IV. Seeding and Planting

Seeding and planting are vital parts of the reclamation process. Most seeding and planting implements and techniques are well-known, conventional farming equipment and methods. However, seeding and planting on mine sites are more difficult than on most agricultural lands. Ecological, legal, and economical problems far different from those found in most agricultural settings prevail on mine reclamation sites.

After the proper plant species are selected, seeds or plants must be obtained. Collection areas and techniques must be identified or a commercial seed and plant supplier found. Seeds and plants must be stored until they can be planted on the reclamation site, as dictated by mining activity and climatic factors. Some seeds must be prepared for seeding by cleaning or dewinging.

Seeding and planting techniques are dictated by the plant species to be grown, the soil type and condition, and the climate. Seeding depth, water catchments, and seeding rates are dependent on the plant species. The use of inappropriate techniques or equipment usually results in reclamation failure.

Species Selection

Selection of reclamation species is an important and difficult task. In the West much of the lands being mined for coal are rangeland. The social, economic, and climatic factors found in these sparsely populated areas ensure that ranching will be the post-mining use of the land. There will be little demand for homesites, intensive recreation facilities, or farmland in the near future, therefore most sites will be restored to range or pasturelands. Many factors must be considered when choosing species to revegetate these sites (Cook and others, 1974; Stoddard and others, 1975).

Legal Requirements

Federal regulations state that mine operators "shall establish on all affected lands a diverse, effective, and permanent vegetative cover of the same seasonal variety native to the area of disturbed land or species that supports the approved post-mining land use" (Federal Register, 1979).

Additionally, all mine operators must submit a reclamation plan when applying for a mining permit. The plan details the post-mining use of the land, how the use is to be accomplished, support activities necessary to achieve the proposed use, and, where grazing is the proposed use, management plans that will be implemented (Federal Register, 1979). Since the ultimate use of the land is determined prior to mining, it is important that plant species meet the predetermined use. A poor choice may doom the revegetation effort and may prevent release from legal responsibility to reclaim the land.

Site Adaptation

The species selected for reclamation must be well adapted for the specific site. They must be able to withstand edaphic, climatic, and topographic conditions of the site.

Soils. — Soil conditions in the West range from clay to sandy soil, deep topsoil to no topsoil, toxic to harmless, stoney to stone-free, alkaline to acidic, sterile to fertile. Some plant species can survive on a wide range of soils, others are restricted to specific soils. Planning must take soil characteristics into account when reclamation species are chosen.

Tolerance for saline or alkaline soils is important in much of the West. Species adapted to clay soils are necessary in some areas. The ability of selected species must be known. In areas where soil changes are rapid and unpredictable, a seed mixture of compatible species, some of which are adapted for each of the soil conditions, will assure that each soil type will be seeded with appropriate species. Soil conditions affect plant survival through amounts of nutrients or toxic materials available to the plants and by the amount of soil moisture available to the plants. Sodic, saline and clay soils often hold moisture so tightly or prevent moisture penetration so completely that many species are unable to survive. Halophytes (salt-tolerant plants) and xerophytes (plants adapted to arid conditions) must be selected to vegetate some sites, even if the species are not productive. Soil protection is the first and most important object of revegetation. Once the site has been stabilized by the halophytes or xerophytes, micro-climatic or edaphic conditions may change enough to introduce ultimately desired species onto the site. Initial species selection, however, must be done with the soil limitations in mind.

Climate. — Climatic conditions are often the determining factor when choosing the plant species to be seeded on mined sites. Many coal mining areas are subject to bitter cold winters; dry, hot summers; intense, short storms; and year-round winds. The growing seasons are short, with moisture availability a critical problem during most of the year. Other western mines are extremely arid, with average rainfall of less than 7 inches per year (Wiener, 1980). Areas that have adequate rainfall in most years are vulnerable to occasional droughts that may last for 3 or more years. Plants that can be established on a site must be able to survive drought to provide a permanent plant community. Plants must be adapted to use soil moisture when the moisture is provided. Mines in the Great Plains, the Intermountain area, and the Great Basin receive most of their moisture during the spring; in the Southwest deserts, precipitation is greatest in summer. Plant species that most efficiently use precipitation will be different in

each of these areas. In the northern Great Plains the winters are cold, windy, and long and the summers are hot, windy, and dry. Plants adapted to these conditions will not necessarily be adapted to areas in the Southwest deserts. Selection must provide species and varieties adapted to the specific climatic conditions on each site.

Moisture availability is the prime limiting factor for most species in the West. Precipitation amounts, as well as precipitation patterns, must be matched by species that can survive and prosper on the amount of moisture provided at the time it is available. The amount, form, and seasonal distribution of precipitation are all important factors in determining moisture availability for plant use (VanEpps and McKell, 1978). Total precipitation amount can be misleading if it comes in a form that is unusable by plants, for example, snow that blows off before it can melt or intense summer storms that run off before the moisture can infiltrate. Precipitation that comes at a time when plant species on the site cannot use it is also misleading unless the moisture is stored in the soil. Cool season plants that efficiently use fall, winter, and spring precipitation dominate the Intermountain area and much of the northern Great Plains. Warm season plants that use late spring and summer moisture dominate the Southwest deserts and parts of the Great Plains.

Wind causes both direct and indirect losses of moisture. Wind reduces the amount of moisture available from snow melt by blowing snow off the reclaimed site. This is most important in the first few years of revegetation, before the plant community is capable of holding the snow. Wind increases evapotranspiration on sites. It dries soils or increases the moisture requirements of plants by drying them and accelerating their transpiration rate. These effects, too, are most important in the early years of revegetation. Moisture stress will usually be alleviated somewhat as the stand grows and matures. Wind can physically damage plants, especially seedlings. Windblown sand particles may injure or destory seedlings (VanEpps and McKell, 1978). Wind can also bury seedlings on the lee side of obstructions (Fig. 60). Occasionally, cultural treatments must be used to moderate the environmental extremes of the site until the plants are well established.

Temperature is very important in choosing reclamation species. High temperatures dry out plants and can cause physiological damage. High surface temperatures are common on mine spoils. In areas where summer temperatures reach over 100˚F, soil surface temperatures on exposed south-facing slopes could reasonably be expected to exceed 130˚F at times. Plants must be capable of withstanding the heat stresses placed on them, either through their natural adaptations or by cultural techniques to protect the plant. Levitt (1972) states that heat injury is most likely to affect plants grown in regions other than where they are normally found. Injury is likely to occur on relatively rare "test summers." This would suggest that unadapted species may survive for a number of years until the critical summer arrives, at which time the unadapted species will be injured or killed.

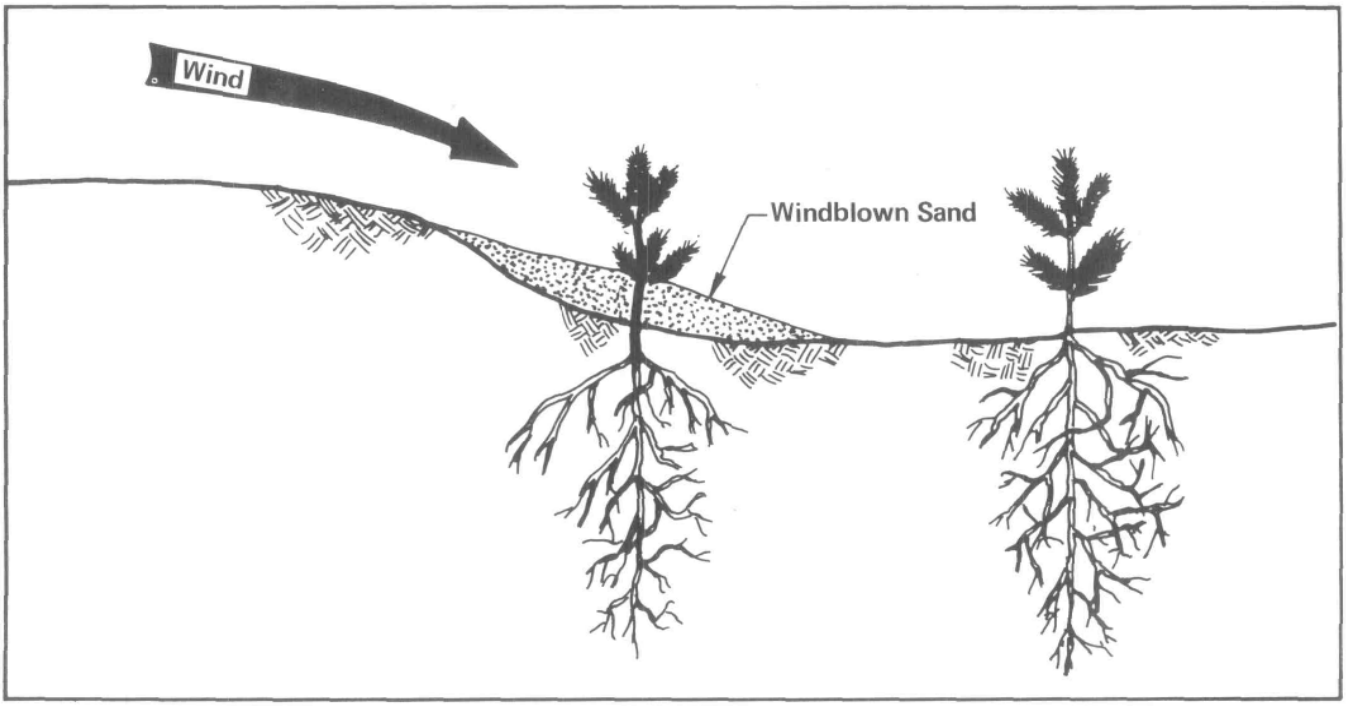

Figure 60.—Seedling covered by wind

Temperature affects the growing season length. Germination or annual growth will not begin until the soil reaches a certain temperature, which differs for different species. The number of days between the last frost in the spring and the first frost in the fall is important to many plants. Some plants are not hardy enough to withstand the long, intensely cold winters on the northern Great Plains, while others do poorly in the long, hot summers of the Southwest deserts. (Problems often arise when unadapted ecotypes of acceptable species are used for revegetation. For example, an ecotype of rubber rabbit-brush *(Chrysothamnus nauseosus)* from the Southwest deserts would, if it survived over winter, begin to grow in the first warm spell in the spring in the northern Great Plains. The normal late spring frosts would severely damage the plant. An ecotype from the northern Great Plains would either not begin growth as early in the spring or would be hardy enough to withstand the late frost. Ecotypes specifically adapted to the climate at the reclamation site are vital.

