Chapter 5: Site Preparation

The main purpose of site preparation is to create suitable growing conditions for tree seeds or seedlings. On sites with minimal disturbance, preparation may consist solely of improving soil structure and reducing the existing plant cover and debris by disking, mowing, or burning. Site preparation may also involve other treatments, such as fertilization, modifications of the site's hydrology, replacing topsoil, or large-scale earthmoving.

Another function of site preparation is to create improved conditions for the use of mechanical planting equipment, which is often necessary following logging (because of all the logging slash, fallen snags, etc.) and is sometimes important in other cases, such as on surface mine sites, where grading may be required.

Site preparation is not always necessary and in some cases may hinder the invasion of woody species. In a study of natural invasion of woody seedlings onto abandoned agricultural fields, Allen and others (1998) found significantly more seedlings in areas that had not been disked. The effects of disking on the long-term survival of seedlings that did become established, however, was not examined in that study, and most studies have shown that site preparation will improve the survival and growth of planted seeds or seedlings. Even though site preparation can add a considerable amount to the costs of restoration, it should never be ignored if the site evaluation indicates it is needed.

Site Preparation on Old-Field Sites

A common type of restoration site is abandoned agricultural land. Since old-field sites are generally well suited for growing agricultural plants, they often require only minimal site preparation to grow trees and other forest vegetation. Trees have often been planted successfully on old fields with virtually no site preparation. The method of regeneration is a key factor in determining the level and type of site preparation on old fields. For example, if seedlings are to be mechanically planted, then the site should not be disturbed unless there is substantial soil compaction (see Restoring Soil section, this chapter). Crop stubble and/or standing weeds should be left alone because they tend to provide better support for the tractor. If seedlings are to be hand planted, then crop stubble should be left standing, but standing weeds in fallow fields should be mowed. For machine planting of acorns on heavy clay soils, the site should be double disked the fall prior to planting to prevent cracking of the soil along the furrow lines during dry weather. If acorns are planted on silty or lighter soils not prone to cracking, the site can be planted without tilling.

Restoring Hydrology

Before any restoration project can be considered complete, the hydrology must be restored to approximate some historic pattern of flooding. As mentioned previously, hydrological records, maps, aerial photos and personal interviews can provide information about hydrologic changes that have taken place. The hydrologic regimes of many old-field sites in the southern United States have been altered either by localized drainage efforts such as ditching or tiling or by larger scale drainage or flood control projects. Some fields are still subject to frequent flooding, although the flooding may not be as deep or as long in duration as it was originally. Other fields flood much less frequently or not at all. In some cases, flooding has been increased by large-scale projects. For example, the Atchafalaya Basin of southern Louisiana is now used as a floodway for a portion of the Mississippi River flow. As such, the bottomland hardwood forests in this area are subjected to increased frequency, duration, and depth of flooding, and they are further subjected to greatly increased sedimentation. The restorationist must also remember that the hydrologic regime refers to groundwater dynamics, soil saturation, and periods of low flow, not just to overbank flooding.

When localized drainage is the primary factor, it may be possible to restore hydrology to its original or an otherwise suitable condition by plugging ditches, removing tiles, building or removing dikes, or some similar manipulation. In many cases, only a portion or portions of a levee or dike will have to be removed, rather than spending the time, effort, and money to remove the entire structure. The remaining portions of the levee will provide topographic relief and increase biodiversity by supporting a different forest community type. In areas where land-leveling has removed ridge and swale topography, a complete restoration will require use of earthmoving equipment to restore surface microtopography and hydrology. Interpretation of historic aerial photography can often provide locations of natural swales and other topographic high and low areas, as well as connections to natural aquatic systems as they existed before land-use conversions, land leveling, and other human-induced modifications.

Ideally, hydrology should be restored by methods that require little, if any, long-term maintenance. Flashboard risers and other water control structures requiring occasional maintenance are acceptable if the area to be restored is under permanent management (e.g., a wildlife refuge) but will become problematic in projects that receive little postplanting attention. If long-term maintenance is required, it is likely that nature will eventually take over, and the area may not remain a wetland.

Wetland restoration projects that rely on pumped water, for example, are suspect because of the long-term maintenance and expense required.

Where hydrologic modifications are the result of larger scale drainage, it may not be feasible to restore the natural hydrology. Flood control projects on major rivers or channel modifications that have resulted in a dropping of the water table, for example, may put hydrologic restoration beyond the capability of the restorationist. It may still be possible to partially restore the hydrology with the realization that under some conditions, such as large-scale flood events, an unnatural hydrology may still dominate. In these situations, the best that can be done is to make sure the species planted are appropriate for the expected hydrology.

Whenever a modification of the existing hydrology of a field site is contemplated, every effort should be made to ensure that adjacent landowners will not be affected. Increasing the flooding on a field to be restored, for example, may also increase the flooding of adjacent fields that are still in crop production or possibly on roads or residential areas. Any modification to the local hydrology will likely have some effect outside of the project area. A reduction of flooding in one area almost always results in increased flooding somewhere else. The possibility of these unwanted effects should be investigated before project initiation.

Restoring Soil

Most old fields have at least a moderate degree of soil compaction, mainly because of repeated use of heavy farm equipment. Soil compaction can usually be easily overcome by disking (fig. 5.1). Ideally, fields should be disked no more than 2 months before planting. However, disking may need to be done earlier if mid- to late-winter planting is planned and if flooding is a possibility. Two passes with the disk plow or harrow should be made, and disking should be to a depth of at least 15 cm (6 inches) but preferably 20-35 cm (8-14 inches). Disking to these recommended depths may be difficult or impractical on some heavy clay sites, although it can sometimes be accomplished by waiting until soils are moist throughout the desired depth.

In cases where compaction is especially severe, the field should be subsoiled by using a chisel plow or ripper (fig. 5.2). Subsoiling is most effective when the soil is dry and should be done far enough in advance of planting to allow rainfall to close up and firm the soil. Normally, the soil should be ripped to a depth of 45-60 cm (18-24 inches). On most soils, the tractor should have at least 40 horsepower per shank, but more power may be required on heavy clays. Ripped furrows should be oriented with the landform contour in areas with potential for erosion. Where trees are to be planted in rows, spacing between furrows should correspond to the desired spacing.

Although the soils on most bottomland old-field sites are naturally fertile, their fertility has often been reduced over time by repeated cropping or poor management. In general, nitrogen is the most limiting nutrient, followed by phosphorus and potassium. If the early growth rate of the planted trees is critical, a soil test should be carried out before planting, and the field should be fertilized as needed.

Since fertilization may cause a lush growth of weedy species, it may be necessary to plan for some postplanting weed control if fertilization is planned. If no postplanting weed control is carried out, fertilization may indirectly reduce survival of planted trees by increasing the population of small rodents, which are attracted to the increased weed cover.

Control of Plant Competition

On old fields that have been fallow through one or more growing seasons, weed cover may need to be reduced or eliminated before planting. Eliminating weeds will reduce plant competition and temporarily reduce the number of small mammals that may destroy planted seeds or seedlings. A particularly effective way to do this is by disking because not only does it reduce soil compaction but it increases soil organic matter (by turning the weeds into the soil). A variety of other types of farm or construction machinery can also be used for weed control if necessary (e.g., bushhog, mowers, scrapers, bulldozers), but disking is generally preferable.

Prescribed fire is another tool that can be used to reduce weed cover effectively. Late spring burns, for example, are generally very effective in reducing the cover of highly competitive pasture grasses such as fescue. Fire does, however, have some potentially serious disadvantages. There is always the danger of the fire escaping and causing damage to nearby property, smoke can reduce visibility on adjacent roads, and the time when burning can be done effectively (and safely) is relatively limited. Prescribed fire for weed control should be carried out only by trained personnel with adequate fire control equipment. Also, permits to conduct prescribed burns are required in some areas.

Herbicides are frequently used for weed control in commercial forestry applications but are not recommended for site preparation on old fields except as a last resort. Examples of situations where use of herbicides may be justified include sites where weed cover is too heavy to use a disk, where use of heavier equipment or prescribed fire is not feasible, and on sites with a

Figure 5.1. Old field being disked to alleviate soil compaction before planting. Disking can also be used to create a fire break around a restoration site.

Figure 5.2. Subsoiling for severe cases of soil compaction.

significant cover of exotic or particularly noxious native weed species.

Site Preparation on Heavily Disturbed Sites

Surface-mining and other activities that drastically alter a site have caused much less loss of bottomland hardwood forests than clearing for agriculture. Coal mining, however, has affected some bottomland hardwood areas, most notably in the lower Midwest, and phosphate mining has caused extensive losses in Florida and smaller losses in North Carolina and Tennessee. Peat mining has damaged pocosins in the Carolinas, and localized sand and gravel mining has affected sites throughout the lower Midwest and southeastern United States.

While the losses of forested wetlands due to mines are relatively small, areas affected are much more dramatically altered than agricultural fields (fig. 5.3). Restoration of these sites is costly and complex and should be attempted only by experienced restorationists working closely with mine managers and reclamation engineers.

