Simple methods for raising tree and shrub seedlings in AFGHANISTAN

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Produced under
the United States Department of Agriculture,
Foreign Agricultural Service, Office of Capacity Building and Development
Under the Participating Agency Service Agreement
with the United States Agency for International Development/Afghanistan

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The authors are part of the United States Department of Agriculture, Forest Service, National Center for Reforestation, Nurseries, and Genetics Resources (RNGR).

Acknowledgments

Funding for this project was provided by the United States Department of Agriculture (USDA), Foreign Agriculture Service, Office of Capacity Building and Development (06-IA-11330122-033 and 07-1A-11330152-016) under the participating agency service agreement with the United States Agency for International Development/Afghanistan. This publication is adapted from *Raising Forest Tree Seedlings at Home: Simple Methods for Growing Conifers of the Pacific Northwest from Seeds*, published by the University of Idaho, Moscow, USA. That publication was written by R Kasten Dumroese, Thomas D Landis, and David L Wenny in 1998. It used material from:

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This publication also uses material from:

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We appreciate the insightful comments provided by Clark D Fleege, Manager of the USDA Forest Service Lucky Peak Nursery in Boise, Idaho. Photographs by Kas Dumroese, Clark Fleege, Tom Landis, Tara Luna, and courtesy of the Afghan Conservation Corp. Graphics drawn by Kent Giard, Jim Marin, and Steve Morrison or reprinted from Volume 6 of Agriculture Handbook 674, *The Container Tree Nursery Manual*.

CAUTION: We discuss pesticides. Pesticides can injure humans, domestic animals, and fish or other wildlife if handled improperly. Read the label before purchasing and using pesticides. Use pesticides selectively and carefully to protect yourself, others, and our environment. Follow label directions for disposal of surplus pesticides and pesticide containers.

Layout by GREYdesigns.
Final proofing by Candace Akins.

Contents

1.0

Why Grow Trees and Shrubs in Nurseries?

Growing trees and shrubs in nurseries is rewarding. You may wish to grow trees and shrubs for many reasons: 1) reforestation; 2) land stabilization; 3) fire wood (energy); 4) improving water quality; 5) urban landscapes; 6) providing shade; 7) producing fruits or nuts. If you enjoy growing plants, you are more likely to produce better trees and shrubs (Figure 1.1). In this book, we intend to provide basic biology and simple, effective techniques to grow trees and shrubs. Although we will discuss growing new trees and shrubs from seeds, cuttings, and grafts, we will refer to them all simply as "seedlings." Moreover, we will refer to trees and woody shrubs simply as "trees."

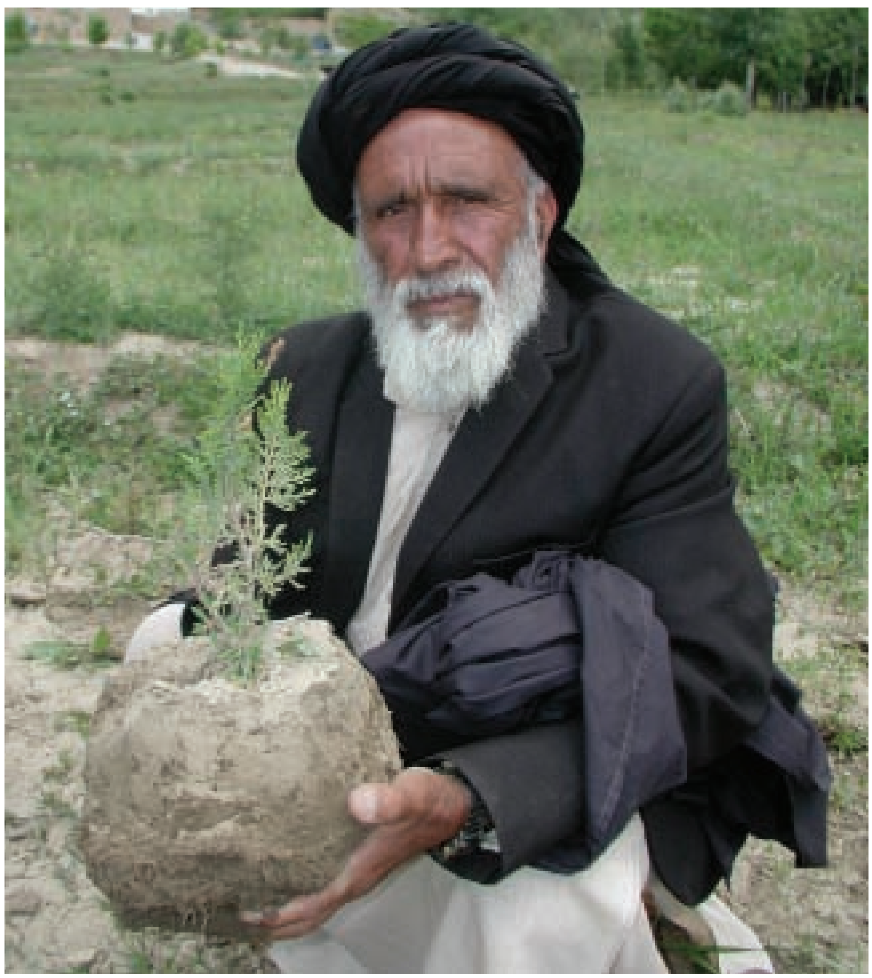


Figure 1.1 *People who enjoy growing trees and shrubs and take pride in their efforts grow better plants than people who find the work tedious.*

1.1 The Right Tree for the Right Place

Although many people think that all plants of the same species are alike, they can be very different. Plants may have different morphology (how they look) and physiology (how they function). Native plants have adapted to their environment and therefore grow best under those local environmental conditions. This concept is important because moving a plant from one environment to another induces stress. Often the result is poor growth or even death. The same is true for growing trees from seeds collected in one region and planting them somewhere distant. It is important to consider where seedlings will be planted *before* you begin to grow them.

In forest nurseries, the best seedlings have the proper morphological characteristics (such as height, stem diameter, and root volume) and physiological characteristics (such as dormancy status and cold hardiness) to have maximum survival and growth for a particular planting site. Seedlings being grown for a very dry place need thicker stem diameters, shorter shoots, and more roots than those being grown for a very moist place. Seedlings being grown for a very mountainous site must survive colder temperatures than seedlings being grown for valley locations. Trees for urban landscapes or orchards can be quite large with a large ball of soil around the roots because they will have better care after planting. The type of tool used to plant the seedlings will also affect how the seedlings must look in the nursery. Remember, before starting your crop, it is always important to consider the conditions on the planting site and the type of planting tool.

2.0

Starting with Cuttings, Buds, and Seeds

Collecting cuttings, buds, or seeds is necessary if you want plants from a specific location or from specific trees. Just like people, trees of a particular species come in different shapes and sizes. Remember that seedlings often look like their mothers. Therefore, if straight trees for timber are desired, do not collect from forked or crooked trees. Instead, look for trees that are tall, straight, and have clear boles. Collect from plants that meet goals for things such as fruit production, timber growth, or drought tolerance.

Ideally, collect cuttings, buds, and seeds from the local area where you plan to plant the progeny. This ensures the new plants are well adapted to the site. If that is not possible, then collect from areas with similar elevation, climate, soils, and rainfall patterns to the planting area. Also collect from vigorous plants in good health without insect problems. It is best to collect cuttings and seeds from at least 20 plants, but the more donor plants the better. For most species, it is best to collect seeds from throughout the canopy.

The following sections present specific information about collecting and processing cuttings, buds for grafting, and seeds.

2.1 Cuttings

Some plants can be grown from cuttings. All new daughter plants grown from cuttings are genetically identical to the mother (donor) plant. Cuttings are portions of plants (stems, leaves, roots) that can develop into new intact plants complete with stems, leaves, and roots. A good cutting consists of healthy stem tissue with some intact buds or leaves. It also has sufficient stored food reserves to sustain it until new roots are formed.

As mentioned above, attempt to collect cuttings from the planting area or an area with similar characteristics, collect healthy tissue, and collect from a variety of individuals. Some species, such as *Salix* and *Populus*, have male and female plants. Identify and collect cuttings from both sexes to ensure future seed reproduction. Taken from lateral branches, cuttings of some species (*Juniperus*, *Taxus*) will continue to grow laterally. This is known as geotropism. Therefore, collect cuttings from upright portions of the plant to ensure upright growth (Figure 2.1). Finally, always label the cuttings with important information such as date, species, collection location and elevation, and name of the collector.

Box 2.1
PROPAGATING PLANTS WITH CUTTINGS

— Collect cuttings from the planting area or area with similar characteristics
— Collect healthy tissue
— Collect from a variety of individual plants (make sure both sexes are represented)
— Collect cuttings from upright portions of the plant
— Label cuttings with important information (species, date, location, elevation, collector)
— Store cuttings properly
— Plant in a protected area
— Once roots form, grow cuttings like seedlings

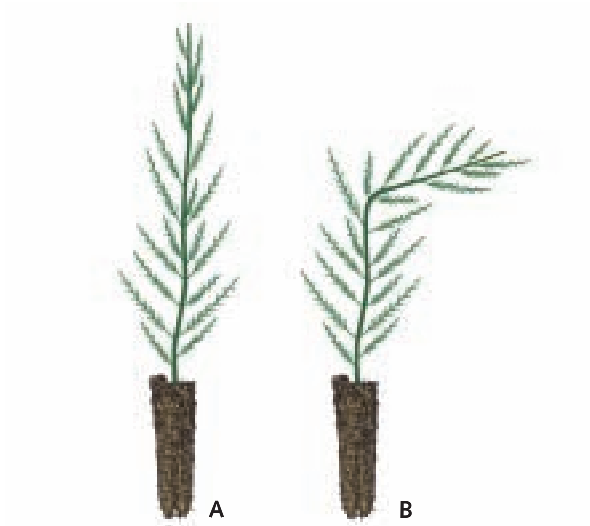


Figure 2.1 *Cuttings taken as shoots continue to grow as shoots (A) but cuttings from branches will continue to grow horizontally like branches (B). Selecting more juvenile wood and upright shoots can help alleviate geotropism.*

Dormant hardwood cuttings are the easiest type of stem cuttings to grow. Many species can be grown from dormant hardwood cuttings (see Appendix 6.1). Dormant hardwood cuttings are collected during late fall through late winter, after trees drop their leaves and when stems are firm. Once taken, the cuttings must be stored properly to prevent them from growing until they are planted in the nursery. Cuttings must be wrapped in moist, shredded newspapers, moist wood shavings, or moss and kept dark and cool. *Salix* and *Populus* are very easy to propagate from cuttings. Small cuttings (5 to 10 cm long) with a good bud can be planted in the nursery, grown one year, and then outplanted where needed.

Juniperus and *Taxus* are often grown from cuttings (10 to 15 cm long) because sometimes it is easier than growing them from seeds. In the nursery, new roots will form only on cuttings that are treated with rooting hormone (see below; Figure 2.2), and it still may take several weeks for roots to grow. Therefore, cuttings must be kept moist until new roots grow or the cutting will die. Cuttings should be planted in a well-protected area, away from wind and in partial shade. The soil should be evenly moist. The foliage should be moistened periodically. Protecting the cuttings with a plastic windscreen or covering them with a plastic bottle can keep them from drying out too much (Figure 2.3).

Synthetic hormones are available in powder and liquid form, and some preparations may contain chemical fungicides. Usually these can be purchased ready-to-use and contain either IBA (indole-3-butyric acid) and (or) NAA (naphthaleneacidic acid). Often, mixtures of IBA and NAA are more effective than either component alone. *Salix* species are a natural source of auxins. To use this source, cut green, actively growing *Salix* stems into 2 to 3 cm pieces, smash them, boil them, and then remove the solution from the heat to cool and steep overnight. The next day, remove the *Salix* stems and soak the desired cuttings in the solution overnight. The cuttings can then be struck the following day. The effect of synthetic and natural rooting hormones varies widely between species and sometimes between genotypes.

Once cuttings form roots they can be treated like either container or bareroot seedlings, depending on where they are planted. Details can be found in 3.1, *Growing Bareroot Seedlings* and 3.2, *Growing Seedlings in Containers.*

2.2 Grafting Buds

Grafting is a way to perpetuate varieties that cannot be propagated by other methods. Grafting is the art of connecting two pieces of living plant tissues together so that they unite and grow as one plant (Figure 2.4 and 2.5). The scion is a short piece of shoot including at least one dormant vegetative bud—the scion will become the new shoot of the plant. The rootstock is the lower portion of the graft that develops into the root system. Budding is grafting when the scion includes only one leaf bud.

Grafts that break where the scion meets athe rootstock are called “incompatible.” Grafts can fail for several reasons: 1) improper union of the rootstock and scion; 2) poor physiological condition of either the rootstock or scion; and 3) the tissues dry out and die before they can grow together. Grafting within a clone is never a problem. Grafting between clones within a species is usually successful. Grafting between species in a genus is sometimes successful and is most often seen in the genus *Prunus*, which includes apricot, peach, plum, and nectarine. Grafting between genera within a plant family is rarely used and the chances of success are much more remote, and grafting between plant families is impossible for woody plants. Some species show excessive sap flow (bleeding) at certain times of the year. Excessive bleeding from the rootstock usually causes incompatibility. Keeping recently performed grafts between 0 and 30 °C with high humidity is essential. In general, the more experienced the grafter, the better the success rate.

Figure 2.2 *Synthetic rooting hormones promote new root formation on cuttings. Similarly, natural rooting hormones from* Salix *plants can be used.*

Figure 2.3 *Cuttings root better when protected from direct sun and dry wind. Covering new cuttings with a clear, plaster, two-liter beverage bottle (with the cap removed) can moderate environmental conditions and improve rooting. The bottle should be removed as soon as roots form.*

2.2.1 Grafting Tools

Grafting is a very precise technique requiring practice and training. Sharp knives, sharpening stones, pruning shears, and saws are tools needed for grafting. These tools should be kept very clean and only used for grafting. Budding knives should be kept very sharp so that very little damage happens to the bud. Dull knives strip and tear wood, leaving cuts that do not heal properly. Materials such as paraffin wax and tape can protect grafted tissues and seal cut surfaces of the graft. Using aluminum foil wraps and plastic bags with twist ties, however, are used in drier climates to protect the graft and provide a little extra humidity around the graft during union. Foil and plastic bags are removed after union.

2.2.2 Collecting Scion Material

Because nurseries have young, small plants, budding is usually the preferred grafting method. Budding is commonly used for fruit tree production. Budding is a form of grafting in which a single bud is

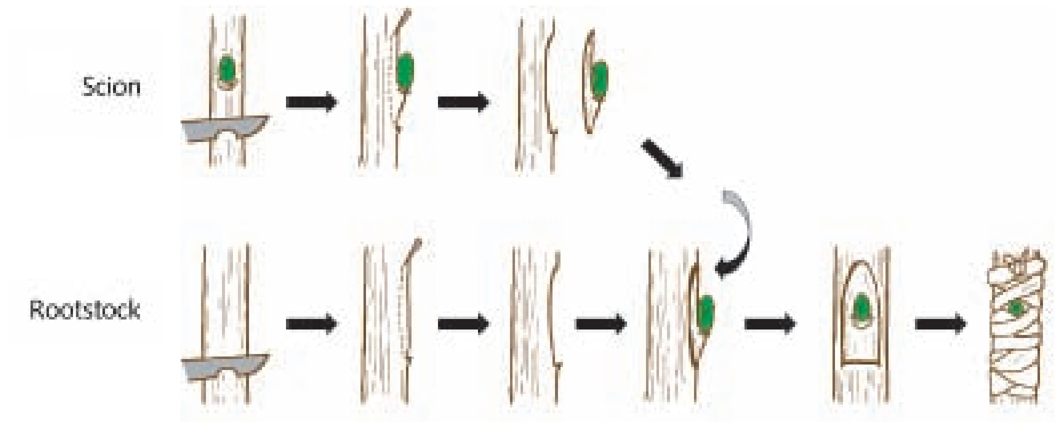


Figure 2.4 *The steps in grafting a chip bud.*

used as the scion rather than a larger section of stem. For success, it is important to use leaf buds (all green inside) and not flower buds (usually plumper and having other colors). A small branch containing several buds suitable for grafting is called a bud stick. Bud sticks should be collected in late winter to early spring while trees are still dormant. If buds have begun to swell or grow, the wood cannot be used successfully. Select parent trees of the desired variety that are disease free. Select straight, smooth bud sticks from one-year-old wood that is 6 to 13 mm in diameter and contains at least three buds or nodes. The best bud sticks usually come from the inside canopy of the tree. Seal about 6 mm of the end of each bud stick with melted wax or grafting paint. When the seal is dry, tie the bud sticks into small bundles. Label each bundle. Surround each bundle of bud sticks with moist paper towels or moist wood shavings to prevent desiccation. The bundles and wrapping material can be kept inside plastic bags. Keep the bundles as cool as possible (0 to 7 °C) and do not allow them to dry out.

2.2.3 Growing Rootstock Material

Plants for rootstocks can be grown using the techniques described in 3.1, *Growing Bareroot Seedlings*. It is important the root systems be undercut to obtain a branched root system. This is described in 3.1.3, *How to Grow Seedlings*. Rootstocks of the same species as the scions are best suited. Apricot scions, however, can be grafted onto peach, plum, and (or) apricot rootstocks.

2.2.4 Budding

Chip budding works well in areas with short growing seasons and can be done whenever mature buds are available. In many areas of the world, chip budding during autumn is widely used for apple propagation. The cuts on the scion and the rootstock must be exactly the same. The first cut on the scion and the rootstock is made below a bud and at a 45 degree downward angle to a depth of about 3 mm (Figure 2.4). The second cut is started about the same distance above the bud and the knife is drawn downward to meet the first cut. If the bud scion happens to be narrower than the rootstock hole, line up one side of the bud scion tightly against the cut on the rootstock. The exact distances above and below the scion bud will depend on species. The entire graft should be wrapped with very thin (2-mil), clear polyethylene tape to prevent desiccation. If clear tape is unavailable, the graft can be wrapped with budding rubber and kept in a cool, shady location with high humidity. The key is to not let the bud dry out.

Slip budding is usually done in summer. Like chip budding, mature buds must be available on the scion and the wood must have bark that will “slip.” Bark that “slips” will easily peel in one uniform layer, without tearing, from the underlying wood. The appropriate time to do this depends on the species and local climate. The first cut on the rootstock is horizontal (Figure 2.5). The second cut, about twice as long as the first, is vertical, originating near the midpoint of the horizontal cut. Where the cuts meet, gently use the

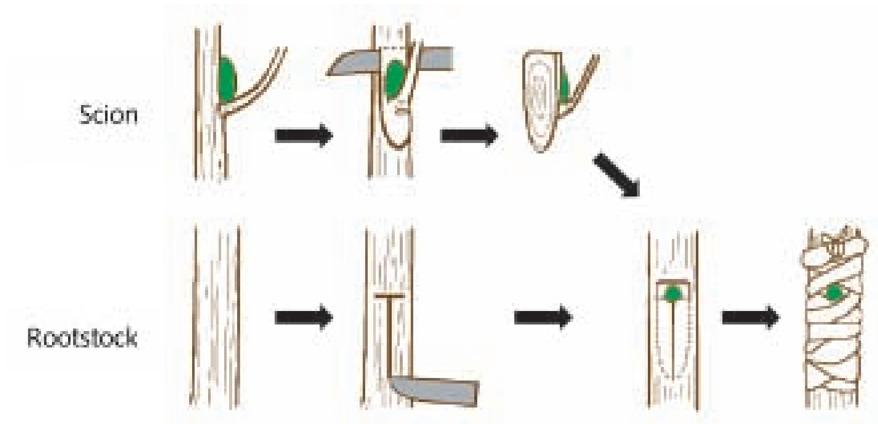


Figure 2.5 *The steps in grafting a slip bud, also know as "T" budding.*

knife to slightly flare open flaps of bark. On the scion, detach the leaf below the bud but retain some of the petiole. Make the first cut about 12 mm below the bud and draw the knife upward just under the bark to a point about 6 mm above the bud. Grasp the petiole and make a second cut horizontally across the bud stick so that it intersects with the first cut. The bud and its accompanying wood, termed a bud shield, is then inserted under the "flaps" on the rootstock, and slid down to ensure that the scion makes intimate contact with the rootstock. Use a budding rubber to hold the stem, flaps, and bud shield firmly together. Do not cover the bud.

2.2.5 Finishing the Graft

Grafted surfaces must be held tightly in place using a budding rubber or grafting tape. This wrap must either breakdown by weathering (as budding rubbers do), or must be removed in 2 to 3 weeks after the union has healed. If the material does not break down and is not removed, it will girdle the rootstock. Once the union has healed, the portion of the rootstock above the graft must be cut away to force the scion bud to grow. Remove any unwanted sprouts as soon as they are visible. Unwanted sprouts can be easily "rubbed off" with fingers.

2.3 Seeds

Seeds can be produced in dry or fleshy fruits (Figure 2.6). The type of fruit influences collection, extraction, refinement, and storage of seeds. It is important

Figure 2.6 *Ripe fruits and seeds ready for processing at an Afghan nursery. Fruits of* Thuja orientalis *(upper left), fruits of* Maclura pomifera *(upper right), and seeds of* Thuja orientalis *(bottom).*

to collect ripe fruits. Ripe dry fruits, like cones and pods, can be placed into cloth bags for transport back to the nursery. Ripe fleshy fruits, like apricots or *Morus*, can be placed into white plastic bags, tubs, or pails for transport back to the nursery. Make sure to label the fruits with important information such as species, date, location, elevation, and the name of the collector. During transport to the nursery, keep fruits cool and out of direct sunlight.

