

3.10.8h Seeding Rates

There is virtually no way to correlate the desired ratio of established plants with a seed-mix formula because of the array of variables: seed viability, time and conditions needed to break dormancy and induce germination, animals that eat seed, soil moisture, seedling survival, and so on. Seeding rates that are too low will not provide enough seedlings for erosion control or competition to keep out nonnative species, while too many seedlings may outcompete one another for limited water and nutrients. The ratio between various life forms (graminoids, forbs, shrubs, and trees) affects the establishment ratio, but the correlation is not direct. For example, on the sagebrush steppe, grasses tend to outcompete forbs, so a mix lower in grass seed may be needed unless the desired outcome is for grasses to dominate (Doerr and others 1983). In the same way, the ratio of species in a seed mix cannot be correlated directly to species establishment. Seeding rates often take years of site-specific experience to develop.

Redente (1993) suggests that broadcast seeding techniques require twice as much seed as techniques based on drilling, but that the result more closely mimics natural processes.

Seeding rates vary by the environment, species, and the viability of the seed. Seeding rates usually are expressed as seeds per square foot or pounds per acre. The USDA Natural Resources Conservation Service recommends 20 pure live seeds per square foot for favorable planting conditions. That rate may need to be increased two to four fold, based on factors such as weed competition, steep slopes, low soil moisture or nutrients, or highly disturbed soils (Redente 1993). Arid land restorationist Dr. David Bainbridge (Bainbridge and others 1995) recommends 100 to 500 seeds per yard (meter) for arid lands such as the Mojave Desert of southern California. Restorationists sow at least 133 seeds per square foot (0.09 square meter) in Mount Rainier National Park in Washington (Rocheffort 1990).

Redente offers the following broadcast seeding rates for forbs and graminoids, based on annual precipitation (table 3–13). The rate needs to be higher for shrubs.

Table 3–13—Broadcast seeding rates for forbs and graminoids (Redente 1993). A square foot is 0.09 square meter.

Annual precipitation inches (millimeters)	Pure live seeds per square foot
6 to 18 (152 to 457)	40 to 60
19 to 30 (483 to 762)	60 to 80
More than 30 (762)	80 to 120

Seed and Fertilizer Rate Conversion Factors

- Pounds/acre x 1.12 = kilograms/hectare
- Kilograms/hectare x 0.892 = pounds/acre
- Kilograms/hectare x 0.10 = grams/square meter
- Pounds/acre x 0.000367 = ounces/square foot
- Pounds/acre x 0.00330 = ounces/square yard

20 pounds/acre = 100 square feet seeded with 0.05 pounds of seed

3.10.9 Working With Cuttings

When it is difficult or impossible to propagate plants from seed, cuttings are a common method of propagation. Depending on the species, cuttings can be taken from different parts of the plant: buds, stems, leaves, or roots. Determine which type of cutting is appropriate for a given species; several types of stem cuttings are the most common when propagating native plants.

Cuttings are usually rooted at a nursery, although a few genera and species lend themselves to rooting directly in moist soil at the project site. Often, these species are used to create bioengineering structures designed to stabilize slopes. Methods for bioengineering are described in section 3.4.9, *Bioengineering Applications*.

3.10.9a Collecting and Handling Cuttings

The plant collection guidelines described at the beginning of this section are used to identify and tag parent or donor plants. This must be done while leaves are on the stem to assure accurate species identification. Some plants, such as willows, have separate male and female plants. It is important to collect cuttings from plants of each gender to establish a population that can reproduce.

Collect two to four times as many cuttings as the desired established population. Mortality of 50 percent is not uncommon during the rooting phase. Another 50 percent of the cuttings may be lost to mortality when the cuttings are outplanted. Cuttings are grouped in bundles, often 25 or 50 cuttings per bundle, to keep track of the total. Bundles should be labeled with the correct plant collection information.

Cuttings can deteriorate rapidly. They must be kept moist, cool, and out of the sun. After the cuttings have been taken out of the field, they should be stored at 34 to 38 degrees Fahrenheit (1 to 3 degrees Celsius). Take care that they do not freeze. Cuttings should be rooted as soon as possible, but some species can be stored for up to several weeks. If cuttings are going to be shipped to a professional grower, ship them early in the week to make sure they arrive before the weekend.

To cut the stem cleanly, use sharp scissor-type, hand-pruning shears. Anvil-type shears will crush the stem. Cut the stems at a 45-degree angle to increase the rooting surface. Recut the upper end of the stem at a 90-degree angle so the upper end can be distinguished from the lower end (figure 3–116).

Cut off side shoots. Save those that are large enough to plant. It is best to collect cuttings in the morning while the stems are fully turgid. Depending on their size, the cuttings can be placed in small wet plastic bags, wet burlap bags inside a plastic bag, or in triple-layer paper bags. To avoid harming a donor plant, do not remove more than 30 percent of the branches from any one plant.