Topography.— Selected species must be well adapted for the topographic conditions of the site. Slope conditions, including slope length, grade, and aspect, influence soil moisture, temperature, and stability. The erosion potential of a slope increases with both length and percent of grade (Buckman and Brady, 1969). Additionally, as the length and grade of the slope increase, the runoff from the slope also increases. This puts two extra stresses on the plants used on these slopes: they must be able to hold the soil tightly to reduce erosion and they must survive on a reduced amount of moisture. Aspect affects the micro-climate in which the plant must survive. North and east aspects are generally cooler and moister than are south and west aspects. Topography affects drainage and runoff patterns by increasing the available and hill crests. Dumping spoils during the mining process pull large materials in the lower areas where gravity carried them. Then erosion carries smaller materials into the lower areas, covering the large materials in the draws and exposing them on the upper slopes and ridges.

The variety of microsites on a reclamation area changes with the amount of topographic variation on the area. Where the variation is significant it is advisable to use different seeding mixtures on different slopes and soils. Figure 61 shows several species used at a mine in Montana. In this case different sites are considered when determining the species mixes. If different species mixes are not used on the various sites, the single seed mix must include adequate amounts and species of seed to revegetate each of the different micro-sites. Some of the species will not be appropriate for some of the land seeded but will be needed for other areas. The overall use of seed will be less efficient than if the areas were seeded separately, but the entire site can be seeded in one operation.

Native or Introduced Species

When selecting species to be seeded or planted the controversy of whether to plant native or introduced species must be considered. Federal law states that introduced plants may be used under certain conditions.

Introduced species may be approved for reclamation use if they meet qualifications, including: (1) They are desirable and necessary to achieve quick, stabilizing cover to control erosion; (3) they are compatible with plants and animals in the region; and (4) they are not poisonous or noxious (Federal Register, 1979). Many introduced species have been approved for use on mine sites. Some states, most notably Montana, require that some native species be used; none prohibit introduced species. Montana's reclamation law specifies that a diverse, predominately native stand of vegetation be established on reclaimed land (DePuitand Coenenberg, 1979). So, even in Montana introduced species may be used, although dominance by native species is required.

Some researchers agree that introduced species are appropriate for reclamation, and suggest that adapted-versus-unadapted species is a more appropriate concept for species differentiation than is the concept of introduced-versus-native species (Lang, 1976; R. Brown, 1979; Monsen and Plummer, 1978; Thornburg and Fuchs, 1978). Adapted species, according to Land (1976), must meet four criteria: (1) Species must be adapted to the soil, (2) the climate, (3) specific site characteristics such as slope and aspect, and (4) the post-mining land use. If these conditions are met, the species is acceptable for reclamation, regardless of whether it is native or introduced. Other researchers, while not excluding the use of introduced plant species altogether, encourage the use of native species whenever possible (Aldon, 1976; Eddleman, 1979;McKell, 1978).

Native plants are obviously well-adapted to the environmental extremes present at the mining site. The species have evolved under the extremes of heat and cold, wet and dry, wind, snow, and growing season. They have survived and dominated the site because they are adapted for long-term viability under the climatic conditions to which the site is subjected. However, some introduced species, such as crested wheatgrass *(Agropyron cristatum* and *A. desertorum),* have survived for 30 to 40 years without signs of succumbing to the environmental pressures of the northern Great Plains (Vallentine, 1980). It is possible to claim that the persisting introduced species, often called naturalized species, are as well-adapted as the native species. Another argument for using introduced species is that the mined site, even if the topsoil is carefully handled, is not an identical replica of the premining area. Since the soils are disrupted in the mining process, even the native plants may not be adapted to specific post-mining conditions. Those

advocating using any adapted plant species may justifiably suggest that naturalized, introduced species are as appropriate as native species for revegetation of these sites.

Introduced species that perform well on disturbed lands generally can survive a wide range of soil and climatic conditions. Many native species, on the other hand, occupy precise ecological niches. Without these niches the species cannot succeed. Using a variety of native species can check the success of a reclamation project. Native species will find their specific niche and show the adequacy of the niche to support vegetation. Eddleman (1979) suggested using native plants with narrow ranges of tolerance to test the quality of reclamation. One possible test proposed for the northern Great Plains would be planting native bluegrass *(Pos sandbergii),* which roots at 2 to 4 feet, and dotted gayfeather *(Liatris punctata),* a deep rooted forb, which roots at 7 to 15 feet in a mixture. If problems establishing one of the species occur, it could indicate a reclamation suitability throughout the year. Introduced species with the ability to handle a broad range of conditions may obscure problems that may be found by using native species. Overlooking present

Western Energy Company
Rosebud Mine

Supplemental Seed Mixture

Species

Grasses
Andropogon hallii
Garden sand bluestem
Bouteloua curtipendula
Pierre side-oats grama
Bouteloua gracilis
blue grama
Calamovilfa longifolia
Goshen prairie sandreed
Oryzopsis hymenoides
Nezpar indian ricegrass

Forbs
Achillea millefolium
western yarrow
Astragalus cicer
Lutana cicer milkvetch
Linum lewisii
lewis flax
Onobrychis viciaefolia
Eski sanfoin
Petalostemon candidum
white prairie clover
Petalostemon purpureum
Kaneb purple prairie clover
Ratibida columnifera
prairie coneflower

Shrubs
Atriplex nuttallii
nuttals saltbush
Atriplex canescens
Wytana fourwing saltbush
Ceratoides lanata
winterfat

Lowland Drainage Cool Season Grass Seed Mixture

Species

Agropyron dasystachyum
Critana thickspike wheatgrass
Agropyron smithii
Rosana western wheatgrass
Agropyron trachycaulum
Revenue slender wheatgrass
Bromus marginatus
Bromar mountain brome
Elymus cinereus
Magnar basin wildrye
Poa pratensis
Troy kentucky bluegrass
Stipa viridula
Lodorm green needlegrass

Uplands Cool-Season Grass Seed Mixture

Species

Agropyron dasystachyum
Critana thickspike wheatgrass
Agropyron smithii
Rosana western wheatgrass
Agropyron spicatum
Secar bluebunch wheatgrass
Agropyron trachycaulum
Revenue slender wheatgrass
Poa compressa
Reubens canada bluegrass
Stipa viridula
Lodorm green needlegrass

Figure 61.— Seed mix at Western Energy Co.'s Rosebud mine

reclamation problems may cause reclamation failure. Using native species for reclamation is more likely to point out problems than using introduced species. Of course, all failures of native species cannot be assumed to be reclamation failures. Some native species will not establish and grow due to changes in the soil from homogenizing the spoils. Some ecological niches will be eliminated entirely and cannot be restored even under the highest qulaity reclamation. Therefore, any native species failures must be carefully evaluated to determine their cause.

Introduced species are usually extremely vigorous competitors both as seedlings and mature plants and aggressively occupy the site. They resist disease, insects and livestock grazing, produce large amounts of seed, and invade new areas (Eddleman, 1979). They are often highly palatable early in the new growth stage and often during late fall, when a late green-up period occurs. However, many species become quite unpalatable throughout the remainder of the year. This feature is very different from the palatability of desirable native forage species. Many introduced species cause problems in maintaining stable, diverse plant communities because of the different preferences livestock and wildlife have for native and introduced species. Where both native and introduced species are available for grazing, animals usually prefer one over the other. When natives are preferred, as is usually the case, the aggressive introduced species often quickly dominate the site. Since the introduced species are so competitive naturally, any advantage provided them by preferential grazing of the native species is capitalized upon. Many introduced species are recommended for use in relatively pure stands; seeding one or two introduced grasses and an introduced legume together might be an alternative. The stand should be fenced away from other stands and from native range, so it can be managed as an individual unit (Interagency Forage, Conservation, and Wildlife Handbook Coordinating Committee, 1977). Using competitive, relatively un-palatable native species leads to a nearly pure stand of introduced plants, especially when the stand is subjected to grazing (DePuit, and others, 1978; DePuit and others, 1977; Vallentine, 1980). If both introduced and native species are seeded together, continued intensive management is required to maintain the stand composition.

Economic factors are also involved in choosing introduced or native species. Introduced species for reclamation are bred for easy collection, production of large amounts of highly viable seed, and adaptability to commercial seed harvesting equipment. Seeds for most of the introduced species are relatively common and inexpensive when compared to native seeds. This is changing somewhat as plant breeders work more with native species. Some cultivated varieties (cultivars) of native species are becoming more reasonably priced all the time. Increased demand for these species will continue to bring the prices down as more work is concentrated on the natives. Of course, any cost comparisons should include the marginal cost of increased management requirements, seeding costs, and finally, the value of the reclaimed land.

Plant Ecology

Ecological factors have a major influence on plant species selection. The species used to reclaim a site must be compatible with the other plants and animals in the area. Plants that are more or less palatable to the major grazing species than other plants on the site will lead to differential grazing and ultimately to a shift in plant community composition. Some plants have special relationships with soil microbes that are vital to the plant's survival. Some plants may have antagonistic effects on other plants, causing problems of plant establishment and continuing plant viability. Species that compete with each other for the same ecological niche, either in space or in time, will not completely occupy the reclamation area. Species that complement each other—shallow and deep-rooting, warm and cool season, shrubs and grasses—more efficiently and completely vegetate the site.