2.3.1 Collecting Fruits

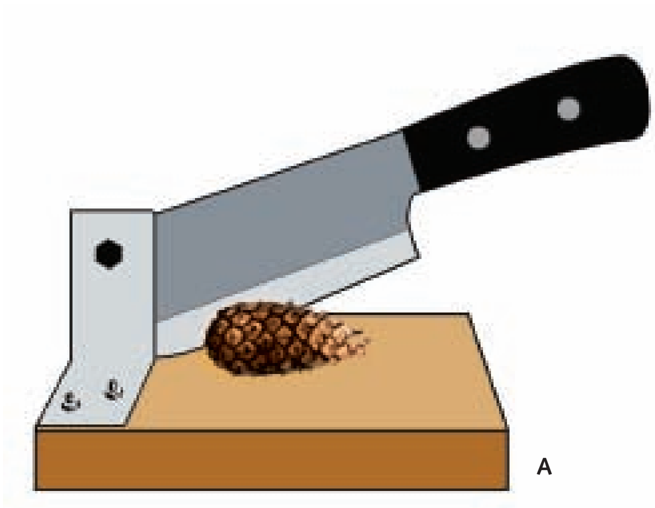
2.3.1.1 Collecting Dry Fruits and Storing until Seeds are Extracted

Dry fruits, like cones and pods, are woody or papery when mature and often split open to release seeds.

Table 2.1

Four common conifers of Afghanistan and the years between good cone crops. See Appendix 6.1 for more species.

Species	Cone cycle (years)
Cedrus deodara	3
Cupressus torulosa	1
Picea smithiana	1 to 3
Thuja orientalis	3 to 5



A

Therefore, these fruits must be harvested before seeds are dispersed. Some dry fruits, like those of *Quercus* or *Ulmus*, have the fruit and seed fused together and do not split open at maturity.

Cones are probably the most common dry fruit that opens to release seeds. Cones are a cyclic crop. Heavy crops appear over a wide area every few years, depending on species (Table 2.1; Appendix 6.1). Other years, crops are scarce or a complete failure because insects concentrate on what few cones are produced. Even when cones are available, the cone-picking season only lasts a few weeks in any locality. Generally, cones at lower elevations ripen first. Start checking low elevation trees in early summer and high elevation trees by midsummer.

It is important to harvest cones when seeds are mature, but before the cones dry sufficiently to flare open and release seeds. Usually, cone color changes from green or purple to yellowish-green to tan as the cone dries. This change occurs gradually and is not a perfect guide to seed maturity. Sometimes, seeds are mature before the cone changes color. To determine if seeds are mature, the cone must be cut open. See Figure 2.7 for details on constructing a cone cutter.

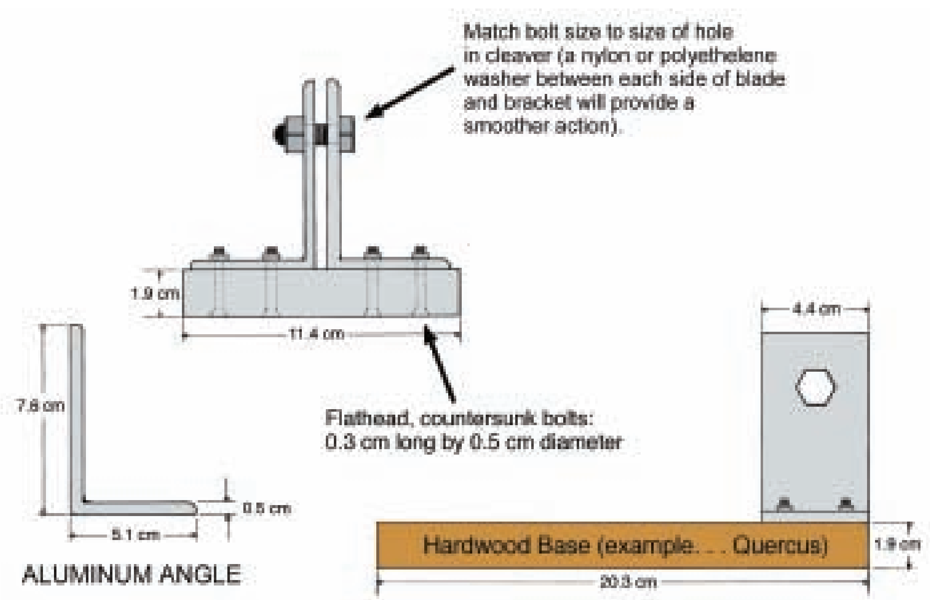


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Figure 2.7 *A cone cutter is useful for seeing how many good seeds are inside a cone (A). A cutter can be made following this schematic (B).*

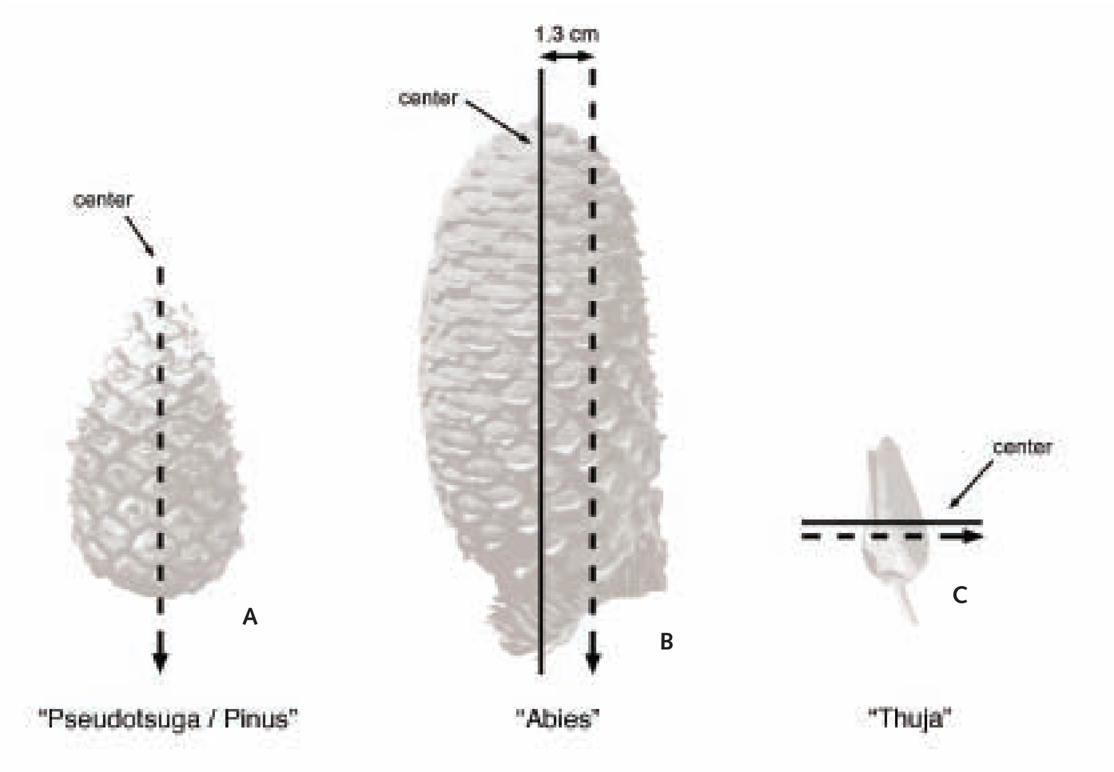

Figure 2.8 *To check for filled seeds, cut cones of* Pseudotsuga, Pinus, *and* Picea *through the middle lengthwise to check for seeds (A). Cut cones of* Abies *lengthwise, but about 13 mm to one side of the cone's core (B) and cones of* Thuja *widthwise just below the center of the cone (C).*

Cutting a cone through the middle lengthwise will expose seeds of *Pinus* and *Picea* for inspection (Figures 2.8 & 2.9). Cones of *Abies* and *Cedrus* must be sliced lengthwise 1 cm to the side of the middle to ensure cutting through seeds. For *Thuja orientalis*, cut the cone widthwise just below the center of the cone. Mature conifer seeds have embryos that fill 90% or more of the embryo cavity, and the material around the embryo is whitish and firm with texture like coconut (Figure 2.10). Immature seeds can be harvested (embryos fill 75% to 90% of the embryo cavity) but will need a period of after-ripening (2 to 6 weeks) to mature. After-ripening is described below. Cones with at least 50% of exposed seed cavities filled with mature embryos are considered good. Collecting cones with fewer seeds is justified if cones are in short supply. How many cones will you need to collect? It depends mostly on the species you wish to grow. The amount of seeds possible from cones is provided in Table 2.2. Currently, this information appears to be lacking for species native to Afghanistan. Obtaining similar data would be relatively easy and would help foresters and nursery managers better plan for reforestation efforts.

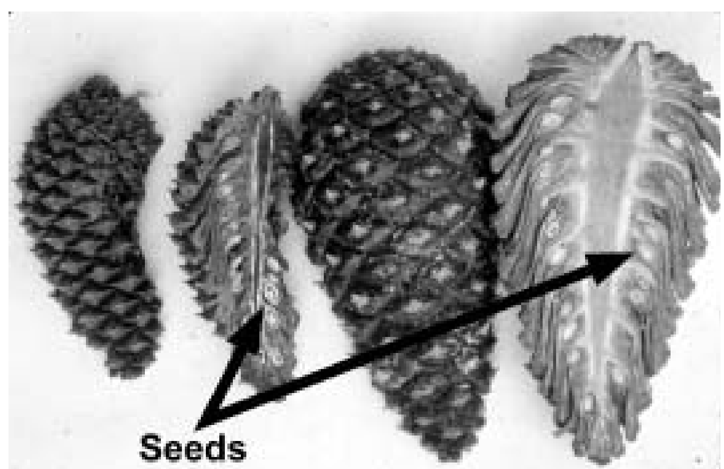

Figure 2.9 *Cross sections of* Pinus *cones.*

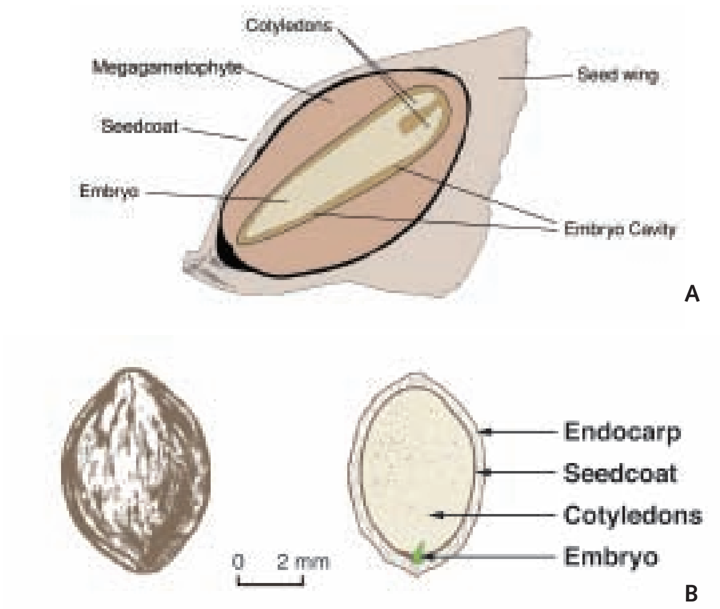

Figure 2.10 *Cross section of a mature conifer seed (A) and* Prunus *seed (B). The embryo and megagametophyte (storage tissue; conifers) or cotyledons (angiosperms) should be white and firm like coconut. In a* Pinus *or* Picea *seed, the embryo should fill at least 90% of the cavity.*

Table 2.2
Seeds per liter of cones for three conifer species introduced from the United States found growing in Afghanistan. See Appendix 6.1 for more species.

Species	Grams of seeds per liter of cones	Number of seeds per gram
Picea engelmannii	340 to 560	2,270 to 3,785
Pinus ponderosa	255 to 900	190 to 685
Pseudotsuga menziesii var. *glauca*	225 to 370	625 to 1020

Box 2.2
COLLECTING CONES AND OTHER DRY FRUITS

— Harvest cones and fruits when seeds are mature but before seeds are dispersed
— Check cones and fruits for filled seeds before collecting large quantities of cones and fruits
— Collect from a variety of individual plants
— Put cones or fruits into burlap or nylon sacks—always handle cones and fruits gently
— Label each sack with species, location, elevation, date, and so on
— Store sacks on racks in dry, well-ventilated shelters
— Inspect often to avoid mold and animal damage

Cones, pods, and other dry fruits can be collected two ways. It is always best to pick cones from the upper third of the tree where seeds are usually the most vigorous. The first method is collection from standing trees. This method requires special climbing equipment, can be dangerous, and is best left to experienced collectors. The advantage of this method is that desirable trees remain for future cone harvests. If the trees are to be harvested, the second method is to coincide tree harvest with cone collection. Then cones can simply be picked from fallen trees; avoid picking damaged cones.

Dry fruits should be put in burlap or nylon screen sacks. Very small collections can be placed into paper sacks. Sacks should be only half full to allow fruits to expand during drying. Avoid contaminating fruits with green or dead foliage or dirt that can introduce mold. Never throw or drop a bag of fruits; lower it from the tree on a rope. Label each sack immediately with species, elevation, collection location, date, and any other pertinent information. Store sacks on open racks in dry, well-ventilated shelters, like open-sided sheds or well-ventilated barn lofts. Sacks can also be hung from ceilings. Paper sacks can be left open at the top. Sacks should be separated to allow good air circulation and maintained between 18 and 27 °C. Stored correctly, fruits will continue to dry with a minimum of overheating and mold damage. Alternately, fruits can be spread out on a canvas or on screens. If screens are used, make sure the seeds do not fall through. Avoid exposure to direct sun during the heat of the day. Check fruits often and inspect them for mold. If mold is present, rearrange sacks to improve air circulation. If fruits were picked with mature seeds, fruits should dry satisfactorily in a few days, depending on the weather. If immature green fruits, especially cones, were picked, it may take a few weeks or months for seeds to finally mature. Make sure the fruits are protected from birds and rodents.

2.3.1.2 Collecting Fleshy Fruits and Storing until Seeds are Extracted

Depending on species, fleshy fruits can contain many seeds per fruit or they can bear a tough, stony pit that encloses only one seed. Keeping fleshy fruits cool and out of direct sun is the most important thing during collection and handling. If the fruits get too warm, seeds can be damaged. It is important to not let the fruits completely dry out because this can make cleaning more difficult. Collect fleshy fruits in white plastic bags, plastic tubs, or buckets and store them in a cool place or a refrigerator until they are cleaned.

2.3.2 Extracting Seeds

Extracting seeds is necessary for proper sowing and (or) storage. Sometimes, seeds will fail to germinate if they are not removed from fruits. Some easy ways to clean seeds from fruits are described below. Regardless of the technique, the seed cleaning area should be well ventilated. Some fruits cause allergic reactions and fine dust can irritate eyes and lungs. Therefore, it is important to wear gloves and dust masks during cleaning. Wash your hands after cleaning seeds.

2.3.2.1 Dry Fruits and Nondormant Seeds

Seeds can be extracted reasonably well with simple, low-cost equipment. Most dry fruits open as they dehydrate. When open, the seeds fall out. Properly stored dry fruits will partially open inside the sacks, and some seeds will fall out. When most seeds fall out with a little gentle tapping, the fruits have opened sufficiently (Figure 2.11). *Abies* cones will simply fall apart. Some nondormant seeds and some conifer species are exceptions and are described now.

Large, non-dormant seeds, such as those of *Juglans* and *Quercus*, are typically separated from other debris by simply floating them in water immediately after collection. Good seeds usually sink but nonviable seeds and debris float. Sometimes seeds collected from very dry ground will float for a while—allowing the seeds to soak overnight will ensure that the good seeds become hydrated and sink. Small, nondormant seeds, such as those of *Salix* and *Populus*, can usually be sown without further cleaning. With these species, the cottony material surrounding the tiny seeds helps hold seeds in contact with soil when they are planted.

Figure 2.11 *A simple window screen-bottomed box allows cones to dry without losing seeds. Put no more than one seedlot and identification label per box. Wood spacers on the corners allow boxes to be stacked for more efficient use of space while still allowing good air circulation. When seeds begin to fall out of the fruits, further processing can start.*

Pinus halepensis, *Pinus contorta* var. *latifolia*, and sometimes, *Pinus eldarica* have cones that require heating before they will open. An easy way to open them is to put cones into a burlap bag and immerse the bag into very hot water (about 82 °C) for 30 to 60 seconds. Remove the bag and place the cones onto a screen-bottomed tray in a warm location. The hot water softens the resins that keep the cones closed. As the cones dry, the scales pull open allowing access to the seeds.

Once seeds fall out of fruits, the next step is separating them from the fruits. This is usually done with screens and air separation. Shake seeds and fruits over a coarse screen (hardware cloth) attached to the bottom of a wooden box or tumble them (Figure 2.12). Dislodged seeds and smaller impurities fall through the screen, leaving the spent cones and fruits and larger debris on the screen. Screen mesh size will vary with species, but 6 to 13 mm mesh works well for *Pinus* and *Picea* seeds, while a 9 to 15 mm mesh is necessary for larger fir seeds. For conifers, separated seeds having wings will be mixed with pitch globules, needles, wings, and small pieces of cone. Repeat the screening process with a

Figure 2.12 *A simple wooden box with a screened bottom and fitted with a wooden cover can be used to separate cones and seeds (A). This can be the same box used to dry fruits as shown in Figure 2.11. A screened box can be fitted to a hand-operated axle to tumble cones and fruits to release seeds (B).*

Figure 2.13 *To separate seeds and smaller impurities, use a screen that retains seeds but allows fine debris to pass through.*

mesh size that retains seeds but allows the smallest debris to pass through (Figure 2.13). After this step, all that remains are seeds and seed-sized debris.

The papery wings attached to conifer seeds should be removed. Put the seeds into a burlap or cloth sack and tie or fold it closed. The bag should be only one-quarter full. Gently knead the seeds by squeezing and rubbing from outside the sack (Figure 2.14). Friction between seeds and between seeds and burlap will detach wings. Remember to knead slowly and gently because too much friction might damage seeds. This process requires only a few minutes. A few species, such as *Thuja orientalis*, have very tight wings that should be left on the seeds. Do not attempt this with *Abies spectabilis*—the resin on the seedcoats will be released and make a sticky mess. Repeat the screening process again with a mesh size that retains seeds but allows the smaller debris to pass through.

2.3.2.2 Fleshy Fruits

Extract seeds from fleshy fruits soon after collection to avoid fermentation, mummification, and microbial damage. Just before extraction, soak fruits in water to soften the pulp. Soak fruits for a few hours to a few days, depending on the species. During soaking, the water should be changed every few hours. Flesh can be removed by squeezing it off with hands, or mashing the fruits with a wooden block or something similar. Seeds can also be extracted by rubbing the soaking fruits against a screen while a steady stream of water washes the pulp away. Floating seeds are empty and should be discarded.

For small quantities of small fleshy fruits, like *Morus*, seeds can be extracted using a food blender. The impeller blades should be covered with tape or coated with rubberized plastic so seeds are not damaged.

The hand- or blender-cleaned mixtures of seeds should be put into a tank—slowly adding water to the seed mixture will force the pulp, other debris, and empty seeds over the top of the container. The good seeds should sink to the bottom. If, after this rinse, seeds require more cleaning, they should be dried (one to three hours).

2.3.3 Refining Seeds

The last step is fanning or winnowing. This technique separates detached wings, hollow seeds, and seed-sized impurities from good seeds. The most efficient, small-scale method is with an agricultural seed cleaning or fanning mill (Figure 2.15). These machines, however, require careful adjustment for each species to prevent retaining too many impurities or blowing away too many good seeds. Another effective way is winnowing on a windy day. Pass seeds and debris back and forth several times by pouring them slowly from one container to another. Lighter chaff will blow away from heavier seeds. Cupping seeds in your hands and blowing on them will also work. A compromise technique between both methods is winnowing in front of a fan. When seeds are poured slowly in front of a small electric fan, they separate according to weight from the base of the fan (Figure 2.16). The heavier, good seeds will drop near the base of the fan while hollow seeds, wings, and lighter impurities will blow farther away. Periodically collect a small sample of seeds, moving away from the fan. Cut them in half to check for soundness (Figure 2.17). This way you can determine where the hollow seeds are and discard

Figure 2.14 *An easy way to de-wing conifer seeds is to put them in a cloth bag and gently knead the bag and seeds.*

Box 2.3
COLLECTING FLESHY FRUITS

— Harvest fruits when seeds are mature
— Check fruits for filled seeds before collecting large quantities of fruits
— Collect from a variety of individual plants
— Put fruits into plastic bags, tubs, or buckets—keep cool and out of direct sun
— Label each sack with species, location, elevation, date, and so on
— Store fruits in cool location out of direct sun
— Do not let fruits completely dry out—they become more difficult to clean

Figure 2.15 *Small-scale seed-cleaning equipment makes use of a variety of screens and air flow to separate seeds from impurities.*

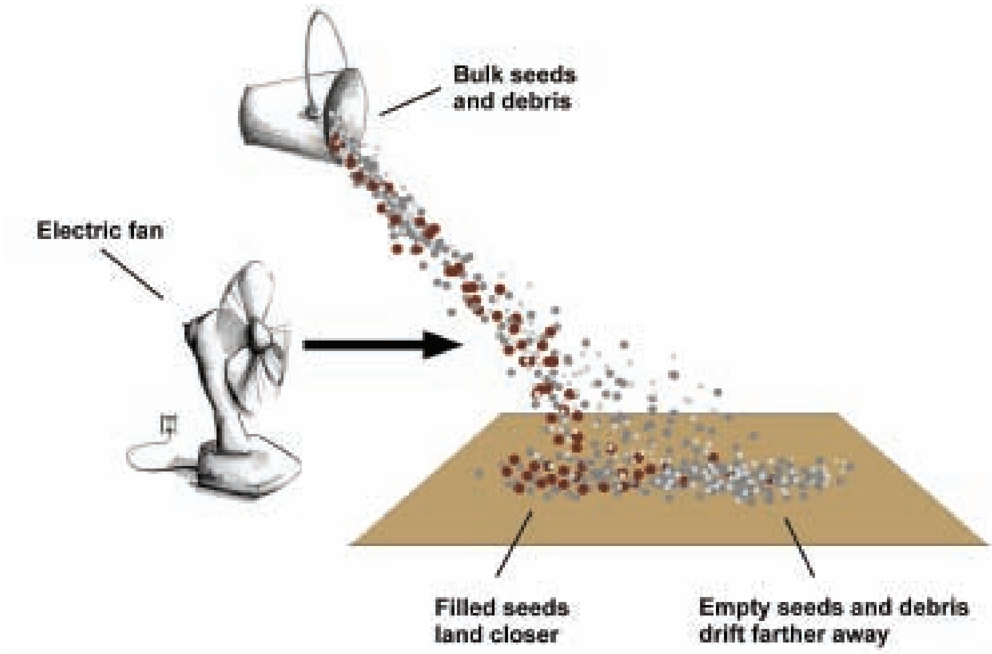

Figure 2.16 *Use a small fan to winnow non-filled seeds and wings from good, filled seeds. Filled seeds, being heavier, will land closer to the fan while empty seeds and wings, being lighter, will land farther away.*

Figure 2.17 *Cut seeds in half with a knife or safety blade to see if they are filled like the seed in Figure 2.10.*

them. All species will probably require several successive separations to obtain a desired degree of seed purity. A good target for most species is 90% or more sound seeds.