3.10.9b Semihardwood Stem Cuttings

Semihardwood cuttings are taken in late summer or early fall from the partially matured growth of woody plants. Stems are ready if they snap rather than crush when they are bent.

3.10.9.c Hardwood Cuttings

Hardwood cuttings are taken when the plant is dormant in the late fall or winter. Cuttings should not be taken after the buds have begun to swell in late winter. Deciduous plants enter dormancy when the leaves have dropped. Cuttings



Figure 3–116—Cut stems with bypass pruning clippers at a 45-degree angle to increase the rooting surface. Recut the upper end of the stem at a 90-degree angle so that the upper end can be distinguished from the lower. This photo was digitally altered.

should include the terminal bud (figure 3–117), and be 6 to 24 inches (152 to 610 millimeters) long and $\frac{3}{8}$ inch (9.5 millimeters) in diameter. Include at least two nodes, with the bottom cut being just below a node. Thick, young stems root best because they have carbohydrate reserves. (Huber and Brooks 1993; Weisberg 1993).

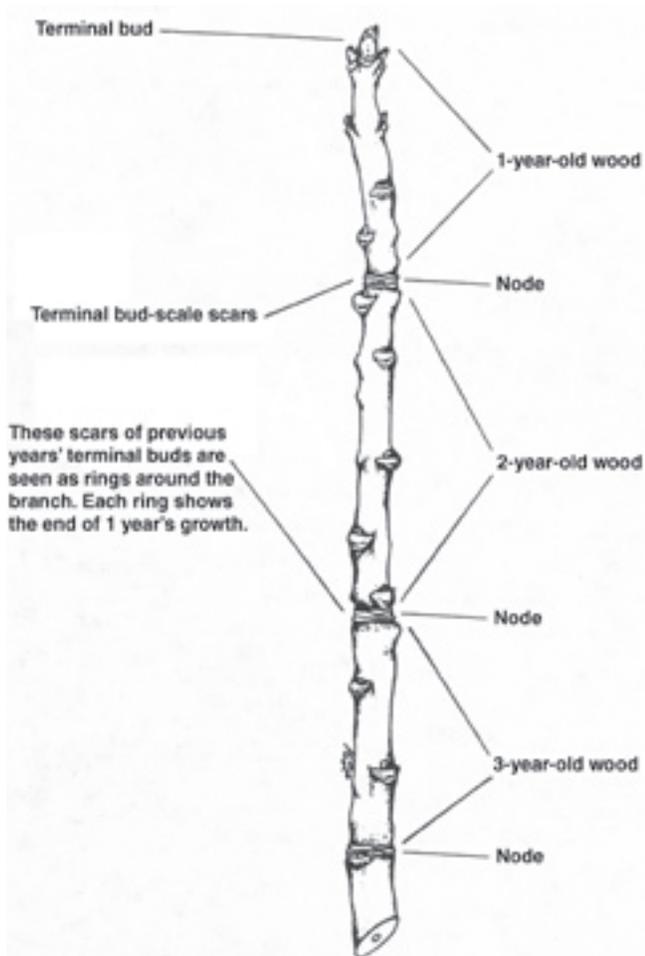


Figure 3–117—Determining the age of a branch. Drawing courtesy of Carol Aubry (Potash and Aubry 1997).

3.10.9d Softwood and Herbaceous Cuttings

These cuttings are taken in spring or early summer from the rapidly growing tip of plants. This type of cutting is subject to wilting.

3.10.9e Root Cuttings

This technique is possible for some species with roots or rhizomes that produce stem buds. Donor plants need to be prepared by closely root pruning them and pruning back the foliage before the growing season (see section 3.10.12, *Transplanting Wildlings*, for this technique). Vigorous new roots that can produce stem buds will form quickly during the growing season. The new portion of the root is the part closest to the crown. Cut the root away at a 90-degree angle (so the upward end remains recognizable), then cut off the thin end with a sloping cut. Remove fibrous lateral roots. The number of plants from each root can be maximized using the following rule of thumb:

- If planting the cuttings directly into the ground, cut the root in 4-inch (100-millimeter) segments.
- If propagating the cuttings in a cold frame or cold greenhouse, cut the root in 2-inch (50-millimeter) segments.
- If planting the cuttings in a heated greenhouse, cut the root in 1-inch (25-millimeter) segments.

Root cuttings are subject to fungal rot. Dust them with sulfur or Captan, an antifungal powder. Use 1 teaspoon of Captan for every 100 inches (2.54 meters) of root. Place the roots and powder in a plastic bag and shake. Plant the segments with the crown end up. The crown has the perpendicular cut. It is best to take root cuttings during the dormant season.

Root cuttings have the potential for onsite propagation. Try replanting 4-inch (100-millimeter) or longer root segments immediately while the soil is moist. Do not water the cuttings until shoots appear (Browse 1979). Sprigging is an onsite technique that uses machinery to closely crop vegetation back to the crown before lifting the root systems from the ground. The sprigs are spread over the restoration site, covered with soil, and lightly tamped. This technique works with grass and shrub species that sprout from their roots or are rhizomatous (Redente 1993).

