

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

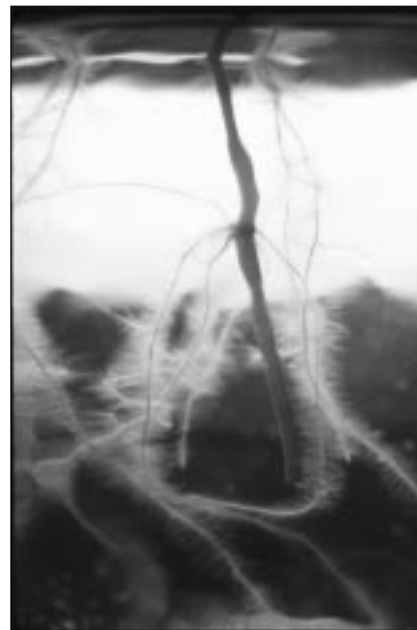


FIGURE 3.14

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

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.

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.

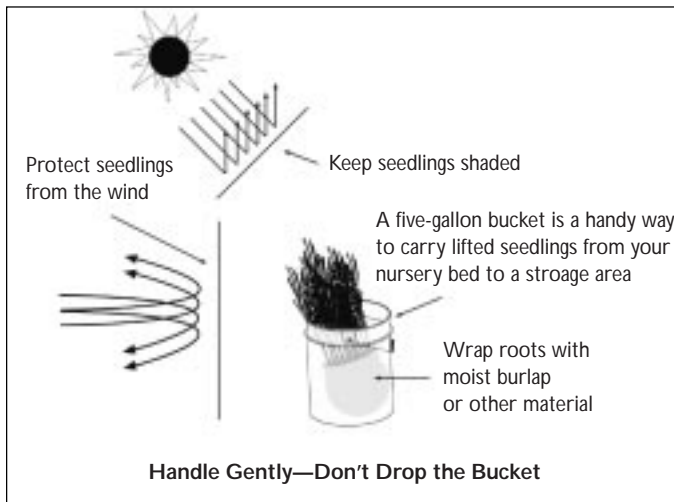


FIGURE 3.15

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 out-planted, the root system often takes on a more natural-looking shape than seedlings grown in hard-sided or styrofoam

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

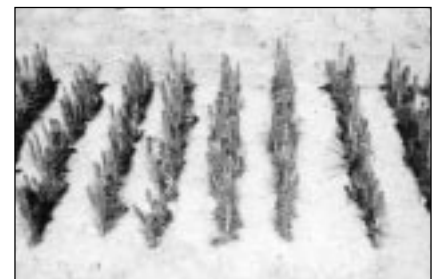


FIGURE 3.16

A nice looking bed of transplants.

"And whenever you sow, if you prevent not the little field mouse, he will be sure to have the better share."

John Evelyn, 1664



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

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.

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

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

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 3.2

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

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

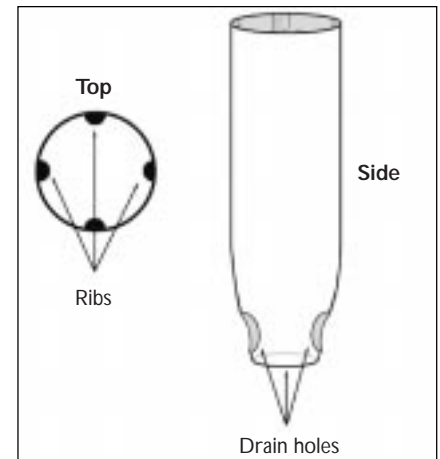


FIGURE 3.20

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.

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.

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.

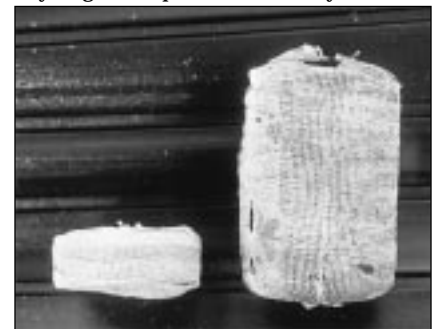


FIGURE 3.23 Peat-pellets are shipped dry and flat (left) but quickly expand to full size when soaked with water (right).