Plant/Animal Relations. — Post-mining use of mined land in the arid and semi-arid West is usually for wildlife habitat and domestic livestock grazing. Provisions must be made to provide adequate food and shelter at the appropriate times of the year. Using the land as spring pasture means that plants grown must be capable of maintaining vigor under early grazing. If the land is to be used as one of several pastures in a rest-rotation grazing system, the plant species must be capable of providing feed at various times throughout the grazing season. The planned grazing system will influence which species are chosen for revegetation. Class of stock, desired wildlife species, seasons of use, and intensity of use all affect which plants will successfully reclaim an area. Even the combination of use is important. Low-growing shrubs that blow clear of snow can be an important source of protein for pronghorns in the winter, but may not provide adequate shelter for sage grouse. The decision of what is grown will favor some wildlife species to the detriment of others. The selection process must include consideration of these differential treatments so the effects are planned rather than a matter of default.

Competition.— If a cover crop designed to temporarily stabilize and protect the soil is planted or seeded, careful selection of the cover crop is required. Several sterile grasses are available; annual grains are also used. Weed-free seed should be used for all seedings, but especially for the cover crop. The cover crop should compete aggressively with the pioneer weedy species that invade the spoils. It should not, however, be a long-lived species nor a prolific seeder that will compete with the species chosen for permanent revegetation of the site.

Species Diversity.—The nutrient values of plant species vary by season. Shrubs provide winter nutrition unavailable from most herbaceous vegetation: forbs

are desirable, succulent foods in the spring and early summer; grasses are most nutritious during spring and summer, with declining value after plant maturation. Shrubs loose their nutritive value more slowly and to a lesser degree than do grasses, with forbs midway between the two. Figure 62, taken from a paper by C. Wayne Cook (1971), shows four nutrients required by large herbivores. When comparing the information and the graphs, recognize that forbs are usually very short-lived, weather quickly, and generally are totally unavailable by late summer.

Grasses mature at various rates, but reach annual maturity before late summer. Shrubs mature at various rates also, but commonly reach annual maturity in late summer or early fall. Some species like some members of sagebrush (Artemesia) and rabbitbrush *(Chrysothammus)* do not mature until late fall or early winter. Therefore, grasses may have ample supplies of a nutrient such as phosphrous for a longer period of time than will forbs, because the forbs may mature much sooner than the grasses.

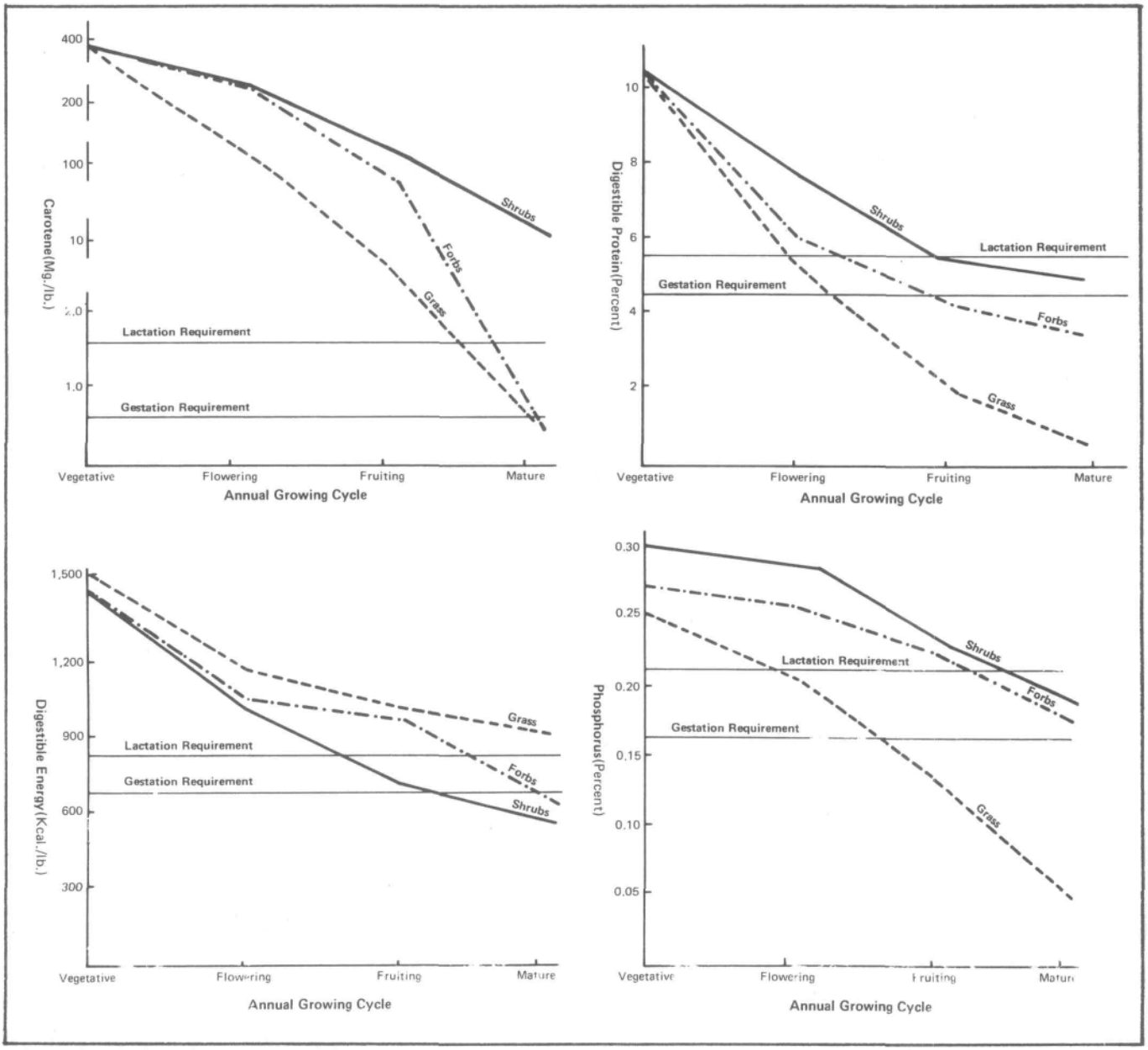

Figure 62.— Selected nutrient values of grasses, forbs and shrubs

Rangeland being used to winter herbivores will be deficient for gestation needs unless: (1) the rangeland contains both grasses and shrubs or; (2) supplemental feeds are provided. Shrubs, while providing sufficient carotene, digestible protein, and phosphorous provide inadequate amounts of digestible energy. Of the four nutrients, digestible energy is the only one that grass provides in adequate quanitites after maturation. The complementary qualities of these two life forms of plants show one reason a diverse plant community is important on rangelands.

Species diversity, in addition to being a legal requirement of reclamation (Federal Register, 1979), is an ecologically desirable goal. By attaining sufficient diversity, the plant community will fully occupy the reclamation site. Different types and species of plants have varied rooting depths, foliage patterns, growing seasons, and nutrient demands. By having varied rooting and foliage patterns, the community can more fully occupy the physical space of the site. Fiberous and tap-rooted plants growing together can use water and nutrients available throughout the soil profile, while a community containing plants with only one type of root uses only a portion of the profile (Fig. 63). Not only is this inefficient use of the site, the chance of soil erosion is greater with a single root type. By filling the profile with roots, the diverse community holds the soil more securely.

A diverse community affords greater variety of both food and shelter for wild and domestic animals. As previsouly discussed, the nutritional needs of herbivores are better provided for on a year-long basis when the plant community has a combination of plant types. Similarly, at any given time of year, the diversity in the community directly influences species that can be supported. Different animal species have different nutritional needs, food preferences, and cover requirements. Increased diversity in these factors increases the number of animal species that can use the community. A wide variety of plant species should be selected for revegetation if reclaimed land will support a wide variety of organisms.

