts. Man-made 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, the real benefit of using organic fertilizers is the organic matter and microorganism additions. Although man-made fertilizers don't supplement organic matter, it should be added by nursery managers.

Fertilizer can be applied to seedlings two ways: incorporated into the soil or top dressed over the crop. 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? Overfertilization 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 3 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 over 6.0 (Appendix 6.2.2), or if you want to use a strict organic fertilization program (Appendix 6.2.3).

#### *3.1.3.2 Sowing and Germination*

After incorporating fertilizer and/or adjusting soil pH, make sure your nursery bed is smooth and level.

**FIGURE 3.3**

*Broadcast sowing seeds is a quick way to plant seeds. Unfortunately, because seeds, and subsequently seedlings, aren't evenly distributed, it's much more difficult to weed, root prune, and harvest seedlings.*

Professionals usually make beds that are 4 feet wide and raised 3 to 6 inches. Raising the beds promotes drainage and soil-warming. Soil should be moist but not wet because saturated soil promotes root diseases and damping-off.

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 3.3), spread three-fourths of the seeds evenly over the nursery bed. Mixing a little baby powder (talc) on the seeds 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.

Sowing seedlings in rows 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 usually 6 inches apart for 2+0 seedlings and transplants. Probably the easiest way to sow in rows is by using a marking board (Figure 3.4). 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). This density is about right for most Pacific Northwest conifer species. 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. You may also use a walk-behind precision garden seeder.

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 (junipers, yew, and some pines). Fall-sown seeds must be protected from predators, especially mice (see below), and from drastic variations in temperature. To moderate weather, seed beds will need to be mulched. A 2-inch-thick layer of straw works well, but must be removed in spring to allow germination.

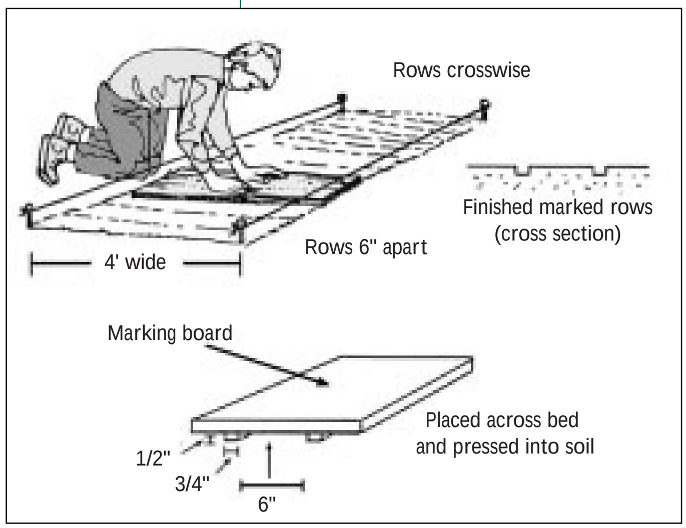


**FIGURE 3.4**

*A marking board can help you plan seeds in straight rows with proper spacing.*

*Source:* Raising Forest Tree Seedlings at Home, *Pacific Northwest Cooperative Extension Publication PNW 96, 1981. 11 p.*

Regardless of when or how seeds were sown, they should be "barely" 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 2X the thickness of the seed, and will keep seeds from drying out. Sowing seeds too deep is a common and serious mistake (Figure 3.5).

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, it 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.

**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* |
|---|---|---|---|
| 80-100 | 32-25 | 35-27 | 1 — 1 1/4 |
| 60-80 | 42-32 | 46-35 | 3/4 — 1 |
| 40-60 | 62-42 | 68-46 | 1/2 — 3/4 |
| 20-40 | 125-62 | 138-68 | 1/4 — 1/2 |

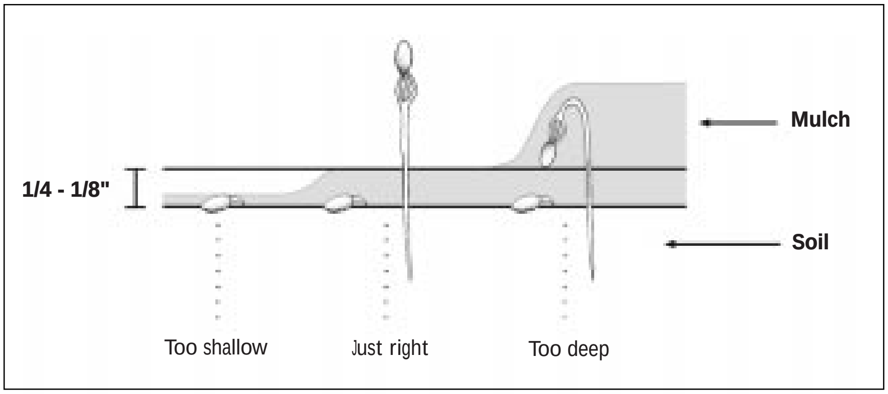


**FIGURE 3.5**

*Make sure you sow at the right depth! If the mulch layer is too shallow, seeds may dry out, and if mulch is too deep, seedlings may not be able to emerge above it.*

Water sparingly at first, but don't let the soil dry out. 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.

### *3.1.3.3 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

**FIGURE 3.6**

*Weeds are your number one enemy. Pull weeds while they are small so you reduce disturbance to seedlings.*

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 herbicides before they grow large and interfere with growth of your seedlings (Figure 3.6). 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 (1/4- to 1/2-inch-thick). Mulch reduces watering needs, keeps soil cool, prevents soil from splashing onto your seedlings, and helps retard weed growth (Figures 3.7 & 3.8). Seedlings should be watered to keep soil evenly moist. On very warm days, you may need to water to cool the ground. If the soil surface temperature exceeds 90°F, it may damage small seedlings. In mid-July to early August, allow the soil surface to dry down between watering. This practice will help condition your seedlings for winter.