Throughout this discussion about site preparation on heavily disturbed sites, the term “restoration” is used. The terms “created” or “constructed,” however, are often more appropriate for such discussions because an entire ecosystem must be established, including soils, hydrology, and biotic communities. Also, the newly established ecosystems may either be the same types of ecosystems originally on the project site but in different locations than the original systems, or they may be entirely new types of ecosystems.

Surface Contouring

The first consideration for site preparation on heavily disturbed sites is to establish an appropriate surface contour. Because the landscape has been so drastically altered, the restorationist first needs to decide what kind of ecosystems are to be created on the reclaimed land, how they should be placed in relation to each other, and how they should interact with existing ecosystems on adjacent unmined lands. The guiding principle is to integrate the new contour into the regional drainage system.

A restored bottomland forest should function ecologically within the regional drainage system in a manner comparable to bottomland forests on undisturbed lands. Therefore, the restored forest must be positioned where

Figure 5.3. Phosphate mine site showing the degree of habitat alteration.

it receives adequate surface runoff and groundwater baseflow to maintain a desirable hydroperiod. Prediction of the hydrologic regime that will occur after contouring is probably the most technically difficult challenge involved in restoration. Such predictions require that surface and groundwater flows be determined, with full consideration given to seasonal hydrologic patterns and expected flows during extreme events (such as 100-yr storms and unusually dry periods). Ideally, the restorationist should work closely with a hydrologist when designing the surface contour for a project site.

The restorationist should know the types of materials that are available for use as fill for the site and how they will influence hydroperiod, surface and subsurface flow, groundwater quality, and soil development. Clayey materials, for example, may swell upon hydration, possibly affecting water table depths and zones of soil saturation. In other cases, much of the fill material might be nearly pure sand, which will cause entirely different groundwater dynamics and tree survival.

The construction of a stream channel poses special challenges. Extensive gullying and downstream sedimentation can happen during a single heavy rainstorm, requiring difficult repairs and disrupting other project activities. Stream channels are less prone to gullying if they are relatively broad, shallow, and have a gently rounded bottom configuration. They should also have a low gradient and be meandering, rather than straight, because this will act to retard erosive flows in storm events. The bottom should either consist of indurated materials or should be vegetated with densely rooted wetland plants. Grading techniques, soil treatments, and cover crops that encourage the rapid infiltration of surface runoff upslope will also diminish the potential for channel erosion.

It is difficult to create a natural-appearing yet completely stable channel, so it is likely that the shape of the channel will change somewhat over time. Natural stream channels also change over time, thus some change in the course of the created stream channel should be expected, tolerated, and even planned. One way to introduce a dynamic element is to place barriers made of logs at intervals along the created channel. The logs will help reduce stream velocities and initiate meandering. Logs are present in natural streams, and in addition to affecting stream morphology, play a major role in the stream ecosystem by acting as a substrate for invertebrate and algal production and as a site for feeding by fish and wading birds.

Restoring Soil Characteristics

Restoring soils on heavily disturbed sites is a much more difficult and expensive proposition than it is on old fields. Among other things, the soils on heavily disturbed sites may have the original soil horizons mixed together, may be more (or less) acidic, may be highly compacted, and typically have much less organic matter.

Where possible, the impacts of projects that drastically alter soils can be minimized by stockpiling the topsoil (organic material and surface mineral horizons) separately from the underlying horizons. Once the surface is contoured, the topsoil can be placed back on the surface.

The postproject soil conditions will not be identical to preproject conditions, of course, but stockpiled topsoil is still generally preferable to a more thoroughly mixed soil. An exception is heavy clay topsoil, which may impede infiltration of water when spread over mined and reclaimed land. Also, it should be recognized that many bottomland soils are Inceptisols or Entisols (soils with relatively little profile development). This makes identification of topsoil rather difficult, but it is generally safer to mix surface and subsurface soil horizons of young soils than it is to mix more developed soils.

When using stockpiled topsoil, every effort should be made to minimize the time that soil is stored because organic matter and numbers of desirable soil organisms usually decline rapidly. Also, stockpiles should be kept as low as possible because the quality of stockpiled topsoil declines substantially when the depth exceeds 1 m.

The surface soil of a recontoured site will often be nearly devoid of organic matter. Cover crops and volunteering weeds contribute humus, but additional organic matter will accelerate forest establishment and soil maturation. If possible, organic matter should be added to the surface soil at the conclusion of final grading. Composted sludge has shown promise in experimental plots as a source of both organic matter and nutrients. Yard trimmings, which municipalities may provide without charge, are another source of organic matter. Experimental plantings conducted by the Florida Institute of Phosphate Research have shown that hay cover significantly increases tree survival and growth. Hay, if applied in a deep enough layer, conserves soil moisture, prevents the establishment of competitive weeds, retards erosion, and reduces the daily changes of soil temperatures in the root zone. If applied in a thin layer that allows sunlight through to the soil surface, though, seeds carried in the hay can foster pernicious growth of weeds and turf grasses. Pine straw (needles) have also been used effectively as a mulch.

Establishment of Ground Cover

In an effort to reduce soil erosion, many regulatory agencies require that surface mined and other highly disturbed sites be planted with a cover of grass immediately after surface contouring. Usually, a rapidly growing and spreading species such as fescue, Bahia grass, or Bermuda grass is required. Unfortunately, the same characteristics that make these ground cover species good for erosion control make them strong competitors with planted tree seeds or seedlings. Tree survival and growth are almost always diminished when the planting site is covered by these species.

While planting a ground cover species may reduce erosion in some cases, the nearly flat soil surface typical of forested wetland restoration sites and the rapid natural invasion of herbaceous species on these sites already reduce the potential for erosion. Such plantings, which are sometimes required in mitigation plans, are therefore of questionable value on wetland sites.

An alternative to planting aggressive grass species is to plant nitrogen-fixing species (such as clovers, alfalfas, or many other legumes) that can be disked under after one growing season as green manure. Green manuring can reduce erosion and at the same time improve soil structure and fertility. The main drawback to this practice, however, is that the desired tree species cannot be planted during the first growing season after contouring.

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Chapter 6: Seed Collection, Handling, and Storage

Quality seed must be obtained regardless of whether the method of reforestation will be direct seeding or by planting seedlings. It is assumed for the purposes of this guide that the restorationist is not planning to grow his or her own seedlings; rather, it is expected that the seed will either be sown directly on the site to be restored or given to a nursery for seedling production. Guides to the production of seedlings in nurseries are provided in the references at the end of this chapter, but nursery management is too large in scope to be covered in this guide.

Seed Collection

Regardless of the type of seed to be collected, five principles will always apply. First, the restorationist must know when the seed of the species of concern ripens (see table 4.1) and should scout the seed crop as it nears maturity. If adequate storage facilities are available, it is advisable to take full advantage of years with good seed production because collection is easier, usually more of the seed is viable, and it ensures an adequate supply of seed during years with poor seed crops.

Second, collection should take place as soon as the seeds are mature. If seeds are collected too early they may not germinate, or high moisture content may lead to handling and storage problems. If collection begins too late, much of the crop may have been eaten or otherwise made inviable.

Seed maturity is often indicated by color. For instance, the fruits of ashes, sweetgum, yellow poplar, and sycamore all should have turned from green to greenish-yellow or yellow by the time they are collected. Maturity of acorns can be recognized by the color of the nut (pericarp), which is green when immature, brown or black for mature acorns in the red oak group (e.g., cherrybark oak, laurel oak, Nuttall oak, pin oak, Shumard oak, water oak, and willow oak), and brown or a mottled-looking, yellow-brown for mature acorns in the white oak group (e.g., bur oak, Delta post oak, live oak, overcup oak, swamp chesnut oak, white oak, and swamp white oak). Another good criterion for acorn maturity is easy release from the cups; immature acorns are more difficult to separate from their cups.

Third, if possible, seeds should be collected from trees in the same general area as the site to be restored. The abiotic factors of the site where the seeds are collected (see Chapter 3) should resemble those of the restoration site as closely as possible to help insure that the seedlings will be adapted to the local environment.

Fourth, to enhance genetic diversity, seeds should be collected from numerous trees, preferably at least ten. To help maximize genetic diversity, seed trees should be at least 100 m apart. If timber production is an objective, collection should be from mature trees of good form, even though this may make collection more difficult. Likewise, if production for wildlife is the main objective, collection should be from the heaviest seedbearers.

Fifth, records should be kept on each batch of seed collected and include at a minimum the species, the date, and the specific location (provenance) of collection. Subsequent seedling performance for each lot can then be checked, and the best seed sources can be used in future restoration projects.

Most collection of bottomland hardwood seed is done in forests rather than in seed orchards. Seeds are typically collected manually, either by collecting freshly fallen seed from the ground, by using pruning poles, by climbing trees, or by collecting from logging slash (fig. 6.1). When possible, it is worth taking advantage of logging operations, because seed collection directly from felled trees can be easy, and many other seeds will fall on the ground during felling. Mechanized seed collection techniques exist (see references at the end of this chapter).

Inevitably, nonviable seed will be collected along with viable seed, but this can be minimized by learning to recognize indicators of seed quality. If there is evidence of insect depredation, decay, or physical damage, or if the seed feels exceptionally light, it should be discarded. Cutting open a small number of seeds to look for signs of insect infestation, decay, or other problems is advisable.