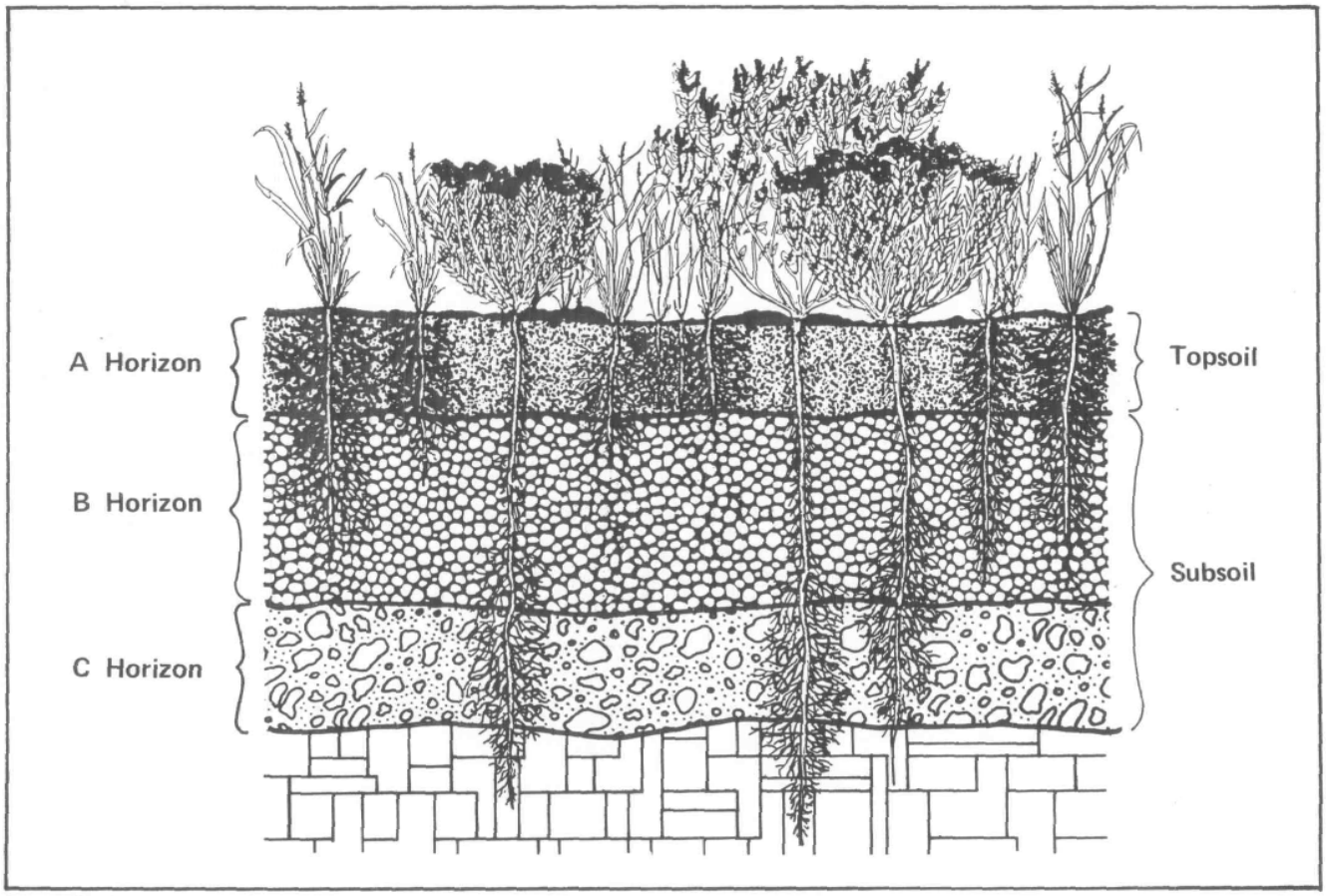

Figure 63.—Soil profile with root systems

Obtaining Seeds and Plants

Seeds and plants for reclamation can be bought from commercial suppliers or collected privately. Commercial suppliers provide seeds, bareroot seedlings, or containerized seedlings of a variety of commonly used species. Mining or reclamation companies can also collect their own seeds or plants. Seeds can be produced under cultivation or can be gathered from naturally occurring stands. Seedlings can be grown in greenhouses or nurseries or can be collected from wildlands.

Commercial Seed Sources

Purchasing seeds from commercial sources exposes the buyer to many potential problems. Since many suppliers have entered the market in recent years, the first task of the buyer is to ascertain whether each potential supply source is reliable. It is easy for an unscrupulous dealer to misrepresent the materials supplied, which can result in a reclamation failure, even when all other practices are done perfectly. Sowards and Balzer (1978) state "the quality of plant materials used in reseeding disturbed lands probably has as much impact on the success or failure of a revegetation project as any other factor subject to the control by the reclamation specialist." The supply of native species is more uncertain and risky than the supply of introduced species. Most introduced species used for reclamation are bred for production of large, viable, easily harvested seed crops. They can often be grown on cultivated soils where they are cared for as any other farm crop. The quality and quantity of these species are dependable and predictable. Suppliers are willing to expand production because they can predict the success of these species. The seeds are cheaper than those of species that are riskier to grow; more ecotypes of each species are often available; problems of low viability are seldom encountered.

Native species, however, are more difficult to grow for seed. Many species produce large seed crops only occasionally. The seed must be checked to determine viability; a large seed crop may not mean a large crop of viable seed. The risk of growing the more difficult species is a hindrance to increased availability. Some native species are adapted to conventional farming techniques. Indian ricegrass *(Oryzopsishymenoides],* for example, can be grown and harvested with relative ease. The supply of Indian ricegrass is predictable and dependable as a result of its ability to be cultivated. Other species, such as western wheatgrass *(Agropyron smithii)* and some salt-bushes *(Atriplex sp.),* have varieties that are adapted to commercial growing. These species are relatively inexpensive and the supply is usually adequate. However, many native species are not so easily adapted to seedcrop production. Seed for species such as bluebunch wheatgrass *(Agropyron spicatum)* and galleta grass *(Hilaria jamesii)* are expensive and sometimes wholly unavailable. Such species have characteristics that hinder mass harvesting of viable seed. Producers are inclined to expand production of such species as Indian ricegrass rather than experiment with more difficult species. The uncertainty of supply of the more difficult species encourages buyers to order the easily grown species so that seed shipments will not be missed. This, in turn, further encourages development of "safe" crops at the expense of developing the riskier crops.

Many native species produce seedcrops that vary widely from year to year. Lack of moisture during seed development, hot, dry weather early in the year, or a cold snap at a critical development stage, can all result in a poor seed crop. When seed production is high, a strong wind can shatter the seed before it can be collected, a hail storm can knock the seed heads to the ground, or insects or disease can destroy the seeds. Many uncontrollable factors can affect the quantity of live seeds obtained from an area. Some natural characteristics of the species may also make seed harvest difficult. For example, galleta grass seed matures from the bottom of the inflorescence to the top, shattering as it matures. This makes it difficult to harvest a large crop, as timing of the collection period must be precise (Sowards and Balzer, 1978).

Precautions must be taken to minimize the problems with seeds that are delivered. Supplies should specify when the seeds were obtained. Some species should not be used if greater than 1 year old. Others have longterm viability and can be used for seeding more than 3 years after harvesting. When ordering seeds, specify the maximum acceptable age of seed by species.

The location of the seed collection site must be specified. Generally, seed should be collected in the area of the mine so that ecotypes are adapted to local conditions. Moving plants to an area where the growing season is shorter will cause the plant to use more of the growing season and will produce a leafier plant. However, if moved where the growing season is too short, plants will winter-kill or fail to produce mature seed. When moved to a longer growing season, ecotypes will grow a shorter period of the season than will local ecotypes and will be overcome by the local plants. Most seeds should not be moved more than 200 to 300 miles north or 150 to 200 miles south of their origin. East or west movements are restricted by precipitation zones, soils, and elevation (Thornburg and Fuchs, 1978; Interagency Forage, Conservation and Wildlife Handbook Coordinating Committee, 1977). Seed users should specify that the ecotypes supplied be from within an acceptable distance of the mine site. Elevations, latitude, longitude, and precipitation ranges should be specified when ordering the seed.

Seed handling by the supplier must be done correctly. When the seeds are dewinged by using a hammermill or other special machine, the seedcoats are susceptible to damage.

Cleaning the seedlot removes seeds of other plant species, dirt, pieces of leaves and stems, insects, and

other plant and animal debris. Cleaning methods for most domestic crops are well established and quite dependable. The methods to clean native species, however, are not so well developed. The purity (percentage, by weight, of the seed lot that is seed of the desired species) is a measure of seed lot cleanliness. High purity assures the buyer of freedom from contamination with undesirable species. All seed lots should be tested for purity.

Seed germination should also be tested. Germination tests determine the percentage of seed in a seed lot that will germinate under certain standard conditions. Other measures of seed viability include back-lighting the seed and counting the number of filled seeds by selecting a sample of seeds, cutting them open, and counting those with embryos. High visibility assures optimal germination to establish good stands.

Any purchase of seeds or determination of amount of seed needed should be based on percent pure live seed (PLS) in a seedlot. Percent PLS is determined by multiplying the percent purity times the percent viability. All prices and seeding rates should be multiplied times the percent PLS to put all seed lots on a common base. Calculations (Fig.64) show how to use PLS to determine the relative costs of different seed lots.

Seed lot	Percent Purity	Percent Viability	Cost/Pound (Bulk)	Seeding Rate (PLS)
1	80	50	$3.00	4 lb/acre
2	95	60	4.50	4 lb/acre
3	70	70	4.00	4 lb/acre

These figures will be known for all seed lots. Purity and viability are determined by test, cost per pound on a bulk basis is set by the supplier or is negotiated, and seeding rate on a PLS basis is determined experimentally or on the basis of experience.

To put all the seed lots on an equal basis calculate percent PLS of each.

Seed lot	Percent Purity x Percent Viability = Percent PLS
1	.80 x .50 = .40
2	.95 x .60 = .57
3	.70 x .70 = .49

On a percent PLS basis, Seed lot 2 is the best, 3 is second, and Seed lot 1 is the worst. But since the bulk prices differ the seed lots must be put on a comparable price basis in order to evaluate their relative costs. Cost per pound of PLS is the most feasible base.

Seedlot	Cost/Pound (PLS) = Cost/Pound (Bulk)
1	$\frac{\$3.00}{.40} = \$7.50$
2	$\frac{\$4.50}{.57} = \$7.89$
3	$\frac{\$4.00}{.49} = \$8.16$

This calculation shows that Seed lot 1 is the most inexpensive on a PLS basis, Seed lot 3 is the most expensive, and Seed lot 2 is intermediate in price.

Since seeding rates are based on the amounts of viable seed of the desired species put on or in the ground, seeding rates must be determined on a PLS basis and then applied on a bulk basis. Therefore seeding rates must be converted to a bulk basis, by individual seed lot.

Seed lot	Seeding Rate (PLS) / Percent PLS	=	Seeding Rate (Bulk)
1	$\frac{4 \text{ lb/acre}}{.40}$	=	10 lb/acre
2	$\frac{4 \text{ lb/acre}}{.57}$	=	7.02 lb/acre
3	$\frac{4 \text{ lb/acre}}{.49}$	=	8.16 lb/acre

If Seed lot 1 is purchased, 10 pounds per acre of the seed would be seeded, 7 pounds per acre of Seed lot 2 would provide the same amount of PLS, as would 8.16 pounds per acre of Seed lot 3.

The cost per acre of seeding 4 pounds per acre of PLS is a major concern for reclamation purposes. The cost can be computed on either a bulk price or PLS price basis.

Seed lot	Cost per acre = Cost/Pound (Bulk) x Seeding Rate (Bulk) or Cost/Pound (PLS) x Seed Rate (PLS)
1	10 lb/acre x $3.00/pound (bulk) = $30 per acre
	or 4 lb/acre x $7.50/pound (PLS) = $30 per acre
2	7.02 lb/acre x $4.50/pound (bulk) = $31.59 per acre*
	or 4 lb/acre x $7.89/pound (PLS) = $31.56 per acre*
3	8.16 lb/acre x $4.00/pound (bulk) = $32.64 per acre
	or 4 lb/acre x $8.16/pound (PLS) = $32.64 per acre

*Difference due to rounding.