3.10.9f Leaf Cuttings

A few native plants have the ability to produce plantlets on leaves that have just expanded to their full size. Bulb scaling is a form of leaf cutting in which a scale from a bulb is peeled off and planted separately. This method of propagation is tricky. The most common failure is that the leaf rots before it can root. Cuttings need to be processed before the leaves wilt or desiccate.

3.10.9g Leaf-Bud Cuttings

This type of stem cutting can be taken from anywhere on the stem. It is an undamaged mature leaf with a very short piece of stem that has a leaf bud in the axil where the stem and leaf join (figure 3–118). The upper portion of the stem is cut away at an angle just above the bud (Browse 1979).

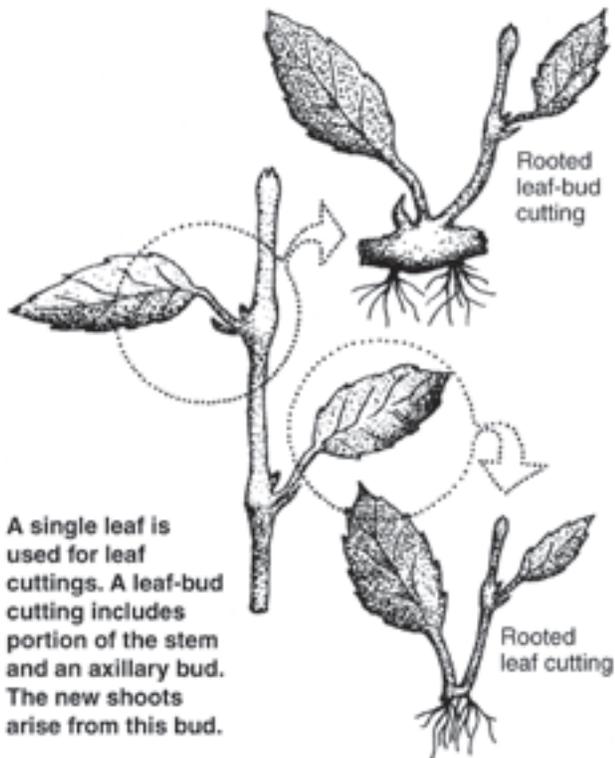


Figure 3–118—Taking a leaf bud cutting. Drawing courtesy of the Washington State University Extension Office (*Propagating Herbaceous Plants From Cuttings*, Pacific Northwest Extension Publications 2001).

3.10.10 Divisions

Divisions are taken from plants where the fibrous root mass or crown lends itself to being split into more than one plant. Each division has both roots and shoots. Divisions can be made easily with strawberries or plugs of grass (figure 3–119). Divisions can be done over and over at a nursery, greatly increasing the amount of plant material gained from a donor plant. Divisions also can be used as an onsite propagation technique. The donor plant is dug from the ground carefully and split with hands or a knife into more than one plant, with each division being replanted. According to Krystyna Urbanska, a Swiss alpine restorationist, alpine grasses can be divided into single tillers, maximizing plant material (Urbanska 1986).



Figure 3–119—Some plants, such as strawberries, are divided easily at the roots.

3.10.11 Layering

In layering, a new plant is rooted while it is still attached to the donor plant. A number of plants reproduce naturally by layering, which is to some degree an adaptation to short growing seasons where a seed crop may not be a reliable way to reproduce. Native plants that layer naturally include juniper, subalpine fir, heather, blackberry, and willow.

This method has more potential for propagation onsite than offsite, because a mature plant donor would need to be grown or established in a nursery. Layering works well to restore closed trails if shrubs are growing alongside the trail.

3.10.11a Simple Layering

With this method, a new plant is rooted from a single branch by burying the branch about 1 foot (about 300 millimeters) back from the tip. This should be done at the beginning of or during the growing season, so roots will begin to form immediately. Prevent the soil from drying too much while the branch is rooting. The newly rooted plant can be cut away from the donor plant at the end of the growing season or during the following spring if the plant was layered during the midseason. Check for roots before cutting the new plant away from the donor. Because the branches are still attached to the donors, your survival rate may look impressive, but it won't be if roots have not formed.

The first technique for simple layering is to dig a 6-inch- (150-millimeter-) deep hole at the correct spacing away from the donor plant, ideally in the site to be restored. The branch is bent into a "U" shape over the hole, about 1 foot (about 300 millimeters) back from the tip (figure 3–120). Leaves are removed from the portion of the branch to be buried. Rooting is stimulated by partially breaking the branch, abrading the bark with a pocket knife, or by twisting or girdling the shoot between the "U" and the donor plant. If necessary, the stem can be anchored to the bottom of the hole with a peg or rock.