2.3.4 Storing Seeds

Seed viability and storage life is affected by how fruits and seeds are handled during collection, extraction, and refinement. Proper handling depends on the type of seeds: nondormant and dormant. Dormancy is defined in 2.3.5.1, *Seed Dormancy*.

Nondormant seeds are viable for only a short time, generally less than one year. Some nondormant seeds are only viable for a few days. Examples of species with non-dormant seeds include *Acer*, *Salix*, *Populus*, and *Quercus*. These seeds do not tolerate being too dry and are usually sown in the nursery immediately after cleaning. Sometimes they can be stored for short durations if they are kept cool, moist, and exposed to air. Nondormant seeds are often stored on top of moist sand, paper, or compost in non-sealed containers covered with moist burlap bags. Just before sowing, seeds (except *Salix* and *Populus*) should be soaked in water for a few hours.

Dormant seeds tolerate drying. If dried to a low seed moisture content and stored at low temperatures, they can remain viable for years or decades. Many species native to Afghanistan have dormant seeds. Examples of species with dormant seeds include *Picea*, *Pinus*, *Acacia*, *Ligustrum*, and *Prunus*. Store only seeds that are not damaged. Seeds must be stored at relatively low moisture contents. Once seeds are clean, reduce their moisture content by placing them in a thin layer in shallow trays or on light-colored cloth or on screens for one day to four weeks. The actual drying time depends on species and weather. Stir them often to promote uniform drying. Protect them from birds and rodents. Once dry, seeds can be mixed with a bit of dry ash to discourage pests. Place the seeds into an airtight container. Add some dry charcoal or small pieces of newspaper to absorb any extra moisture. Label the container well (Figure 2.18). Glass jars with screw lids, metal cans with tight-fitting lids, and thick (6-mil or greater) plastic containers with screw on or tight-fitting lids work well. Protect the containers from rodents and only open containers when necessary.

Three methods of seed storage are used by nurseries: freezer storage, refrigerated storage, and room temperature–low humidity storage. Many dormant seeds can be stored at temperatures at or slightly below freezing (-1 to -2 °C). Often, seeds will remain healthy for 10 or more years. This is the best way to store dormant seeds. Seeds stored under refrigerated conditions should be kept in air-tight containers at 3 to 5 °C. If possible, use a self-defrosting refrigerator that maintains relative humidity at 10% to 40%. If the door is rarely opened, the humidity in a self-defrosting unit will stay at lower humidity levels. Seeds

Box 2.4
STORING DORMANT SEEDS

- — Store only clean seeds dried to a low seed moisture content.
- — Coat seeds with a bit of ash to discourage pests
- — Put seeds into an air-tight container—add a little charcoal or newspaper to absorb moisture
- — Label each container with species, location, elevation, date, and so on
- — Store as cool as possible
- — Protect containers from rodents

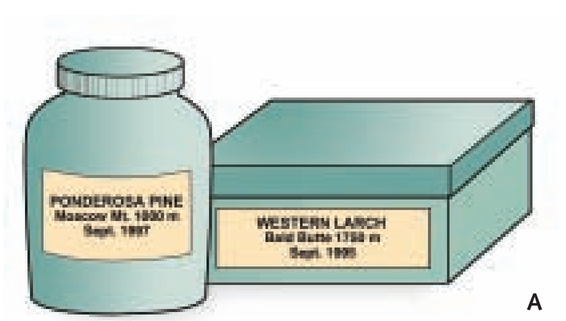

Figure 2.18 *Store seeds in an airtight container in a cool, dark room, a refrigerator, or a freezer. Label the container with the name of the species, collection location, elevation, date collected, and other important information (A). If you use a cardboard box, put seeds, like these* Pinus eldarica*, inside a ziplock-type bag before placing them into the box (B).*

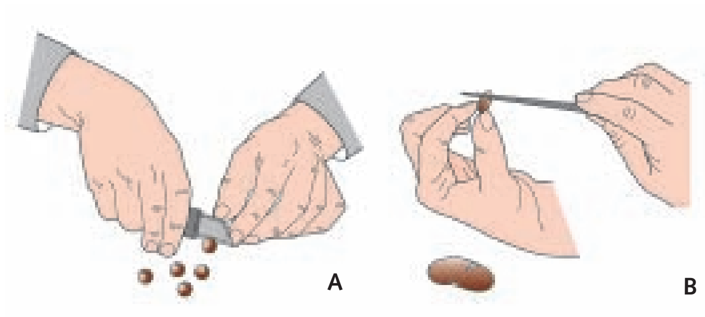

Figure 2.19 *Large seeds can be scarified by nicking them with a knife (A) or using a file (B) to abrade the seedcoat.*

stored at room temperature age faster than those that are frozen. Ideally, room temperature storage should only be used on seedlots that are stored for a short time. Seed moisture content for room temperature storage should be lower than that for seeds stored at low temperatures. Seeds must be placed in airtight containers and stored in a cool, dark room with low relative humidity. Keep seeds as cool as possible to retain their health.

2.3.5 Treating Seeds before Planting

As will be discussed in the following sections, seeds of most temperate species require exposure to specific environmental conditions before they will sprout (germinate) and grow. Often nursery managers will sow seeds in autumn, exposing them to warm autumn temperatures and cold winter temperatures. This natural cycle prepares seeds to germinate. This practice comes with risks. Seeds may be eaten by birds and rodents. Extreme weather conditions, like an intense rain storm, may wash away seeds. Seeds may be damaged in early spring by unexpected cold temperatures. For these reasons, many nursery managers choose to expose their seeds to particular temperatures under controlled conditions, and then sow the treated seeds in spring. This minimizes losses to animals and weather.

2.3.5.1 Seed Dormancy

Seed dormancy is an adaptation that ensures seeds will germinate only during the time period that is favorable for survival. Seed dormancy can be highly variable among species or among seed sources of the same species.

Nondormant seeds can germinate immediately upon maturation and release from the parent plant. (see page 11). The time required for nondormant seeds to germinate, however, is variable. Some species may germinate immediately (*Salix* and *Populus*) while others may take up to a month (*Quercus*).

Dormant seeds will not germinate immediately upon maturation and release from the parent plant, even when proper environmental conditions exist. Dormant seeds may take a long time before they will germinate. Dormancy may be caused by factors inside (internal) or outside (external) the seeds. Some species have a combination of internal and external dormancy factors. This condition is termed double dormancy.

Internal dormancy is caused either by underdeveloped embryos or by the need for a particular set of metabolic processes to occur. If dormancy is caused by immature embryos, a period of proper environmental conditions is needed to allow the embryo to mature. This period is often called "after-ripening." Internal dormancy can often be alleviated by exposing seeds to a period of warm, moist and (or) cold, moist conditions. Sometimes, holding seeds in dry storage for a period of time can alleviate dormancy. As indicated above, some species may require a combination of conditions. Often, these treatments may require extended period of times. *Prunus persica* is an example of a species with internal dormancy needing stratification (defined in the next section) before it can germinate. *Fraxinus floribundus* is an example of a species requiring a warm, moist treatment (probably as an after-ripening treatment) followed by stratification before it can germinate.

External dormancy is usually caused by hard, thick seedcoats that prevent water from moving into the seed. Depending on species, various environmental factors cause these seeds to become permeable during a certain time of year, or after several months or years. In nurseries, scarification is any process that modifies seedcoats so that water can enter seeds. Scarification is discussed more later in this section. *Cercis griffithii* is an example of a species with an impermeable seedcoat.

2.3.5.2 Seed Treatments

Exposing seed tissue to clean water is the first step for planting seeds in the nursery. Clean water must enter seeds to begin the metabolic processes that lead to germination. Nondormant seeds and seeds with internal dormancy can simply be exposed to water as described below. Seeds with external dormancy must be scarified to amend the seedcoat to allow water entry.

Scarification of seeds in nature occurs during exposure to fire, extreme temperatures, digestive acids in the stomachs of animals, microorganisms, or by abrasion of blowing sand or ice. Some examples include *Acacia, Cercis, Gleditsia, Robinia* (see Appendix 6.1). Other native species that inhabit desert environments may benefit from scarification.

Seeds can be scarified many ways. Mechanical scarification and hot water scarification are the two easiest methods. Efficacy of the methods depends on species and thickness of the seedcoats. Whichever method is used, it is very important not to damage the tissue inside the seeds. Therefore, take time to learn the anatomy of the seeds and record results in order to determine the best method for particular species and seed sources.

Mechanical scarification is used mostly on large seeds. The seedcoat is filed or nicked with a knife or metal tool on the side of the seed away from the embryo (Figure 2.19). Although effective, this method is time consuming. It requires that nursery workers be precise so that the seedcoat is scarified without damaging the seed. Sandpaper can be used to scarify smaller seeds, but the degree of scarification achieved can be variable.

Using hot water to scarify seeds works well for many species. This technique provides a rapid, uniform treatment and results can easily be seen within a few hours. Depending on species, this treatment can be done two ways. The first method is to add seeds to boiling water for a few seconds and then transfer them to a vat of cold water. The second method is to add seeds to boiling water and then immediately remove the boiling water from the heat source, allowing the water to cool over time. Either way, if seeds have been scarified they will enlarge while soaking in the cool water. It may take a few hours to a day to see noticeable swelling. If the seeds do not swell, then the seeds will need to be treated again. It is best to test the scarification process on small samples of seeds using both techniques for different durations of time. In addition, some species cannot tolerate excessively high temperatures, so testing seeds in 70 °C water first is a good idea.

Box 2.5
DAMPING-OFF

Sprouting seeds are very susceptible to diseases. Nursery managers generally refer to most of the diseases that infect very young seedlings as "damping-off," and damping-off can be caused by fungi, chemicals, or even high temperatures. When fungi cause damping-off, seedlings usually topple over at the soil surface and have dark, discolored roots (Figure 2.20). Generally, when seedlings damp-off because of chemical damage or heat injury, the root remains white. Damping-off is most serious on seeds that take a very long time to germinate, seeds that germinate during periods of cold and wet weather, and when seeds receive too much irrigation. Reduce damping-off by using clean seeds and well-drained soil. If damping-off is particularly bad, do not use any nitrogen fertilizer as this worsens disease. Remove dead and dying seedlings immediately to help prevent infection of other seedlings; do not leave them in a pile where diseases may build up and infect your remaining seedlings—either burn them or bury them.

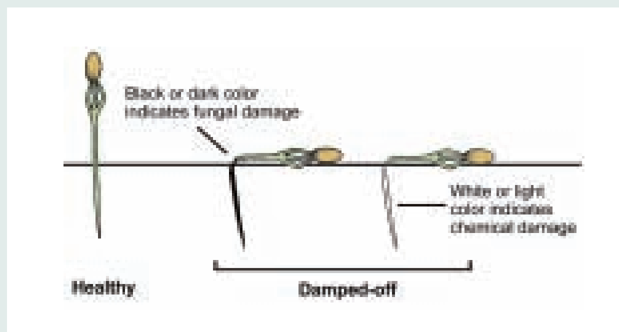

Figure 2.20 *Typical healthy and damped-off conifer seedlings. Damped-off seedlings usually topple over at the soil surface.*

Box 2.6
PREPARING SEEDS FOR PLANTING

— If necessary, scarify seeds
— Soak seeds at least two days in running water
— Expose seeds to cold temperatures and moisture, either by fall sowing or stratification
— If stratified, check seeds often to ensure mold is not a problem
— After stratification, soak seeds one day in running water
— Surface dry seeds to facilitate handling
— Plant immediately

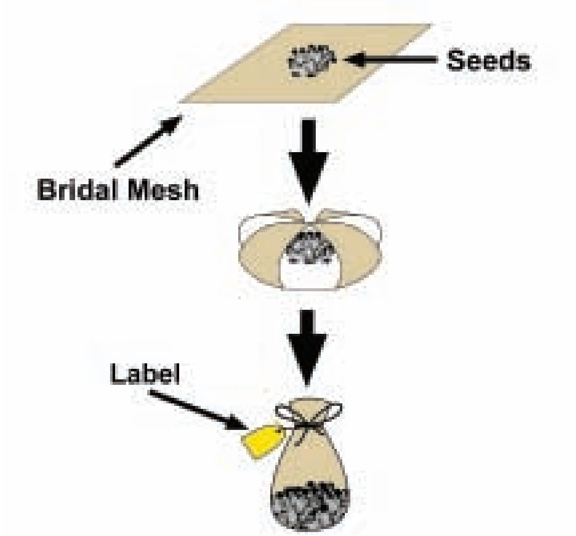

Figure 2.21 *Use mesh or cheesecloth to form a crude bag to soak and stratify seeds. Start with a square piece, add seeds, fold the corners toward the center and fasten with a twist-tie, making sure there are no holes. Do not forget to label it.*

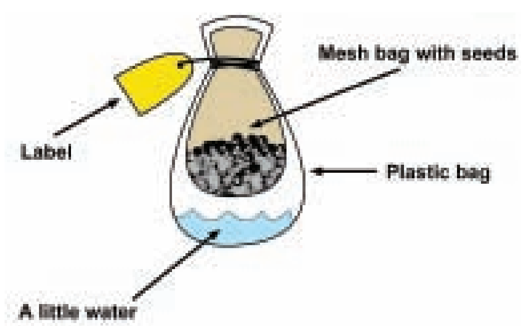

Figure 2.22 *Soaked seeds hung within a plastic bag and ready for stratification. The bag is tagged for identification. Put a little water in the bottom of the plastic bag to maintain 100% humidity around the seeds, but make sure seeds are not soaking in water.*

Soaking seeds in running water is necessary because seeds must have exposure to water and oxygen before they can germinate. Stored seeds usually have very low moisture contents, and must become fully hydrated before they can germinate, or before cold temperatures can effectively remove dormancy. To hydrate seeds, it is best to soak them in running water for one to several days. Just a trickle of water is needed. The continual movement of water helps remove any naturally occurring chemicals within or on seeds that prevent germination. In addition, the movement of water helps remove pathogens and can reduce need for fungicides in nurseries. If a source of running, clean water is not available, seeds can be soaked in clean water. Seeds may be soaked in clean water in a clean bucket, but the water should be changed regularly. If seeds are soaked 24 hours, the water should be changed at least two times. If seeds are soaked 48 hours, the water should be changed at least four times.

Seeds of some species often become moldy, even when rinsed in running water. Bacteria and fungi on seeds can be fatal. One common nursery disease is "damping-off" (see Box 2.5), which occurs during germination. Several seed cleansing techniques are used to prevent losses from disease. Seed cleansing is especially important for species that take a long time to germinate. Often, seeds are lost to disease before they complete a long after-ripening period and (or) long exposure to cold temperatures required for germination. Besides running water soaks, common household bleach and hydrogen peroxide can be used to cleanse seeds.

Seeds can be cleansed by soaking them in 3% hydrogen peroxide for up to four hours, or in a 40% bleach solution for 10 minutes. Mix two parts bleach (5.25% sodium hypochlorite) into three parts water for an effective treatment on *Pinus* and other large-seeded species. After the chemical soak, rinse seeds with lots of flowing water and then soak for 48 hours in a running water rinse. It is a good idea to test the cleansing treatment on a small sample of seeds to ensure the treatment will not kill the seeds. Species with very thin seedcoats, such as *Abies*, should not be cleansed with bleach.

Stratification is the practice of combining cold temperatures and moisture to mimic natural winter conditions that alleviate seed dormancy. Most dormant seeds require this cold, moist period before they germinate and grow. Historically, stratification meant layering seeds between moist strata of soil and exposing them to cold temperatures. Now, however, "stratification" is often used to describe any temperature treatment that causes metabolic changes. In this book, however, stratification will only refer to the historic cold, moist treatment. For most species, we can now use some shortcuts in the nursery.

During stratification, seeds are kept at temperatures of 1 to 5 °C for a period of time. Some species may only require a few days or weeks of stratification (*Cedrus*) while other species may require several months (*Prunus*). Different seed sources of a given species may break dormancy at different times during stratification. Sowing seeds in fall in bareroot beds and allowing them to be exposed to winter conditions is a form of stratification. Unfortunately, during winter, seeds can be eaten by pests and (or) washed away by rain. Warm weather in very early spring may stimulate germination that a late frost can kill. As a general rule, it is best to use the maximum length of time recommended to break dormancy (Appendix 6.1) and several ways to stratify seeds are described below. Another valuable, desired advantage to stratifying seeds is that it increases germination energy (how fast seeds germinate) and uniformity.

Seeds can be stratified several ways. A good way to start is by placing up to a kilogram of seeds onto a piece of square mesh fabric or cheesecloth. The ends of the fabric can be tied to form a crude bag. Make sure the cloth is large enough so the seeds have room to move and expand (Figure 2.21). Label it. Soak the bag of seeds in running water for 48 hours so the seeds can absorb sufficient water to start metabolic processes necessary for germination. After soaking, allow the bag to drip dry for a minute or so and suspend it within a plastic bag (Figure 2.22). If the species is prone to molding, open the bag, spread the seeds, and surface dry the seeds to barely remove the sheen of water from the seedcoat. Either way, then hang the bag in a refrigerator for the required time (Table 2.3; Appendix 6.1). If the seedlot is small an alternate method can be used. Stack paper towels about 3 to 5 mm thick (or use a moisture-retentive material like cloth or burlap for larger seeds) and moisten them completely. Drain off the excess water by holding the towels as shown in Figure 2.23. After soaking the seeds, place them about one layer deep and evenly on half the paper towel surface and then fold the paper towels over the seeds (Figure 2.24). Put the "sandwich" into a clear, plastic bag and refrigerate the required time (Table 2.3; Appendix 6.1).

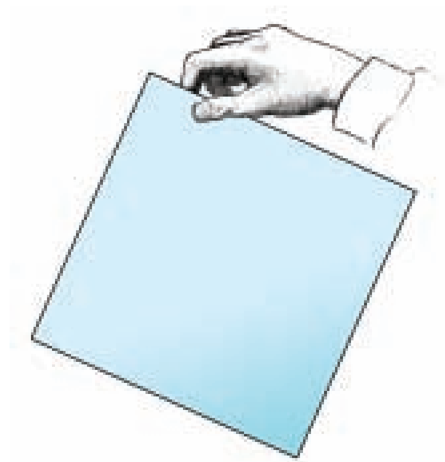

Figure 2.23 *Hold paper towels or other absorbent material by the corner until the excess water drips off. Too much water on the towels promotes mold and restricts oxygen movement to seeds.*

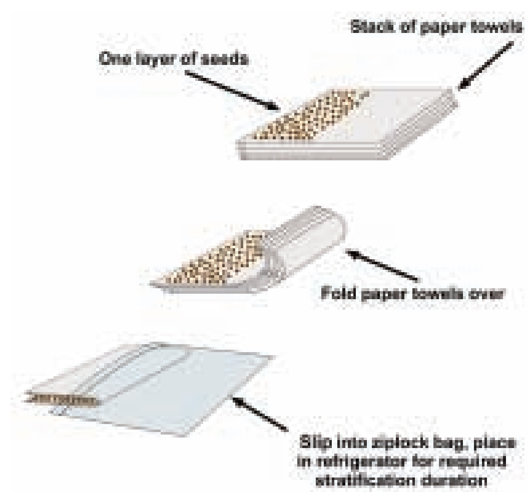

Figure 2.24 *Cover one-half of a stack of soaked paper towels with seeds. Fold paper towels over seeds and place into a plastic bag. Place into refrigeration for the required stratification period.*

Table 2.3
Stratification durations for four common conifers of Afghanistan. See Appendix 6.1 for more species.