In the field, freshly collected seed should NOT be kept in plastic or other containers providing low aeration (fig. 6.1), especially if large batches of seed are being collected at one time and it will be a day or more before the seed is processed. The combination of heat buildup due to cellular respiration and the high moisture content of fresh seed can damage seed and promote the growth of molds.

Seed Handling

Seed handling steps include seed extraction and drying, separation of chaff and nonviable seed from sound seed, and in some cases, prestorage treatments. Depending on the type of seed and the type of planting operation planned, not all of these steps may be necessary.

Most seeds, other than heavy-seeded species such as oaks and hickories, require some type of drying and/or extraction process. The first step is usually air-drying. Screens or trays can be set up outdoors (and protected

Figure 6.1. Fresh acorns being collected in an appropriate container in the field.

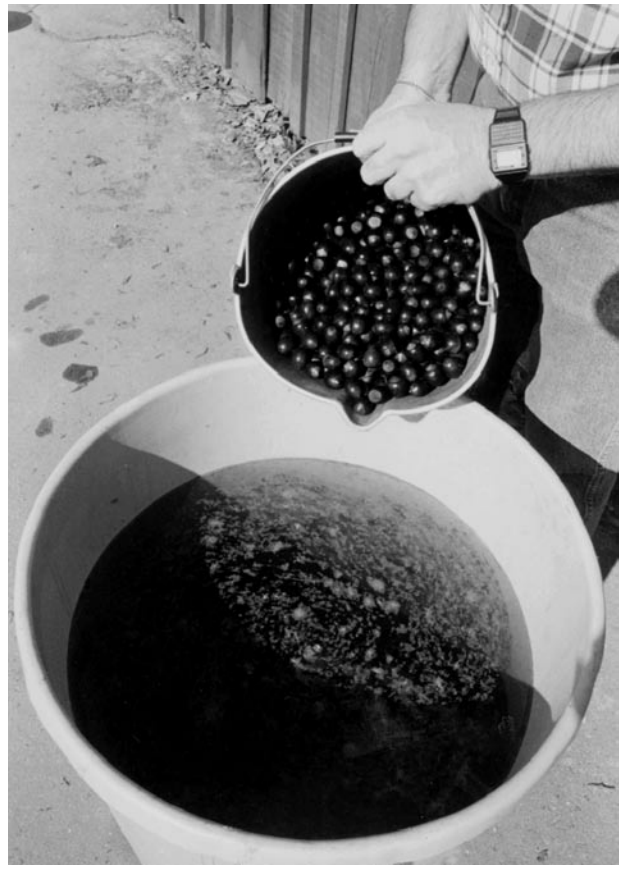

Figure 6.2. Processing acorns using the float test to determine viability. Nonviable acorns float to the top and are discarded.

from rain, dew, and excessive direct sunlight) in a greenhouse or in a building. Fruits and cones should be air-dried only until the point where extraction is possible (e.g., the cones or pods open up); longer drying may reduce viability. Solar driers, kilns, and other mechanized means of drying are recommended when large batches of seed will be handled annually.

Seeds within fleshy coverings should be extracted before drying to avoid fermentation or spoilage. The fleshy material can be removed first by macerating the fruit by hand (perhaps by rubbing the fruits across hardware cloth) or with a machine such as a feed grinder or commercial seed macerator and separator. The seed of some small stony-seed species (e.g., the hollies) can be extracted using an ordinary blender with a little water added. Following maceration of the fruits, seed can be separated from the fleshy material and other debris by swirling in a bucket of water. Once the seed is completely separated, it will sink if viable.

Because viable acorns of most oak species sink in water, a float test is highly recommended (fig. 6.2). The float test will work for all oak species except overcup oak, which floats when viable because it retains its cup after the acorns are mature. In addition to separating viable acorns from unsound acorns and other chaff, the float test can also serve to rehydrate desiccated acorns.

Acorns should be floated on the day of collection but can be placed in cold storage for several days before floating if necessary. If conditions are dry at the time of collection, acorns should be left in the water for 16-24 h because many viable acorns will float at first if a little dry. The acorns should be stirred once or twice to allow all unsound acorns to float up to the surface. After flotation, the unsound acorns and chaff should be skimmed off the surface and the water drained away. Complete surface drying of the acorns is not necessary, but there should not be enough water remaining to form a pool in the bottom of the container.

Seed Storage

Seeds of many species can be stored for several years (at least five) if dried to a moisture content of 6-10%, placed in airtight containers, and kept at temperatures slightly below freezing (-18 to -1 °C [0-30 °F]). Storage for shorter periods can often be successful at normal refrigerator operating temperatures of around 2-3 °C (36-37 °F) (table 4.1).

Acorns, however, are a special case. Even with the best of care, acorns of white oaks generally cannot be stored longer than a few months, and the percentage of viable red oak acorns drops substantially after 3 years. Following guidelines provided by the U.S. Forest Service's Southern Hardwoods Laboratory (Johnson, 1979; Bonner and Vozzo, 1985), the Louisiana Department of Wildlife and Fisheries has been able to store overcup oak acorns for up to 2 years and Nuttall oak acorns for up to 6 years (Larry Savage, Louisiana State Department of Wildlife and Fisheries, personal communication).

To store acorns successfully, high moisture content must be maintained: about 35% for red oaks and 50% for white oaks (wet weight; see table 4.1). High moisture content is best accomplished by placing the acorns in storage immediately after completing the float test (fig. 6.3). Occasional testing of moisture content is recommended during storage. If the moisture content drops below 30% for red oaks or 40% for white oaks, the acorns should be immersed in water for at least half a day. Actual measurements are not always required; when acorns are stored in clear plastic, condensed moisture on inside bag walls indicates that acorns are still moist.

Figure 6.3. Sacks of acorns in a large cold storage unit.

It is important to keep acorns cool but at temperatures above freezing (1-3 °C [34-37 °F]). Bags or other containers used to store acorns should not be completely airtight but should be loosely fastened. Containers should be separated within the cold storage unit to allow for air circulation. If bags are used, they should be placed on wire racks rather than on solid shelves (fig. 6.3). Turning the bags frequently is also recommended. Polyethylene bags 0.1-0.15 mm (4-6 mils) thick holding up to about 11 kg of acorns work very well because they hold in moisture but allow exchange of oxygen and carbon dioxide, which is necessary because cellular respiration still occurs. Drums or boxes with polyethylene liners are also satisfactory. There is some evidence that because white oak acorns tend to respire more rapidly than red oak acorns, they may store better in cloth bags or polyethylene bags (or liners) as thin as 0.04 mm (1.5 mils) thick. If facilities for refrigeration are not available, acorns can be stored successfully over a winter by burying them 30-60 cm (12-24 inches) underground.

Nuttall oak acorns have also been stored successfully over one winter in refrigerated tap water and wet sand. Storage in water apparently also reduces the number of acorns that germinate in storage.

A 4-8 week period of cold stratification is recommended for most southern oaks. A somewhat longer period (8-12 weeks) is recommended for Shumard oak and water oak. In general, the needs for stratification are met by proper cold storage.

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Chapter 7: Direct Seeding

Direct seeding is an important bottomland hardwood forest restoration technique, particularly for establishing oaks on old-field sites and sites surface-mined for coal. In situations where it can be applied successfully, direct seeding is very appealing because it is relatively inexpensive compared with planting tree seedlings (table 7.1). Direct seeding may cost as little as half of what planting seedlings costs on a per area basis, although the cost depends on factors such as the price of seed and labor, the availability of suitable equipment, and the success of the first direct seeding effort.

Direct seeding is also appealing because of its flexibility. The planting window for direct seeding is much longer than for planting seedlings (see the seasonal timing section, this chapter, and Chapter 8); therefore there is greater freedom in scheduling site preparation and planting operations.

Another advantage of direct seeding is that it allows the tree's roots to develop naturally. In contrast, seedlings taken from a nursery or the wild usually have had their roots pruned, balled up, or twisted. Also, it is very difficult to plant a seedling so that its roots are as spread out as they would be naturally, even if seedlings arrived from the nursery in perfect condition. To do so requires digging a wider planting hole and taking much more care placing soil around the roots than is typically done. This extra attention to planting slows the planting operation and ultimately costs more money. Roots that develop unnaturally may cause the tree to be more susceptible to drought stress and windthrow.

On the other hand, many direct seeding projects have failed, sometimes because newly germinated seedlings lack sufficient energy reserves to survive stresses caused by events such as dry periods. It is likely, however, that most failures have been caused by lack of attention to one of eight controllable factors described by Toumey and Korstian (1942): (1) seed quality; (2) species selection; (3) competing vegetation present on planting site; (4) soil condition; (5) presence of seed predators; (6) seeding rate; (7) timing of seeding; and (8) depth of sowing. The Louisiana Department of Wildlife and Fisheries suggests that proper handling of seeds from cold storage to actual planting be explicitly considered in item (1) above because seed quality can diminish very rapidly if the seed is not protected from heat and sun before planting.

