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.

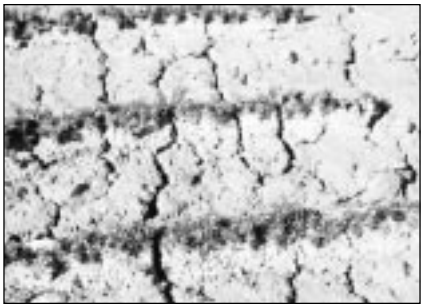

FIGURE 3.1

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

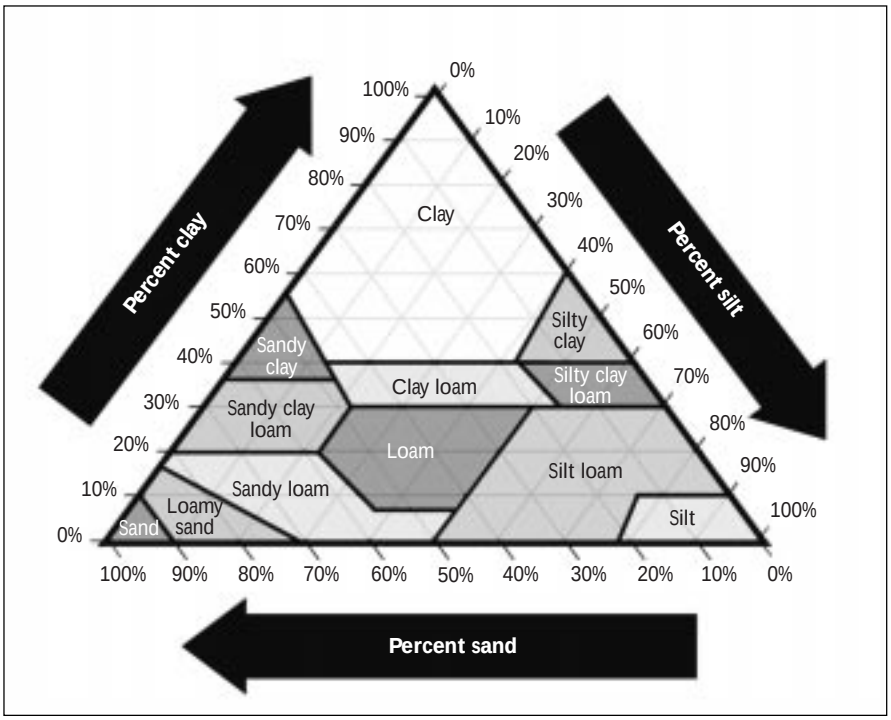

FIGURE 3.2

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.

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.

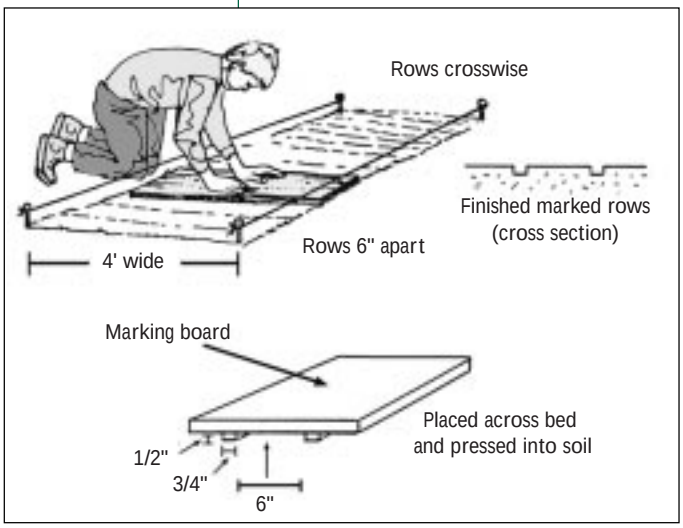

FIGURE 3.4

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.*

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.

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

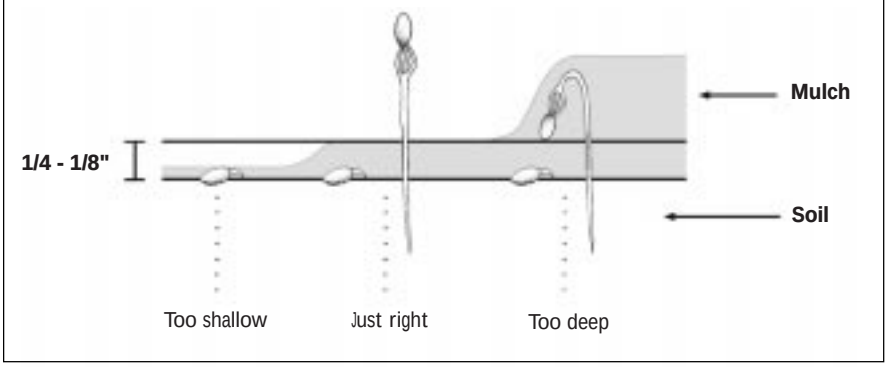

FIGURE 3.5

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 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.