FIGURE 3.22 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.

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)	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



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

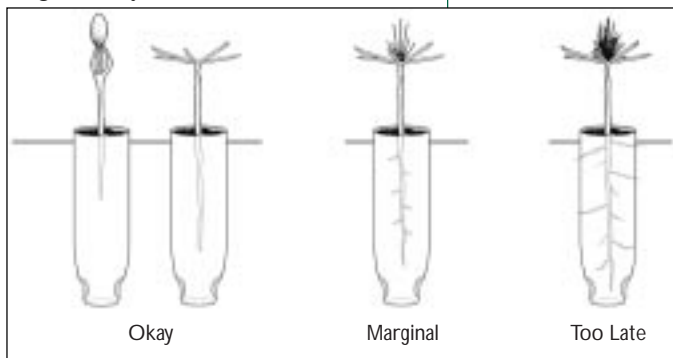


FIGURE 3.25

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.

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.

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

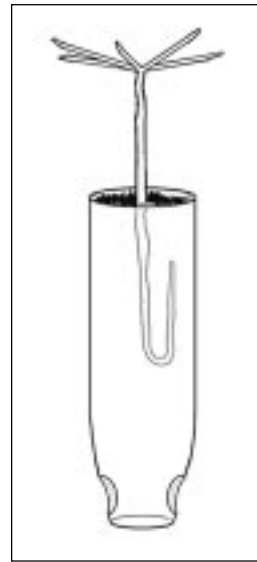


FIGURE 3.26

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.

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.

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-



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.

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.

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

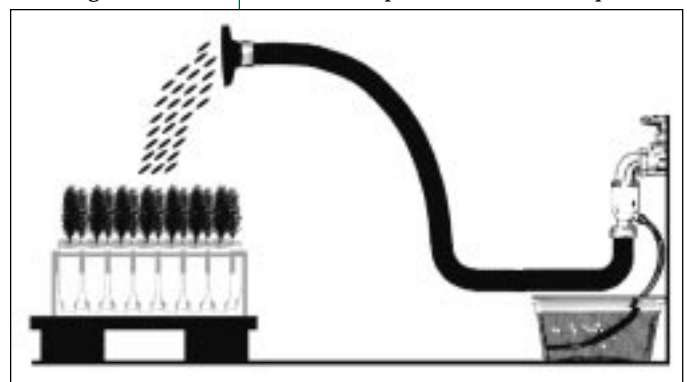


FIGURE 3.28

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.

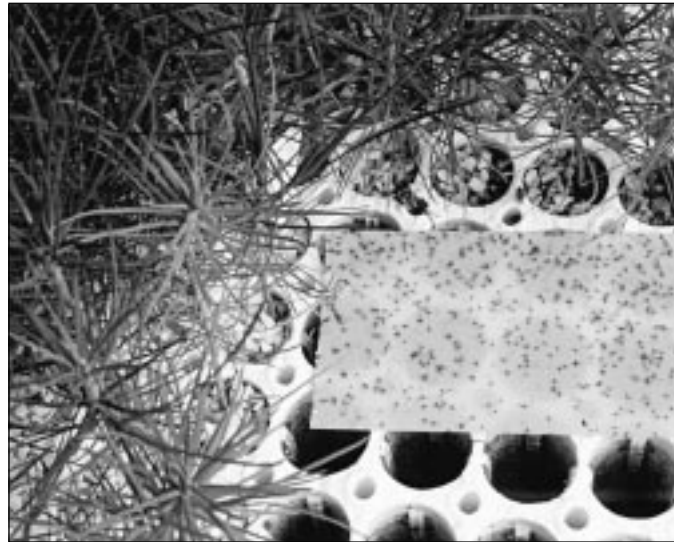
**FIGURE 3.29**

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.