Recent successes, such as those obtained by Louisiana Department of Wildlife and Fisheries personnel in northern Louisiana (fig. 7.1), demonstrate that direct seeding can be effective. In addition, recent evidence suggests that some sites planted by direct seeding of acorns that were considered failures were later determined to meet density requirements. The lack of apparent early success may have been a result of delayed germination, rodents clipping the stem (but not killing the roots), or the difficulty of locating small seedlings in dense herbaceous vegetation. Most practitioners recommend that sites planted by direct seeding should not be abandoned until they have been evaluated at least 5 years after planting.

A major limitation of direct seeding as currently practiced is that its use is restricted mostly to oaks and other large-seeded species. The few efforts that have been made with light-seeded species (such as ashes, sweetgum, and elms) have almost all failed, although some successes with green ash have been reported in West Virginia and eastern Kentucky. The failures were primarily due to depredation by birds and rodents or to drought stress shortly after germination. Because small-seeded species have low energy and moisture reserves they are particularly susceptible to drought. It is probable that these light-seeded species, which must be sown on or near the soil surface, will require some sort of protection in order to become established. Use of rodent and bird repellents may eventually prove successful, but none have been demonstrated to work on bottomland hardwood species at this time. Mulches, slurries, and other techniques may also work, but no evidence exists that these have been tried in bottomland projects. Limited trials in Florida suggest that direct seeding of light-seeded species requires exposed, moist mineral soil and regularly distributed rainfall for several months after seeding.

Seasonal Timing

Most direct seeding is done in late fall, spring, or early summer. Research with red oak acorns indicates that direct seeding may also be successful at all other times of the year; however, Wood (1998) showed that cumulative germination of Nuttall and willow oaks was greatest with December planting (~70%), less with March planting (~50%), and least with June planting (~15%). The period of June through October is not recommended in most of the Deep South.

Species such as the white oaks, which are difficult to store successfully, are most likely to do well when planted immediately after seed collection (i.e., in late fall). Other types of seed can be stored and planted when labor and equipment are not engaged in other activities or when planting conditions on the site are most favorable for the type of equipment being used. At least some red oaks (Nuttall and willow) perform best when planted in December, regardless of flood conditions (Wood, 1998).

Table 7.1. Pros and cons of direct seeding and planting seedlings (from Haynes and others, 1995).

Pros	Cons
Direct Seeding	
Typically about half to one-third as expensive as planting seedlings.	Proven reliable only for oaks and some other large seeded species.
Roots develop naturally without problems caused by disturbing roots and removing seedlings from nursery.	Slower initial establishment and development, although long-term growth and survival may not be significantly different from seedlings.
Acorns may remain in a dormant state for a period of time under adverse site conditions (drought or too wet), thereby increasing survival potential.	Local acorn supply for one or more species may be scarce or difficult to obtain from commercial sources.
Can plant twice as fast, normally using a two-row planter versus a one-row with a seedling planter (however, there are some two-row seedling planters now being used).	Rodents can sometimes be a problem by digging up and eating the acorns; however, planting in large open fields typically results in little damage.
Proven method of reforestation when site is properly prepared using viable seed that has been properly stored.	Cold storage of acorns is generally limited to red oaks (see table 4) and sweet pecan. White oaks do not usually store well for periods greater than 3 months.
Window for planting is longer than for seedlings (acorns can usually be planted successfully from October through April or May).	Acorn-adapted planters (i.e., J.D. Max-Emerge 7100, converted) have more working parts, thus more potential for breakdowns than seedling planters.
	More difficult to monitor success, since it takes several years for germinated seedlings to become large enough to find easily.
Planting Seedlings	
Planting tree seedlings is a reliable and well established method of reforestation.	About two or three times as expensive as direct seedling of acorns.
Usually a good selection of reliable commercial suppliers of seedlings; seedlings available for many species.	Seedlings subjected to adverse site conditions (drought or severe flooding) will perish quickly.
Initial seedling development is faster than for planting acorns, although long-term growth and survival may not be significantly different.	Seedlings must be planted during the dormant period (January through March) when many bottomland forest sites may be flooded. Planting in extreme wet conditions must be done by hand.
Taller seedlings may be able to survive flooding events during the growing season if water does not top the seedling for extended periods.	Seedlings that have been fertilized in the nursery are a preferred food for rodents and deer.
For monitoring compliance and determination of planting success, planted seedlings are easier to locate than newly germinated seedlings from acorns or other seed.	

Depth of Sowing and Spacing

Acorns and other large seeds can be sown successfully at depths between 5-15 cm (2-6 inches). Sowing 5-10 cm (2-4 inches) deep usually results in better germination and survival than sowing between 10-15 cm (4-6 inches), and is easier (and faster) than sowing deeper. Wood (1998) observed significantly greater germination for seeds sowed at 7-10 cm (3-4 inches) than sowed at 3-5 cm (1-2 inches) in the absence of herbivory. Sowing deeper than 10 cm (4 inches) may pay off, however, in situations where there are a lot of rodents or the soil surface is subject to freezing or drying out completely.

Experience has shown that as many as 25% of acorns sown in relatively weed-free old fields, and about 10% of acorns sown in cleared forests, will produce trees still growing well after 10 years. Initial germination and establishment success may be as high as 80%, but usually it is closer to 35 or 40%. Based on these initial germination and longer term survival estimates, sowing of acorns should range from 1,700-3,700 acorns per ha (700-1,500 per acre). On old fields with good site preparation, 1,700-2,500 acorns per ha (700-1,000 per acre)

Figure 7.1. Restoration site where oaks have been successfully established by direct seeding (Ouachita Wildlife Management Area, Louisiana).

Table 7.2. Number of seed or seedlings required per hectare (acre) at various spacings.[1]

Spacing		Number	
Meters	Feet	per ha	(acre)
0.75 × 3.65	2.5 × 12	3,586	(1,452)
0.9 × 1.80	3 × 6	5,977	(2,420)
0.9 × 2.75	3 × 9	3,984	(1,613)
0.9 × 3.65	3 × 12	2,989	(1,210)
0.9 × 4.57	3 × 15	2,391	(968)
1.8 × 1.80	6 × 6	2,989	(1,210)
1.8 × 2.75	6 × 9	1,993	(807)
1.8 × 3.65	6 × 12	1,494	(605)
1.8 × 4.57	6 × 15	1,195	(484)
2.44 × 3.05	8 × 10	1,346	(545)
2.75 × 2.75	9 × 9	1,331	(539)
2.75 × 3.65	9 × 12	995	(403)
2.75 × 4.57	9 × 15	798	(323)
3.05 × 3.05	10 × 10	1,077	(436)
3.05 × 3.65	10 × 12	897	(363)
3.65 × 3.65	12 × 12	746	(302)
3.65 × 4.57	12 × 15	598	(242)
3.65 × 6.10	12 × 20	450	(182)
4.57 × 4.57	15 × 15	479	(194)
4.57 × 6.10	15 × 20	358	(145)
6.10 × 6.10	20 × 20	269	(109)

[1] Assuming a 25% survival rate for direct seeding of acorns, reduce number per area by 75% to estimate the number of surviving trees per area (ha or acre) (Haynes and others, 1995).

should be adequate. Sowing rates of 3,000-3,700 acorns per ha (1,200-1,500 per acre) are recommended for sites where seedling survival is questionable, including mine spoils and areas with a dense vegetative cover. Savage et al. (1996) reported that seeding rates of 5,900 acorns per ha (2,400 per acre) were necessary in a field with a particularly high population of rice and cotton rats. Because acorns are a relatively inexpensive part of the overall direct seedling operation, higher seeding rates should be seriously considered where appropriate.

Direct seeding is generally done in rows, which are most often spaced between 2.5-4.5 m (8-15 ft) apart. Spacing within rows will depend on the distance between rows and the number of seeds sown per acre; a range of possible spacings is depicted in table 7.2. If the aesthetics of the reforested site are an important consideration, the restorationist can avoid the appearance of a plantation, with its neat rows of trees, by planting in wavy lines or even at random. The main thing to keep in mind is to allow adequate growing space around each seed.

Hand Sowing

Direct seeding by hand can be accomplished using very simple and inexpensive equipment. The simplest approach is to use a metal bar, broomstick, or even a stick found in the woods, to make a planting hole. The seed is then dropped in the hole, after which the planter closes the hole with his or her foot. A hand tool, such as the one developed by the U.S. Forest Service (fig. 7.2), can make the job easier because the seed is dropped down the tube to a preset depth in the ground, thereby avoiding the need to bend over to put the seed in the hole. The hole is then closed by foot.

On a relatively clean site with favorable soil moisture conditions, a single planter with the Forest Service's hand planter can sow 2.8-3.2 ha (7-8 acres) per day at a rate of 3,000-3,700 seeds per ha (1,200-1,500 per acre). A planter using just a stick or bar probably will plant no more than 2.0-2.5 ha (5-6 acres) per day. These rates can decline considerably depending upon the experience and physical condition of the planter, the depth of sowing, the distance the planter has to hand carry seed before being able to start planting, and the actual site conditions.