This calculation shows that Seed lot 1 is the most inexpensive seed lot in a cost per acre basis, with Seed lot 2 and Seed lot 3 successively more expensive.

Figure 64.—PLS calculations

They also show how to determine the amount of bulk seed to use to get desired seeding rates based on PLS and how to compare the costs of seeding each seed lot. These calculations ignore such indirect costs as those incurred from using an impure seed lot that has many weed seeds in it. Use of seed lots with viability rates well below normal for the species is not recommended, even if the seed is relatively inexpensive. Many factors that affect viability rates also reduce the quality and vigor of the viable seeds. As a result, stands established with the low-viability seed lot may be weak and uncompetitive (Interagency Forage, Conservation and Wildlife Handbook Coordinating Committee, 1977). Any decision on seed lot economics must consider not only prices based on PLS percentages, but also indirect costs of purchasing seed lots with large amounts of undesirable seed and the possibility that an unsuccessful stand may result from defective, yet viable seed.

Storage problems often arise if the seeds are kept under moist or hot conditions. Storing seeds with a moisture content of 8 percent or greater promotes various forms of biological life. According to Sowards and Balzer (1978). "at 8 to 9 percent moisture, insects become active; at 12 to 14 percent, fungi become active; at 18 to 20 percent, heating may occur; and at 40 to 60 percent germination may begin." They state that even a few hours at greater than 20 percent moisture may reduce seed viability. The moisture content is affected by the maturity of the seeds, by the time the seeds were dried, and by storing and handling conditions. Most dry seeds are stored best at temperatures between 33˚F and 38˚F (Monson, 1979). For most species storage should be in an airtight container and in a cool, dry environment. Deviations from these conditions reduce viability or reduce storage life. There are exceptions to these requirements, however, so each species should be handled according to its specific needs.

Private Seed Sources

Purchasing seeds or seedlings from a commercial supplier is not always an option. Commercial sources may not be acceptable for a number of reasons. The cost may be too high, supplies may not be adequate, or the mining company may simply wish to have greater control over what they plant. The alternative is to collect seeds privately. To insure the optimum chance of collecting high quality, viable seed, several guidelines should be followed. The foremost requirement is that.the seed should be collected from an area as similar to the revegetation site as possible. One of the greatest benefits of collecting seed privately is that the seed source can be closely controlled. By collecting seed near the revegetation site, where the climate, soils, and plant and animal communities are similar to those on the mined area have influenced and directed the evolution of certain ecotypes, ecologically adapted seeds are insured.

The timing of seed collection operations is vital. Some seed has a short life span; winterfat *(Ceratoides lanata)* seed, for example, should not be used if it is more than 1 year old (Soward and Balzer, 1978). Collection of seed with short-term viability must be scheduled every year. Species whose seeds remain viable for several years may only need to be harvested during years when the seed crop is good. Stockpiling seed from good years eliminates the need to search for seed during years when the seed production is low or of poor quality.

Stands to be harvested should be located well before collection operations begin. The stands should be vigorous, with many healthy, productive, competitive individuals of the desired species. Seed should be collected from a number of individuals of each species, or even from individuals on several different collection sites. Collecting from several sources will improve genetic variability on the reclamation site (Monson, 1979). Plant phenology observations conducted throughout the growing season indicate the proper time for harvesting seed, Eddleman (1978) states that there is a continuum of seed shatter patterns ranging from rapid total seed shatter, represented by Idaho fescue *(Festuca idahoensis)*—(Fig. 65), to slow dispersal over a longer period of time, as shown by Indian ricegrass (Fig. 66). In rapid total seed shatter, virtually all the seed of all the plants on a site mature at the same time. Seed is dispersed over a very short period, sometimes as short as 1 week. Seed collection from plants with this dispersal pattern will yield large amounts of seed if the collection is done at the precise time the seeds are ready. If the collection is done a week earlier, the seeds will not be mature; a week later and the seeds will be gone. Only by close observation of stage of maturity can seed collection be correctly timed.

Species that disperse seed slowly over a long period of time present an altogether different problem. Collecting mature seed can be done over a long period so timing is not as vital; however, the amount of seed available and mature at a single collection time is small. Therefore, seed must be collected from a large number of plants or must be collected several times thoughout the period in which the seeds are ripe. Since different species have different dispersal patterns, the pattern employed by each species to be collected must be determined by observation or by literature research. A schedule to collect the necessary seeds can be designed using phenology data and knowledge of each species dispersal pattern.

Equipment and labor for seed collection must be ready as soon as the seed crop is ready to be harvested. Many species' seeds become loosened on the receptable and are easily dispersed as soon as the seed ripens. A severe rainstorm or strong winds can cause the loss of an entire crop (Plummer and others, 1968). Collections should be done before, not after storms (Monsen, 1979).

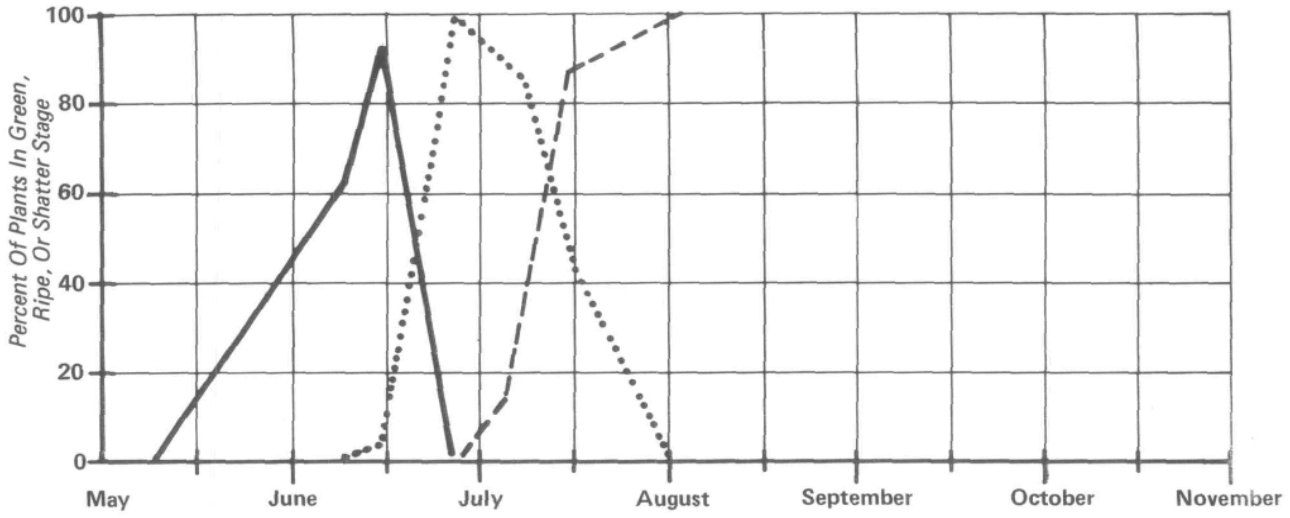

Figure 65.—Idaho fescue seed shatter

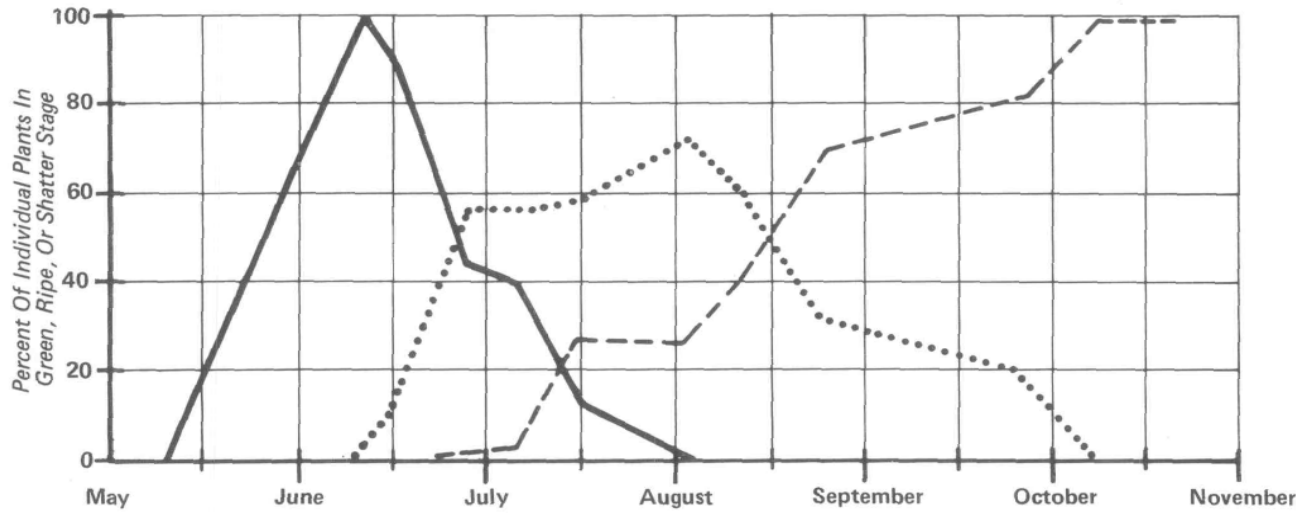

Figure 66.—Indian ricegrass seed shatter

Very few native species produce abundant viable seed crops from year to year (Eddleman, 1980). Phenological observations will provide information about the current year's crop, so that the collection schedule can be adjusted in time to insure collection of enough seeds of the proper species. Collecting a surplus of long-lived seed in years when the seed crop is abundant can safeguard against the lack of seed in years when production is low.

Collected seed should be carefully handled from the time of harvest until it is seeded. Cloth bags are preferable to plastic bags when collecting seed. The seed must be cleaned, dried, and dewinged or deawned. Cleaning, dewinging, or deawning requirements are species specific and should be investigated before the seed is collected. Commercial seed dealers often have specialized equipment to clean and dry native seed. Equipment designed to handle small seed lots is available and can be appropriate for handling native seed.