Species	Days of stratification
Cedrus deodara	0 to 14
Pinus sylvestris	15 to 90
Pinus gerardiana	30 to 60
Thuja orientalis	0 to 14

Regardless of how seeds are stratified, it is important to check them often for mold. If mold is present, gently rinse the seeds in running water, surface dry them to barely remove the sheen of water from the seedcoat, and return them to the refrigerator. If paper towels are used, replace the moldy towels with fresh towels prepared the same way.

A few species have double, internal dormancy that is best removed through a combination of a warm, moist treatment followed by stratification. The warm, moist treatment enhances the after-ripening of seeds with under-developed embryos. *Juniperus* and *Taxus* are examples of species that often benefit from both treatments. The requirements and procedures for warm, moist treatment are basically the same as for stratification, except temperatures are increased to around room temperature (about 22 to 27 °C). Seeds can be handled as described above (bagged, soaked, seedcoats surface dried). Instead of going into a refrigerator, seeds for the warm treatment are kept in a dark area at room temperature. For some *Pinus* species, a two to four week period is probably sufficient, but *Juniperus* and *Taxus* seeds may require 15 to 20 weeks of warmth. (Because of the long warm treatment, bareroot growers should probably sow *Juniperus* and *Taxus* seeds in late summer or early fall [see 3.1.3.2, *Sowing and Germination*]). Once the warm period is over, seeds are transferred to a refrigerator to complete their stratification. Check often for mold since it can grow rapidly at the warmer temperatures. If your seeds begin to germinate during the warm, moist treatment, surface dry them until the seedcoats are dull, not glossy, and begin stratification.

If seeds begin to sprout before it is time to sow them, remove the seeds from stratification and gently spread them out to surface dry. Dry seeds until the sheen of water on the seedcoat disappears, then put the seeds back into a plastic bag and refrigerate—the reduced moisture content will greatly reduce the germination process.

After stratification, remove seeds from the refrigerator and re-soak them in running water for 24 hours. Soaking ensures the seeds have plenty of water to begin the germination process.

2.3.6 Germination Testing

Germination tests provide information about how well seeds will sprout. Knowing how well seeds germinate allows more efficient use of seeds, and production of higher-quality seedlings. The most basic test of seed viability is a "cut test." A sample of seeds is cut in half to determine if the seeds are full and the tissue looks healthy. To know how well seeds will germinate, however, a germination test is required. Germination tests usually start by stratifying seeds. Some species may not require stratification for germination (*Picea*, some *Pinus*, and some *Cedrus*), and a non-stratified germination test should be included as well. A germination test uses 100 to 400 seeds.

After stratification, rinse seeds 24 hours in running water. If the test includes non-stratified seeds, rinse them at the same time, but for 48 hours. Divide the test seeds into four groups. Stack paper towels about 3 to 5 mm deep and moisten them completely. Drain off the excess water by holding towels as shown in Figure 2.23. Put the paper towels into a clear plastic container, or a shallow metal pan. Spread the seeds evenly over the towels, maintaining each group. Close the plastic lid or place a piece of glass on top of the metal pan and place the container in a location with room temperature and out of direct sunlight. Every five days thereafter, count seeds with primary roots at least as long as the seedcoat, and remove them from the test (Figure 2.25). After 30 days, average the counts from the four groups to get the percentage germination. Another

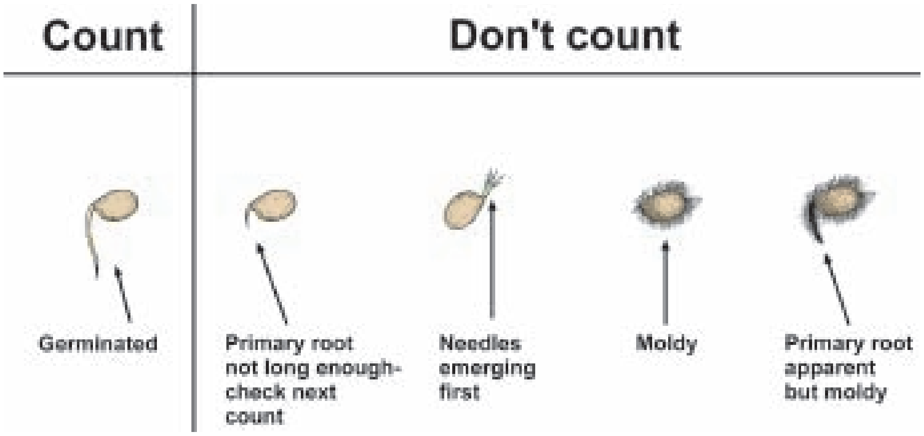

Figure 2.25 *When checking a germination test, do not count seeds as germinated that have primary roots shorter than one-half the length of an individual seed, have needles emerging rather than roots, or are moldy.*

value that can be obtained is germination energy (speed). Germination energy tells how rapidly seeds germinate, and is usually given in days. Of the total number of seeds to germinate, check to see by what day 50% had sprouted. Ideally, most will germinate in the first 10 to 21 days or sooner. If not, seeds may need a longer stratification. Keep detailed notes for future reference.

3.0

Growing Trees

Seedlings and cuttings can be grown two ways—in the ground or in containers. Both methods have advantages and disadvantages. Because the techniques for growing seedlings and cuttings are the same (except for the propagule you start with), this section will focus on seedlings. In general, seedlings in the ground (bareroot seedlings) grow slower than seedlings in containers (container seedlings), especially when containers are in a greenhouse or sheltered growing area.

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 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 3.2 for determining your soil texture). Avoid soils with a claypan, hardpan, numerous rocks, or bedrock within a meter of the surface. The soil should have a pH between 5.0 and 6.0. Techniques to amend marginal soils will be discussed later.

The best sites are on 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, soils with 40% or more sand are best because: 1) seedlings must be harvested during winter dormancy, and 2) removing seedlings from sandy soils does not damage fine roots as badly.

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

Box 3.1
GROWING BAREROOT SEEDLINGS—AN OVERVIEW

— Select a good nursery site—good sites are mostly level, have well-drained soils, and access to abundant, clear water
— Prepare the site—determine how much production area is needed, till the soil, test and adjust soil pH
— Treat seeds to enhance germination
— Sow correct number of seeds using germination test results
— Sow seeds at the correct density and protect from predators and erosion
— Keep seeds moist but do not overwater
— After germination, adjust density if necessary
— Control weeds
— Consider applying mulch to conserve water and reduce weeds
— Fertilize and irrigate to encourage desired growth
— Prune roots to encourage fibrous root systems
— Lift (harvest) seedlings gently to minimize damage to roots
— Keep roots moist
— Transplant if necessary
— Store and ship properly
— Add soil amendments before planting the next crop

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

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 be forced out of the ground by repeated freezing and thawing of the surface layer of soil.

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

Good nursery sites require close access to clear, clean, abundant water. They also 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 large trees exist near seedbeds, competition can be controlled by trenching one meter deep between the trees and the nursery. Windbreak trees planted near nurseries should be a different species than crop seedlings because older trees may harbor insects and diseases harmful to nursery seedlings.

3.1.2 Site Preparation

How big a nursery site is needed? It depends on how many seedlings will be grown, what species are grown, and how long those seedlings will be grown. In Afghanistan, seedlings are grown in single rows, double rows, and occasionally up to four rows per "bed" (Figure 3.3). If seedlings, such as *Pinus* or *Malus*, are grown the first year every 5 cm within a row, and rows are 20 cm apart, a square meter of nursery could grow about 400 plants. For species such as *Juglans* or *Prunus*, seeds might be sown every 10 cm within a row but rows might be 80 cm apart. Therefore, the same nursery area (one square meter) would only yield about 50 seedlings. So, if 10,000 *Pinus* seedlings were desired, and those seedlings were sown in a double row, with 5 cm between seeds and 20 cm between rows, 25 square meters of nursery would be needed (four seedlings every 100 square cm [5 cm x 20 cm spacing] equals 400 seedlings per square meter; 10,000 seedlings divided by 400 seedlings per square meter = 25 square meters). Plan on adding about 50% more space for walkways between beds.

Soil should be thoroughly tilled at least 25 cm deep the year before sowing seeds. If the site was recently cultivated and is free of heavy grass and weeds, one tillage in autumn is sufficient. That tillage should be followed by fine disking and harrowing, spading and raking, or rototilling just before sowing the beds.

If the nursery site has not been recently cultivated, the soil must be deeply tilled a full year before establishing seedbeds. Remove debris such as roots, rocks, wood chunks, and other foreign matter. This should be followed by summer fallowing (repeated cultivation) to break down heavy organic matter and control new growth of grass and weeds. Herbicides may be needed to remove persistent, deep-rooted plants.

Drainage problems can be corrected by ditching, leveling, burying drainage tile, and (or) raising the seedbeds at least 45 cm above the extreme high water table. During any work, protect the topsoil. All soil productivity is in the topsoil.

If the nursery is on an otherwise good site but the soil is marginal, the soil can be modified with large quantities of amendments. Either till into the nursery soil sandy loam soil or organics. Organic matter, like compost, aged sawdust, or well-composted manure, can improve water retention, tilth, and fertility. Adding organic amendments and (or) coarse sand to heavy clay loams will improve drainage, texture, and fertility. Any amendment should be about 10 cm deep on top of the soil and tilled into a depth of 15 cm (see 3.1.6, *Soil Management*).

Soil should be tested for pH. Soils with pH under 7.0 are considered "acid" while those over 7.0 are considered "basic." A good nursery soil for conifer seedlings has a pH between 5.0 and 6.0. If the soil pH is too basic (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 the soil.

Box 3.2
SOIL TEXTURE

Judge the relative amounts of sand, silt, and clay in a soil through a simple test. Pour dry soil into a glass jar to a depth of 10 cm. The volume of the jar should be twice that of the 10-cm-deep layer. Fill the jar almost full 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 the soil. For example, after settling, a soil with 2 cm of clay, 4 cm of silt, and 4 cm of sand (20% clay, 40% silt, 40% sand) would be a "loam" soil.

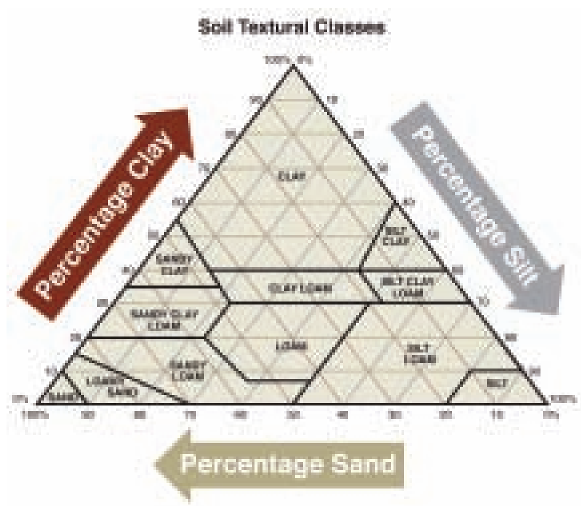

Figure 3.2 *After using the technique described in the box, use this soil texture triangle to find the intersection of the amounts of sand, silt, and clay in the soil.*

3.1.3 How to Grow Seedlings

Generally, it takes two years to grow seedlings large enough for outplanting. Larger trees for landscaping can take much longer. Some slow-growing species may take three or four years. For reforestation, most seedlings are grown two years in the same

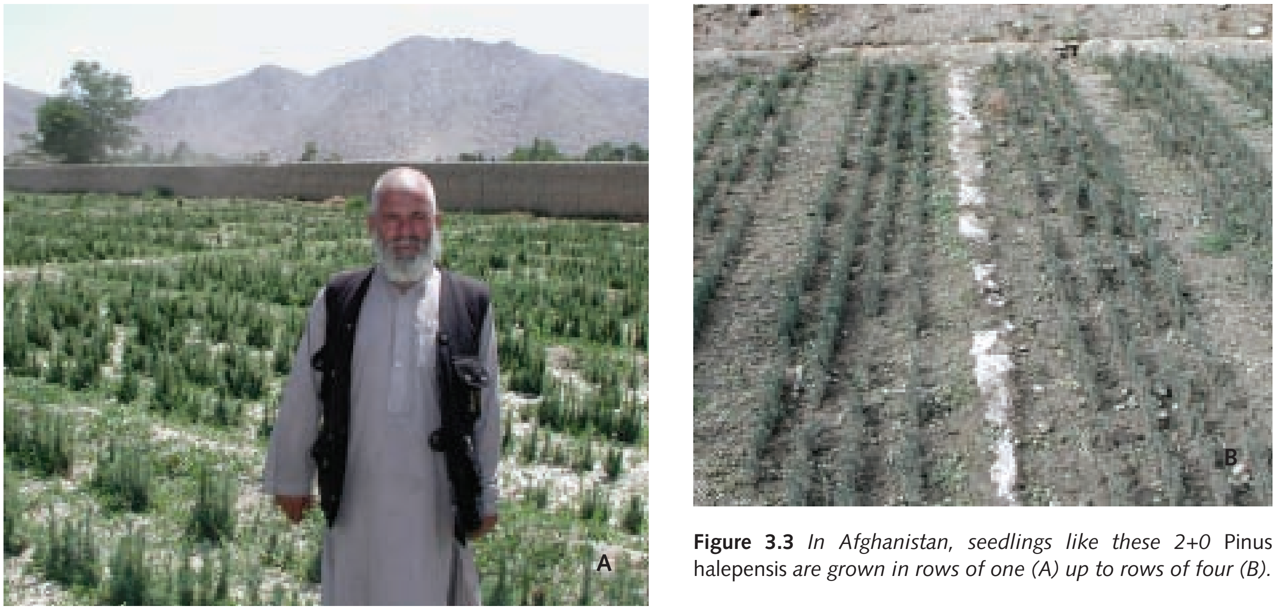

Figure 3.3 *In Afghanistan, seedlings like these 2+0* Pinus halepensis *are grown in rows of one (A) up to rows of four (B).*

nursery bed. These are called 2+0 seedlings because they grew two years in the same bed plus zero years in a transplant bed (Figure 3.3). Huskier seedlings can be grown by transplanting 2+0s into another bed for an additional year. These seedlings would be called 2+1s (two years in the seedbed plus one year in a transplant bed). For most species for reforestation, 2+0 seedlings are sufficient. Seedlings grown longer, that is, 2+1, 2+2, or 2+3, often have very large tops but insufficient root mass to support those tops. On dry planting sites, it is better to have short shoots, thick stem diameters, and large root systems.

3.1.3.1 Fertilizers—"Organic" versus 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. These nutrients are commonly supplied through fertilizers. Nitrogen 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 seedlings with either "organic" fertilizers (manure, compost, kelp) or man-made fertilizers available. Organic fertilizers have low percentages of N:P:K; N ranges from 0.5% to 1.5% in manure and 2% to 4% in composts. Man-made fertilizers have much higher concentrations of N, ranging up to 33% or more. Organic fertilizers, such as manure and compost, are associated with lots of decomposing organic matter and microorganisms (bacteria and fungi). Because 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 do not supplement organic matter, it should be added by nursery managers.

Fertilizer can be applied to seedlings two ways: incorporated into the soil or spread over the top of the crop (topdressed). The application technique depends on the solubility of the fertilizer. Nitrogen and K fertilizers are water-soluble so they can be topdressed because 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.

Overfertilization is a common mistake. It is better to put slightly too little fertilizer on a crop rather than too much. The label on any man-made fertilizer always shows the percentages of N, P, and K, and always in this order: N:P:K. (Well, that is not completely true, and this can be complicated, as shown in Appendix 6.2). The easiest way to apply fertilizer is to use a whirlybird-type spreader or a drop-type spreader. With these devices, or even using a cup and spreading fertilizer by hand, the important thing is to spread the fertilizer evenly across the bed. The actual fertilizers to be applied, and the rate of application, will vary by species and location. A generalized plan is provided in Appendix 6.2. If fertilizers are applied over the top of growing seedlings, the fertilizers should be washed off the foliage immediately to prevent damage and to move it into the ground so roots can absorb it.

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) and basic soils with pH over 6.0 (Appendix 6.2.2).

3.1.3.2 Sowing and Germination

After incorporating fertilizer and (or) adjusting soil pH, make sure your nursery bed is smooth and level. Beds should be no more than a meter wide and raised about 8 to 15 cm. Raising beds promotes drainage and soil-warming. Soil should be moist but not wet because saturated soil promotes damping-off and root diseases.

Sow seeds in rows or by broadcasting. Either way, the objective is to have enough seedlings per area to achieve good seedling growth without causing too much competition among seedlings. If seeds are broadcast sown (Figure 3.4), 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 the within-row distance between seeds is managed, but it is worth it—seedlings in rows are easier to weed, root prune, and harvest. Seedlings in

Figure 3.4 *Broadcast sowing seeds is a quick way to plant seeds. Unfortunately, because seeds, and subsequently seedlings, are not evenly distributed, it is much more difficult to weed, root prune, and harvest seedlings.*

rows are usually more uniform, nicer looking, and healthier. For conifers, apples, and pears, rows are usually 20 cm apart for 2+0 seedlings with a desire to have a seedling about every 5 cm within the row. An easy way to sow in rows is by using a marking board (Figure 3.5). Based on the germination percentage, seeds should be sown so that about 400 seedlings will grow per square meter (Table 3.1). For *Juglans* and apricots, peaches, and other fruit trees, the desired density is about 50 seedlings per square meter (80 cm between rows and 10 cm between seedlings within a row. Walk-behind precision seeders also work well (Figure 3.6).

Seeds may be sown in autumn, allowing them to stratify under natural conditions. Autumn sowing can be particularly advantageous for species that required some warm, moist treatment before stratification (*Juniperus*, *Taxus*, and some *Pinus*). Autumn-sown seeds must be protected from predators, especially mice (see page 29), and from drastic variations in temperature. To moderate weather, seedbeds should be mulched. A 5-cm-thick layer of straw works well, but must be removed in spring to allow germination.

Regardless of when or how seeds were sown, seeds should be "barely" covered by a thin (3 to 5 mm)

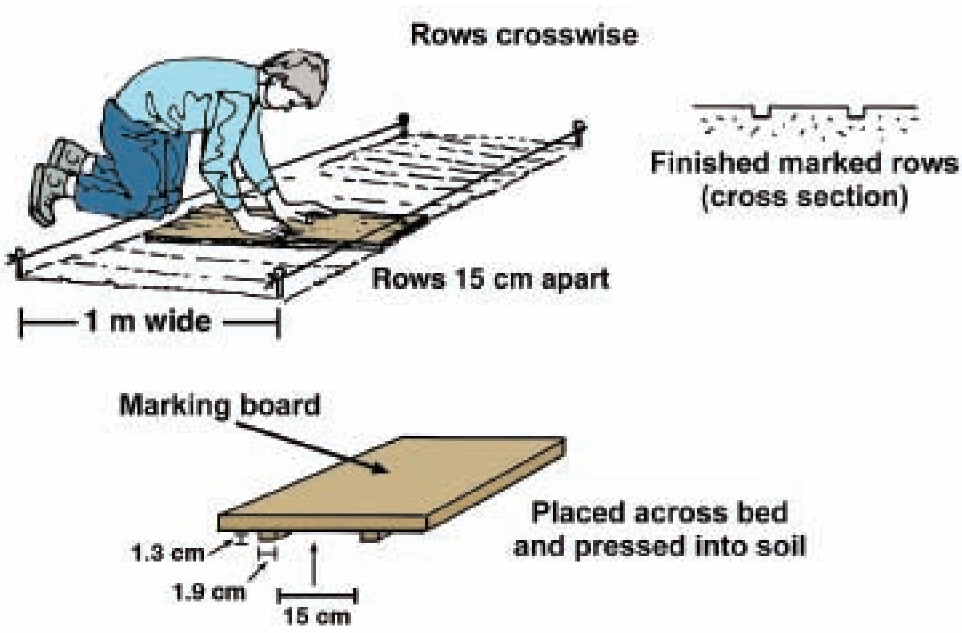

Figure 3.5 *A marking board can help plant seeds in straight rows with proper spacing.*

Table 3.1

Based on germination percentage of a seedlot, assuming that 10% more seeds will be sown to compensate for losses, and that rows are 20 cm apart, this table provides an estimate of how many seeds to sow per square meter and how far apart those seeds should be in each row.