You may wish to inoculate with mycorrhizal fungi (Figure 3.9), beneficial microorganisms found on roots of forest trees. In spring, spreading some forest duff (decomposing needles, twigs, etc.), collected from where you plan to plant, will act as mulch and inoculate your seedlings at the same time. There's potential danger here; you may also introduce diseases to your nursery crop. Larch needle cast (*Meria laricis*) is a common disease on western larch and can be transported to your nursery on recently fallen needles collected from the forest floor. Collect only the dark, mostly decomposed (can't recognize plant parts anymore), rich-smelling portion of the forest floor (humus layer). This will ensure mycorrhizae while greatly reducing the possibility of other diseases. If your nursery is near the forest, you'll probably get enough natural inoculation by mycorrhizae anyway. And if you don't, don't worry. Seedlings become infected soon after outplanting on a forest site.

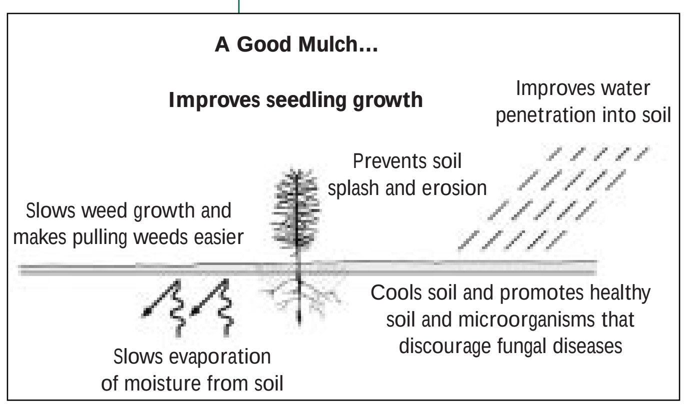


**FIGURE 3.7**

*Use mulch to grow a healthier crop with less water and less weeding.*

### *3.1.3.4 Watering*

Once seeds germinate, the basic philosophy for watering seedlings is to water deeply and infrequently (Figure 3.10). You'll want to wet the entire seedling root zone. How long you need to water will depend on how much water is going through your irrigation system, how much sand, silt, and clay are in your soil, and whether or not you've mulched. 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 garden hose with a soft-spray nozzle or a watering can. 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. Check the output from any sprinkler system by systematically placing small jars or cans throughout your bed (Figure 3.11). Run the sprinkler system for a known time, and then measure how much water is in each collection vessel. Using a trowel, see how deep the water has infiltrated into the nursery bed. 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.

**FIGURE 3.8**

*Without mulch, rain drops and irrigation water can splash soil onto seedlings. This seedling is almost completely encased in splashed soil.*

> *“...to preserve the roots, and especially the earth adhering to the smallest fibrills, which should by no means be shaken off... ...that those tender hairs are the very mouths, and vehicles which suck in the nutriment, and transfuse it into all the parts of the tree...”*
>
> John Evelyn, 1664

The next step up 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.

Drip irrigation isn’t really an option, unless you have very large transplants. However, soaker hoses (primitive drip systems) may work very well in small nurseries; they could be laid along seedling rows. This system is 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 because soaker hoses deliver water more slowly than a sprinkler system.

Using an anti-siphon device on any irrigation system connected to water sources used for domestic purposes is a good idea, and required by law. Such devices prevent contaminated water from flowing back into your drinking water supply.

### *3.1.3.5 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 and slice in on an angle under the rows of seedlings (Figure 3.12). 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 3.13). 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

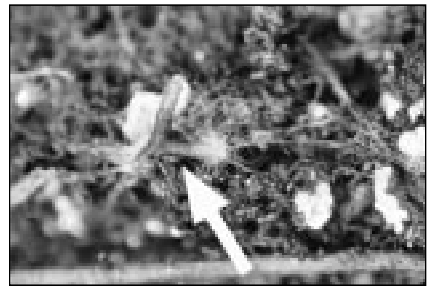

**FIGURE 3.9**

*Mycorrhizae on seedling roots are often easy to spot. Look for swollen root tips that are often “Y-shaped” with lots of fine, fuzzy, mycelium (root-like structures). The arrow points to “Y-shaped,” mycorrhizal root. Note the white mycelium growing from the tip of the right fork.*

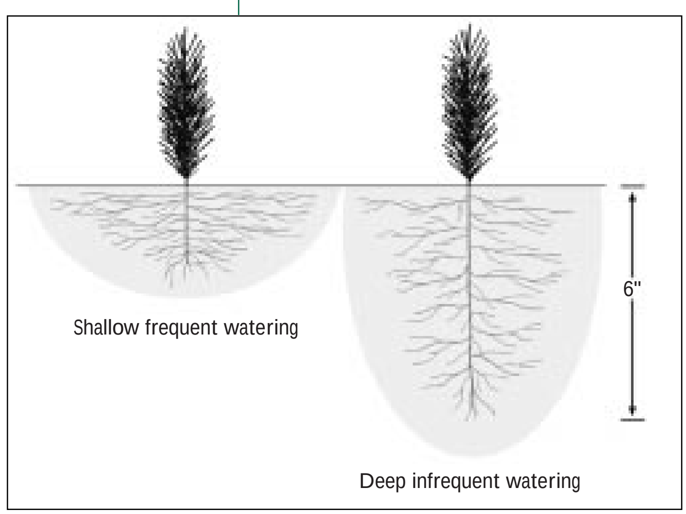


**FIGURE 3.10**

*Water deeply and infrequently to encourage deep root growth. Shallow, frequent watering encourages shallow rooting and makes seedlings more susceptible to drought.*

slice vertically halfway between rows, and an equal distance outside the outer row. Coincide root pruning so seedlings are watered and fertilized after the treatment. Transplants should be root-pruned with the same timing and frequency of 2+0's.