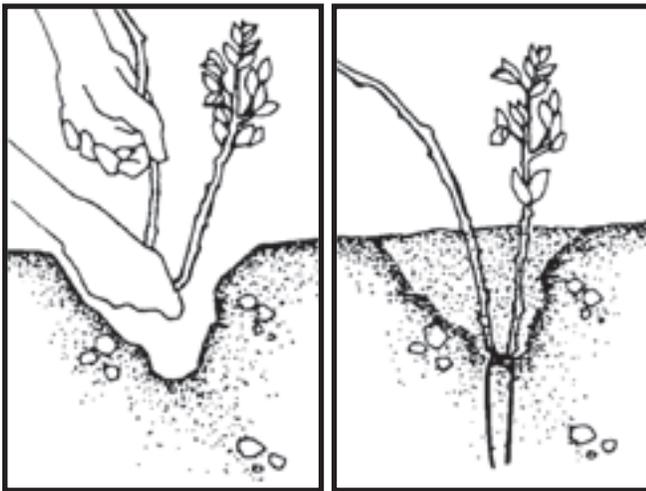


Figure 3–120—These drawings show simple layering. Drawings courtesy of Jenny Tempest (Hanbey 1992). The plant's stem is abraded or girdled to stimulate root production before the stem is pinned underground.

Firmly pack the hole with soil. You may want to stake the branch to keep it upright.

The second technique for simple layering is used on plants with branches that are low. The branch is covered with 3 to 4 inches (76 to 101 millimeters) of soil, 12 inches (about 300 millimeters) back from the tip (Weisberg 1993). Once roots have formed, the stem from the parent plant can be cut and the new plant can be moved.

3.10.11b Mound Layering

The concept behind mound layering is to root many new plants from the same shrub (figure 3–121) by forcing each branch to develop roots. This technique works well with shorter shrubs or stiffly branched plants. The shrub does not need to be immediately adjacent to the restoration site. Mound layering is begun just before the growing season begins, and plants are cut from the donor in the spring or following fall.



Figure 3–121—Heather can be propagated with mound layering (Weisberg 1993). This technique holds promise for a species that is challenging to propagate.

Select a mature shrub and prune each branch back to 3 inches (76 millimeters). Once new shoots are 3 to 4 inches (76 to 101 millimeters) long, soil is mounded over the crown of the plant (similar to hilling potatoes), leaving 2 inches (50 millimeters) of shoot tips above the soil. With species that

are more difficult to root, the entire crown is covered with soil ½ inch (13 millimeters) above the branch tips as soon as the branches are pruned. Continue to mound soil several times throughout the growing season to a total depth of 8 to 10 inches (200 to 250 millimeters), leave several inches of the growing tip above the soil. The soil must be well drained and kept moist.

If the new plants are cut away in the fall, the donor plant should be protected with soil for the winter. The same donor plant can be used for several years in a row (Weisberg 1993).

3.10.11c Tip Layering

Tip layering works with a few species, such as blackberries. The concept of tip layering is that the attached shoot tip is buried upside down in the ground, where the terminal bud will turn to push right-side up through the soil.

The growing tip of the side shoots are cut back early in the growing season. By the middle of the growing season, new shoots with small, curled tips will have formed. These tips are bent to the ground, and buried firmly, tip down in a 4- to 6-inch- (100- to 150-millimeter-) deep hole. The soil must be kept moist until fall, by which time a well-developed root system should have formed. At this point, the new plant can be cut 6 to 8 inches (150 to 200 millimeters) above the soil, separating it from the donor plant. The new plant can be transplanted immediately or during the following spring.

3.10.12 Transplanting Wildlings

A wildling is an indigenous plant growing in its native habitat. You may also hear wilderness folk referring to wildlings as transplants or plugs. This guide avoids calling wildlings plugs because we also transplant greenhouse-grown plugs.

Some species can be transplanted successfully as wildlings. This procedure should be used only if adequate plant material exists and care is taken not to cause too much damage to the collection site. If plants can be salvaged from a ground-disturbing project nearby, transplanting wildlings

can be relatively inexpensive and effective, especially if volunteer labor is available.

Transplanting wildlings tends to provide vertical relief to a site more quickly than other methods, and there is no risk of introducing nonnative organisms such as weeds, insects, or pathogens. In some environments wildlings establish and spread quickly. Plants that spread underground or with stolons perform exceptionally well. However, on dry, compacted sites, the rate of spread can be slow to nonexistent. Taprooted plants do not transplant well; most are difficult to transplant as wildlings and require special care so that as much root is left on the transplants as possible (figure 3–122). Some taprooted plants are best propagated offsite, where they can be grown in tall pots. Plants having long, brittle, horizontal roots, such as heather or vine maple, also are difficult to transplant. Such plants probably should only be transplanted if they are being salvaged and the plants will be destroyed anyway.



Figure 3–122—Be sure to have pruning clippers or a root saw handy if you salvage wild plants that have taproots. Drawing courtesy of Jenny Tempest (Hanbey 1992).