Germination percentage	Seeds to sow per square meter	Seeds to sow assuming a 10% loss during the first year	mm between seeds within rows
80 to 100	500 to 400	550 to 440	36 to 45
60 to 80	670 to 500	740 to 550	27 to 36
40 to 60	1,000 to 670	1,100 to 740	18 to 27
20 to 40	2,000 to 1,000	2,200 to 1,100	9 to 18

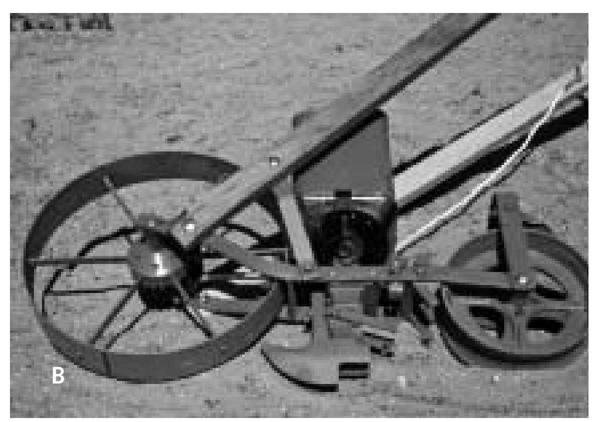

Figure 3.6 *(A) A walk-behind seeder, like this Planet Junior seed drill, can expedite sowing. (B) The guide wheel (left) is followed by the "shoe" that makes the furrow. Seeds fall from the hopper above the shoe, and the rear wheel (right), covers the furrow.*

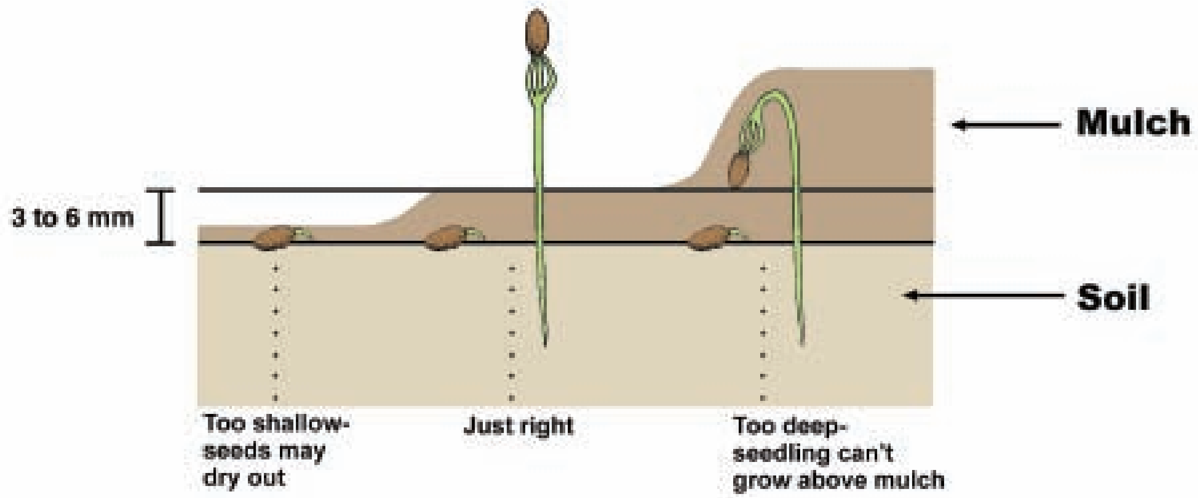

Figure 3.7 *Make sure to sow at the right depth! If the mulch layer is too shallow, seeds may dry out, and if mulch is too deep, seedlings may not be able to emerge above it.*

mulch of pine needles, sawdust, fine-screened bark (3-mm diameter), sand, very fine gravel, or screened garden compost (only use the fines). Mulch should be no more than 2X the thickness of the seeds, and it will prevent seeds from drying out. ***Sowing seeds too deep is a common and serious mistake*** (Figure 3.7).

Newly sown seeds should be protected from pests, especially mice and birds. Covering seedbeds with mesh, elevated 15 to 30 cm above the soil but extending to the soil around the edges, will minimize losses to birds. If the mesh is small enough, this will also exclude mice and help prevent wind and water erosion. Keep the area around seedbeds free of weeds and debris to eliminate hiding places for mice and other pests. Water sparingly at first, but do not let the soil dry out.

3.1.3.3 Young Seedlings—
Establishing Your Crop

About a month after germination, check seedling densities. If too many seedlings are growing per square meter, they should be thinned to the target sowing density. This ensures healthy seedling growth. Discard thinned seedlings by composting, burning, or burying them to prevent possible spread of disease.

Diligently remove weeds before they grow large and interfere with seedling growth. Good weed control everywhere on the nursery will diminish the number of weed seeds sprouting in the nursery beds.

As seedlings grow, maintain a good mulch layer (5- to 10-mm-thick). Mulch reduces watering needs, keeps soil cool, prevents soil from splashing onto seedlings, and helps retard weed growth (Figures 3.8 & 3.9). Seedlings should be watered to keep soil evenly moist. In summer, allow the soil surface to dry down between watering. This practice helps condition seedlings for winter.

Seedlings can be inoculated with mycorrhizal fungi or *Rhizobium* bacteria (Figure 3.10), beneficial microorganisms found on roots of trees. There are two types of mycorrhizae: endo- (inside) mycorrhizae grow inside roots and are not visible with a naked eye, and ecto- (outside) mycorrhizae that grow inside and outside of roots and are visible with a naked eye. Generally, ectomycorrhizae are associated with conifers, whereas endomycorrhizae are associated with angiosperms. *Thuja*, however, have endomycorrhizae. Most legumes have *Rhizobium*. In spring, spreading some forest duff (decomposing foliage, twigs, and so on), collected from beneath mature trees, will act as mulch and inoculate seedlings at the same time. There is potential danger here, as diseases can be introduced to the nursery. Therefore, collect only the dark, mostly

A GOOD MULCH . . .

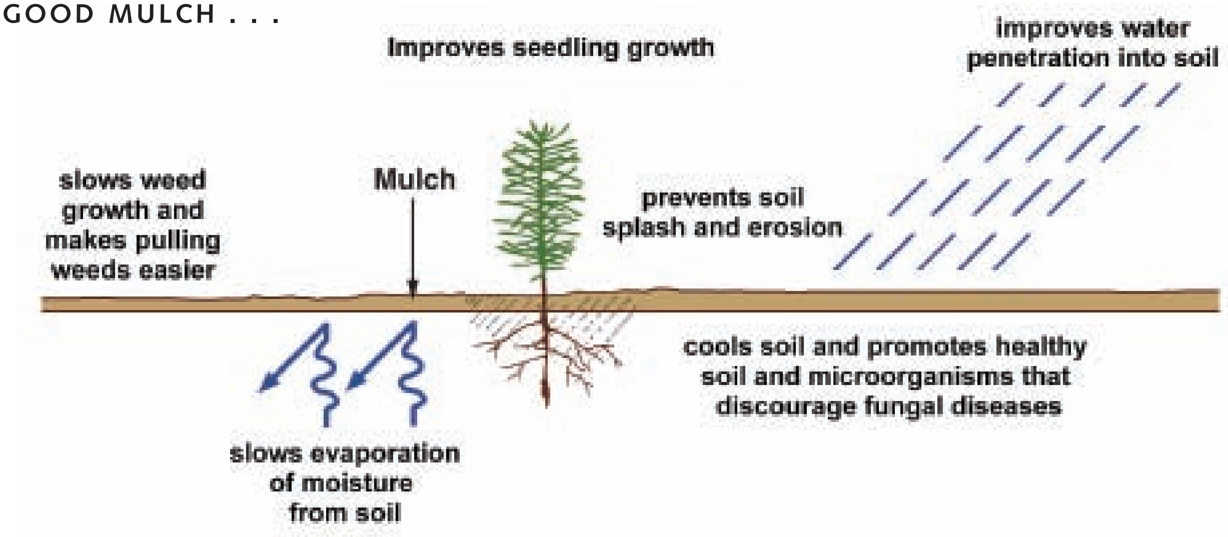

Figure 3.8 *Use mulch to grow a healthier crop with less water and less weeding.*

Figure 3.9 *Without mulch, rain drops and irrigation water can splash soil onto seedlings. These seedlings are almost completely encased in splashed soil.*

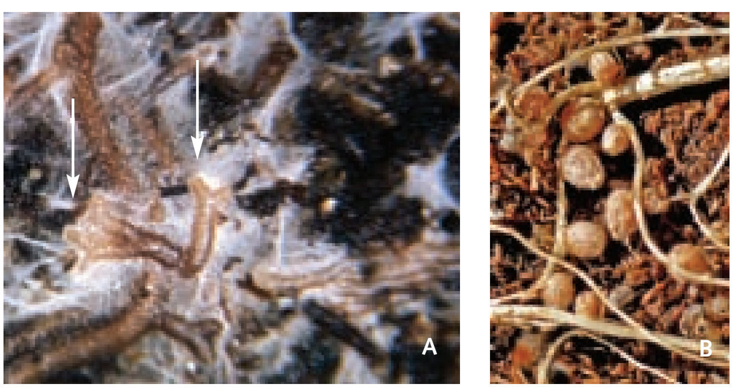

Figure 3.10 *(A) Ectomycorrhizae on seedling roots are often easy to spot. Look for swollen root tips that are often "Y-shaped" with lots of fine, fuzzy, mycelium (root-like structures). (B) Rhizobium occur in round nodules that form on the roots. Healthy nodules are usually pink on the inside.*

decomposed (cannot recognize plant parts anymore), rich-smelling portion of the forest floor (humus layer). This will ensure microorganisms are introduced while greatly reducing the possibility of other diseases. If the nursery is near the forest, enough natural inoculum is probably present. Even if seedlings are not inoculated, seedlings generally become infected soon after outplanting on a forest site. Remember, mycorrhizae will make a good seedling better, but they will not make a poor seedling a good seedling.

3.1.3.4 Watering

Once seeds germinate, the basic philosophy for watering seedlings is to water deeply and infrequently (Figure 3.11). When watering, moisten the entire seedling root zone. Keep the nursery soil evenly moist— use a small hand trowel to see if the soil is dry or moist. It is usually best to irrigate early in the day.

Seedlings can be watered with furrow irrigation or by a sprinkler system. In a furrow system, allow the water to run until, using a trowel to monitor, water has infiltrated into the nursery bed to the proper depth (Figure 3.12).

Seedlings can be watered with sprinklers many different ways, from low-technology to high-technology systems. For very small nurseries, the easiest technique is a watering can or using a garden hose with a soft-spray nozzle. For small nurseries, an oscillating yard sprinkler hooked up to a hose works well, provided you check its output over the entire nursery bed—all areas should receive adequate amounts of water. For larger nurseries, a fixed irrigation line with systematically spaced nozzles works very well. Such a system will provide a more even irrigation, yielding more uniform seedlings and probably wasting less water. Fixed-line systems can be placed in exact locations and put on timers to use water most efficiently. For any sprinkler system, check the output from any nozzle by systematically placing small jars or cans throughout the bed (Figure 3.13). Run the sprinkler system for a known time, and then measure the amount of water in each collection vessel. Using a trowel, see how deep the water has infiltrated into the nursery bed. Then, knowing how long the system operated to achieve adequate watering, the system can be put 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, but less than a furrow system.

3.1.3.5 Root Pruning

Root pruning promotes a fibrous root system. Root pruning facilitates harvesting seedlings. Remember, only seedlings in rows can be root pruned efficiently—it is nearly impossible to root prune broadcast sown seedlings. Prune 2+0 seedlings at a depth of about 20 cm during autumn of the first growing season. The easiest way to do this is to use a sharp tile spade or shovel. Slice in on an angle under the rows of seedlings (Figure 3.14). Cuts may need to be angled from both directions to ensure seedlings are fully undercut. During the second growing season, prune lateral roots 2 or 3 times, first in late spring and the last time in late summer (Figure 3.15). Lateral pruning keeps roots of seedlings in one row from intertwining with roots of seedlings in another row. Lateral prune by using a sharp tile spade or shovel and slicing 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

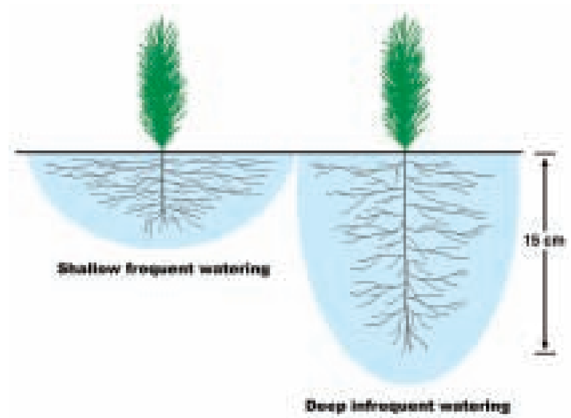

Figure 3.11 *Water deeply and infrequently to encourage deep root growth. Shallow, frequent watering encourages shallow rooting and makes seedlings more susceptible to drought.*

Figure 3.12 *Using furrow irrigation at Guzar Gha Nursery near Kabul.*

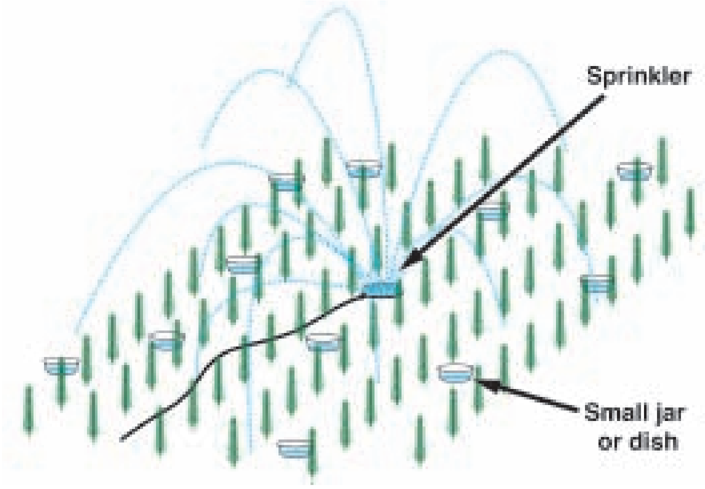

Figure 3.13 *Use small jars to check the water distribution of an irrigation system, even if you water by hand. Managers must know how well irrigation water is distributed to ensure that all nursery beds receive adequate water.*

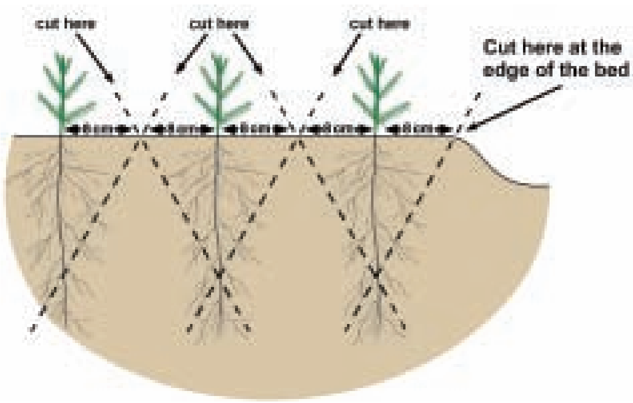

Figure 3.14 *Use a sharp spade to undercut seedlings. Make sure to push the spade in on an angle. Spade in both directions to ensure proper undercutting.*

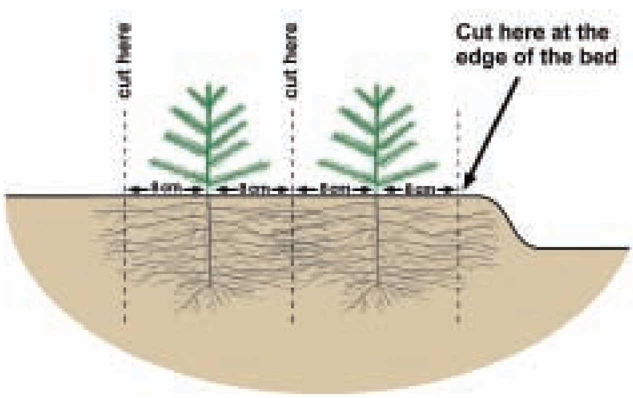

Figure 3.15 *Prune lateral roots to keep seedling roots from intertwining between rows. Preventing roots from intertwining will allow for easier harvesting with less damage to seedlings.*

root-pruned with the same timing and frequency of 2+0s but at a depth of 25 to 30 cm.

3.1.4 Lifting, Handling, and Storage

The process of digging seedlings out of nursery beds is called "lifting" or "harvesting." Lifting should be done when seedlings are dormant, either late autumn, winter, or very early spring before new growth starts. Dormant seedlings handle stresses of lifting, storage, and planting better than nondormant stock—the result being better planting survival and growth. Using a garden fork, seedlings for reforestation should be *gently* dug from moist ground and the soil *gently* removed from their roots while preserving the fine roots (Figure 3.16). Ideally, seedlings should be immediately, and *gently*, put into boxes, plastic tubs, or buckets (Figure 3.17) for transport to the field. *Gentle handling is the key*. If that is not possible, a trench can be made in the soil and the seedling roots placed within the trench—the roots should then be covered with moist soil. When seedlings are transported to the field, 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. Plant seedlings as soon as possible. See Chapter 4 for more information.

Larger plants destined for urban landscapes can be harvested with a ball of soil around the roots. This helps protect the roots. The root ball should never dry out, and can be wrapped with burlap and twine for physical support during transport.

3.1.5 Transplanting

Larger seedlings can be grown by transplanting them after 1, 2, 3 or even more years in the nursery. Seedlings can be lifted as described above and replanted into another bed while they are still dormant. Usually, seedling density in a transplant bed is much less than in a seedbed. The actual density will depend on how often the seedlings have been transplanted (Figure 3.18). The resulting seedlings have bigger stem diameters and larger, more fibrous root systems. Care for transplants the same way you care for seedlings. Very large transplants can be harvested with soil retained around their roots—this is excellent for urban landscapes but less practical for reforestation. The ball of soil around the roots should be moist and wrapped with burlap to maintain the integrity of the root mass. If the soil dries out, the seedlings may die.

3.1.6 Soil Management

Between crops, add organic 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. Green cover crops should be cut and tilled into the soil while green. Other good organic amendments include compost, manure, straw, fine-screened bark, shredded leaves, and peat. The layer should be 7 to 10 cm deep, and incorporated into the soil to a depth of 15 to 20 cm. With amendments such as fresh sawdust, straw, leaves, bark, and manure, extra N should be added at a rate of 2.5 to 5 kg per 900

Figure 3.16 *The fine, wispy root hairs are the portion of the root where water and nutrients enter seedlings.*

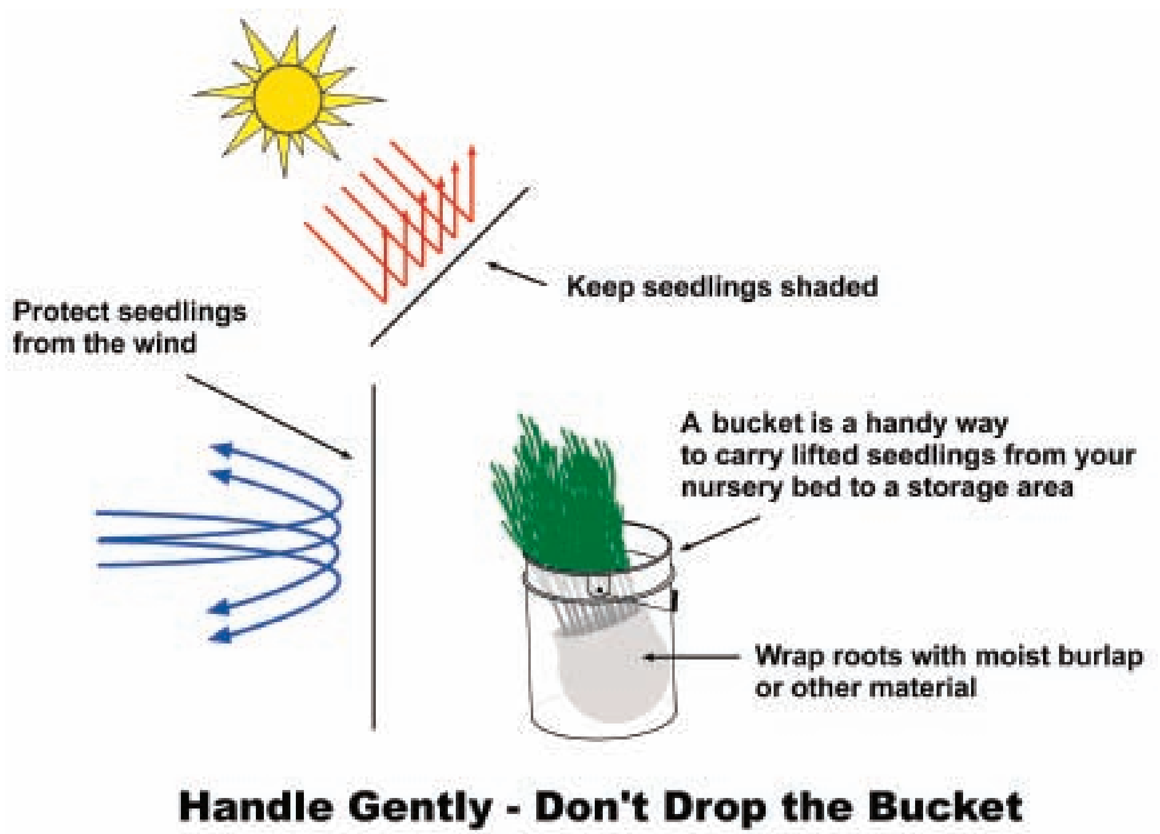

Figure 3.17 *Handle seedlings gently. Remember to keep roots moist at all times.*

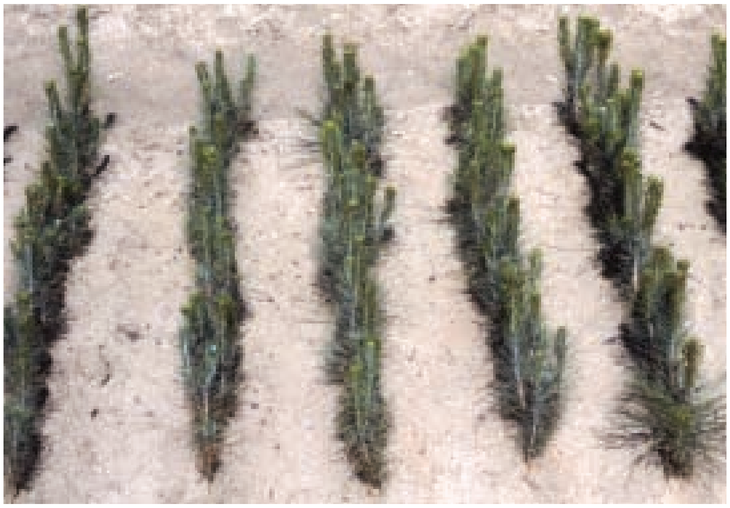

Figure 3.18 *A nice-looking bed of transplants.*

Box 3.3
GROWING CONTAINER SEEDLINGS—AN OVERVIEW

— Select a good nursery site—good sites are mostly level, have well-drained soils, and access to abundant, clear water
— Select an appropriate container
— Mix an appropriate medium
— Carefully fill containers—do not compact the medium
— Treat seeds to enhance germination
— Sow correct number of seeds using germination test results
— Protect seeds from predators
— Keep seeds moist but do not overwater
— After germination, thin to one seedling per container
— If possible, elevate containers to encourage air-pruning of roots
— Control weeds
— Fertilize and irrigate to encourage desired growth
— Use container weights to avoid applying too much irrigation water
— Once seedlings reach target size, begin hardening process—allow plenty of time to harden the crop
— During winter, protect roots from frigid temperatures
— Never hold plants over from year to year in the same container
— Clean containers before reusing

kg of amendment. Otherwise, soil microorganisms that decompose the amendments will use all available N in the soil, leaving little available for 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. Or, seedlings can be grown in polybags in outdoor growing areas. One big advantage of container seedlings is that they can be grown larger than bareroot seedlings in less time. Unfortunately, they can be killed a lot faster too!