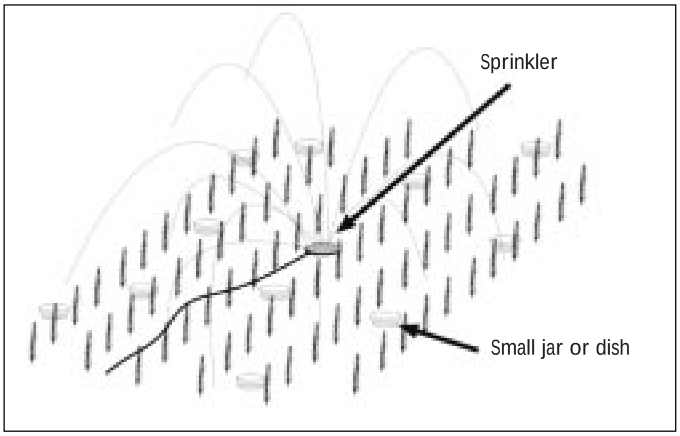


**FIGURE 3.11**

*Use small jars to check the water distribution of your irrigation system, even if you water by hand. By knowing how well distributed the water is, you can ensure all of your nursery beds receive adequate water.*

### 3.1.4 Lifting, Handling, and Storage

Nursery managers call the process of digging seedlings out of nursery beds "lifting." Lifting 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 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 3.14), and seedlings gently put into boxes, plastic tubs, or buckets (Figure 3.15).

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 lifted seedlings out of the sun and wind. If you fall-lifted 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 needles. 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.

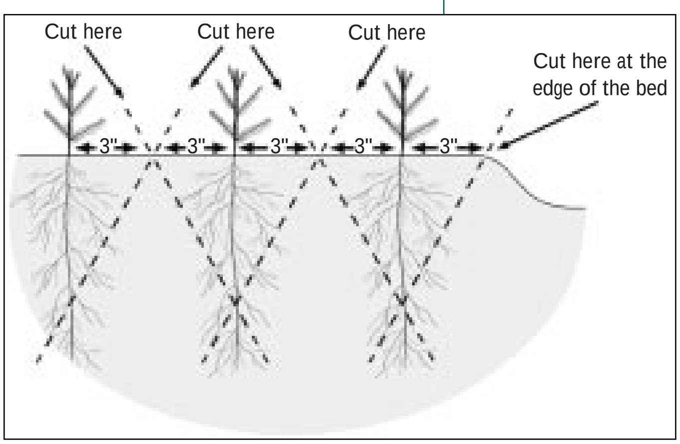


**FIGURE 3.12**

*Use a sharp spade to undercut seedlings. Make sure to push the spade in on an angle. You'll have to spade in both directions to ensure proper undercutting.*

*Adapted from:* Raising Forest Tree Seedlings at Home, *Pacific Northwest Cooperative Extension Publication PNW 96, 1981.*

### 3.1.5 Transplanting

You can grow bigger seedlings by transplanting them after 1, 2, or even 3 years in the nursery. Seedlings can be lifted as described above and should be replanted into another bed while they are still dormant. Usually, seedling density in a transplant bed is less than in a seedbed, about 10 seedlings per square foot (spaced 6 inches by 6 inches apart)(Figure 3.16). The resulting seedlings have bigger stem diameters and larger, more fibrous root systems. Care for transplants the same way you care for seedlings.

### 3.1.6 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. Good green cover crops include rape, 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, 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 N in the soil, leaving little available for your seedlings.

> *"...this of the soil... ... being of greater importance for the raising, planting, and propagation of trees in general, must at no hand be neglected..."*
>
> John Evelyn, 1664

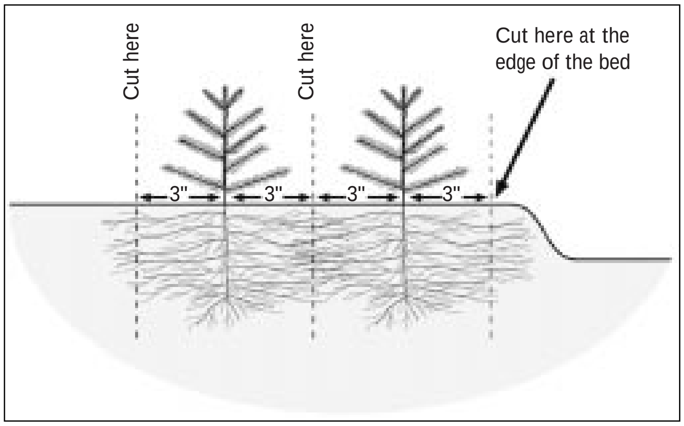


**FIGURE 3.13**

*Prune lateral roots to keep seedling roots from intertwining between rows. Keeping roots from intertwining will allow for easier harvesting with less damage to seedlings.*

## 3.2 Growing Seedlings in Containers

Seedlings can be grown in containers in a greenhouse or shelterhouse, where temperature, water, and fertilizer are slightly or strictly controlled. One big advantage of container-grown seedlings is that you can grow them larger in less time than a bareroot seedling. Unfortunately, you can also kill them a lot faster too! Keep in mind seedlings will need direct sunlight most of the day to optimize growth and to avoid becoming spindly—this rules out growing them on most windowsills.

### 3.2.1 The Growing Environment

Conditions necessary for optimum seedling growth change as seedlings mature. 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 home set-up will probably be less sophisticated than commercial nurseries, and that's okay. Specific environmental conditions will be discussed below.