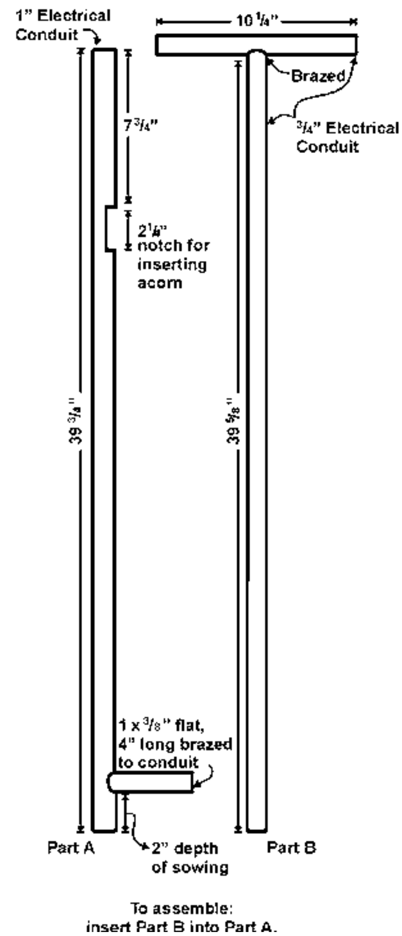

Figure 7.2. This hand tool, developed by the U.S. Forest Service, can make hand sowing of acorns much easier.

Machine Sowing

On clean sites with slopes of 10% or less, sowing seeds with a mechanical planter may work very well. Almost all of the planters that have been used on bottomland hardwood sites in the past are modified agricultural planters.

Two main types of modifications to agricultural planters have been made to date. One modification involves placing seats behind the drop tubes and requires personnel to ride on the planter and drop seeds in by hand (fig. 7.3a). The second modification involves adapting a no-till planter so that it can handle both the deeper planting depths and larger seeds that are necessary when direct seeding acorns, while still dropping the seeds automatically (fig. 7.3b). Specifically, use of agricultural (no-till) planters requires modification of the hopper bottoms and drop tubes to handle acorns (especially the larger species, such as Nuttall oak) and installation of heavy-duty coulters, down pressure springs, closing wheels, and other equipment that allows the planter to dig deep enough into the soil, cut through a heavy weed cover, and drop in large seeds.

Although not essential, an electronic seed monitor is desirable when using modified no-till planters. Seed monitors let the tractor operator know if the hoppers become jammed and seeds are not being planted properly, which is a frequently encountered problem. Jammed hoppers are common because tree seeds tend to be more irregular in size, and more foreign matter is likely to be present than in agricultural seed lots.

Electronic seed monitors are expensive, yet they can be very cost effective. They eliminate the need for constant checking of the hoppers (and replanting rows that were "planted" with a jammed hopper). They can also reduce the size of the planting crew needed, since one person can both drive the tractor and continually ensure that seed is actually being planted.

Use of modified agricultural seed planters can greatly increase the rate of planting. Three people can sow at least 16-24 ha (40-60 acres) per day with the first type of modified planter, and one person can sow up to 8 ha (20 acres) per hour with the second type of planter equipped with a seed monitor.

At least two recently developed planters designed specifically for acorns or other large, irregular seeds appear to have real potential: the Truax large seed planter (fig. 7.4), and a planter designed by the U.S. Forest Service's Missoula Technology and Development Center for sowing multiple rows of acorns in nursery seedbeds (fig. 7.5a,b). The basic design of the U.S. Forest Service planter (fig. 7.5a,b) could probably be adapted for use on restoration sites.

To date, very little direct seeding has been done using broadcast seeders, but this would appear to be quite possible and may become a viable method when there is a desire to avoid the look of a tree farm (i.e., with the trees in neat rows). One trial on the Ouachita Wildlife Management Area in Louisiana showed that the technique is feasible, but another trial showed that the method is less efficient than direct seeding by hand or machine, mostly because of rodent damage (Tom Dean, Louisiana State University, School of Forestry, Wildlife, and Fisheries, unpub. data). A few attempts at broadcast seeding have been made in Florida, but most have resulted in failure. The few successes were on freshly disked sites. More research and development work is needed before any specific guidelines on this approach can be published.

a.

b.

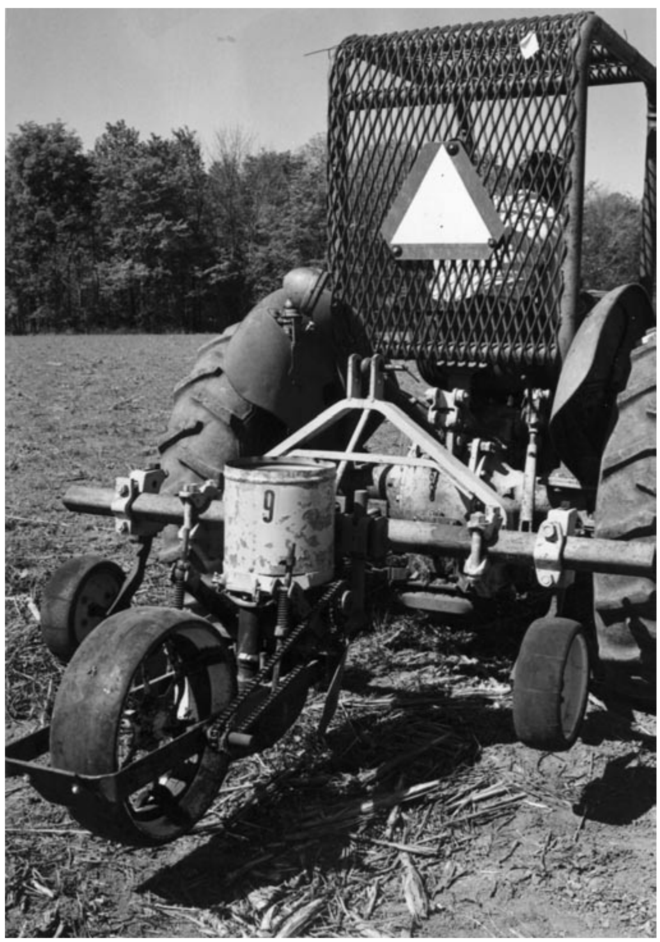

Figure 7.3. Two types of modified agricultural planters used for direct seeding: (a) planter requiring personnel to drop seeds in manually and (b) planter that drops seeds in automatically.

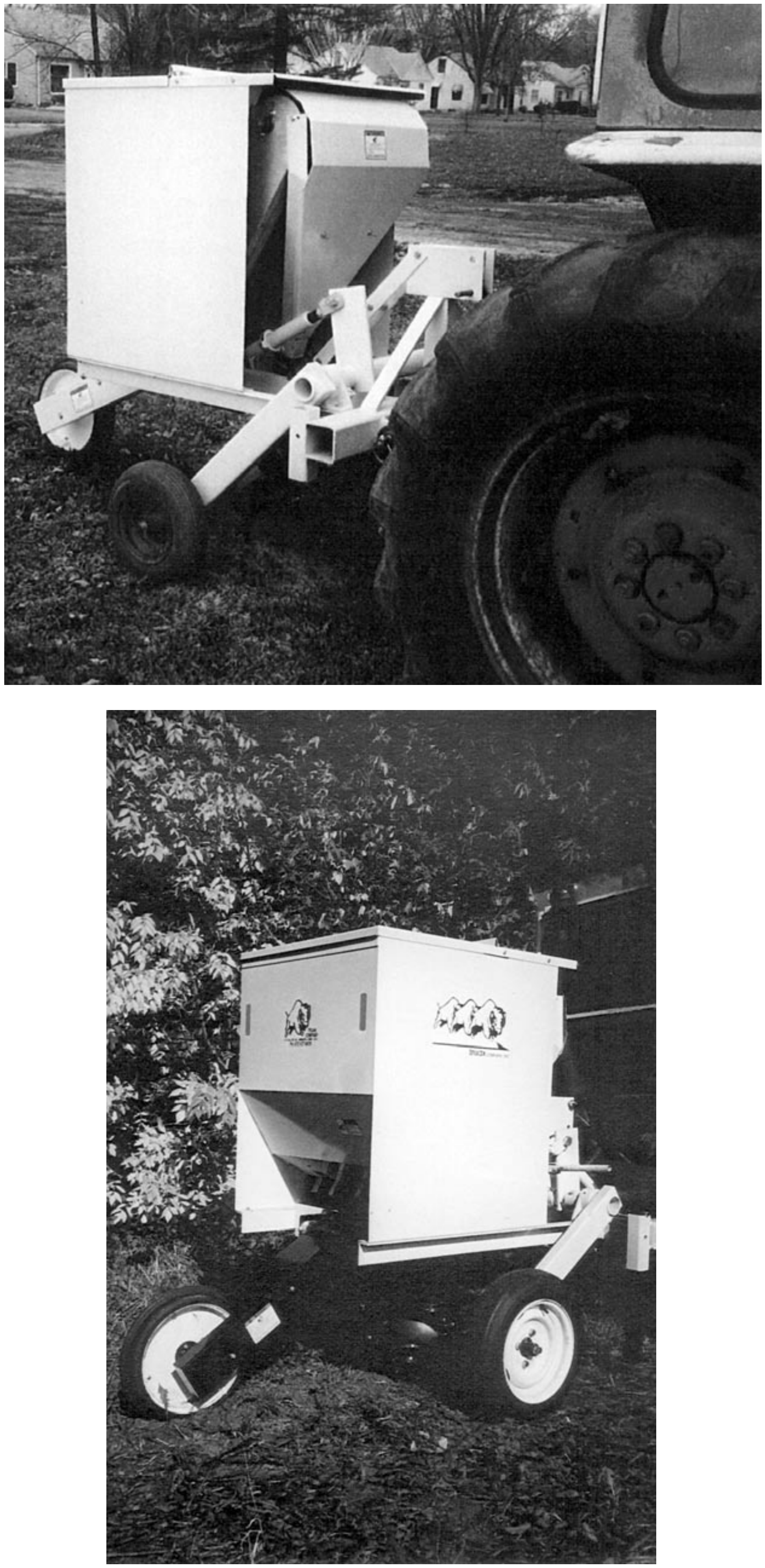

Figure 7.4. The Truax large seed planter.