3.2.1 The Growing Environment

Conditions necessary for optimum seedling growth change as seedlings mature. Professional growers who have a greenhouse or shadehouse 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. 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 is not mandatory. Greenhouses, plastic-covered cold frames, hotbeds, and similar facilities work well (Figures 3.19 to 3.21). 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 during germination and the first weeks of seedling growth.

3.2.1.2 Media

Garden or nursery soils are generally too heavy and lack sufficient pore space to grow a good container seedling. Mixtures of sand or pumice, soil, and compost will work fine in polybag containers. A common recommendation for polybags in Afghanistan is to use two parts organic matter (compost or dried animal manure) with three parts screened soil with one part sand. Another good polybag mix is one part sand with one part dried, composted animal manure. For smaller containers described in the next section, the medium must be soilless in order to provide sufficient porosity.

In many parts of the world, 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, such as perlite or vermiculite, are added to increase aeration within the container—usually 50% peat moss to 50% vermiculite mixture by volume. When peat moss is not available, a good compost will work well. The medium must have good drainage.

3.2.1.3 Containers

The best containers all have drainage holes in the bottom and vertical ribs on the sides (Figure 3.22). Vertical ribs prevent root spiraling. Hard-sided plastic containers come in a variety of sizes and shapes. 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. Some of the newer containers have slits cut in the sides or copper coatings to prevent root spiraling. When seedling roots reach the air slits or 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. Plastic containers that are round in cross section can be made useful by cutting vertical slits in the sides of the container.

One common type of container consists of individual cells housed in a block (Figure 3.23). These individual plastic containers come in different sizes and can be removed from the plastic block used to hold them upright and in groups. This type of container system has several advantages. The biggest advantage is that 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, such as *Abies*. Blank containers provide breeding places for pests. Also, seedlings will generally grow more uniformly if empty containers are removed.

Another common type of container is made from Styrofoam® (Figure 3.24). Each block of Styrofoam® may have from 8 to 240 containers in it, ranging in volume

Figure 3.19 *A wood-framed, fiberglass-covered structure for growing container seedlings. The front and roof panels can be opened on sunny days to reduce the temperature.*

Figure 3.20 *With a plastic (PVC) pipe or metal frame, structures can be covered with plastic in the spring and winter to protect seedlings (as long as you do not get much snow!).*

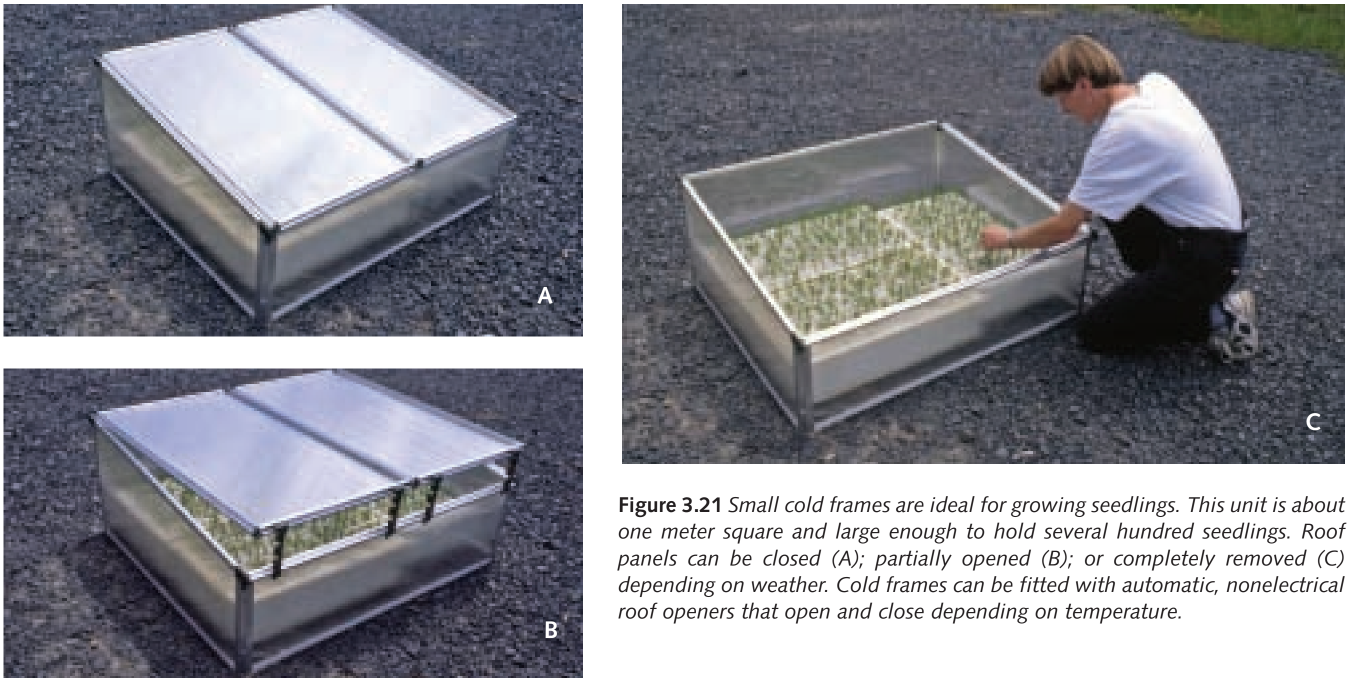

Figure 3.21 *Small cold frames are ideal for growing seedlings. This unit is about one meter square and large enough to hold several hundred seedlings. Roof panels can be closed (A); partially opened (B); or completely removed (C) depending on weather. Cold frames can be fitted with automatic, nonelectrical roof openers that open and close depending on temperature.*

from 40 cubic cm up to 3,200 cubic cm. These blocks are lightweight and easy to handle, but containers cannot be consolidated in the event of poor germination.

Polybags are another common type of container. These work well too, although roots can spiral within them (Figure 3.25). Newer polybags can be purchased impregnated with copper to reduce spiraling. Polybags have a large volume and can be heavy when filled with native soil. Using a soilless medium will reduce weight and conserve precious topsoil.

3.2.2 Sowing

3.2.2.1 Filling Containers

When filling, it is important to put a uniform amount of medium in each container. ***Do not compact the medium.*** 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. These problems increase seedling susceptibility 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 once or twice from a height of 15 cm onto a concrete floor works well. Then top-dress medium over the containers and

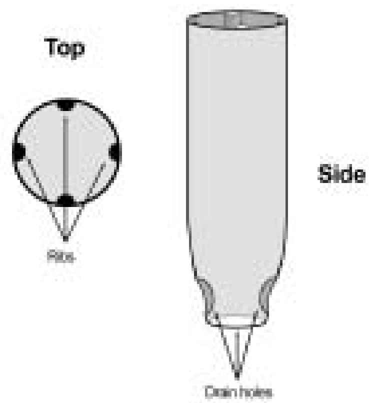

Figure 3.22 *Good containers for growing seedlings have ribs or slits in the sides to keep roots from spiraling, and least one drain hole in the bottom.*

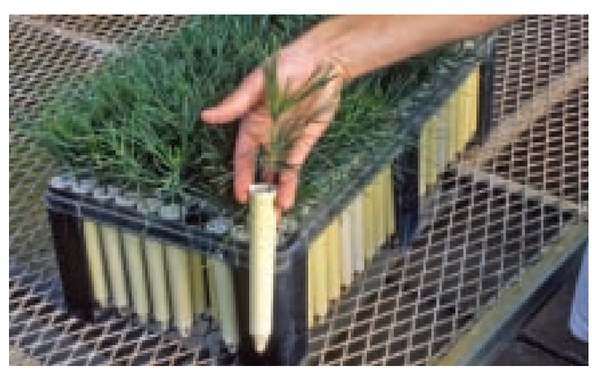

Figure 3.23 *A block of 200 containers. Each container is about 2.5 cm wide and 15 cm long, with a volume of 65 cubic cm. The block holding the containers is about 30 cm wide and 61 cm long.*

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 5 mm 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

Prepare seeds as described in 2.3.5, *Treating Seeds Before Planting*. Before sowing, water your medium until it is saturated and water is dripping out the bottom. Depending on the local climate, growing structure (or lack thereof), and temperatures that can be maintained around seedlings, plan on sowing in March or April. If you cannot control temperatures well, you may wish to hold off sowing until late spring to avoid problems with frost. Good air temperatures during the germination period range from 18 to 27 °C.

3.2.2.3 Sowing Seeds

Sowing by hand is the easiest and quickest way to sow a few thousand seedlings. Coating seeds with a little baby powder (talcum) makes the seeds easier to sow and easier to see on top of the medium. The number of seeds to put into each container will depend on the germination expected from the seeds. Use Table 3.2 for an approximate number of seeds to sow per container to end up with 90% or more of your containers with one seedling. Ideally, minimize the number of empty containers, but, as can be seen in the example in Table 3.3, there is a point when adding another seed fails to result in appreciably more filled containers. Nursery managers must decide whether seed economy (saving seeds for next time) is more important than a few empty containers. Using more seeds than necessary will require time to pull out the extra seedlings (thinning) after germination. After sowing, seeds should be barely covered with a thin mulch of perlite or coarse chicken grit, with mulch depth being no more than twice (2X) the thickness of the seeds. Make sure the covering material does not 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. A good mulch reduces disease problems.

Figure 3.24 *Each of the 160 conatiners in this block of Styrofoam® is about 2.5 cm wide and 15 cm deep. The block is about 35 cm wide and 58 cm long.*

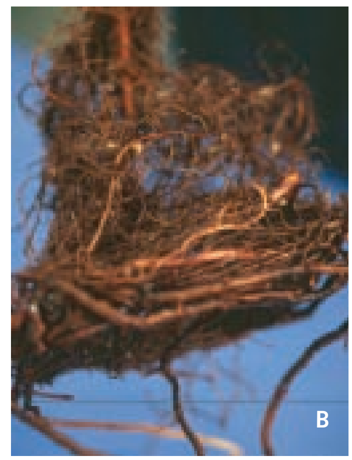

Figure 3.25 Pinus *seedlings growing in polybags (A). Although seedling tops look fine, root spiraling (B) can cause serious problems after seedlings are planted in the forest, orchard, or landscape.*

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 is a good idea to begin removing the rodents a week or so before you sow, rather than trying to remove them while they are eating your crop!

3.2.2.4 Planting Germinants

Germinants are seeds beginning to sprout—the root is emerging but no leaves are yet visible. It is best to plant germinates when the desire is to maximize seedlings from just a few valuable seeds or if the seedlot has poor germination (especially if empty containers cannot be

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

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

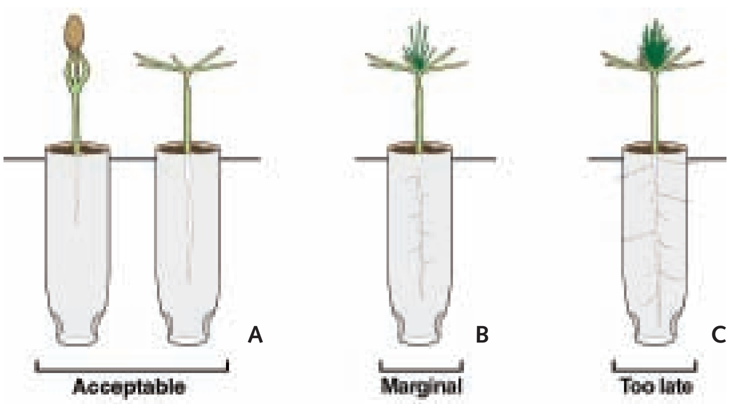

Figure 3.26 *Transplanting seedlings will be more successful if done before lateral roots begin to grow (A) or lateral roots are still very short (B). Once lateral roots grow (C), it is very difficult to pull the seedling out of medium and get it replanted correctly.*

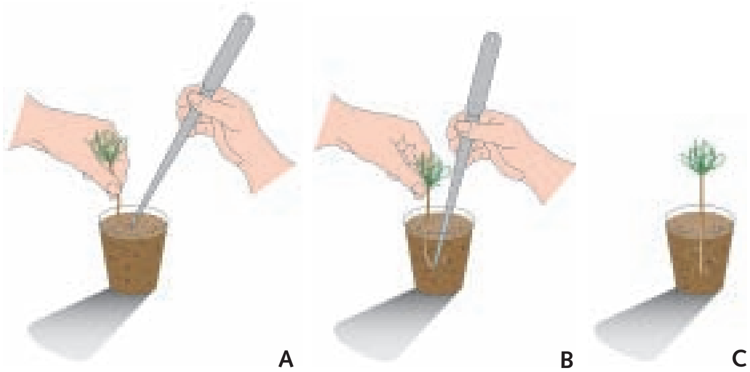

Figure 3.27 *The steps in transplanting a seedling. Use a small dibble to insert the germinate into new medium (A). A small notch at the end of the dibble will hold the small root in place. By pushing down on the dibble, the notch will cut off the end of the taproot (B). This will encourage the taproot to form lateral roots. Properly transplanted, the plant will grow a fibrous root system (C).*

consolidated). Sprout seeds as you would for a germination test (see 2.3.6, *Germination Testing*) and, as soon as a primary root is evident (Figure 2.25), plant that germinant on top of moistened medium in the container and gently cover with mulch.

If multiple seedlings are emerging from within 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 3.26). 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 (Figure 3.27). 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 planting in the field (Figure 3.28). If the root has grown too long to easily transplant, the length can be reduced (up to 50%) before transplanting. 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 two to three weeks after sowing, seedlings will have germinated and will start growing new leaves. At that time, thin (or transplant) any extra seedlings out of the containers, leaving the best-looking seedling that is closest to the center of the container. Fertilization should start at this time. The easiest way to apply nutrients is to use a water soluble fertilizer every time the seedlings are watered.

3.2.3.1 Watering

In general, seedlings may need water one to three or more times per week. The frequency depends on the size of the container, seedling size, conditions inside the 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.

Many growers use a "tactile" method for determining when to water containers. If water can be squeezed

Table 3.3

A sowing example for a seedlot of Cedrus deodara *having 65% germination. Assuming 1,000 seedlings are desired, notice that adding more than three seeds per container does not improve the number of containers with seedlings but does use (waste) many seeds.*

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	10	5,000	1,000	0

from the medium, no additional water needs to be added. As the medium dries out, it will be less likely to stick together. The containers will also feel "lighter." After time, a grower will be able to tell by touch or weight if seedlings need to be watered. This method requires skill and experience by growers and is difficult to teach to new growers. It can be risky too. Using a tactile method also makes it difficult for a nursery manager at one location to help a nursery manager at a different location, because this technique can not be quantified. It is more of an art than a science.

Another method to determine when to irrigate can be quantified and is relatively easy. This method uses an ordinary balance. Right before sowing, after the medium has been saturated, weigh the container on a scale. For example, let us say it weighs 12 kg. This is the saturated container weight. When the weight drops to a certain percentage of saturated container weight, it is time to water the seedlings (Table 3.4). This is the "target container weight" and it changes with the age of the crop. When seedlings are small, it may take several days, or even a week, depending on weather, to dry from saturated to target container weight. Once seedlings are bigger, however, and depending on climate, the change in container weight from saturated to target can happen often, perhaps every other day or even daily! About once every six weeks or so, obtain a new saturated weight to compensate for the weight of the seedlings.

The simplest way to water seedlings is with a watering can (Figure 3.29). Make sure an even amount of water is applied across all the containers. Make sure enough

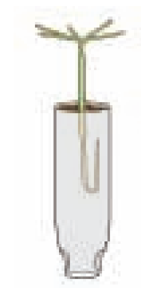

Figure 3.28 *An incorrectly transplanted seedling. This kinked or "J-rooted" transplant may grow more slowly while in the nursery, and depending on severity of the deformation, may grow poorly or die on the planting site as well.*

Table 3.4

An example record of container weights assuming a saturated container weight of 12 kg, and that seedlings will be watered when target container weight reaches 70% of the saturated block (12 kg x 0.70 = 8.4 kg).

	17 July	18 July	19 July	20 July	21 July	22 July
Saturated weight	12	12	12	12	12	12
Actual weight	8.4	11.5	10.2	8.4	10	7.8
Percentage	70%	96%	85%	70%	94%	65%
Need to water?	**Yes**	**No**	**No**	**Yes**	**No**	**Yes**

water is applied so that some drips out the bottom of the containers. Often containers around the edges of the crop will be drier 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 many seedlings will be grown, constructing a permanent irrigation system is prudent. For any type of sprinkler system, check the output to make sure all the seedlings receive about the same, and adequate, moisture. See 3.1.3.4, *Watering*, and Figure 3.13 for details on evaluat-

Figure 3.29 *Using a watering can is the easiest way to water and fertilize seedlings. It is important to apply water evenly, and watch seedlings around the edges of the growing area—they often dry out more and require extra water.*

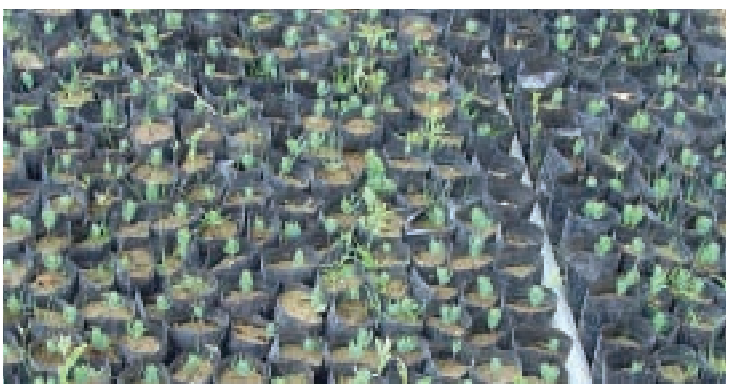

Figure 3.30 *Polybags can be placed into depressions and flood irrigated. It is best, however, to raise polybags off of the ground to prevent roots from growing from the bags into the soil.*

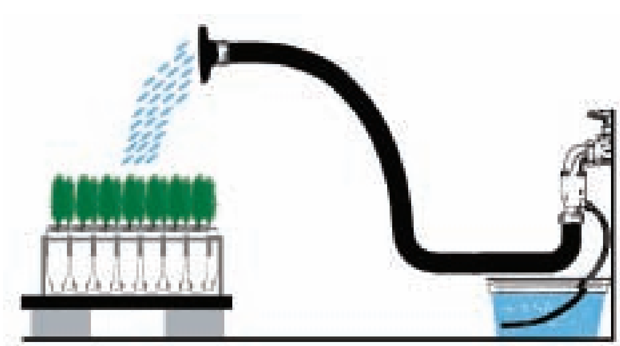

Figure 3.31 *Siphon mixers are handy devices when you need to apply a lot of fertilizer. Usually the siphon attaches between the faucet and the hose. The siphon's intact tube is placed into the concentrated fertilizer stock solution, and as water flows through the hose, the concentrate is sucked up into 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 preventer, or that a backflow preventer is in place, to avoid contaminating your water source.*

ing sprinkler output. Large areas of polybags can be flood irrigated as well (Figure 3.30), but it is usually best to grow any container plants, including polybags, off of the ground. This prevents roots from growing from the bottom of the bag into the soil. Roots growing into soil must be pruned before the seedlings can be planted in the field. If the roots are not pruned regularly during the nursery cycle, one severe pruning immediately before planting in the field can lower survival and reduce growth.

Fertilizers are easily and uniformly applied with water. The type and amount of fertilizer is discussed in the next section. If a watering can is used, an appropriate amount of fertilizer can be dissolved in water in the can. If a hose, lawn sprinkler, or permanent irrigation system is used, soluble fertilizer can be "injected" into the water. A simple injector is a siphon mixer. These devices have a piece of tubing that is inserted into a fertilizer stock solution (concentrated fertilizer). The flow of water through the hose causes a suction that pulls the fertilizer stock solution up and mixes it with the water in the hose to the desired concentration (Figure 3.31). ***Use this type of device only if it has a built-in backflow preventer or if some other type of backflow preventer 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 liter of concentrated fertilizer stock solution will make about 16 liters of diluted fertilizer that can be applied directly to seedlings (therefore, the injection ratio is 1:16).