Seed should be stored in a dry cool environment. Airtight glass or metal containers are preferable to plastic or porous containers (Monsen, 1979). Seeds must be thoroughly dried before they are put into containers for storage. Of course, there are exceptions to these guidelines, so each species should be researched to determine the optimum storage conditions to maintain its viability.

All seed should be properly labeled. Labels should be placed on the outside and inside of each container of seed. Each label should include species name (including the scientific name), suppliers's or collector's name, the date the seed was collected, and detailed information about the location of the seed source. A complete, permanent file kept on each seed lot should include all label information, information about seed purity, viability, and PLS percentages, site characteristics about the collection site, precisely where and when the seed was planted, and dates the collector recommends for future collections (Monsen, 1979). The file should also contain information about the success or failure of the seeding. Any data that could help evaluate the quality of the seed source for reclamation use should be included in the file.

Seed Collection Equipment

Seed collection equipment ranges from conventional farm combines for harvesting uniform stands of grass to sticks and cloth bags for collecting shrub seeds from individual plants. The collection equipment can be purchased or handmade; it can be designed to harvest enough seed to sell commercially or a small amount to seed an experimental plot.

Combines.—Combines (Fig. 67a, b, and c) are machines that cut a crop, thresh it, and store the seed in a bin. The bin can be unloaded into a truck or seed bags. Combines range from very large, expensive grain harvesters used on conventional farms to small machines used to harvest experimental plots. The larger combines are inefficient for harvesting native seeds, but can collect seed from pure stands of such species as crested wheatgrass on a large-scale commercial basis. The smaller combines, particularly those that are towed or attached to a tractor, are more appropriate for harvesting naturally occurring stands, although level, uniform stands of grasses or shrubs can be harvested. Plummer and others (1968) suggest field plantings of native forbs to enable use of combines for harvesting. McKenzie (1977) and Larson (1980) provide further information on small combines.

Figure 67a.— Combine

Figure67b.—Combine

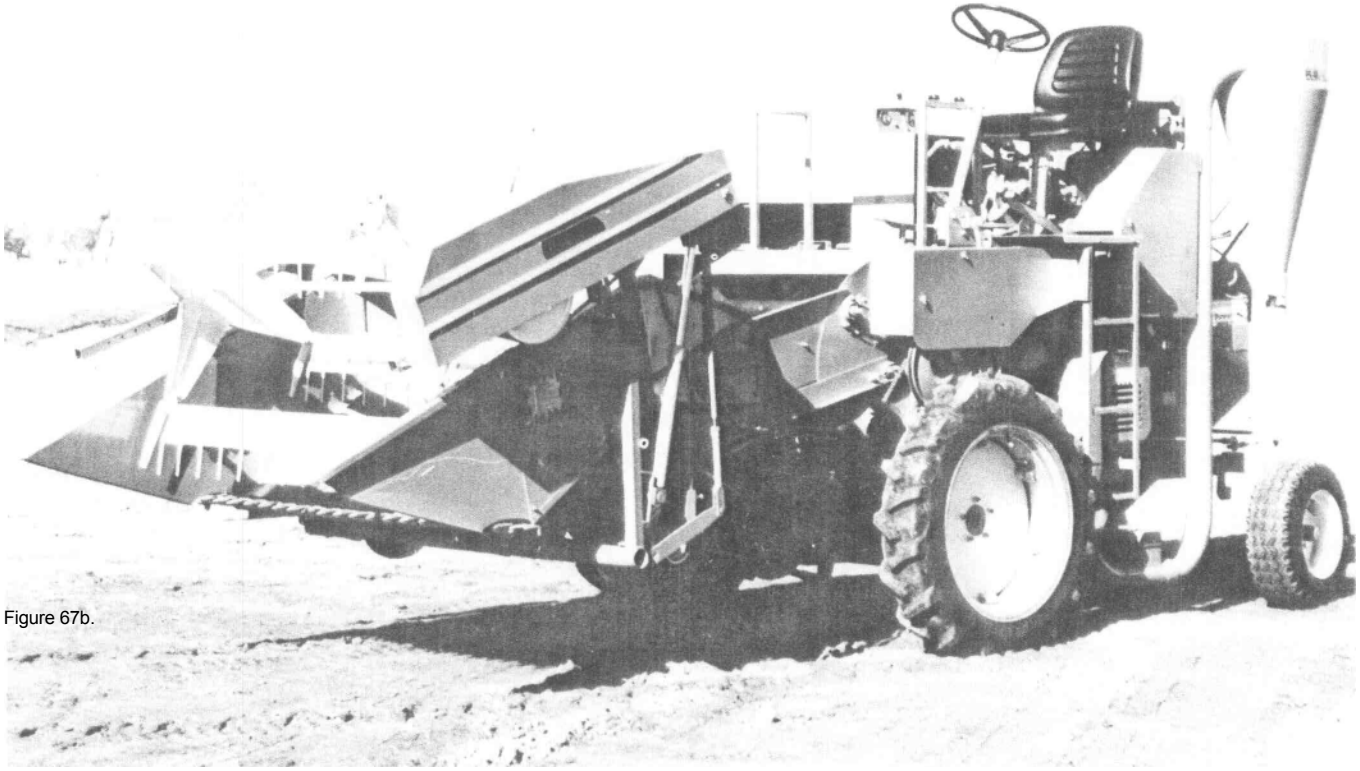

Figure 67b.

Figure 67c.—Combine

Seed Strippers.—These (Fig. 68) machines strip seed from plants, usually grasses, without cutting the plants. They use brushes, beaters, or reels to knock the seeds off the seed stalks. The seeds are mechanically or pneumatically carried to storage bins or sacks. Strippers collect a variety of seed at the same time; different size, maturity, and species of seed are collected, including small, chaffy seed (Larson, 1980). Since a variety of seeds is collected, seed cleaning and processing must be extensive to produce relatively pure seedlots. Seed strippers are not efficient for large-scale seed collection operations. They are generally used for small plots or native stands. When collecting seed from a winterfat stand, Plummer and others (1968) found strippers lost more seed than did either combines or handpicking.

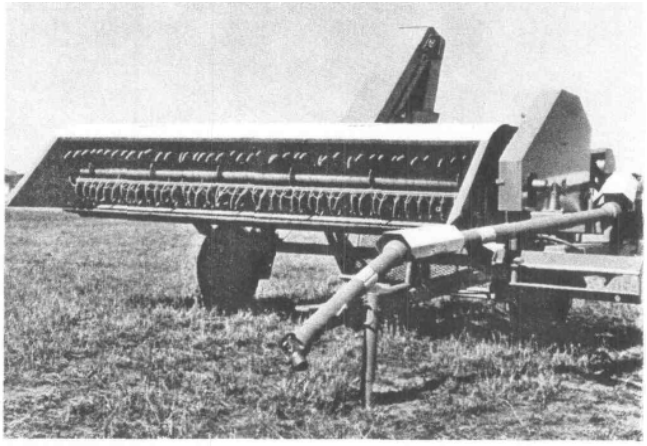

Figure 68.—Seed stripper

Vacuum Seed Collectors.—Collectors range in size from battery-powered, hand-held vacuums to large tractor- or truck-mounted machines with flexible hoses (Fig. 69a and b).

Figure 69a.—Vacuum seed collector

Figure 69b.—Jeep-mounted vacuum seed collector

Vacuums collect seed that is easily dispersed or is on the ground. They do not injure the plants as do combines and seed strippers. Portable vacuums, whether hand-held or backpack models, are not limited by rough terrain. They are well-adapted to collecting seed from plants that are mixed with other species in a stand. Eddleman (1978) used vacuum collectors to gather small seed at or near ground level. Vacuums are ineffective for collecting seed that is firmly attached to the plant seed head; many plants require more force to remove the seeds.

Headcutters.—Headcutters are hand-held shears or clippers used to clip the inflorescences of plants. Rechargeable electric shears or hedge trimmers are lighweight, portable, easy-to-use headcutters. These products, which have gained popularity as lawn-care tools, rapidly and easily cut through dense stands of plants. The inflorescences are clipped, gathered, and stored in paper bags until they can be threshed. Conventional hand-powered clippers can also be used, although they can be fatiguing and are not as productive as the electricity-powered models. When working away from a power source, interchangeable, rechargeable battery packs are essential. Head-cutters are not effective for mass production of seed as they are labor-intensive.

Hand Flails.—Flails are sticks used to hit the limbs of trees or shrubs to dislodge seeds. The seeds are collected in cloth bags or hoppers or by spreading cloth on the ground under the shrub or tree. Hand flails are labor-intensive tools that are most appropriate for collecting seeds from individual plants or plants too large to harvest with mechanical equipment.

Hand Picking.—This method is simply stripping or picking seed by hand and placing the seed into a basket or bag. Eddleman (1978) used handpicking or harvest seeds when the inflorescence was mixed in with the plant

leaves or when a low percentage of ripe seed was available at any one time. Plummer and others (1968) suggest handpicking for several shrubs in the composite family and for many native forbs. By definition, handpicking is labor-intensive, with little potential for large-scale collection.

Seed Processing Equipment

Seed process!ng equipment ranges from blowers to macerators to dryers. All are designed to physically prepare the seed for seeding, whether it is to be done aerially, by hand, or through a farm drill.

Seeds must be dried before processing or storage. Different species have different moisture requirements, depending on whether the seed will be stored, the length of time the seed will be stored, and the unique physiological requirements of the species. Seeds are cleaned after they have been dried. Macerators remove pulp from fleshy fruits and berries, dewingers remove awns or utricles, and separators remove empty seeds and trash.

Seed processing equipment for trees and common ornamental shrubs is commercially available. They have been well-designed and used for years. Equipment for processing seeds of native forbs, rangeland shrubs and many native grasses, however, has not been developed. These seeds must be processed with equipment designed for other kinds of seed.

Dryers.—Dryers reduce the moisture content of seeds to the optimum level for storage or planting. The optimum level is different for different species, but for most range species a moisture level below 8 is desired (Sowards and Balzar, 1978). Kilns and ovens can dry seed, but usually native seed collected in relatively small amounts will be air-dried. Drying should take place in a cool, shaded, well-ventilated area. The seeds must be well protected from heat and moisture to prevent molding or other seed degeneration.