#### *3.2.1.1 Structures*

Many types of structures are suited for growing container seedlings, but a structure isn't mandatory. Greenhouses, plastic-covered cold-frames or hotbeds and similar facilities work well (Figures 3.17 to 3.19). A good structure will allow air circulation on sunny days, block precipitation, and provide good light transmission. Some type of structure will be of highest benefit to the hobbyist during germination and the first weeks of seedling growth.

#### *3.2.1.2 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 soil-less potting mixes (media). Popular growing media generally have peat moss as the major component. Peat moss is used because of its high water-holding capacity and ability to hold nutrients until used by the seedling. Because peat moss holds a lot of water, other additives, like perlite or vermiculite are added to increase aeration within the container. Most professional growers use a 50% peat moss to 50% vermiculite mixture by volume. Don't use off-the-shelf mixes often sold in garden centers or chain stores. Often, these mixes are just floor sweepings after companies package their "professional" grade mixes and contain too many "fine" particles which reduce aeration and hamper seedling growth.

**FIGURE 3.14**

*The fine, wispy root hairs are the portion of the root where water and nutrients enter seedlings.*

#### *3.2.1.3 Containers*

Professionals use a variety of containers that all have drainage holes in the bottom and vertical ribs on the sides (Figure 3.20). Vertical ribs prevent root spiraling. Three types of containers are useful for growing seedlings at home: hard-sided plastic, styrofoam, and peat-pellets. All have advantages and disadvantages. 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."

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.

One common type sometimes used by professionals is the RL container (Figure 3.21). These individual plastic containers come in three sizes and can be removed from the plastic block used to hold them upright and in groups.

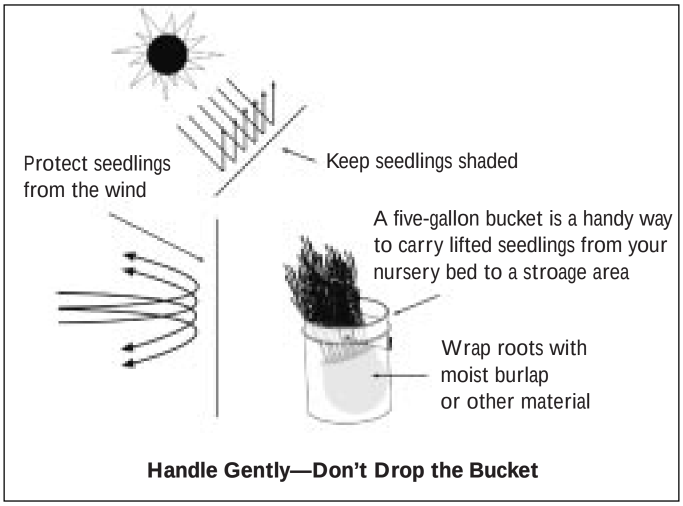


**FIGURE 3.15**

*Handle seedlings gently. Remember to keep roots moist at all times.*

Two sizes, 4 cubic inches (200 containers per block) and 10 cubic inches (98 containers per block), are probably best suited for backyard enthusiasts. The RL container has several advantages for beginners, the biggest advantage being the empty containers can be removed and containers with seedlings can be consolidated, thus reducing space. This feature can be especially important when growing species with erratic or poor germination, like true firs. 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.

Many professionals use containers made from styrofoam (Figure 3.22). Each block of styrofoam may have from 8 to 240 containers in it, ranging in volume from 1 cubic inch up to gallon size. These blocks are lightweight and easy to handle, but containers can't be consolidated in the event of poor germination.

Another option is peat-pellets, sometimes found in garden stores. Peat-pellets are shipped and stored as hard, flat disks. When watered, they expand (Figure 3.23). These also come in a variety of sizes and have blocks to hold individual pellets (Figure 3.24). A mesh covering keeps the peat moss intact. (Don't confuse them with peat-pots. Peat-pots are smooth-sided, designed for starting garden plants, and will allow roots to circle.) Like RL 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 or styrofoam containers that lack a copper coating. The downside of this feature, however, is that you'll 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 whenever you sow, if you prevent not the little field mouse, he will be sure to have the better share."*

John Evelyn, 1664

### 3.2.2 Sowing

#### *3.2.2.1 Filling Containers*

When filling, it's important to put a uniform amount of medium in each container. Don't compact it. If containers are filled with varying amounts of medium, seedlings will also vary in size. Overly-compacted medium restricts root growth, reduces shoot growth, and disrupts water drainage, all of which increase the susceptibility of your seedlings to diseases.

In general, spread medium evenly over the tops of containers, and gently tap the block a time or two to settle the medium. Gently dropping it from a height of 6 inches onto a concrete floor works well. Then top-dress medium over the containers and tap the block once again. The containers are ready to plant. Pushing the medium down into the containers with your fingers is the quickest way to overly compact it. Once the containers are filled, take a hand brush and sweep medium out of the containers until the surface of the medium is about 1/4 inch below the top of the container. This process will result in room to sow seeds and add some mulch.

#### *3.2.2.2 Preparing Seeds and the Medium*

Stratify seeds as described in Section 2.2 (Seed Pre-treatments). Before sowing, water your medium until it's saturated and water is dripping out the bottom. Depending on your local climate, your growing structure (or lack thereof), and the temperatures you can maintain around your seedlings, plan on sowing in March or April. If you can't control temperatures well, you may wish to hold off sowing until May 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 media will help promote faster germination and decrease the possibility of disease.

#### *3.2.2.3 Sowing Seeds*

For even 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

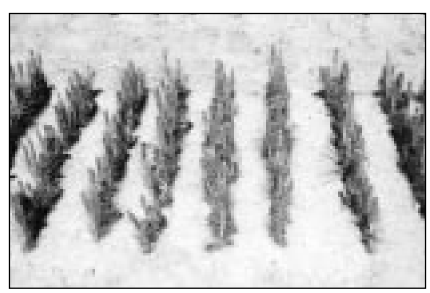

**FIGURE 3.16**

*A nice looking bed of transplants.*

**FIGURE 3.17**

*A wood-framed, fiberglass-covered structure for growing container seedlings. The lower portion of the fiberglass panels can be removed after danger of frost is gone.*

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. After sowing, seeds should be barely covered with a thin mulch of perlite or coarse grit, with mulch depth being no more than 2X the thickness of the seeds. Make sure the covering material doesn't have any fine particles. A good covering 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.