If the injection ratio of the siphon is unknown, it can be determined quickly and easily. Put a known amount of water into a container (this is the "stock solution"), put the siphon hose in it, and then measure how much water comes through the hose (use a 20-liter bucket or some other container of known volume to measure outflow) until the stock solution container is empty. For example, if you had one liter of stock solution, and collected 20 liters of water while waiting for the stock solution to be used up, the siphon has an injection ratio of 1:20. In the next section we 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 by way of fertilizers. For container seedlings, fertilizers are usually added as a liquid when seedlings are watered. Nitrogen is the most important nutrient (Figure 3.32). Nitrogen is critical for aboveground seedling growth, especially new shoots, needles, and buds. Plants lacking sufficient N grow slowly or are stunted and have pale green or yellow needles near their bases. Phosphorus 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 is much easier to apply too much fertilizer, resulting in tall, spindly seedlings. Many factors influence how much fertilizer should be applied, including the species being grown, container size, seedling age, weather, and type of medium. As mentioned earlier, the label on any fertilizer bag always shows the percentages of N, P, and K, and always in this order: N:P:K. (Well, that is not completely true, and this can be complicated, as shown in Appendix 6.2.)

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

As mentioned above, container seedlings are usually fertilized with liquid fertilizer. They can, however, also be given granular fertilizer. This is especially true for plants growing mostly in native soil, as is often the case with polybags. A decent application rate is one gram of urea per 10 cm x 20 cm polybag.

Use Table 3.5 to decide if the species has a "slow," "medium," or "fast" growth rate. All seedlings have three distinct growth phases: initial, rapid, and hardening. During each phase, fertilizer and water are manipulated to control seedling growth.

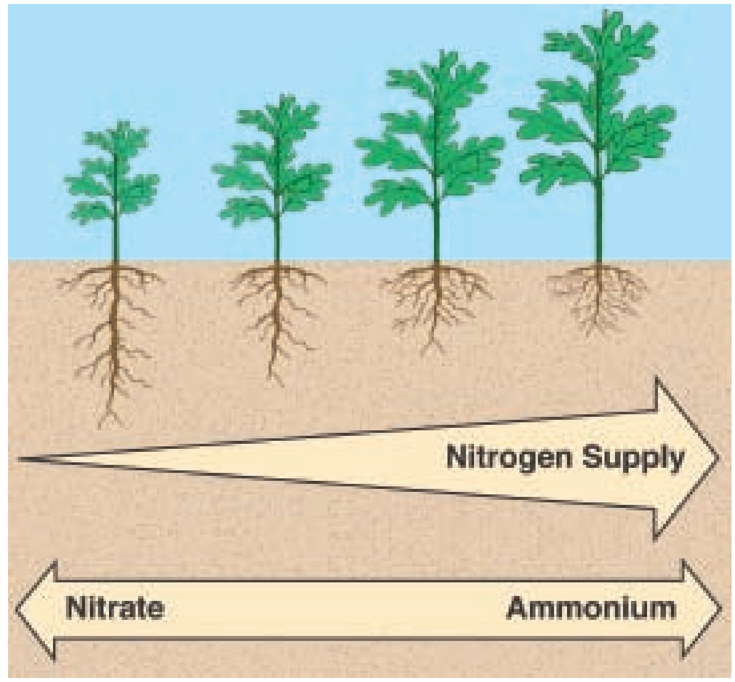

Figure 3.32 *Seedlings grow larger with higher doses of nitrogen (eventually, too much nitrogen, however, will reduce growth and cause death). The type of nitrogen also affects growth. Nitrate nitrogen reduces shoot growth and promotes root growth whereas ammonium nitrogen encourages shoot growth and discourages root growth. For outplanting on hot, dry sites it is best to grow shorter seedlings with large root systems.*

Table 3.5

Relative growth rates of common conifers. Species with "slow" growth rates require more fertilizer to grow larger, whereas species with "fast" growth rates grow rapidly with little fertilizer. In general, conifer species from high elevations are "slow," species from mid-elevations with determinant growth (such as Pinus*) are "medium," and species with non-determinant growth (such as* Juniperus*) are "fast." Nearly all of the angiosperms are "fast."*

"Slow"	"Medium"	"Fast"
Abies spectabilis	*Pinus contorta*	*Populus nigra*
Pinus wallichiana	*Taxus wallichiana*	*Thuja orientalis*

Throughout the initial growth phase, seedlings should be well-watered (70% to 85% container weights) and receive daytime temperatures between 18 to 30 °C and nighttime temperatures above 16 °C. This phase lasts about a month and helps seedling root systems get started. During the rapid growth phase, seedlings receive their highest doses of N to encourage height growth. Target block weights are still 70% to 85% of a fully watered container and temperatures are similar to the initial growth phase. Depending on species, the rapid growth phase may last from 3 to 15 weeks. When

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 container weight.

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

seedlings are about as tall as desired (10 to 20 cm is usually good), the rapid growth phase ends and hardening begins.

Hardening is the most important part of growing container seedlings. For the first stage of hardening, levels of N in the applied fertilizer solution are greatly reduced and target container weights are lowered to 60% to 70%. This stage encourages seedlings to decrease shoot growth and for some species, to stop shoot growth and form terminal buds. The appearance of brown buds at the tip of shoots usually takes a few weeks to a month. Sometimes *Pinus*, which usually form terminal buds, will form a rosette of dense needles at the tip of the shoot. This is acceptable. Conversely, some species, such as*Juniperus*, do not form buds or rosettes, so the objective with them is to slow growth to keep seedlings stocky.

After about a month, the objective is to increase seedling resistance to stress (Table 3.6), especially to cold temperatures. Levels of N can be slowly increased, but target container weights are usually still low (75%). Increasing N in the applied fertilizer helps the seedling increase in stem diameter, form large buds, and continue to develop roots. Temperatures are allowed to go to ambient, especially at night, and along with the low target container weights help to condition the seedling for life on the outplanting 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 6.3.

Here is an example to help pull all this information together. Assume the crop is *Pinus wallichiana*. Table 3.5 shows *Pinus wallichiana* is a "slow" grower. Assume the crop is in the rapid growth phase; Table 3.6 indicates seedlings with a "slow" growth rate should get 195 ppm N. Using a 30:10:10 fertilizer, Table 3.7 shows 650 mg of fertilizer per liter of water to get 195 ppm N. Assume seedlings are watered with a hose that has a siphon injector (1:15) with a built-in backflow preventer (Figure 3.31). Assume 60 containers each with a saturated container weight of 10 kg and that they must be irrigated when the container weight is 8.5 kg (85%). Therefore, each container must receive 1.5 liters of water, or 90 liters of fertilizer solution containing 195 ppm N. That means 6 liters of concentrated fertilizer stock solution will be needed to run through the siphon (90 liters ÷ 15 [the injection ratio] = 6 liters of fertilizer stock solution). To make the concentrated fertilizer solution, mix 58,500 mg (650 mg for every liter of applied water [90 liters total]) of fertilizer into 6 liters of water.

Having said all of this, remember that the amount of fertilizer applied will depend on the type of container, growing medium, and other environmental factors. If seedlings seem to be growing too fast (they are too spindly; flop over when not supported), reduce the rate of fertilizer (less N) or reduce how often fertilizer is applied (every other watering or less). Conversely, if they are growing too slowly, increase the rate of fertilizer (more N) to encourage growth. It is extremely important to keep detailed records of what is done to the crop and how the seedlings grow. Measuring seedling height every two to three weeks and matching that to the amount of fertilizer applied will help nursery managers adjust their 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. Some species are very sensitive to slight changes in day length. A species like *Abies spectabilis* grown under normal daylight conditions may form buds before they are as tall as desired. Fortunately, it is 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 1.5 to 2 meters above the crop for every 5.5 to 7.5 square meters of growing area is sufficient light. The easiest way to "fool" seedlings is to put the light on a timer set to come on before sundown and to extend the length of day to 18 or 20 hours. Once seedlings reach desired height, turn off the light. The abrupt change in daylength, along with changes in target block weight and fertilization rate, will encourage seedlings 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. Damping-off is the first disease that may be encountered (Figure 2.20). Damping-off affects germinating seeds and very young seedlings. Damped-off seedlings tip over at the ground line and shrivel up. Prevent damping-off by watering sparingly when seedlings are small, and by prompt removal of dead and dying seedlings.

The second important disease is root rot. This disease can become a problem when seedlings are larger. Seedlings turn brown, often from the top of the stem and (or) from the tips of the leaves. Generally, once symptoms are apparent, it is 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 2.5 cm x 15 cm piece of wood laid on end to shade the edges of containers exposed to direct sunlight.

Table 3.7

Milligrams per liter of two types of fertilizer to achieve desired parts per million (ppm) of N for container seedlings. If you use any other type of fertilizer, you'll need to calculate ppm using directions found in Appendix 6.3.

mg per liter	ppm Nitrogen	
	30:10:10 (N:P:K)	15:30:15 (N:P:K)
217	65	33
433	130	65
650	195	98
867	260	130
1300		195
1733		260

Figure 3.33 *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 (A), or blocks of seedlings can be separated (B). Both methods improve air circulation, which allows seedling foliage to dry more rapidly and inhibit fungal growth.*

The last disease problem is caused by the fungus *Botrytis*. *Botrytis* is a gray, fuzzy, mold that grows on leaves, eventually infecting seedling stems and causing death. *Botrytis* generally becomes a problem when foliage from one seedling touches foliage from another seedling. The fungus gets its start on dead foliage and disease is favored by cool temperatures and high humidity. *Botrytis* can be controlled by proper watering, removing dead and dying seedlings, and brushing foliage after watering. A piece of plastic (PVC) pipe works well as a brush, but be gentle so buds are not damaged. During hardening, seedlings can be spread apart to encourage air movement between them, thus reducing disease (Figure 3.33).

One last problem with container seedlings is fungus gnats (*Bradysia* species). These small, dark flies are more nuisance than problem, although in large enough quantities their larvae will feed on seedling root systems. Fungus gnats are usually more troublesome when medium is overwatered, and their populations can soar when moss and algae grows on the medium, especially in empty containers. Proper watering and removing moss help control populations. Fungus gnats can also be controlled with yellow cards covered with a sticky layer. Place the cards at or near the surface of the containers and when the flies land on them, they become entangled. The cards work best when laid flat.

3.2.3.5 Mycorrhizae

If seedlings are planted in a forest site or in close proximity to a forest, adding mycorrhizal fungi or *Rhizobium* bacteria to the medium is unnecessary. Once planted, seedlings will be quickly colonized by microorganisms native to that site. If seedlings will be planted on a disturbed site or old field they may need to be inoculated in the nursery. One good way to inoculate them is to mulch them with some material collected from the forest, as described in 3.1.3.3, *Young Seedlings — Establishing Your Crop*. Because N fertilization often inhibits mycorrhizal and *Rhizobium* nodule formation, and because of the amount of N used to grow container seedlings, it can be very difficult to inoculate seedlings with microorganisms and still have plantable seedlings in a single growing season.

3.2.4 Lifting, Handling, and Storage

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

If seedlings will be planted in spring, seedlings can be kept in their containers in the greenhouse or other protected area until about midwinter. Keep seedlings as cold as possible, but try not to let the root plugs freeze. A few gentle freezes of –2 to –5 °C are probably okay, especially if the seedlings have been exposed to cold temperatures before freezing. Seedlings suddenly exposed to a drastic drop in temperature can be damaged or even killed. If refrigerated storage is possible, seedlings should be removed from their containers in midwinter, enclosed in plastic bags, and kept at –2 to +2 °C until they can be planted. Seedlings can be stored in this manner for up to six months. Thaw frozen seedlings slowly, at low temperatures, and out of direct sunlight before planting.

If refrigerated storage is unavailable, make sure seedlings are stored in a cool, protected location, such as a shadehouse. 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 subfreezing temperatures. Storage molds usually begin growing on dead foliage. Therefore, be diligent when seedlings are put 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 seedlings are too small to plant, two options are available: transplant seedlings into larger containers or grow seedlings another year as bareroot transplants (see 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 will not grow well after planting. Seedlings can be transplanted into larger containers anytime from autumn to spring. Irrigate and fertilize seedlings transplanted into larger containers as described in 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 (70 to 82 °C) 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 shorter dip time (15 seconds) than Styrofoam® containers (1 to 2 minutes).

3.3 Growing Plug+one Transplants

Plug "plus" ones (P+1) are a hybrid type of planting stock—they are seedlings grown up to one year as a container seedling plus another one (P+1) or two (P+2) years as a bareroot transplant. 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 cannot be planted after growing in the container. To grow plug+ones, follow the directions for growing container seedlings (3.2, *Growing Seedlings in Containers*) and then the directions for growing 2+0 seedlings the second year (3.1, *Growing Bareroot Seedlings*).

Plant seedlings as soon as possible after lifting. Always protect seedlings from sun and wind. Never transport seedlings in the presence of petrol. Always keep roots moist. Avoid transport during the heat of the day.

4.0

Field Planting Considerations

4.1 Microsites

Microsites are places on planting areas where conditions favor seedling survival and growth. Good microsites include the north and east sides of downed logs, stumps, or large rocks. Slight soil depressions or where debris provides some shade are also good planting spots. Avoid planting in ruts left by vehicles wheels. On very steep sites, it may be necessary to cut a terrace in which to plant the seedling. The terrace will help collect rainwater for the plant (Figure 4.1).

4.2 Proper Planting Techniques

Plant seedlings in either spring or autumn when the soil is moist. In autumn, soil must have enough moisture to support seedlings for six to eight weeks before winter weather begins. Root growth makes seedlings less likely to be pushed out of the ground by frost and suffer from winter desiccation. Fall-planted seedlings have an extra advantage—they can grow new roots in spring before spring-planted seedlings can be planted. This extension of the growing season improves first year survival and growth. Often, high-elevation sites should be planted in autumn because persistent snow on the planting site in spring prohibits planting then.

In spring, seedlings should be planted when the ground has dried enough. If the soil is too wet, planting may compact the soil and restrict seedling root growth. Here is a way to determine if your soil is too wet to plant: dig a hole, then shovel the soil back into the hole—if the soil does not fit back into the hole, it is too wet. Wait until the soil dries more before planting. If the seedlings were properly hardened, they can withstand frosts after planting. The earlier in spring seedlings are planted, the better; early spring planting allows seedlings to take full advantage of the growing season and available water. See Figure 4.2 for proper planting techniques.

After seedlings leave the nursery and before they are outplanted, keep the seedlings cool, shaded, and out of the wind. Keep the roots moist. On the planting site, temporarily store seedlings in a snowbank or in deep shade. Never

Figure 4.1 Pinus halepensis *seedlings growing well in depressions made during planting Tapi Maranjan near Kabul. The depressions collect rain water.*

place seedlings in full sun. Always carry polybags and seedlings with a solid, soil root-ball by the bag or the ball, never by the stem. Do not lay a tarp directly on them for shade from the sun. A tarp lying directly on seedlings will cause them to become warmer than if they were in direct sunlight. If a tarp is used, suspend it above the seedlings at least one meter so air will circulate between the tarp and the seedlings.

When planting, make sure the soil is moist, that the hole is large enough for the entire root system, and that the entire root system can be planted in a natural vertical position. Always fill the hole with moist soil. Form a basin around the plant so that rainwater will collect (Figure 4.3).

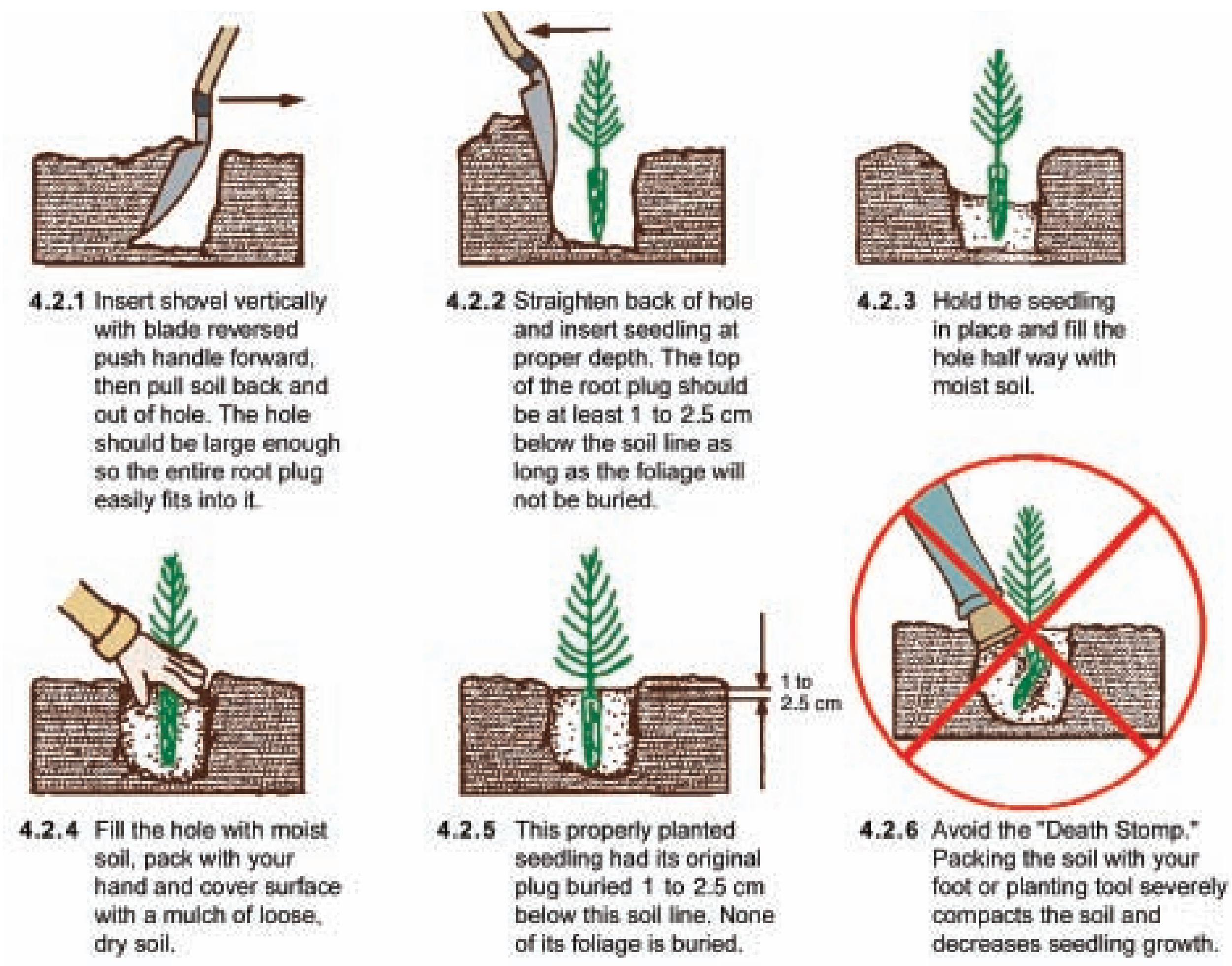

Figure 4.2 *Proper planting technique. Although this illustration shows a container seedling, follow the same steps for a bareroot seedling. For bareroot plants, ensure the root collar is about 2.5 cm below the soil surface.*

In urban plantings, seedlings can be irrigated during the first growing season to increase survival and growth. It is important to fully saturate the soil deeply, but irrigate infrequently to encourage deep rooting. A good mulch applied around the seedling will decrease evaporation from the soil.

4.3 Controlling Weeds

Seedlings grow better when weeds are controlled because weeds out compete seedlings for water and nutrients. Maintain at least a one meter by one meter weed-free square around seedlings for at least the first two to three years; the longer the better. Weed-free zones can be accomplished with hand-weeding or herbicides. Providing shade and mulches may also increase seedling survival and growth (Figure 4.4).

4.4 Controlling Animal Damage

Many animals eat seedlings. Small rodents can quickly do serious and widespread damage to seedlings. Large wild animals and domestic livestock can also destroy seedlings and harm young plantations. The best way to protect seedlings from small rodents is with a solid barrier. A plastic tube (a clear two-liter beverage container) or a mesh-wire ring would work well (Figures 4.4 & 4.5). Rodent populations can be reduced by natural predators such as hawks and owls. Placing some wooden fence posts or taller poles around the planting site offers predatory birds a place to sit and hunt. Fencing works well for larger animals but can be extremely expensive.