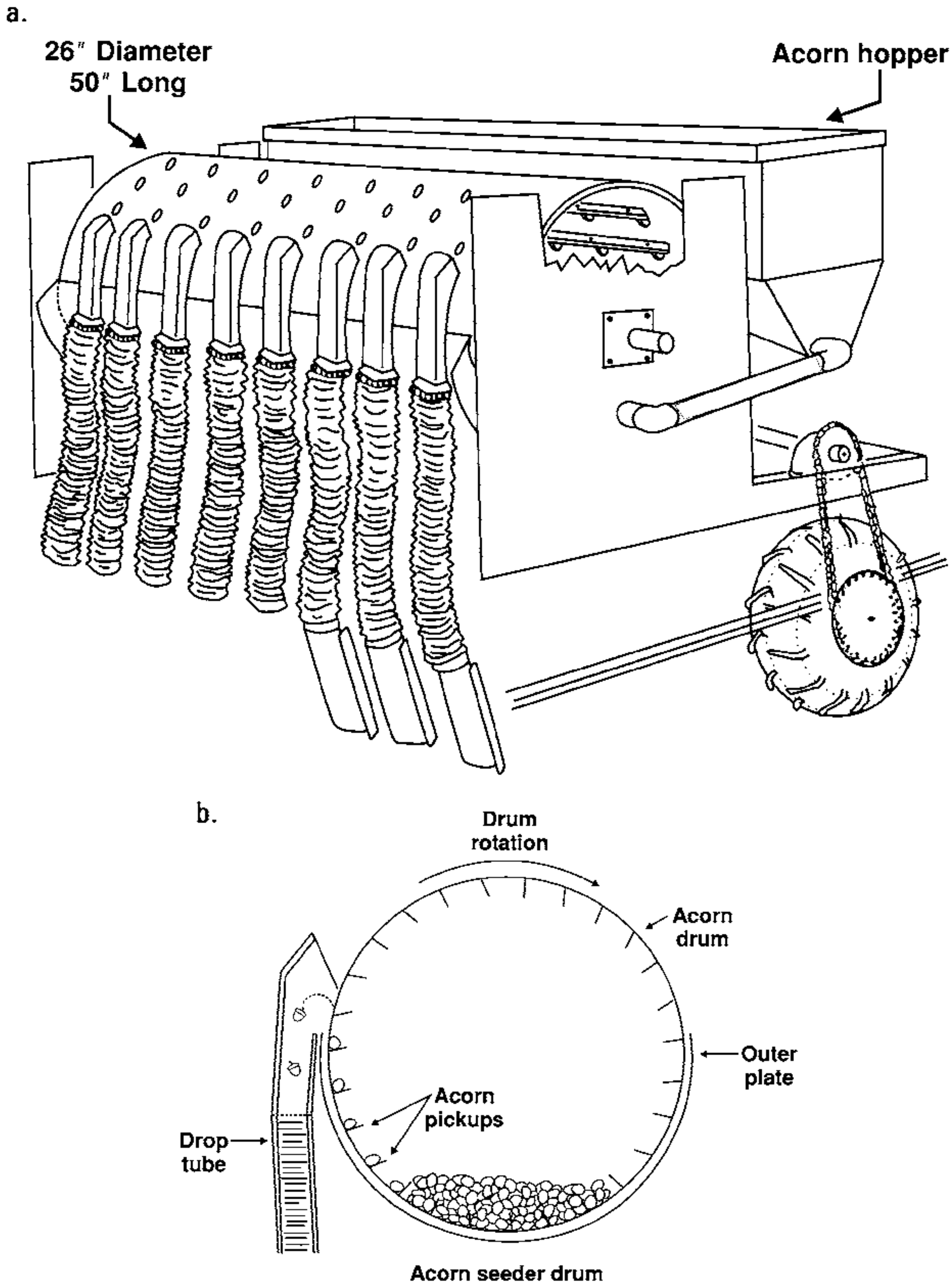

Figure 7.5. Machine developed by U.S. Forest Service for sowing acorns in nursery seedbeds: (a) machine sowing acorns and (b) schematic drawing of hopper mechanism.

Aerial Seeding

Aerial seeding has been widely used in the southern United States to sow pine seed, but it has rarely been used for direct seeding of hardwood species. The primary advantages of aerial seeding are that seeding rates are increased dramatically over manual and mechanical seeding; it can be more cost effective on large projects; it can be employed on sites too wet or unstable for mechanical seeders; and, because it is much faster than machine planting, more area can be planted during the sometimes brief window of suitable site conditions that exist on heavy clay soils. Also, in much of the area covered by this guide, aircraft normally used for crop dusting can be hired for direct seeding. Crop dusters often are not busy at the time of year direct seeding is carried out and may welcome the additional business.

Several small trials carried out between 1989 and 1992 in southern Arkansas, and more recently in the Mississippi delta by U.S. Fish and Wildlife Service, Division of Refuges (Larry Threet, Felsenthal National Wildlife Refuge, oral commun.), have shown that aerial seeding has potential on bottomland sites. In these trials, fields were disked in the fall prior to seeding so that large clods were produced. Then, a crop duster was loaded with acorns (fig. 7.6), and the seeds were broadcast over the field either in the fall or the following spring.

Several methods of burying the seeds after aerial seeding have been tried by the various refuge staffs. The simplest method was aerial seeding immediately before predicted rains with the hope that acorns would be buried as soil clods were broken up by raindrops. In other cases, the soil surface was rebroken in the spring just before seeding using a cutting disk or a field cultivator. All fields in the latter trial were also disked or cultivated after seeding, and some of the area was compacted using a roller drum.

These trials, although promising, showed that several aspects of the process need to be resolved before aerial seeding of bottomland hardwoods is considered a truly

Figure 7.6. Crop duster used for sowing acorns.

effective technique. One problem with aerial seeding is that the standard hopper and gate system on cropdusters cannot handle more than one size class of acorns at a time. Unless a more flexible system is developed that allows several sizes of acorns to be sown simultaneously, multiple passes over a field will be required.

Applied research on calibration of hoppers, gates, and air speeds is needed to ensure desired sowing rates are achieved. Also, definitive guidelines need to be developed on the best ways to ensure that seed is buried deeply enough. For example, the field cultivator worked better than disking when the soil moisture was high. In short, testing of aerial seeding methods needs to be expanded and replicated over a variety of site and soil types.

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Chapter 8: Planting Seedlings

Planting tree seedlings is an old, well-established method of reforestation. The primary advantage of using seedlings is that, overall, the chances for success appear to be higher than with direct seeding. Also, the initial development of the trees is usually somewhat faster. The main disadvantage is the higher cost, since seedlings must first be raised in a nursery (or dug up from under existing stands; see Chapter 9).

Although chances for success are high when planting seedlings, incorrect or careless handling or planting of seedlings can easily result in an expensive failure. In addition to selection of the appropriate species for the site, the keys to successful establishment of tree seedlings are obtaining good quality seedlings, taking proper preplanting care of the seedlings, and using proper planting techniques.

Choice of Seedling Type

There are two major types of seedlings used in planting operations, bare-root and containerized. Bare-root seedlings have been separated from the soil in which they were growing at the nursery by a process known as “lifting,” which usually involves cutting the tap root 15-30 cm (6-12 inches) below the soil surface and mechanically loosening the soil around the roots. Containerized seedlings come in a variety of forms, ranging from very small seedlings in small tubes to larger seedlings (or saplings) in gallon-sized or larger pots or bags (fig. 8.1). The choice of seedling type depends to a large degree on the conditions at the restoration site. In some situations bare-root seedlings will be preferred, and in other situations containerized stock will be preferred.

Bare-Root Seedlings

Bare-root seedlings can be expected to survive and grow well as long as the planting site is not too drought-prone and the soil conditions are not otherwise unfavorable. They are less expensive, lighter, easier to transport, and generally easier to plant than containerized seedlings. Bare-root seedlings must be planted during the dormant season, December through mid-March. Some species, such as baldcypress, can be planted along water bodies in flood prone areas later in the season as the water recedes.