Wildlings should be transplanted in their new location as quickly as possible. Some delay may be unavoidable if restoration follows a salvage operation. Dig the holes at the restoration site before digging out the transplants. Holes need to be refilled after transplants are removed.

Larger plants, such as small trees, tend to be difficult to transplant successfully. Their root-to-shoot ratio is not high enough to allow them to survive transplant shock. Large plants can be prepared for transplanting by root pruning, a common technique in the nursery and landscape industry that increases the root mass dramatically. A sharp shovel is inserted into the ground, making a vertical cut through the roots all the way around the outer perimeter of the plant's foliage, known as the drip line (figure 3–123).



Figure 3–123—Roots are pruned two or more times to stimulate root production before transplanting. The roots are pruned by sinking a shovel blade vertically into the soil around the drip line of the plant that will be transplanted. Drawing courtesy of Jenny Tempest (Hanbey 1992).

A tree spade is the tool of choice, because it has a relatively flat blade. A scoop shovel can work if care is taken to keep the blade perpendicular to the plant. Root pruning needs to begin early in the growing season of the year the tree will be transplanted, or even the year before, with several cuts made throughout the growing season. Not only will

survival rates be higher after root pruning, but the tree will be easier to lift for transplanting as well. Root-pruned plants need to be tagged to facilitate relocation.

Wildlings should be transplanted in the spring or fall, or better, when the plant is fully dormant. Otherwise, transplant shock is likely.

If possible, wildlings are watered the day before they are lifted from the collection site. Transplanting should take place during the morning or on a cloudy, cool day while the plant is fully turgid. The digging technique is similar to root pruning. The shovel cuts are made into the soil around the plant with the blade as nearly perpendicular to the surface of the ground as possible. It is important to have a good ball of soil around the wildling's roots, and to dig out as much of the root system as possible.

Pay attention to root morphology. On well-developed soils or on arid lands, roots will grow down more than out. On shallow soils or on areas with permafrost, roots will spread out, making it necessary to dig up a much larger area around the plant. In general, larger plugs have a better chance of survival than small plugs. For relatively small plants, such as graminoids or forbs, a good rule of thumb would be to have the plug about as wide as a scoop shovel, and about 8 inches (200 millimeters) deep. Experimenting with various plug sizes is a worthy endeavor. If all plugs survived, smaller plugs would allow more transplants.

Some shrub and tree species transplant more successfully if their north-to-south orientation is maintained. Mark the orientation in some way, such as by hanging a flag from the north side of the plant.

Use the shovel and your hands to lift the root ball gently out of the hole, keeping the root ball together. Hand pruners can be used to cut away woody roots that do not come free with the shovel. The root ball can be transferred into a 5-gallon (19-liter) bucket, a wheelbarrow, or plastic or burlap bags for transport to the restoration site. If wildlings are dug from sandy soil, the soil will fall away from the roots. Use buckets of water, wet rags, or jelly roll material to protect the roots until the wildling can be transplanted. Denali National Park uses heavy equipment to salvage large, shallow pieces

of sod (up to the size of a bucket on a front-end loader). If the use of machinery is not an option, smaller pieces of sod can be cut and moved by several people (Densmore and Vander Meer 1998).

3.11 Transplanting, Protecting, and Establishing Native Plantings

Proper transport and transplanting procedures are critical to the survival of transplants. In addition, all plants must be given adequate water, mulch, shade, protection from animals that might eat them, and so forth.

3.11.1 Timing of Transplanting

The timing of transplanting will vary depending on the species, the environment, and the ability to provide initial care, such as irrigation, for transplants. In general, transplants need time to become established before being subjected to potentially lethal environmental extremes. In most environments, transplanting takes place during the spring or fall while the plants are dormant, just emerging from dormancy, or preparing for dormancy. Transplanting in winter is possible in environments where the ground is not snow covered or frozen. Although transplanting during the summer should not be ruled out completely, doing so risks subjecting plants to drying winds, too much heat, and inadequate moisture. The roots of some species grow only when they have adequate soil moisture.

For arid lands, most practitioners advocate fall or early winter plantings (figure 3–124). Desert plants have warm- or cool-season growth patterns. Cool-season species are best planted in the fall, while warm-season species, such as blackbrush (*Coleogyne ramosissima*), may transplant better with a spring planting. Planting in hot deserts is often done



Figure 3–124—For arid sites, fall or early winter plantings are the most likely to be successful.

during winter (Belnap and Furman 1997). According to some practitioners, timing is not as critical as one might expect. Midsummer plantings of mesquite (*Prosopis glandulosa*) have had high survival rates, but other species such as palo verde (*Cercidium floridum*), were more sensitive to drying wind and high heat (Bainbridge and others 1992).

In subalpine environments, transplanting generally occurs in September and into October (figure 3–125) when soils are moist (minimizing the need for additional watering after planting) and plants are slowing their metabolism before



Figure 3–125—In subalpine areas, planting is done in September and October just before the winter snowfall.

entering a dormant phase. It is possible to transplant just after the snow has receded in the early summer, or by late August, but the survival rate of plantings will be lower. Irrigation is likely to be needed throughout the remainder of the growing season.