Figure 4.1
CHECKLIST FOR PLANTING SEEDLINGS

— Handle seedlings gently
— Plant seedlings as soon as possible after lifting
— Protect seedlings from sun and wind
— Always keep roots moist
— Do not transport seedlings near petrol
— Transport during cooler periods of the day
— Plant seedlings in microsites
— Plant seedlings correctly (see Figure 4.2)
— If possible, water seedlings to improve survival and growth
— Control weeds in plantations, especially near seedlings
— Protect seedlings from animal damage

Figure 4.3 *Planting seedlings in basins allows rainwater to collect, and also facilitates watering the plants.*

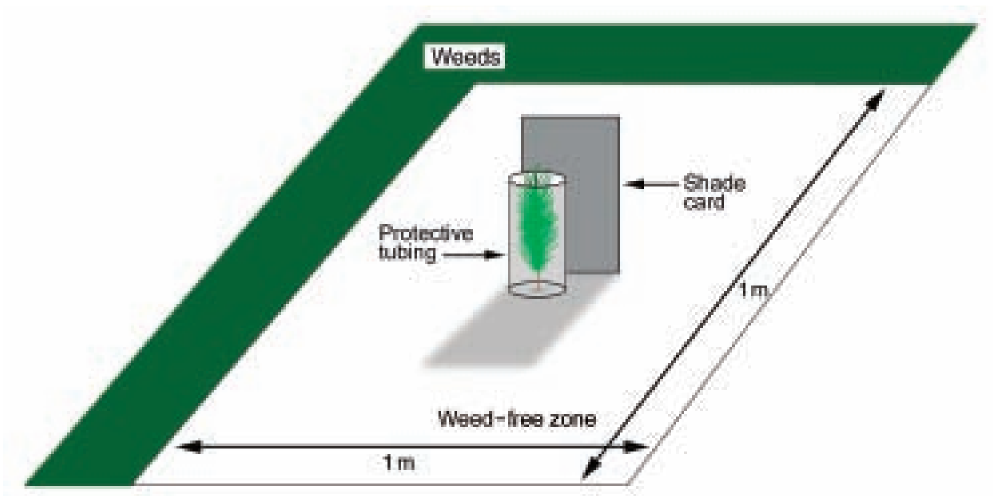

Figure 4.4 *A properly planted seedling. Weeds are controlled with cultivation, herbicides, weed barriers, and (or) mulches. A plastic tube prevents rodent damage. On very hot, south-facing planting sites, a shade card placed on the south and west sides of the seedling will help conserve soil moisture. A good mulch will also help conserve soil moisture.*

Figure 4.5 *This 30-cm-tall plastic tree tube will prevent small rodents from eating this seedling, help prevent the foliage from drying out (especially on a windy site), and make a great barrier against sprayed herbicides or a string trimmer. Plus, the seedling is easier to find when fitted with a tube. Plastic two-liter beverage containers with the tops and bottoms removed also work well.*

5.0

Keeping Records

Collecting seeds, cuttings, or grafts and growing them into seedlings is rewarding. Keep detailed notes from year to year on every aspect of the nursery program—when seeds were collected, how seeds were cleaned, how seeds were stored, how seeds were treated, and the results. It is wise to record anything done to the crop while it grows in the nursery. It is also wise to record the time of outplanting, the weather conditions, and how well the seedlings survive and grow. One good way is to track a particular seedlot from the time the seeds are collected until the seedlings are planted in the field—and why stop? Collect data for a few more years to see how the seedlings survive and grow. Keeping good, detailed notes will make you a better grower. Experience is the best teacher.

6.0 Appendices

APPENDIX 6.1 Seed Characteristics of Common Trees and Shrubs of Afghanistan and Potential for Propagation by Cuttings

Scientific name	Pashtu name	Dari name	Native, introduced, or naturalized?*	Seed crop cycle (years)	Seeds per kilogram	Scarification	Warm, moist treatment (days)	Stratification (days)	Cuttings?
CONIFERS	**Stinpani laronki**	**Sozani bargan**							
Abies spectabilis	Bijur	Bijur	Native				60 to 90		
Cedrus deodara	Ilmanza	Archa	Native	3	5,100 to 13,000		0 to 14		
Cupressus arizonica	Sabir	Sarw arizona	Introduced	1	103,200 to 387,000		30		
Cupressus torulosa	Sabir	Sarw torulosa	Native		200,000 to 238,000		30 to 90 **		
Juniperus communis	Obakht	Archai badal	Native	irregular	56,120 to 120,170		60 to 90	90 to 150	Yes ***
Juniperus excelsa	Obakht	Archai badal	Native				60 to 90	60 to 90	Yes ***
Juniperus semiglobosa	Obakht	Archai badal	Native						Yes ***
Juniperus squamata	Obakht	Archai badal	Native						Yes ***
Picea engelmannii	Srup	Srup	Introduced	1 to 2	151,800 to 708,400			0 to 30	
Picea smithiana	Srup	Srup	Native	1 to 3	52,800 to 88,000			30	
Pinus contorta var. *latifolia*	Naju	Najui contorta	Introduced	1	173,800 to 250,800			30 to 56	
Pinus eldarica	Naju	Najui eldarica	Native	1	16,720 to 25,520			0 to 45	
Pinus gerardiana	Jalghoza	Jalghoza	Native		2,420 to 2,860			30 to 60	
Pinus halepensis	Naju	Najui halepensis	Naturalized	1	48,400 to 88,000			0	
Pinus nigra	Naju	Najui siah	Naturalized	2 to 5	30,800 to 84,460			0 to 60	
Pinus ponderosa	Naju	Najui pandarosa	Introduced	2 to 5	22,440 to 33,660			30 to 60	
Pinus sylvestris	Naju	Najui nuqrai	Introduced	4 to 6	74,360 to 244,200			15 to 90	
Pinus wallichiana	Nishter	Najui nishter	Native	1 to 2	15,840 to 22,440			15 to 90	
Pseudotsuga menziesii var. *glauca*			Introduced	3 to 11	63,700 to 95,900			21 to 45	
Taxus wallichiana	Serikh	Surkhdar	Native	1	13,860 to 18,040		120	365	Yes
Thuja orientalis	Morpan	Morpan	Native	3 to 5	44,000 to 55,000			0 to 14	Yes

Footnotes on page 56

Scientific name	Pashtu name	Dari name	Native, introduced, or naturalized?*	Seed crop cycle (years)	Seeds per kilogram	Scarification	Warm, moist treatment (days)	Stratification (days)	Cuttings?
ANGIOSPERMS		**Tukhum putan**							
Acacia modesta		Acaci kohi	Native	1 to 3		Yes		0 to 30	
Acer negundo		Gulbarg	Introduced	1	18,040 to 44,880			60 to 90	
Ailanthus altissima (syn = *gradilosa*)		Bid rosi	Naturalized	1	29,260 to 43,340			60	
Alnus species			Native	1 to 2	565,400 to 882,200			60 to 100 *	
Betula alba		Zerishk (Rima)	Native	2 to 3	1,606,000 to 1,892,000			30 to 40 *	
Catalpa bignonioides		Katalpa	Introduced	2 to 3	32,560 to 40,040			0 to 21	
Cercis griffithii		Arghawan	Native	1 to 2	26,400 to 39,600	Yes		35 to 120	
Corylus species		Badami paroni species	Native	2 to 3	352 to 1,243				
Elaeagnus angustifolia	Sinzila	Sinjid	Native	1	7,634 to 15,378			60 to 90	
Fraxinus floribundus	Shing	Shing	Naturalized				70 to 90	30 to 90	
Forsythia species		Barishtila species	Naturalized	1				30 to 60	
Gleditsia triacanthos	Badal	Acaci khardar	Introduced	1	3,800 to 9,000	Yes			
Jasminum officinale		Yasaman asli	Native	1				0	
Juglans nigra	Tor ghoz	Charmaghz siah	Introduced	1	25 to 220			90 to 120	
Juglans regia	Ghoz	Charmaghz	Native	1	66 to 110			30	
Ligustrum species		Bid irani species	Native	1	40,920		15	60 to 90	
Lonicera sempervirens	Olinoj	Lonicira	Introduced	1			60 to 90	60 to 90	
Maclura pomifera		Orange	Introduced	1	30,800			30	
Malus bracteata	Siib		Introduced	1				30 to 90	
Morus species	Tut	Tut species	Native	1	517,000 to 792,000			30 to 90	
Nerium oleander	Gandirai (Oleander)	Gandiri	Naturalized	1				0	
Passiflora edulis			Introduced	1		Yes		0	
Pistacia vera	Pista	Pista	Native	1		Yes		30	
Populus alba	Safidar	Safidar	Native	1	16,000,000			0 **	Yes
Populus nigra	Arar	Arar	Native	1	16,000,000			0 **	Yes
Prunus armeniaca	Khobanai	Zardalu	Native	2	594 to 1,089		14	80 to 189	
Prunus brahuica	Khobanai	Zardalui kohi	Native					65	
Prunus dulcis (syn = *gradilosa*)	Khobanai	Zardalui sherin	Native	1	57 to 102			60 to 90	Yes

Footnotes on page 56

Scientific name	Pashtu name	Dari name	Native, introduced, or naturalized?	Seed crop cycle (years)	Seeds per kilogram	Scarification	Warm, moist treatment (days)	Stratification (days)	Cuttings?
Prunus persica	Khobanai	Shaftalu	Native	1 to 2	123 to 255			70 to 105	
Quercus baloot	Sili	Baloot	Native					0 to 30	
Quercus dilatata	Sili (Morou)	Baloot	Native					0 to 30	
Quercus semicarpifolia	Sili (Katchou)	Baloot	Native					0 to 30	
Robinia pseudoacacia	Acaci	Acaci	Introduced	1 to 3	52,800	Yes		0	
Salix acomophylla	Wola	Bid	Native	1	5,000,000			0 **	Yes
Sophora japonica		Soforai japani	Introduced	1		Yes		0	
Spiraea bamalda	Spira		Native	1	3,000,000+			30 to 60 **	Yes
Syringa afghanica	Yasaman	Yasamani afghani	Native	1				30 to 90	Yes
Syringa vulgaris	Yasaman	Yasamani germani	Naturalized	1	74,800 to 286,000			30 to 90	Yes***
Tilia americana		Tiliai amricai	Introduced	1 to 2	6,600	Yes	30 to 60	90	
Ulmus pumila		Pashakhana	Natrualized	2 to 4	88,000 to 260,700			0	

* Naturalized=introduced species that have become established in Afghanistan as if native.

* Denotes seeds need light to germinate; need to be sown on the soil surface and kept moist during germination.

** Cuttings from very young plants root fairly well; difficult to root cuttings from older plants.

APPENDIX 6.2 More Intensive Fertilization for Bareroot Seedlings—An Introduction

The percentage of N, P, and K in a bag of fertilizer is always given in the order of N:P:K. Well, that is not quite right. Because of some archaic convention, the percentages of P and K are really given as percentages of the oxides of P and K: P_2O_5 and K_2O. Therefore, a bag of 8:10:3 has 8% N, 10% P_2O_5, and 3% K_2O by weight. To convert P_2O_5 to P, the percentage of P_2O_5 must be multiplied by 0.437 to reflect only the amount of P. Similarly, to convert K_2O to K, multiply K_2O by 0.83. This process may sound confusing, but this example should help:

$$\frac{\text{Amount of Nutrient Required (Kg per Hectare)}}{\text{\%Nutrient within Fertilizer}} \times \frac{\text{Square Meters Needing Fertilizer}}{\text{10,000 Square Meters per Hectare}} = \text{Kg of Fertilizer Needed}$$

For example, the fertilizer is 8:10:3. The application rate is 35 kg of N per hectare. The nursery bed is one meter wide and 30 meters long (30 square meters).

First, divide 35 kg of N by the percentage of N in the fertilizer (0.08):
35 ÷ 0.08 = 437.5 kg of fertilizer per hectare to get 35 kg of N per hectare.

Divide the 437.5 kg of fertilizer by 10,000 (the number of square meters in a hectare):
437.5 ÷ 10,000 = 0.04375 kg of fertilizer per square meter.

Multiply 0.04375 kg of fertilizer per square meter by the 30 square meters in the nursery bed:
0.04375 x 30 = 1.31 kg of fertilizer should be applied to the nursery bed.

How much P and K were applied at the same time?

For P, multiply the 1.31 kg of fertilizer by 0.1 (remember the fertilizer has 10% P_2O_5):
1.31 x 0.1 = 0.131 kg of P_2O_5 were also applied to the nursery bed.

Convert that to P:
0.131 x 0.437 = 0.057 kg of P was applied to the nursery bed.

You may convert that back to a kg-per-hectare rate by dividing it by 30 (that gives you kg of P per square meter) and then multiplying by 10,000:
0.057 ÷ 30 = 0.0019 and 0.0019 x 10,000 = 19 kg of P per hectare.

Similarly, to determine how much K was applied, multiply the 1.31 kg of fertilizer by 0.03 (3% K_2O in the fertilizer); 0.04 kg of K_2O was applied. Multiply 0.04 kg of K_2O by 0.83; 0.03 kg of K was applied. Like P, the amount of K per hectare applied can be found by dividing by 30 and multiplying by 10,000; we applied 10.8 kg of K per hectare.

In commercial bareroot nurseries in the United States, commonly used fertilizers are ammonium phosphate (11:55:0), ammonium nitrate (33:0:0), ammonium sulfate (21:0:0), calcium superphosphate (0:20:0), triple superphosphate (0:45:0), potassium sulfate (0:0:50). In general, for soils with pH less than 6.0, the best fertilizers are ammonium phosphate and ammonium nitrate. These fertilizers help maintain pH around 5.0 to 6.0. However, for soil pH with high pH (over 6.0) ammonium sulfate is better.

One advantage of using single element fertilizers is the ease of manipulating the amounts of each nutrient applied; only one nutrient is in each fertilizer formulation. Commercial operators have the luxury of using a particular fertilizer to apply a particular nutrient. Novice growers who wish to use an organic alternative may find that their choices for fertilizers usually include multiple nutrients per fertilizer formulations (for example, 9:1:1 or 0:3:1). This means more arithmetic for organic farmers because they may have to do some "tinkering" with their formulations and application amounts to achieve recommended fertilizer rates.

Regardless of the situation, right before the first growing season, P and K should be incorporated into nursery soil. If the soil is very sandy, adding some N is also recommended. If the soil is too acidic (pH under 5) or too basic (pH over 6) for conifer seedlings, this is also the time to add lime to bring the pH back up or sulfur to lower pH. Use a whirlybird-type spreader or drop-type spreader to apply fertilizer. Make sure fertilizer is applied evenly! Spade or rototill the fertilizer into the soil. Once the crop is growing, it will be necessary to topdress N and K over the top of the seedlings. If damping-off is a problem, avoid early applications of N during the first season.

APPENDIX 6.2.1 Intensive Bareroot Fertilization for Soil with pH under 6.0

	Nutrient	Number of applications	Rate (kg per hectare)	Fertilizer (see footnote)	Grams of fertilizer per square meter
FIRST SEASON					
Pre-sow	N	1	40	11:55:0 *	36
	P	1	135	0:20:0	55
	K	1	50	0:0:62	10
Top-dress	N	4 (mid-Jun, early and mid-Jul, & late Sep)	22	33:0:0	7
	K	1 (midsummer)	22	0:0:62	4
SECOND SEASON					
Top-dress	N	1 (Mar)	40	33:0:0	12
	K	1 (Mar)	22	0:0:62	4
	N	4 (May, Jun, Jul, late Sep)	22	33:0:0	7
	K	2 (early and midsummer)	22	0:0:62	4
TRANSPLANTS					
Pre-plant	P	1	65	0:20:0	32
	K	1	50	0:0:62	10
Top-dress	N	4 (May, Jun, Jul, late Sep)	50	33:0:0	15
	K	2 (early and midsummer)	22	0:0:62	4

Fertilizer:

11:55:0	Ammonium phosphate
33:0:0	Ammonium nitrate
0:20:0	Calcium superphosphate
0:0:62	Potassium chloride

* Note the application of 36 g of 11:55:0 supplies the necessary rate of N (40 kg per ha) and 87 kg of the suggested 135 kg of P per hectare. Therefore, the amount of 0:20:0 supplies only 48 kg of P per hectare (the difference between 135 and 87).

APPENDIX 6.2.2 Intensive Bareroot Fertilization for Soil with pH over 6.0

	Nutrient	Number of applications	Rate (kg per hectare)	Fertilizer (see footnote)	Grams of fertilizer per square meter
FIRST SEASON					
Pre-sow	N	1	40	11:55:0 *	36
	P	1	135	0:45:0	25
	K	1	50	0:0:50	12
Top-dress	N	4 (mid-Jun, early and mid-Jul, & late Sep)	22	21:0:0	10
	K	1 (midsummer)	22	0:0:50	5
SECOND SEASON					
Top-dress	N	1 (Mar)	40	21:0:0	195
	K	1 (Mar)	22	0:0:50	
	N	4 (May, Jun, Jul, late Sep)	22	21:0:0	10
	K	2 (early and midsummer)	22	0:0:50	5
TRANSPLANTS					
Pre-plant	P	1	65	0:45:0	33
	K	1	50	0:0:50	12
Top-dress	N	4 (May, Jun, Jul, late Sep)	45	21:0:0	21
	K	2 (early and midsummer)	22	0:0:50	5

Fertilizer:

11:55:0 Ammonium phosphate

21:0:0 Ammonium sulfate

0:45:0 Triple superphosphate

0:0:62 Potassium sulfate

* Note the application of 36 g of 11:55:0 supplies the necessary rate of N (40 kg per ha) and 87 kg of the suggested 135 kg of P per hectare. Therefore, the amount of 0:45:0 supplies only 48 kg of P per hectare (the difference between 135 and 87).

APPENDIX 6.3 Calculating Parts Per Million and More Intensive Fertilization for Container Seedlings

For any fertilizers other than the ones listed in Table 3.7, the amount of fertilizer to mix in a volume of water to get the suggested concentration (ppm) must be calculated. Review Appendix 6.2 to understand the basics of fertilizer terminology. Fortunately, for fertilization of container seedlings most interest is on the rate of N. Calculating parts per million (ppm) is simple because ppm equals milligrams per kilogram and one liter of water weighs one kilogram. Therefore, ppm equals milligrams per liter. For example, if the fertilizer is 30:20:15, and the desired rate is 135 ppm N, divide 135 ppm N by the percentage of N in the fertilizer (30%):

135 ppm ÷ 0.3 = 450 mg fertilizer per liter.

With that 450 mg rate, the amount of P would equal:
450 mg x 0.2 P_2O_5 x 0.437 P = 39 ppm P

With that 450 mg rate, the amount of K would equal:
450 mg x 0.15 K_2O x 0.83 K = 56 ppm K

Some professional growers in the United States strictly use premixed fertilizers (such as 20:7:19), some only use custom-mixed formulations (such as 33:0:0 plus 0:20:0 plus 0:0:62), and others use a combination of premixed and custom-mixed fertilizers. The difference usually depends on the background of the grower. Growers using custom-mixed fertilizer feel they have better control over the growth of their seedlings and can manipulate fertilizers to achieve particular growth responses in the crop. Customized fertilizers blend the "science" of growing seedlings with the "art" of growing seedlings, and usually experience is key. Most growers like to add calcium to their fertilizers to promote stem diameter development in their seedlings. Some growers like to reduce the rate of N while maintaining high levels of K to promote bud initiation and hardening; raising K levels can be easily done with a custom-mixed fertilizer. Commonly used fertilizers for growing container seedlings can be found in Appendix 6.3.1. Go ahead, experiment! Keep detailed notes so you can develop your own "art" in seedling production.

Appendix 6.3.1 Soluble Fertilizer Chemicals for Container Seedlings

Compound	Chemical formula	Percentage of nutrient supplied						
		NH_4-N	NO_3-N	P	K	Ca	Mg	S
Ammonium nitrate	NH_4NO_3	17	17	—	—	—	—	—
Ammonium sulfate	$(NH_4)_2SO_4$	21	—	—	—	—	—	24
Calcium nitrate	$Ca(NO_3)_2$	—	15	—	—	17	—	—
Diammonium phosphate	$(NH_4)_2HPO_4$	21	—	24	—	—	—	—
Dipotassium phosphate	K_2HPO_4	—	—	18	45	—	—	—
Magnesium sulfate	$MgSO_4$	—	—	—	—	—	10	13
Monoammonium phosphate	$NH_4H_2PO_4$	11	—	21	—	1	—	3
Monopotassium phosphate	KH_2PO_4	—	—	23	28	—	—	—
Nitric acid	HNO_3	—	22	—	—	—	—	—
Phosphoric acid	H_3PO_4	—	—	32	—	—	—	—
Potassium carbonate	K_2CO_3	—	—	—	56	—	—	—
Potassium chloride	KCl	—	—	—	52	—	—	—
Potassium nitrate	KNO_3	—	13	—	37	—	—	—
Potassium sulfate	K_2SO_4	—	—	—	44	—	—	18
Sodium nitrate	$NaNO_3$	—	16	—	—	—	—	—
Sulfuric acid	H_2SO_4	—	—	—	—	—	—	33
Urea	$CO(NH_2)_2$	45	—	—	—	—	—	—

APPENDIX 6.3.2 Fertilization of a Container Crop of Seedlings

Application rates of nutrients in parts per million (ppm) given to a moderate to fast growing Pinus crop in the northern Rocky Mountains, USA.

Initial Growth Phase (2 to 6 weeks after sowing)

	Total N	**Nitrate N**	**Ammonium N**	**P**	**K**	**Ca**	**Mg**	**S**	**milligrams of fertilizer per liter**
Target	50	35	15	100	100	80	40	60	
Ammonium nitrate									
Ammonium sulfate	15		15					17	71
Calcium nitrate	35	35				38			226
Monopotassium phosphate				90	100				412
Magnesium sulfate							20	26	200
Potassium nitrate									
Potassium sulfate									
Total	**50**	**35**	**15**	**90**	**100**	**38**	**20**	**43**	

Rapid Growth Phase (6 to 12 weeks after sowing)

	Total N	**Nitrate N**	**Ammonium N**	**P**	**K**	**Ca**	**Mg**	**S**	**milligrams of fertilizer per liter**
Target	150	100	50	60	150	80	40	60	
Ammonium nitrate	60	30	30						176
Ammonium sulfate									
Calcium nitrate	70	70				77			451
Monopotassium phosphate				60	67				275
Magnesium sulfate							40	52	400
Potassium nitrate	20	20			57				154
Potassium sulfate					25			10	57
Total	**150**	**120**	**30**	**60**	**149**	**77**	**40**	**62**	

Hardening Growth Phase (12 weeks to harvest [usually 23 to 35 weeks after sowing])

	Total N	**Nitrate N**	**Ammonium N**	**P**	**K**	**Ca**	**Mg**	**S**	**milligrams of fertilizer per liter**
Target	50	50		60	150	80	40	60	
Ammonium nitrate									
Ammonium sulfate									
Calcium nitrate	50	50				55			323
Monopotassium phosphate				70	78				321
Magnesium sulfate							30	39	300
Potassium nitrate									
Potassium sulfate					50			20	114
Total	**50**	**50**		**70**	**128**	**55**	**30**	**59**	