Bare-root hardwood and cypress seedlings should have a top height of at least 46 cm (18 inches). The root collar (the part of the root just below ground level) should be at least 0.6 cm (1/4 inch) thick. When possible, though, selected seedlings should have a minimum top height of 60 cm (24 inches) and a minimum root collar diameter of 0.9-1.3 cm (3/8 to 1/2 inch). The use of larger seedlings may be especially important for projects where no site preparation or weed control will be carried out. Although larger seedlings may be more expensive, their use will still generally be cost-effective because mortality will be lower, meaning that less seedlings need to be planted. The cost of planting is usually considerably more than the cost of seedlings; therefore, the higher cost of large, good-quality seedlings may be more than offset by the reduced expense of planting a large number of seedlings. On the other hand, seedlings that are much larger than about 90 cm (36 inches) in top height are difficult to handle and plant. Seedlings in the 60-90 cm (24-36 inches) range are ideal for most applications.

In addition to their large size, bare-root seedlings should have a good balance between shoot size and root volume. The roots should be healthy looking, well-developed (i.e., have several lateral roots greater than about 1 mm [1/25 inch] in diameter), and pruned to a length of about 20 cm (8 inches) (fig. 8.2). Seedlings that have too much top growth for the roots to support will often die back and resprout from the root collar. It is preferable to top prune the seedlings back to a favorable size.

Figure 8.1. Selection of larger sized containers for growing seedlings.

Figure 8.2. Good quality bare-root oak seedlings.

In some cases, it might be desirable to obtain top-pruned, bare-root seedlings. Top-pruned seedlings are cheaper to ship and easier to plant, and they may have better survival or less dieback on sites prone to drought stress. Seedlings can be top-pruned after purchase using simple equipment such as a machete. In general, though, few differences in long-term performance have been found, so the primary advantages of top-pruning may be in lower shipping costs and easier planting.

Containerized Seedlings

When planting on harsher sites and/or outside of the dormant season, containerized seedlings are preferable because their roots are protected by the same soil they were grown in at the nursery. This can lessen the initial shock of transplanting and ensures that the roots of the seedlings remain moist for a longer period after planting.

Containerized seedlings are used most extensively in peninsular Florida, where prolonged dry, hot seasons occur in late spring and again in late autumn. Small containers are also gaining in popularity in the Lower Mississippi Alluvial Valley. The U.S. Army Corps of Engineers has planted over 800 ha (2,000 acres) with containerized stock. Most containerized seedlings are grown in gallon-sized pots, and the seedlings are outplanted upon attaining heights of 45-125 cm (18-48 inches); however, a wide variety of small containers have been recently developed for seedling propagation. Containerized seedlings offer the advantage of reducing transplant shock and have a wider planting window. Burkett (1996) suggested that the more extensively developed root system of containerized stock may offer potential advantages when seedlings are planted at sites prone to drought. Also, inoculation of the containerized seedlings with mycorrhizae slightly but significantly enhanced root fibrosity (Burkett, 1996). If grown in too small of a container, however, containerized seedlings can often be root bound with the roots curled around the inside of the pot (fig. 8.3). Root-bound seedlings tend not to form vigorous root systems when planted. They may grow for several years as vigorous saplings and then suddenly die, their roots apparently unable to supply adequate water during especially dry periods. Quality is

Figure 8.3. Root-bound seedling grown in a 1-gallon container.

hard to summarize for containerized seedlings because of the variety of container types. In general, seedlings should have good root development but should not be root bound. There should be a good balance between root mass and size of the shoot.

Recently, restorationists in Florida have been planting sack-grown trees with much better success. The thin plastic sacks are 0.3 m (12 inches) long cylinders with drain holes at the bottom (fig. 8.4). Roots of sack-grown trees grow downward without curling. After the roots have reached the sack bottom, the seedling is approximately 60 cm (24 inches) tall and ready for planting. Gasoline-powered soil augers drill holes into which the root ball fits snugly. The roots are deep enough when planted to reach moist soil layers during dry seasons. Experimental plot studies by the Florida Institute of Phosphate Research are corroborating the generally superior results of restorationists who have tried sack trees. Costs of growing and planting sack trees are lower than for gallon-sized seedlings, but start-up costs are much higher. The substitution of fabric containers for sacks is still more promising because aeration and root development are more uniform than in plastic sacks. No large-scale trials with fabric containers, however, have been tried.

Another seedling type, used in Florida, is the tubeling or "plug." Plugs have features of both bare-root seedlings and containerized stock. Their densely compacted roots enclose only a very small amount of soil (fig. 8.5). They are grown in specially designed flats, called "liners," from which they are removed before delivery at a project site. Planting of plugs can be accomplished with a bulb planter that extracts a plug of soil, leaving a cylindrical hole (fig. 8.6). They combine the convenience and low cost of bare-root seedlings with a somewhat higher probability of survival on harsh sites. They are less likely to survive during prolonged dry seasons, however, than seedlings grown in larger containers. For this reason,

Figure 8.4. Carolina ash seedlings grown in plastic sacks.

Figure 8.5. Dahoon tubelings removed from their pots and ready for planting.

Figure 8.6. A bulb planter is a commonly used hand tool for planting seedlings.

most restorationists opt for more traditional types of containerized stock. No matter what type is used, only good quality seedlings should be planted. The importance of this cannot be overemphasized. Even if everything else is done right on a restoration project, the project will still be a failure if poor quality seedlings are used.

Handling Seedlings

As discussed, bare-root seedlings have important advantages, but they require especially careful handling. Because their roots are exposed, care must be taken to prevent them from drying out. The seedlings will typically come from the nursery in bundles of about 50 to 200 (up to 400), ideally with their roots packed together and wrapped in sphagnum moss or some type of water-retaining material and the whole bundle wrapped in waterproof paper bags or cardboard boxes.

If the seedlings are not planted immediately, they should be stored at a temperature slightly above freezing, preferably in a cold storage unit. Storage in a barn, shed, or dense shade will be adequate for a few days to a few weeks, as long as the seedlings stay reasonably cool and the roots are not allowed to freeze or dry out.

Another method of temporary storage is "heeling-in." Using this method, seedlings are spread out in a V-shaped trench (dug in a shaded location), and their roots covered with loose soil. The soil is then watered and gently packed down to remove any air pockets, and the roots are kept moist throughout the storage period.

Only as many seedlings as can be planted in one day should be taken to the field. The seedlings should either be taken out of the nursery-supplied bundles and planted immediately or transferred in small groups to a bucket or a planting bag (fig. 8.7). A group of seedlings should never be carried by hand while planting. Smith (1986, p. 296) wrote, "In any step in handling bare-rooted seedlings it is vital that the roots always remain visibly moist. They should not be uncovered for more than 2-3 minutes at any time whether it is just after lifting, in the packing shed, or when it is finally planted. Even briefer exposure is preferable . . . Tree roots are so easily killed

Figure 8.7. A good field method to protect the roots of seedlings is to carry them in a planting bag.

that it is remarkable indeed that many millions of bare-rooted seedlings survive planting."

Although containerized seedlings are less susceptible to freezing or drying out, they can also be damaged or destroyed by careless handling. If containerized seedlings are transported in a closed truck, they can become overheated, especially when planting in late spring or summer. On the other hand, if seedlings are transported in an open vehicle they can become desiccated or damaged by having their stems and leaves blown about in the wind. Seedlings should be transported in ways that provide good ventilation (especially on hot days so that they do not overheat), although too much wind directly on the leaves causes desiccation.

Timing of Planting

The best time to plant bare-root seedlings is when they are dormant and the soil is moist. Generally, planting conditions in the South are most suitable from January through March. Planting can usually be done in November and December, especially for species which have lost their leaves, such as green ash and sycamore, but planting earlier than November is not usually recommended. Planting can also be done later than March if the seedlings are kept in cold storage and the roots kept moist until planting. Planting bare-root seedlings that have broken dormancy is not recommended.

The most frequent limitations on planting are excessive cold and flooding. Bare-root seedlings should not be planted in subfreezing temperatures. The more flood-tolerant species can be planted in shallow water, up to about 15 cm. Disked soils should be moist but not flooded.

An advantage of containerized seedlings is that they can be planted safely once they have broken dormancy. It is still advisable to plant in the winter or early in the growing season while the temperatures are cool and the soil is moist, but as long as conditions are not excessively hot and dry, later plantings will usually be successful. In Florida, containerized seedlings are also successfully planted at the beginning of the summer rainy season, which usually starts in June.

Spacing

Spacings of planted seedlings will depend on objectives. Spacings of 3 × 3 m (10 × 10 ft) or closer are often used for wood production and may be required to ensure the number of surviving seedlings stipulated in some permits. In other cases, wider spacings can be used, such as 3.6 × 3.6 m (12 × 12 ft), 4.5 × 4.5 m (15 × 15 ft), or 6 × 6 m (20 × 20 ft). The standard spacing for the Natural Resources Conservation Service and the U.S. Fish and Wildlife Service is 3.6 × 3.6 m (12 × 12 ft). Because fewer seedlings are required per hectare (see table 7.2), wider spacings are more economical and may be just as effective in meeting the project objectives. Also, using a wider spacing will allow openings for the natural invasion of light-seeded tree species. Wide spacing of the seedlings is one potential, but not always reliable, method for increasing species diversity on the restoration site.