And finally, plants should be transplanted before they seed. Otherwise, seed will be churned in too deeply or fragile seedlings will be damaged.

3.11.2 Transporting Nursery-Grown Plants to the Project Location

Nursery-grown plants may have their foliage or roots desiccated, their foliage crushed, or their stems broken when they are transported to the restoration site. The method of transport also can have an impact on the physical landscape or soil. For example, using a helicopter to transport plants quickly and with no disturbance to soil and vegetation may be a good option, but this practice conflicts with wilderness values. Even though mules or llamas (figure 3–126) may cause noticeable soil disturbance when they are used to transport plants to a fragile location, this disturbance may be less than the disturbance caused by the feet of the many workers needed to accomplish the same task.



Figure 3–126—Llamas or mules work well for transporting plant materials to most work sites. It's best to get the packstock in and out quickly so the animals don't damage your project site.

Plants should not be brought into the project area before transplanting is scheduled. This is especially important in arid environments, where shade and water are scarce. In a more temperate environment, plants can be held over for short periods by storing them in the shade and watering them as needed.

A number of methods have been developed for packing and transporting plants. It is critical to protect plants from exposure to air, heat, cold, or sunlight. Containerized plants should be watered before being transported. If weight is an issue, plants may be transported for a brief time with partially moist soil. Weed seedlings or moss growing on the potting medium should be removed before transport. If heat is a concern, some ventilation needs to be provided, while the plants also need to be protected from wind. Light-colored canvas tarps work better than plastic tarps because the canvas allows for some ventilation, reducing the risk of overheating.

3.11.2a Jelly Rolls for Protecting Bareroot Stock

When bareroot seedlings are lifted out of their growing medium, they can be dipped in a slurry of water and vermiculite and placed on damp fabric. The fabric is rolled as more plants are added. The rolls are placed in plastic bags and kept cool (39 degrees Fahrenheit, 3.9 degrees Celsius) in a controlled environment or by placing them on ice. Dry ice should not be used, because it is too cold and is toxic to plants. In addition to keeping roots moist, jelly rolls reduce the weight of the materials needed to transport seedlings and the space required to do so. For example, 98 plants in a sand-filled rack of supercells weigh about 50 pounds (22.7 kilograms), compared to 30 pounds (13.6 kilograms) for an ice chest holding 300 plants in jelly rolls packed on ice (Bainbridge and others 1992). Plants can be rolled in wet burlap, but reusable toweling works best for jelly rolls. For additional information on jelly rolls and reusable toweling, refer to *Reusable Toweling for Wrapping Tree Seedlings*, available at <http://www.fs.fed.us/t-d/pubs/htmlpubs/htm05242323/> (Username: t-d Password: t-d).

3.11.2b Moving Plants In Containers

Plants that are in containers need to be placed in a relatively rigid device with enough packing material between pots or flats to prevent them from being damaged by jostling during transport. If packstock are used to carry the plants, plan for “rodeos”—try to pack the plants so they will not be damaged if loads are thrown topsy-turvy. Containers help protect the roots from desiccation during transport and make it easier to hold and move plants at the project location. Disadvantages include the larger volume of containers that will need to be carried in and out.

Tree-planting boxes are large, sturdy waxed-cardboard boxes in which the Forest Service receives shipments of tree seedlings. These boxes, usually discarded after planting, are the perfect size for stacking rectangular flats of plants in small containers (figure 3–127). Stacking works well for plants that can withstand moderate crushing, such as graminoids, or plants with rhizomes or stolons. Small spacers can be added across the corners of the flats to reduce crushing. The boxes fit one to a side in canvas panniers or manties for transport on packstock and can be flattened for packing out.



Figure 3–127—Discarded Forest Service tree-planting boxes are the perfect size for loading flats of plants. Spacers can be used between flats to prevent crushing delicate species. Packing material can be added to take up excess room. These boxes fit in panniers, so they can be used with packstock.

For plants that cannot withstand the abuse of being stacked, find shallow boxes that will hold one layer of containers. Many office supply stores or shipping businesses sell a variety of boxes and are likely to have some that meet your needs. Racks can be devised for transporting plants in cells.

3.11.2c Moving Container-Grown Plants Without the Container

In general, it is best to move the plant in its container because the container will protect fragile roots. Some species, such as grasses and sedges, have well-developed root systems that can withstand the abuse of being removed from pots for transport. The soil around the plants should be moist to protect roots from desiccation.

Package plants by removing them from their pot and placing them in layers in large plastic bags lining larger containers, such as 5-gallon (19-liter) buckets (figure 3–128), boxes, or stock panniers. A sheet of newspaper between each layer of plants may help keep the seedlings separated.