Dewingers.—Dewingers break off appendages attached to the seed (Fig. *70s* and b) to assist in natural dispersion. These appendages inhibit broadcast or drill seeding. Hammermills, threshers, debearders, or other dewingers (Fig. 71) break seed wings, plumes, or other extraneous materials away from the seed. They usually have revolving shafts with brushes or rubber flails to rub the seeds against each other or against the inner surface of the dewinger cylinder (Fig. 72). After the trashy materials have been broken or rubbed off the seed, the seed and trash is carried across an airstream. The airstream carries the trash away to a collection receptical and the heavier seed falls into a bin or box. Thus the dewinger can often be used to separate trash from seed as well as dewing the seed. Seeds from species like cliffrose *(Cowania sp.),* saltbush *(Atriplexsp.*), and mountain mahogany *(Cercocarpus sp.)* cannot be

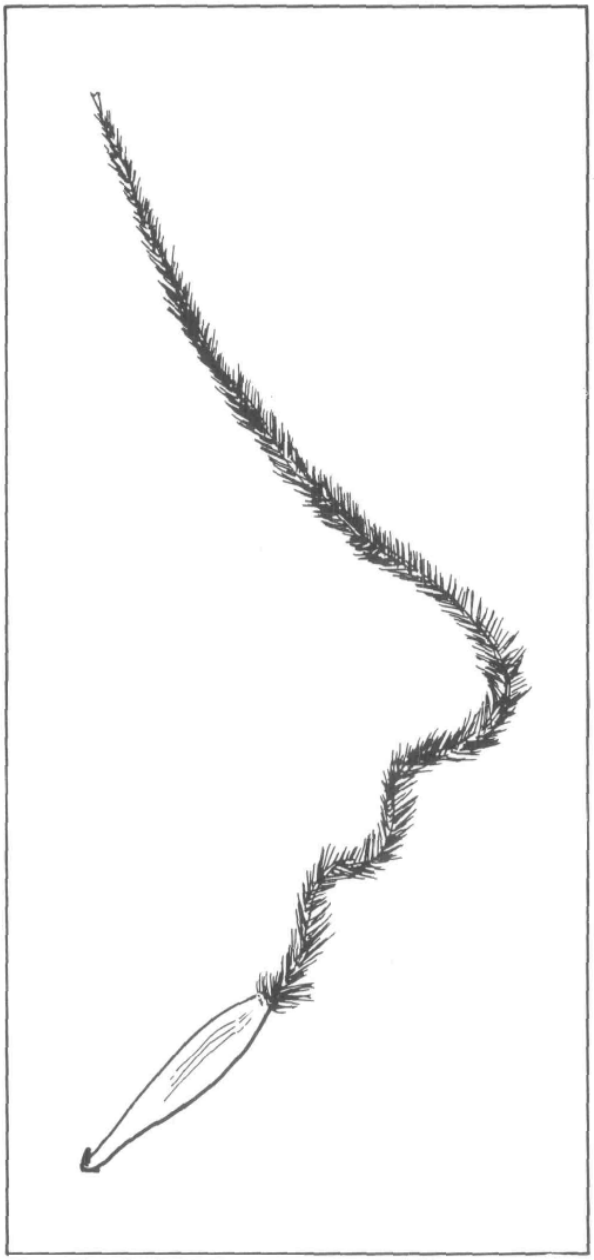

Figure 70a.—Seed with appendages

completely separated from the utricles that enclose them; only the plumes and outer portions of the wings are removed in dewinging (USDA Forest Service, 1974). Hand rubbing the seed in a sack is the safest way to dewing seed, but it is not practical for any but the smallest seed lots (Lowman, 1975). Dewinging is harmful to some seeds, but the damage can be minimized by choosing dewingers with care and by minimizing the time seeds are treated.

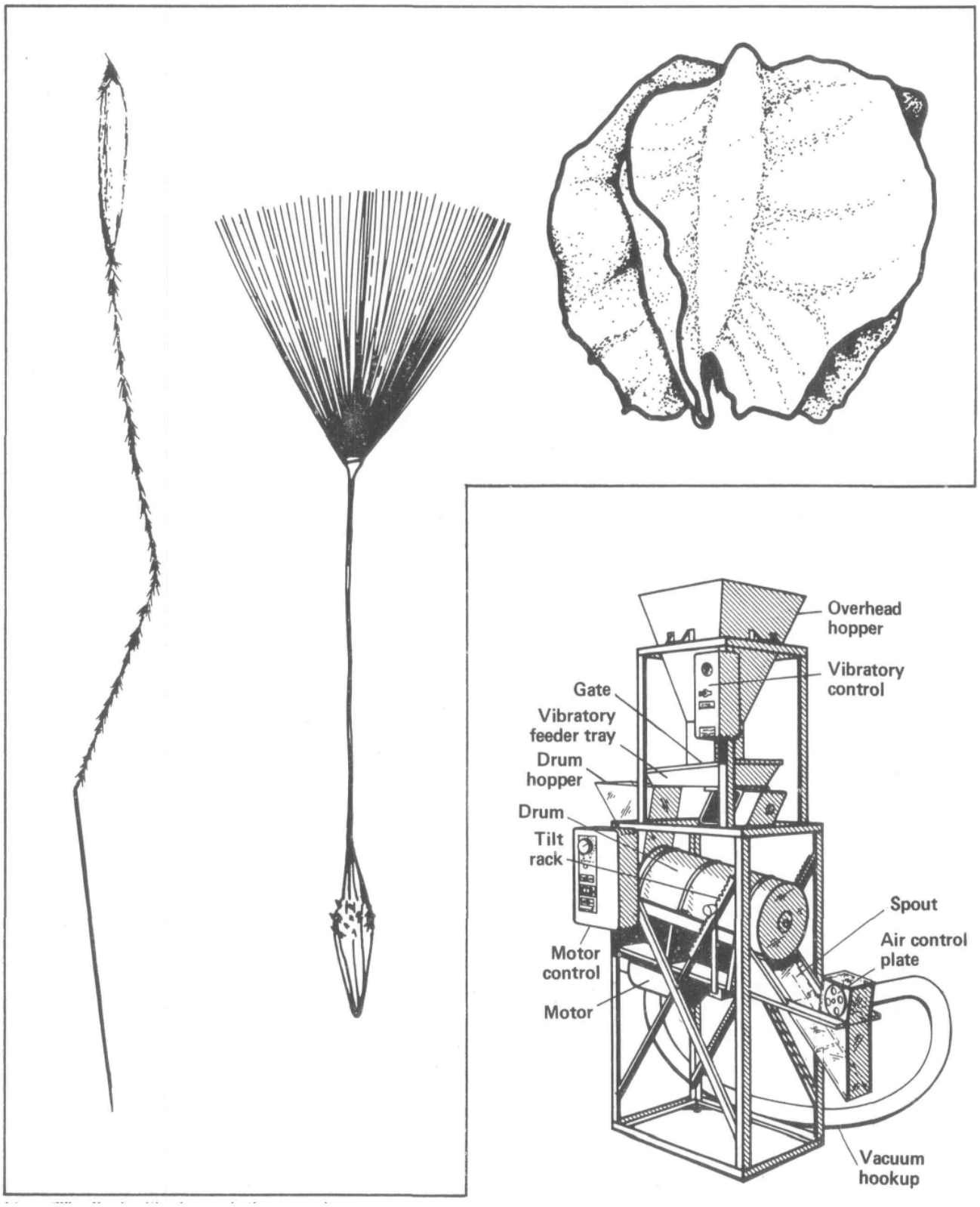

Figure 70b.—Seeds with wings and other appendages

Figure 71.—Dewinger

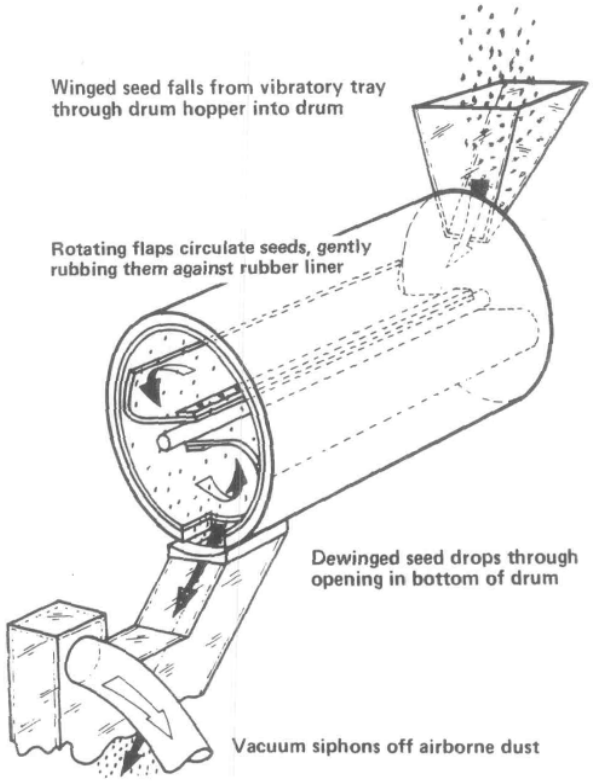

Figure 72.—Dewinger

Cleaners and Separators.—This equipment separates filled seed from empty seed, chaff, and other extraneous materials. Some cleaners can also separate seeds of different species. Cleaners are screens, pneumatic blowers, specific gravity separators, or vibrating separators. Many use two or more methods to improve their cleaning abilities. Figure 73a, b, and c shows several basic methods for cleaning seeds with screens and blowers. The separators are generally used to segregate several different kinds of seed, when the seed collection harvests undesirable seeds along with the desirable seed. Both cleaners and separators improve seed lot purity.