**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 + | 1-2 | 90-100 |
| 80-89 | 2 | 96-99 |
| 70-79 | 2 | 91-96 |
| 60-69 | 3 | 94-97 |
| 50-59 | 4 | 94-97 |
| 40-49 | 5 | 92-97 |

Be watchful for mice. A mouse will quickly learn to work its way down a row of containers, leaving a straight path of eaten seeds. It's a good idea to begin removing the rodents a week or so before you sow, rather than trying to remove them while they're eating your crop!

*3.2.2.4 Planting Germinants*

Plant newly germinated seeds if you have a poor germinating seedlot

**TABLE 3.3**

*A sowing example for a seedlot of western larch 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 use (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 |

**FIGURE 3.18**

*With a PVC pipe frame, this structure can be covered with plastic in spring and winter to protect seedlings (as long as you don't get snow!).*

(especially if you can't consolidate empty containers) or wish to maximize seedlings from just a few valuable seeds. Sprout seeds as you would for a germination test (see Section 2.3, Germination Testing) and, as soon as a primary root is evident (Figure 2.18), place that germinant on top of moistened medium in the container and gently cover with mulch.

If you have multiple seedlings emerging from a container, the extras may be transplanted into empty containers. Transplanting should be completed as soon after germination as possible, especially before the new root sends out lateral roots (Figure 3.25). 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. Unfortunately, this procedure sometimes produces a "J-root" or kink in the seedling stem that can reduce growth in the nursery and cause mechanical weakness or mortality after outplanting (Figure 3.26). 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.

### 3.2.3 How to Grow Seedlings

About 2 to 3 weeks after sowing, your seedlings will have germinated and will start growing new needles. When the seed coats drop off the enlarging needles, thin (or transplant) any extra

**TABLE 3.4**

*An example record of block weights assuming a saturated block weight of 26 lbs., and that seedlings will be watered when target block weight reaches 85% of the saturated block (26 lbs. x 0.85 = 22 lbs.)*

| | July 21 | July 22 | July 23 | July 24 | July 25 | July 26 |
|---|---|---|---|---|---|---|
| Saturated weight | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 |
| Actual weight | 22.0 | 25.0 | 23.5 | 22.0 | 24.5 | 21.5 |
| Percentage | 85% | 96% | 90% | 85% | 94% | 83% |
| Need to water? | Yes | No | No | Yes | No | Yes |

**FIGURE 3.19**

*Gardening catalogs often advertise small cold frames ideal for growing seedlings. This unit is about 40 inches square and large enough to hold several hundred seedlings.*
**Top photo:** *Roof panels can be closed;* **middle photo:** *partially opened;* **bottom photo:** *or completely removed depending on weather. Cold frames like this can also be fitted with automatic, non-electrical roof openers that open and close depending on temperature.*

seedlings out of the containers, leaving the best looking seedling that's closest to the center of the container. You may also start fertilizing your seedlings at this time. The easiest way to apply nutrients is to use a water soluble fertilizer every time you water.

### *3.2.3.1 Watering*

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

The easiest way to determine when to water is by using an ordinary bathroom scale. Right before sowing, 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 saturated block weight. When the weight drops to a certain percentage of saturated block weight, it's time to water your seedlings (Table 3.4). We call this target block weight and it changes 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. However, once seedlings are bigger, and depending on your climate, the change in block weight from saturated to target can happen often, perhaps every-other day or even daily! About once every 6 weeks or so, obtain a new saturated weight to compensate for the weight of the seedlings.

The simplest way to water your seedlings is with a watering can (Figure 3.27). 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

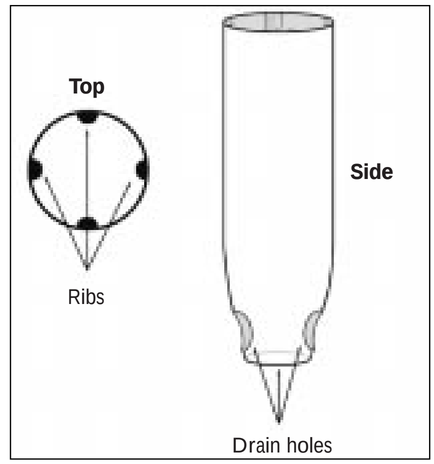


**FIGURE 3.20**

*Good containers for growing seedlings have ribs or slits in the sides to keep roots from spiraling, and at least one drain hole in the bottom.*

make sure all the seedlings receive about the same, and adequate, moisture. See Section 3.1.3.4 (Watering) and Figure 3.11 for details on evaluating sprinkler output.

Fertilizers are easily and uniformly applied with water. The type and amount of fertilizer is discussed in the next section. If you use a watering can, an appropriate amount of fertilizer can be dissolved in water in the can. If you decide to use a hose and nozzle, a lawn sprinkler, or a permanent irrigation system, you can still apply fertilizer with water by using some type of chemical injector. A simple injector is a siphon mixer. These devices have a piece of tubing that you insert into your fertilizer stock solution (concentrated fertilizer). The flow of water through the hose causes a suction which pulls the fertilizer stock solution up and mixes it with the water in the hose to

**FIGURE 3.21**

*A block of 200 RL containers. Each container is about an inch wide and 6 inches long with a volume of 4 cubic inches. The block holding the containers is about 12 inches wide and 24 inches long.*

the desired concentration (Figure 3.28). Use this type of device only if it has a built-in backflow preventor or if some other type of backflow preventor is installed, to prevent contamination of your drinking water. Usually, these siphons require a minimum amount of water pressure to work. Depending on the type of siphon, one gallon of concentrated fertilizer stock solution will make about 16 gallons of diluted fertilizer that can be applied directly to seedlings (therefore, the injection ratio is 1:16).