As mentioned previously, making the spacing very precise is undesirable unless timber production is the primary goal or weed control by mowing or disking is planned. A tree farm appearance should be avoided if wildlife, aesthetics, or a more natural appearing forest are the primary goals.

Planting with Hand Tools

Bare-root seedlings can be planted using a dibble bar or sharpshooter shovel (fig. 8.8). The proper technique for use of these tools is shown in fig. 8.9. Occasionally, other tools are used, such as grub hoes, mattocks, and hoedads. Regardless of what type of tool is used, roots should be placed in the hole so they can spread out naturally; they should not be twisted, balled up, or bent.

Figure 8.8. Bare-root seedlings can be planted using a sharpshooter shovel, dibble bar, or bulb planter.

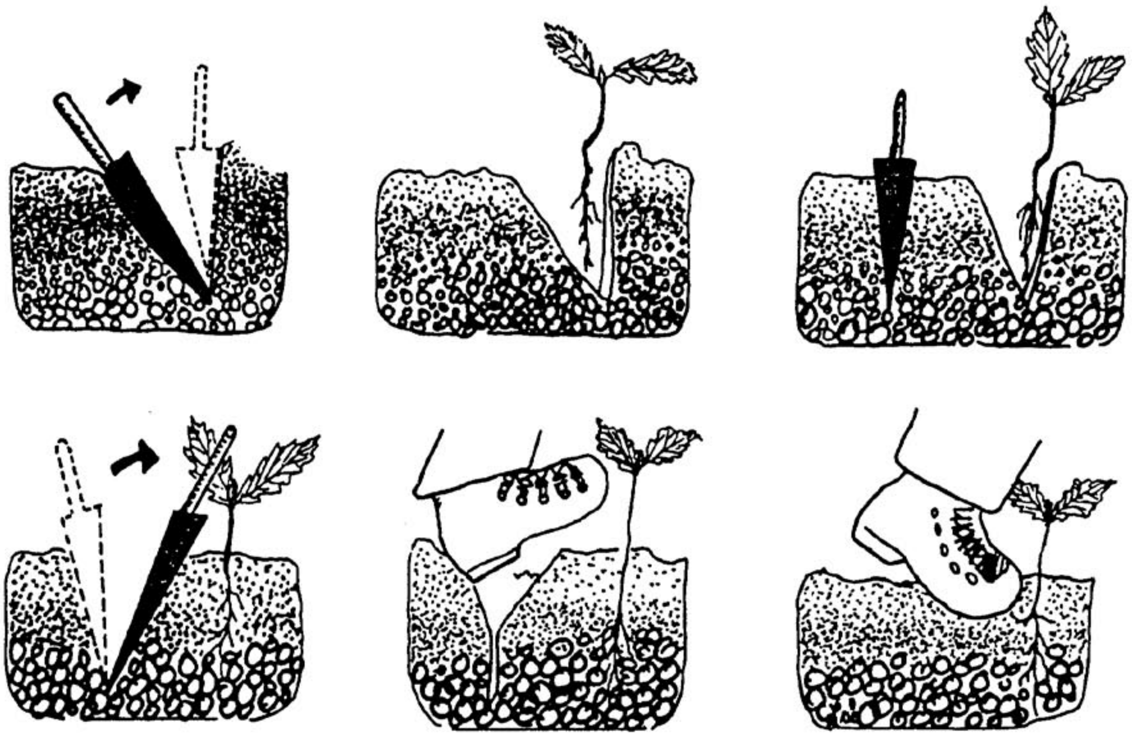

Figure 8.9. Planting technique for use with hand tools.

Moist soil should then be firmly packed around the roots. Hand planting of most types of containerized seedlings is done with a shovel, although specialized hand tools have been developed for some of the smallest types of containers.

Planting a tree by hand is a simple task but nevertheless is often done incorrectly. If a crew of inexperienced tree planters is used, it is essential to demonstrate clearly to them the proper way to plant. The crew should be supervised closely, especially the first time they plant and late in the day after they have become tired and perhaps careless.

Seedlings should be planted with their root collars just below the soil surface (fig. 8.10a). One of the most common planting mistakes is planting seedlings either too deep (fig. 8.10b) or not deep enough (fig. 8.10c). Another common mistake is digging a hole too shallow for proper root placement. If this occurs, roots may be bent upwards, or "J-rooted" (fig. 8.10d), which results in roots not penetrating deeply enough into the soil to protect the tree from windthrow or drought. Additional mistakes are planting so that settling soil leaves the root-collar exposed and leaving an air pocket near the roots after closing the hole (fig. 8.10e), which allows the roots to dry out.

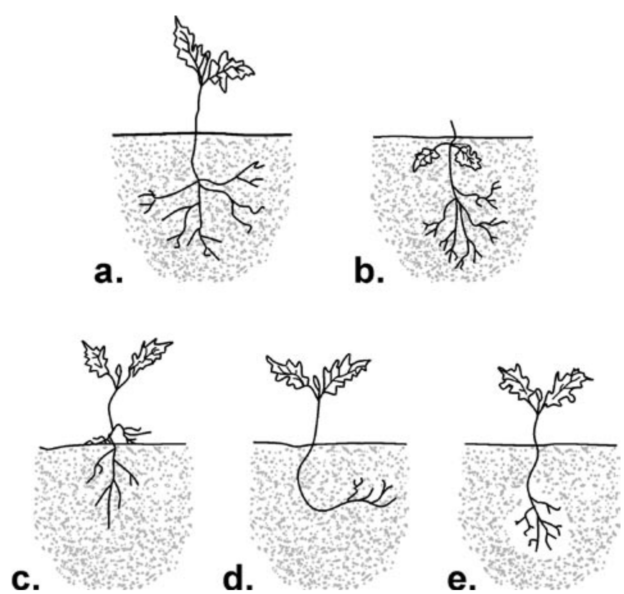

Figure 8.10. It is critical that tree seedlings be (a) planted properly; they should not be planted (b) too deep, (c) too shallow, (d) with roots bent upwards, or (e) with air pockets.

When planting containerized seedlings, the container should be removed first, although this may not be as critical if the container is biodegradable. If a biodegradable container is not removed, it should be trimmed so as not to protrude above the ground, since this can cause drying of the soil through a process known as "wicking." When seedlings are removed from their containers, any roots encircling the outside of the root ball should be loosened up and pointed outwards and downwards or removed. Otherwise, these roots will not spread out properly and could even girdle the stem. The seedlings should be planted in a hole deep enough so that the tops of the root balls are slightly below ground level. The final step in planting a containerized seedling is to fill the hole and pack the soil firmly around the root ball to remove any air pockets and keep the seedling pointed straight up.

Just like the number of seeds a single person can plant in a day will vary widely, the number of seedlings that can be planted will also vary, depending on factors such as the size and type of seedling, degree of site preparation, spacing, soil type, soil condition, weather, experience and physical condition of the planter, and distance the planter has to carry seedlings before being able to start planting. On a clean, level site, a planter should be able to plant at least 500 to 800 bare-root seedlings per day or sometimes up to 1,000 seedlings per day for planters with more experience. Because planting quality can diminish through the day as the crew becomes tired, planting quality should be monitored more closely after several hours of work. The number of seedlings planted per day will be much less if containerized seedlings are being planted, the locations of individual seedlings must first be marked, or if planting conditions are suboptimal.

Planting with Machines

When site conditions are favorable, machine planters can speed up the planting of bare-root seedlings dramatically on soils other than heavy clays. An experienced crew of two or three may plant from 4,000 to 10,000 seedlings a day with a machine planter. Also, survival will often be better than that achieved by a large, relatively inexperienced crew of hand planters. Some of the newer planting machines perform well in heavy clays, planting 5,000 to 8,000 seedlings per day with an experienced crew.

One disadvantage of machine planters is that intensive site preparation may be required. Machines cannot readily operate where there are stumps or heavy debris. On heavy clays, planters may become clogged or be unable to penetrate deeply enough to ensure that the roots are completely covered. Also, the furrows dug by the planter may reopen in the summer when the clay dries out, thereby exposing the roots. On abandoned agricultural

Figure 8.11. Mechanical seedling planter.

fields, no site preparation may be needed for mechanically planting seedlings. Machine planting is becoming a more extensively used reforestation method and, as new tools are being developed, may become preferred even on heavy clay soils as long as soil conditions (e.g., moisture) remain favorable.

Another disadvantage of mechanical planters is their high cost, which is prohibitive for most small planting projects. It is possible in some areas to rent or borrow a planter; a good source of information on the local availability of planters is the county, parish, or district forester.

An example of one type of mechanical planter is shown in fig. 8.11. Other types of planters, including some that are considerably less expensive, are available through sources such as forestry supply companies.

The planting rate for containerized seedlings may also be increased by using machines to dig the planting holes. Machines that have been used for this purpose range from augers to backhoes, depending on the size of the planting stock.

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