Figure 3–128—Sturdy plants, such as sedges, can be removed from their pots and transported directly in buckets or boxes to save space.

3.11.2d Protecting Fragile Foliage

Plants with fragile stems, such as lupine, are difficult to transport. The fragility may influence the type of transport; packstock may not be appropriate. Cylinders can be made around the plants. For instance, each plant could be rolled securely in newspaper and packed so they remain upright. Use enough packing material to keep the plants from shifting.

3.11.2e Moving Plants With Helicopters or Other Vehicles

Plants can be packaged for planting using any of the methods described above. During transport, the plants need protection from wind. A canvas tarp can be used to cover loads that would be exposed otherwise.

3.11.2f Handling Plants After They Arrive at the Project Location

Upon arrival, plants should be watered and stored in the shade. If no shade is available, a shelter can be constructed from a canvas tarp or shade cloth. Most subalpine species can be placed in shallow water for short-term storage, such as in a pond, a shallow pool or a creek, or even in toddler wading pools set up in the shade. Branches or leaves that were damaged during transport should be cut back.

3.11.3 Transplanting Techniques

The same method is used for planting wildlings as for nursery stock. Good transplanting technique will improve the survival rates significantly. Common mistakes include planting seedlings too shallow, too deep, or too loosely; orienting wildlings incorrectly; damaging roots by exposing them to air; or failing to place root stems properly. With transplanting, the quality of the work needs to be monitored and supervised carefully. Quality—not production rate—should be given first priority.

Ideally, the spacing of plants is specified. For a natural appearance, plantings should be grouped in irregular

patterns. The planters should observe the natural distribution and spacing of each species and try to emulate that pattern. When plants are not available at the correct ratios for such a pattern, planters must use their best judgment to mimic the native stand. If seedlings are planted too densely, they may need to be thinned or moved as they mature. It may be wise to plant a few more seedlings than desired to compensate for mortality.

Ideally, seedlings should be planted on a cool, cloudy day or while the restoration site is in shade. Experience will determine how important these recommendations are for your project. Water the seedlings before planting them. Dig the planting holes before exposing the seedlings' roots to the air. Planting holes should not be allowed to stand empty for too long, because the exposed soil will dry out rapidly. When possible, planters should take advantage of microsites, such as rocks, logs, or depressions, to give the seedlings a bit more protection from sun or wind (figure 3–129).



Figure 3–129—Planting seedlings against a log or rock helps protect them and provides them additional water. (This photo was digitally altered.)

A variety of tools, including shovels, hoedads, and dibbles, can be used to dig planting holes. For small containerized stock, small hand-held pick hoes (figure 3–130) are the most efficient planting tools. In areas where soils are deeply compacted, a rock bar or soil auger may be needed to dig

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planting holes. Power augers may be the minimum tool for digging holes on especially difficult soils, such as caliche. In clayey soils, augers may leave a smooth glaze on the soil that is difficult for roots to penetrate; this glaze can be prevented by using specialized auger attachments.



Figure 3–130—Trowels are not the tool of choice for planting. A hand-held pick hoe (shown) or plow share works well for planting smaller plants. A shovel is needed when planting larger plants.

The planting hole is dug about one-third larger than the root system of the transplant. The soil should be loose on the sides and bottom of the hole. Water the planting hole with enough water to saturate the soil. Trim damaged roots off transplants, and gently tease roots apart if containerized plants are rootbound.

When placing the plant in the hole, maintain the natural alignment of the roots. Be sure that the roots are not doubled back. Taprooted plants, such as tree seedlings, will die if their roots are doubled back because the root system cannot correct its orientation to reach water in the deeper soil layers. If transplants have fibrous root systems, it sometimes helps to build a mound in the bottom of the hole and spread the roots out around this mound.

The crown of the plant should be at or slightly below ground level; some species will die if the crown of the plant is buried. A slight depression will catch water and afford a measure of protection from the elements. Another way of catching water is to build up a rim of soil around the transplant. The hole is backfilled, tamping the soil firmly without crushing plant material, and watered layer by layer (figure 3–131). Make sure to spread roots in the hole. Finally, planters should use the weight of their forearms or feet to snug soil down, removing air pockets from the soil around the transplant's roots.

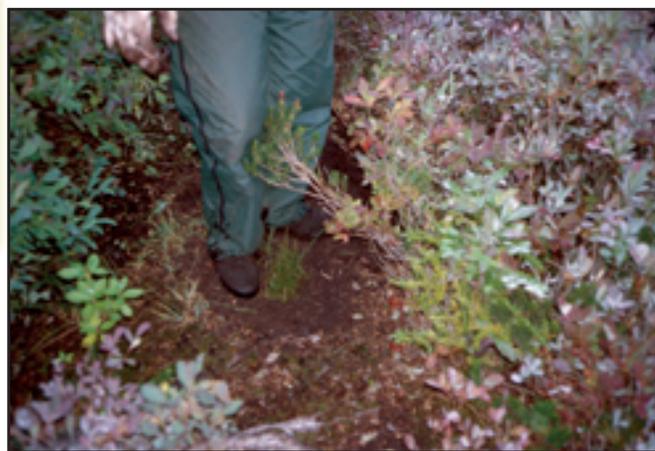


Figure 3–131—Once a transplant is placed in a hole, soil is packed firmly around it to eliminate large air spaces. Gently stepping around the transplant helps snug it in. A shallow depression around the transplant will help retain water.