If you're unsure about the injection ratio of your siphon, you can quickly and easily determine it. 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. Let's move on to the next section to see why this is important.

### *3.2.3.2 Fertilization*

Nitrogen (N), phosphorus (P), and potassium (K) are the most important nutrients for healthy plant growth, and are commonly added via fertilizers. For container seedlings, fertilizers are usually added as a liquid when seedlings are watered. N is critical for above-ground 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.

When growing container seedlings, fertilizer application is more critical than with bareroot seedlings, and it's much easier to over-fertilize, 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, etc. As mentioned earlier, 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 6.4.)

It's really difficult to give a "recipe" for fertilizing container seedlings. Use the following methods as a general guide, because growth rates can vary drastically between species and between seed sources within a particular species. Be prepared to modify it as your seedlings develop.

Use Table 3.5 to decide if you have a species with a "slow," "medium," or "fast" growth rate. All seedlings have three distinct growth phases: initial, accelerated, and hardening. During each phase, you manipulate fertilizer and water to control seedling growth. During the initial growth 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 accelerated 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 accelerated growth phase may last from 3 to 15 weeks. When seedlings are about as tall as desired (4 to 8 inches is good), the accelerated 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 lowered to 70 to 75%. 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

**TABLE 3.5**

*Relative growth rates of common conifers of Idaho, Oregon, and Washington. Species with "slow" growth rates require more fertilizer to grow larger, whereas species with "fast" growth rates grow rapidly with little fertilizer.*

| "Slow" | "Medium" | "Fast" |
|---|---|---|
| Subalpine fir | Knobcone pine | Coast Douglas-fir |
| Whitebark pine | Foxtail pine | Western larch |
| Bristlecone pine | Shore pine | Western redcedar |
| Pinyon pine | Lodgepole pine | |
| Limber pine | Jeffrey pine | |
| Sugar pine | Ponderosa pine | |
| Singleleaf pinyon | Rocky Mt. Douglas-fir | |
| Western white pine | Subalpine larch | |
| Juniper species | Western hemlock | |
| | Mountain hemlock | |
| | Incense-cedar | |
| | Pacific yew | |
| | Most firs | |
| | Most spruces | |
| | White-cedars | |

**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 3.7 for converting ppm.*

| Seedling growth types | Initial growth phase | Accelerated growth phase | Hardening | |
|---|---|---|---|---|
| | | | Bud set | Stress resistance |
| | ppm N | | | |
| "Slow" | 65 | 195 | 33 | 65 |
| "Medium" | 65 | 130 | 0 | 65 |
| "Fast" | 33 | 65 | 0 | 33 |
| Block weights | 85% | 85% | 70% | 75% |

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. And, some species like western redcedar, incense-cedar, junipers, and the white-cedars, don't form buds or rosettes, so your objective with them is to slow growth to 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 (75%). 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.

**FIGURE 3.22**

*Each of the 160 containers in this block of styrofoam (commonly called a styroblock) is about an inch wide and 6 inches deep. The block is about 14 inches wide and 23 inches long.*

So, the general guideline for fertilizing and watering "slow-," "medium-," or "fast-" growing seedlings can be approximated by using Table 3.6. A more advanced guideline can be found in Appendix 6.4.

Here's an example to help pull all this information together. Let's assume you're growing ponderosa pine seedlings. Table 3.5 shows ponderosa pine is a "medium" grower. Let's also assume the crop is in the accelerated growth phase; Table 3.6 indicates seedlings with a "medium" growth rate should get 130 ppm N. Using Miracle-Gro®, Table 3.7 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 (1:15) with a built-in backflow preventor (Figure 3.28) to apply 30 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 (30 gallons ÷ 15 [the injection ratio] = 2 gallons stock solution). To make the concentrated fertilizer solution, mix 30 teaspoons (1 teaspoon for every gallon; 10 tablespoons total) of fertilizer into 2 gallons of water.

**TABLE 3.7**

*Teaspoons of Miracid® or Miracle-Gro® to add per gallon to achieve desire ppm's of 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.*

| Teaspoons per gallon of water | ppm Nitrogen Miracid 30:10:10 (N:P:K) | ppm Nitrogen Miracle-Gro 15:30:15 (N:P:K) |
|---|---|---|
| 1/4 | 65 | 33 |
| 1/2 | 130 | 65 |
| 3/4 | 195 | 98 |
| 1 | 260 | 130 |
| 1-1/2 | | 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; flop over when not supported), 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.

### *3.2.3.3 Lights*

As mentioned earlier, seedlings 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 only with grow lights. However, many species are very sensitive to slight changes in daylength. A species like Rocky Mt.

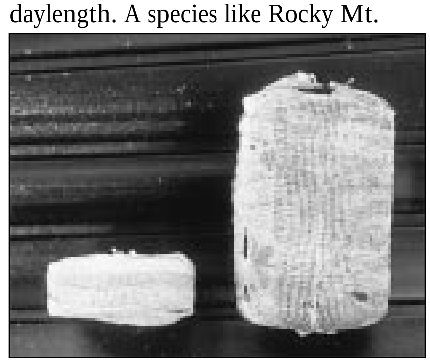

**FIGURE 3.23**

*Peat-pellets are shipped dry and flat (left) but quickly expand to full size when soaked with water (right).*

**FIGURE 3.24**

*One-month-old ponderosa pine seedlings growing in Jiffy-pellets® (peat-pellets) contained in a special block that holds 72 expanded pellets. Once expanded, each pellet is about 1.5 inches wide and 2.25 inches tall. The block is about 11 inches wide and 21.5 inches long.*

Douglas-fir grown under normal daylight conditions will form buds before they are as tall as desired. However, it's fairly easy to "fool" seedlings 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 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 as 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 begin forming buds.