FIGURE 3.6

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

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.

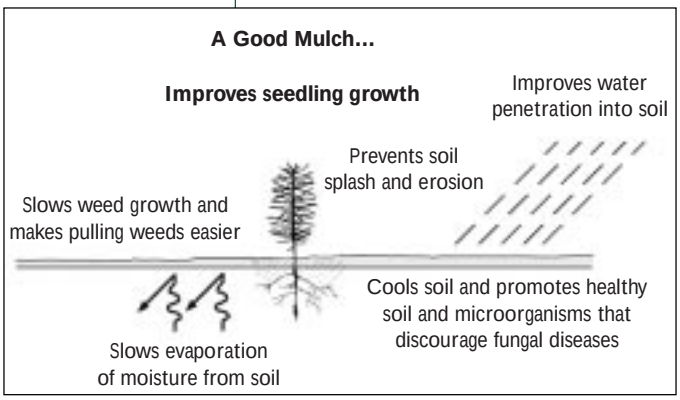

FIGURE 3.7

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

FIGURE 3.8

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

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.

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.

> *"...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

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

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.

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

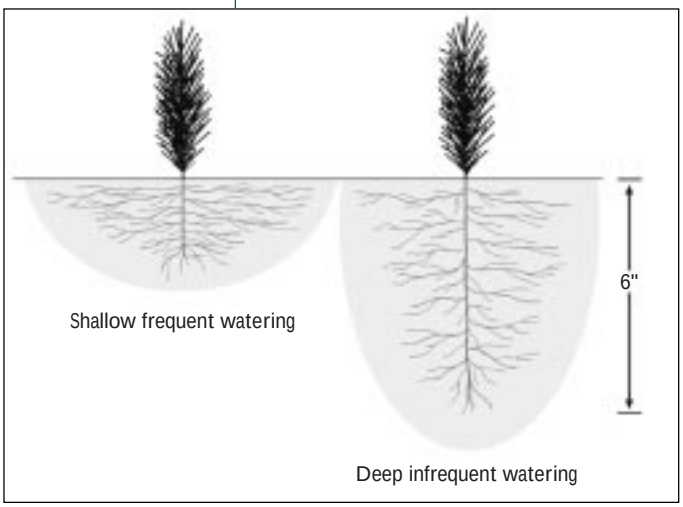

FIGURE 3.10

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.

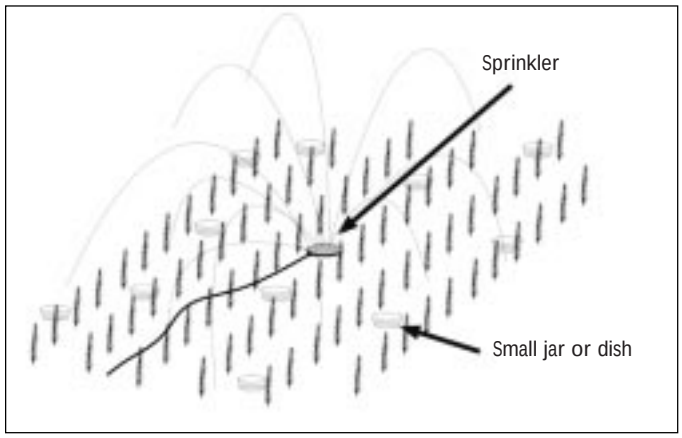

FIGURE 3.11

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.

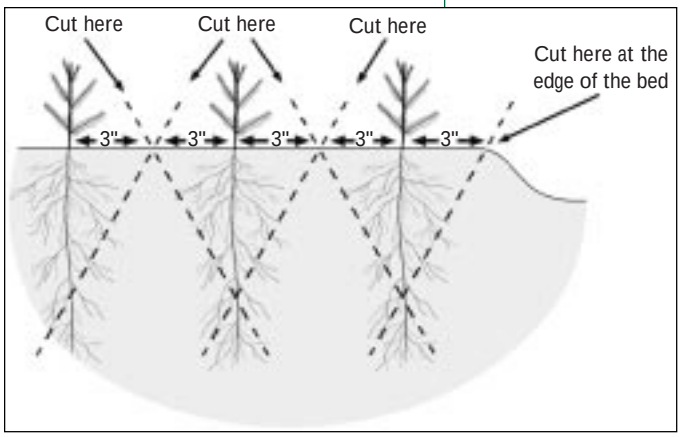

FIGURE 3.12

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