Tamping also helps prevent frost heave. Shallow plugs of sod may need to be anchored with pegs so they maintain firm soil contact. At Denali National Park, restorationists use U-shaped pins made from rebar to anchor shallow-rooted trees. The pins help keep the trees from toppling over (Densmore and Vander Meer 1998).

The quality of the transplanting job can be monitored by tugging gently at each seedling. If a plant pulls loose, it needs to be replanted more securely. The planters should monitor their own work, and a supervisor should conduct spot checks for quality control.

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When planting seedlings among living roots, plant between the roots as much as possible. In some cases, such as with huckleberry, roots resprout once growing conditions are favorable. Ruth Scott has found the opposite to be true at Olympic National Park; sites where root systems were minimally disturbed during planting were slow to recover. Better overall results were obtained by thoroughly scarifying the soil before replanting (Scott 2002).

Plants have tiny root hairs that are destroyed almost immediately when they are exposed to air. These root hairs represent a large percentage of the total surface area of the root system. It is crucial to avoid exposing the root hairs to the air. At Joshua Tree National Park in the Southwest, the tall pots used to grow seedlings with long roots have a screen on the bottom. When the seedling is planted, the screen is removed and the entire plant—including the pot—is lowered into the planting hole. While a stout dowel is used to push the plant down, the pot is removed slowly as soil and water are added into the hole around the roots. Holes drilled near the rim of the pots allow hay hooks to be used to lift the pot away from the plant. This technique protects the delicate root systems (figures 3–132a and 132b).

Transplants should be watered as soon as they have been planted. Wildlings should be pruned back by one-half to one-third of their original size if the plant's morphology allows pruning. If transplant shock is anticipated, an antidesiccant spray can be applied to the foliage. Mount Rainier and Denali National Parks water their transplants with Vitamin B1 to prevent transplant shock (Densmore and Vander Meer 1998; Rochefort 1990). Vitamin B1 is available from nursery suppliers or garden supply stores.

If soils at the restoration site are altered significantly, the site could be inoculated with mycorrhizal fungi or nodules containing nitrogen-fixing bacteria by spreading a thin layer of inoculum in the planting hole. The methods for doing so are described in section 3.2.5b, *Inoculating Plants With Mycorrhizal Fungi*.

Consider situating some plantings against rocks or logs. The rock provides additional protection and additional water, especially if a long, sloped surface directs water to the plant.



Figures 3–132a and 132b—Roots can be kept moist when seedlings are grown and planted in PVC pots with removable screen bottoms. Once the pot and seedling have been planted (top), the pot can be removed (bottom), as shown here at Joshua Tree National Park, CA.

Some irrigation devices, such as deep pipes or clay pots, are installed as part of the planting process. Mulch, shade cards, signs, and devices to reduce wildlife damage generally are installed immediately after planting. These techniques are described in section 3.12, *Plant Protection and Establishment*.

Transplanting Checklist

- Protect plants during transport and at the work site.
- Select a staging area with resilient vegetation where supplies can be stored and workers can take breaks.
- Dig and water planting holes.
- Expose the seedlings' roots to air only when they are ready to be planted.
- Inoculate seedlings with mycorrhizal fungi or nitrogen-fixing bacteria, if needed.
- Orient wildlings correctly (the side of the wildling that faced north before transplanting should face north afterward).
- Position the seedlings' roots naturally when filling the hole.
- Gently tamp in layers of soil around the roots to remove air pockets.
- Water each layer of soil, and water again when done planting.
- Check that each small transplant is planted securely by gently tugging it upward; replant, if necessary.
- As appropriate, protect the plant with mulch, devices to reduce wildlife damage, shade cards, or signs.
- Clean up the work area daily to minimize damage.



Figures 3–133a and 133b—For a short time, salvaged plant materials can be stored in shallow water (top) or in the shade (bottom).

Sometimes, salvaged materials cannot be planted quickly because they need to be removed long before the area is ready. The plants may have to be held for an extended period.

In general, holding beds, similar to a garden, are used for the salvaged plants. Plants are provided with irrigation and shade, as needed. You may need to prune back the crowns of the plants to improve the root-to-shoot ratio. If you plan to salvage plants, check with local restorationists to learn the methods that work best for your species. Plants may require additional protection, such as a thick layer of mulch or sawdust, if they are held over winter.

3.11.4 Salvaged Materials

Ideally, transplants should be planted as quickly as possible. Plants can be held for a short period of time in the shade or shallow water (figures 3–133a and 133b).