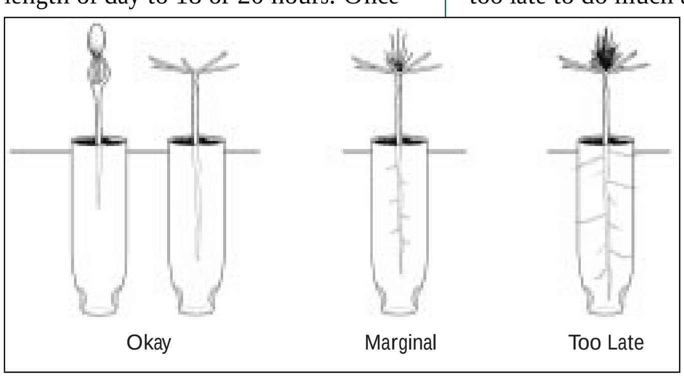



**FIGURE 3.25**

*Transplanting seedlings will be more successful if done before lateral roots begin to grow (left) or lateral roots are still very short (center). Once lateral roots grow (right), it's very difficult to pull the seedling out of medium and get it replanted correctly.*

### *3.2.3.4 Pests*

Disease can occur rapidly in a crop of container seedlings because the nursery environment is also conducive to disease. 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 Damping-off and Figure 2.18, page 13). 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 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.

The last disease problem is Botrytis disease. The fungus *Botrytis* grows 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 needles 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 buds aren't damaged. After bud set, you can also spread seedlings out to encourage air movement between them, thus reducing disease (Figure 3.29). If you're using RL cells or peat-pellets, you can rearrange them to have an empty row between rows of seedlings.

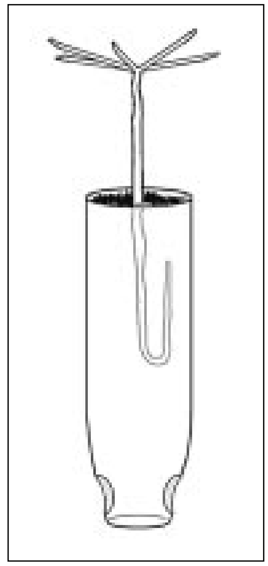

**FIGURE 3.26**

*An incorrectly transplanted seedling. This kinked or "J-rooted" transplant may grow more slowly while in the nursery, and depending on severity of the deformation, may grow poorly on the planting site as well.*

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. They're usually more troublesome when medium is over-watered, and their populations soar if you have a lot of moss and algae, especially in blank cells. Fungus gnats can be controlled with yellow sticky cards, available through garden catalogs and at some garden centers. Place the cards at or near the surface of the containers and when the flies land on it, they become entangled (Figure 3.30). The cards work best when laid flat.

### *3.2.3.5 Mycorrhizae*

If you plant seedlings on a forest site or in close proximity to a forest, adding mycorrhizal fungi to the medium is unnecessary. Once outplanted, your seedlings will quickly be colonized by mycorrhizae native to that site. If you think seedlings will need mycorrhizae because they won't get any naturally (planting on disturbed sites, old fields, etc.), our best advice is to outplant the seedlings and then mulch them with some material collected from the forest, as described in Section 3.1.3.3 (Young Seedlings—Establishing Your Crop). Because N fertilization generally inhibits mycorrhizal formation, and because of the amount of N used to grow container seedlings, it's very difficult to inoculate them with mycorrhizae and still get a plantable seedling in a single growing season.

### 3.2.4 Lifting, Handling, and Storage

The outplanting season will determine how and when seedlings are lifted, handled, and stored. Properly hardened seedlings can be planted in fall if proper site conditions exist (good soil moisture and warm soil temperatures). Seedlings can be pulled directly from containers and immediately fall planted without storage. Follow the planting site storage techniques and planting methods provided in Section 4.2 (Proper Planting Techniques).

If you plan to outplant the following spring, seedlings can be kept in their containers until about mid-December. Keep seedlings as cold as possible, but try not to let the root plugs freeze (it's nearly impossible to pull a frozen root plug out of a styrofoam container). A few gentle freezes of 28°F or higher are probably okay, especially if you've exposed seedlings to cold temperatures before freezing. Seedlings suddenly exposed to a drastic drop in temperature can be damaged or even killed. If you have access to a cooler, 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 keep them in a cooler, make sure you store them in a cool, protected location, such as a shade-frame or lath house. Keep mice and rabbits away. Seedlings may need to be irrigated during warm or windy weather during winter and early spring.

Regardless of storage method, check seedlings often for storage molds. Yes, storage molds can even grow at sub-freezing temperatures. Storage molds usually begin growing on dead needles. Therefore, be diligent when you put seedlings into storage, and remove as much dead foliage as possible. Storing seedlings in an upright position also helps reduce mold problems. Remove moldy seedlings immediately.

**FIGURE 3.27**

*Using a watering can is the easiest way to water and fertilize your seedlings. It's important to apply water evenly, and watch seedlings around the edges of blocks— they often dry out more and require extra water.*

### 3.2.5 Holding Over Seedlings

If your seedlings are too small to plant, you have two options: transplanting into larger containers or growing them as bareroot transplants (see Section 3.3, Growing Plug+one Transplants). Seedlings cannot be held over in the same container for a second growing season. Unless transplanted, seedlings will have too many roots for the container and won't grow well after planting in the forest. Seedlings can be transplanted into larger containers anytime from fall to spring. Use a 50% peat moss and 50% vermiculite growing medium to fill the new container. Irrigate and fertilize as shown in Section 3.2.3 (How to Grow Seedlings).

### 3.2.6 Cleaning Containers Between Crops

In between crops, containers should be thoroughly cleaned of old medium, algae, and other debris. Fungal spores can remain after vigorous cleaning, however, waiting to infect your next crop. Dipping containers in very hot water (160 to 180°F) for 15 seconds to 2 minutes (depending on the temperature and type of container) will kill nearly all the fungal spores. Smooth-sided, hard plastic containers require a

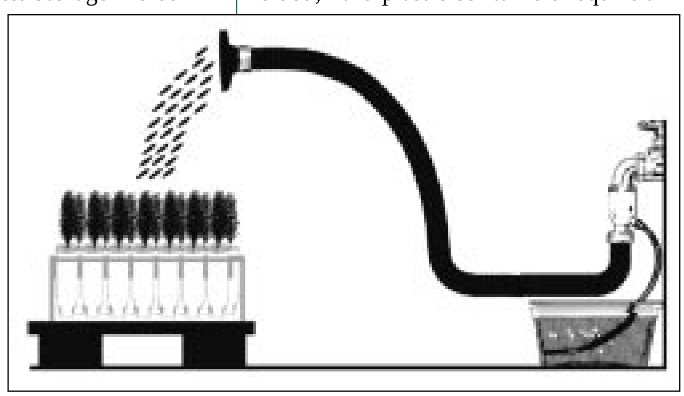

**FIGURE 3.28**

*Siphon mixers are handy devices when you need to apply a lot of fertilizer. Usually the siphon attaches between the faucet and the hose. The siphon's intake tube is placed into the concentrated fertilizer stock solution, and as water flows through the hose, the concentrate is sucked up into the hose at a particular rate. Water sprayed from the hose contains the proper concentration of fertilizer for the seedling growth phase. Make sure the siphon mixer has a built-in backflow preventor, or that a backflow preventor is in place, to avoid contaminating your water source.*

*Adapted from: Hummert's 1997-1998 Horticultural Supply Catalog © Permission granted by Hummert's International, Earth City, MO 63045.*

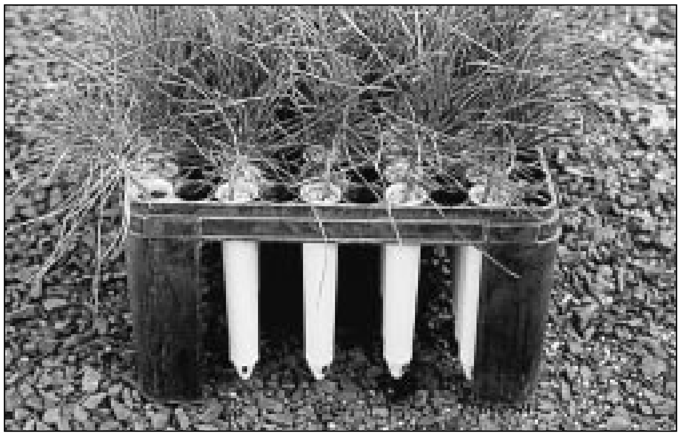

**FIGURE 3.29**

*Spreading seedlings apart late in the growing cycle helps prevent a serious foliage disease of seedlings* (Botrytis). *Individual containers can be spread apart by removing every other row (left), or blocks of seedlings can be separated (right). Both methods improve air circulation which allows seedling foliage to dry more rapidly and inhibit fungal growth.*

shorter dip time than styroblock containers. With 180°F water RL containers can be sterilized in 15 seconds while styrofoam containers need to be dipped at least 1 minute.

## 3.3 Growing Plug+one Transplants

Plug+ones are a hybrid—they're seedlings grown up to 1 year as a container seedling and then another 1 or 2 years as a bareroot transplant. Professional nursery managers use this technique to take advantage of the quick growth possible in containers, and the sturdiness, fibrous root system, and acclimation attained by growing bareroot seedlings. This growing procedure is also a useful technique if for some reason, seedlings can't be planted after growing in the container. To grow plug+ones, follow the directions for growing container seedlings (Section 3.2, Growing Seedlings in Containers) and then the directions for growing 2+0 seedlings the second year (Section 3.1, Growing Bareroot Seedlings).

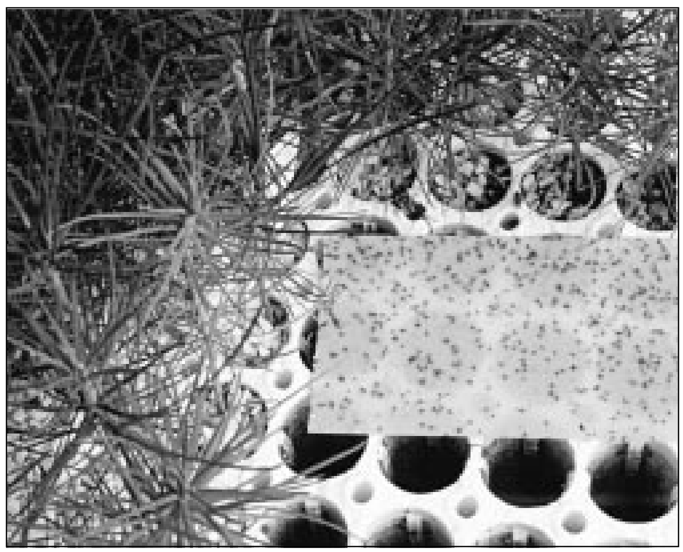

**FIGURE 3.30**

*A yellow sticky-card, often available through gardening catalogs and sometimes at garden centers, is effective in controlling fungus gnats and other small insect pests, especially when laid flat at the soil surface.*