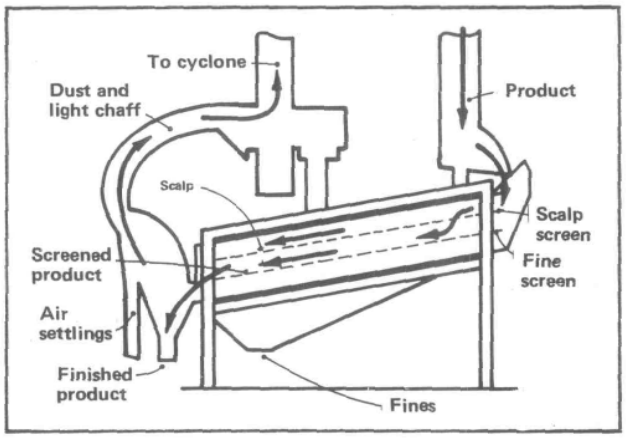

Figure 73a.—Screeners and blowers

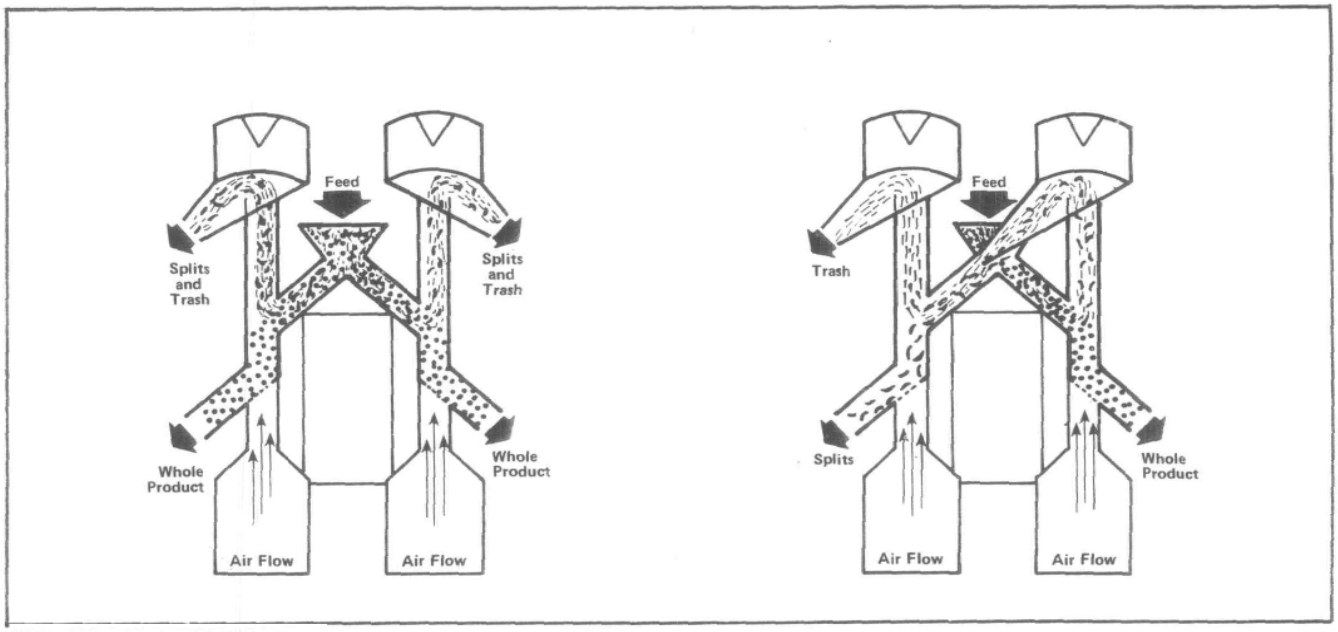

Figure 73b.—Screeners and blowers

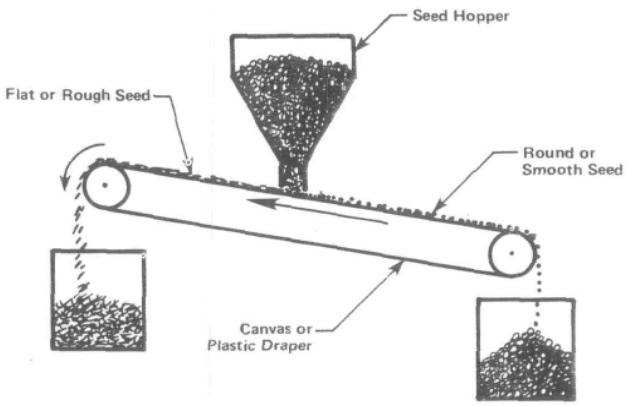

Figure 73c.—Screeners and blowers

Macerators.—Macerators (Fig. 74) clean the seed of pulpy or fleshy fruits. The fruits are put in the macerator, where they are mashed to break up the pulpy materials. Water is flushed through the macerator to carry away the ground pulp. After the maceration is completed, the seeds are left in the bottom of the machine and the pulp is washed away. Plummer and others (1968) report that seeds can be cleaned to 90 percent purity by macerating them and then blowing away the trashy material.

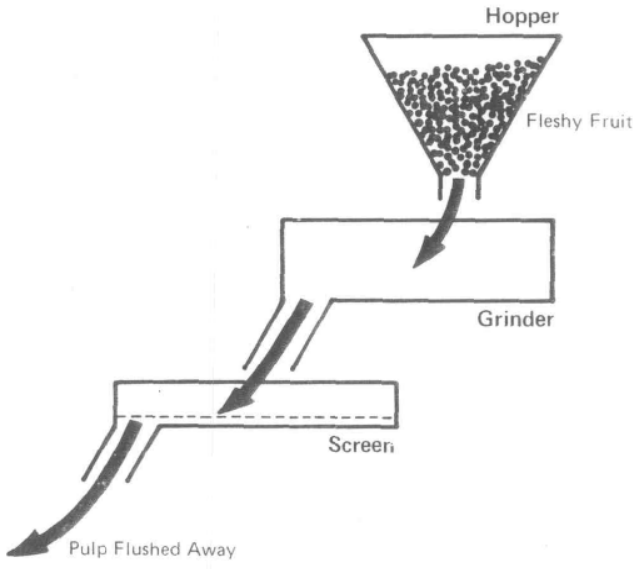

Figure 74.—Macerator

Storage Containers—Containers should keep seed dry, cool, and pest-free. Insects, rodents, and birds will all feed on seeds if given the opportunity. Seeds can be protected in metal cans, granaries, or glass jars. The seed must be dry before closing the containers. Storage in airtight, dry, cool conditions will promote optimum long-term viability. Even so, some species will not be viable after 1 year; most will not maintain viability for more than 5 years. Before collecting seed, the expected storage life of the seeds must be determined.

Lowman (1975), USDA Forest Service (1979b), Eddleman (1978), and Plummer and others (1968) describe equipment for processing seeds. Sources of equipment are cited in these references.

Topsoil As A Seed Source

Topsoil holds a multitude of seeds, bulbs, rhizomes, and roots. Since federal law requires that most mine spoils be covered with topsoil before revegetation, the topsoil is an obvious seed source. The seeds are from species adapted to the site, species that have been on the site prior to mining. The seeding mix is broader than even the most ambitious reclamation project's, but the quality of the seed mix may not be adequate. Topsoil from poor quality range will carry seeds of poor quality species. These species are usually weedy, very competitive, rapidiy spreading pioneer species, and are seldom desirable for reclamation. Poor quality topsoil is not only a poor source of seed, but may actually hinder reclamation efforts. Aldon (1975) reported that most of the seeds germinated from a topsoil study were annuals. Even good quality topsoil may not provide an adequate seed source. Beauchamp and others (1975) found that "although viable seed in the top 2 inches is plentiful,... seeding or transplanting of desired species on strip mine spoil areas would be required." The study showed that the dominant species on the topsoil prior to mining seldom produced the greatest numbers of seedlings when the topsoil was the only seed source. Successful use of topsoil at a time of year when the desired seeds, bulbs and other propagules will be best able to compete with propagules of undesirable species will improve success. Only in very rare cases, however, should supplementary seeding be neglected.

Plant Sources

Plants are available in four forms—bareroot seedlings, containerized seedlings, cuttings, and full grown plants. They are all established plants moved to and planted on the mine site. Problems involving seed germination are eliminated by using plants rather than seeds to revegetate a site. This is particularly important on sites where microclimatic conditions seldom favor germination of desirable species. In the Southwest deserts, on steep slopes, or on other hot, arid sites, seed germination and establishment is particularly difficult. To avoid these problems, plants with established root systems and adequate size are sometimes used. Although seeding is much less expensive than planting, planting

is required for some species and on some sites because of the poor results achieved with seed. All plants and ecotypes must be adapted to the sites on which they will be planted.

Bareroot Seedlings. —Bareroot seedlings (Fig. 75) are trees or shrubs that have grown naturally or in a nursery, are dug out of their soil and transplanted on a new site. Most are grown in nurseries. Bareroot seedlings are usually taprooted shrubs or trees. They are seeded in a closely controlled bed, and are grown for 1 to 2 years. The seedlings are removed from the nursery bed while dormant and are kept in a cold storage facility until the site is ready for planting.

Handling and storing bareroot seedlings must be done carefully to preserve seedling viability and vigor. Seedlings should be kept at 32˚F and 35˚F and between 90 and 95 percent humidity. Most seedlings will not survive if they have broken dormancy or have dried out before they are planted. The plants should be allowed to warm slowly the day before they are planted. This acclimatization reduces the shock of planting for the seedling. Seedlings should never be exposed to direct sunlight or to wind.

Containerized Seedlings. —Containerized stock (Fig. 76) are seedlings planted with a soil "plug." The plug is the soil in which the seedling roots have been growing. Containerized seedlings have plugs from 2 inches long to 36 inches long. They are grown in nurseries or greenhouses, then transported to the planting site in the container in which they were grown. Containerized roots are not subjected to the same shocks as bareroot seedlings. Container seedling roots are planted with soil attached to them, allowing them to continuously supply nutrients to the plant. Bareroot seedlings must first penetrate the soil before transporting nutrients. Containerized seedlings are more expensive than bareroot seedlings, therefore they should be used for species that are relatively difficult to establish and for sites that are difficult to vegetate.

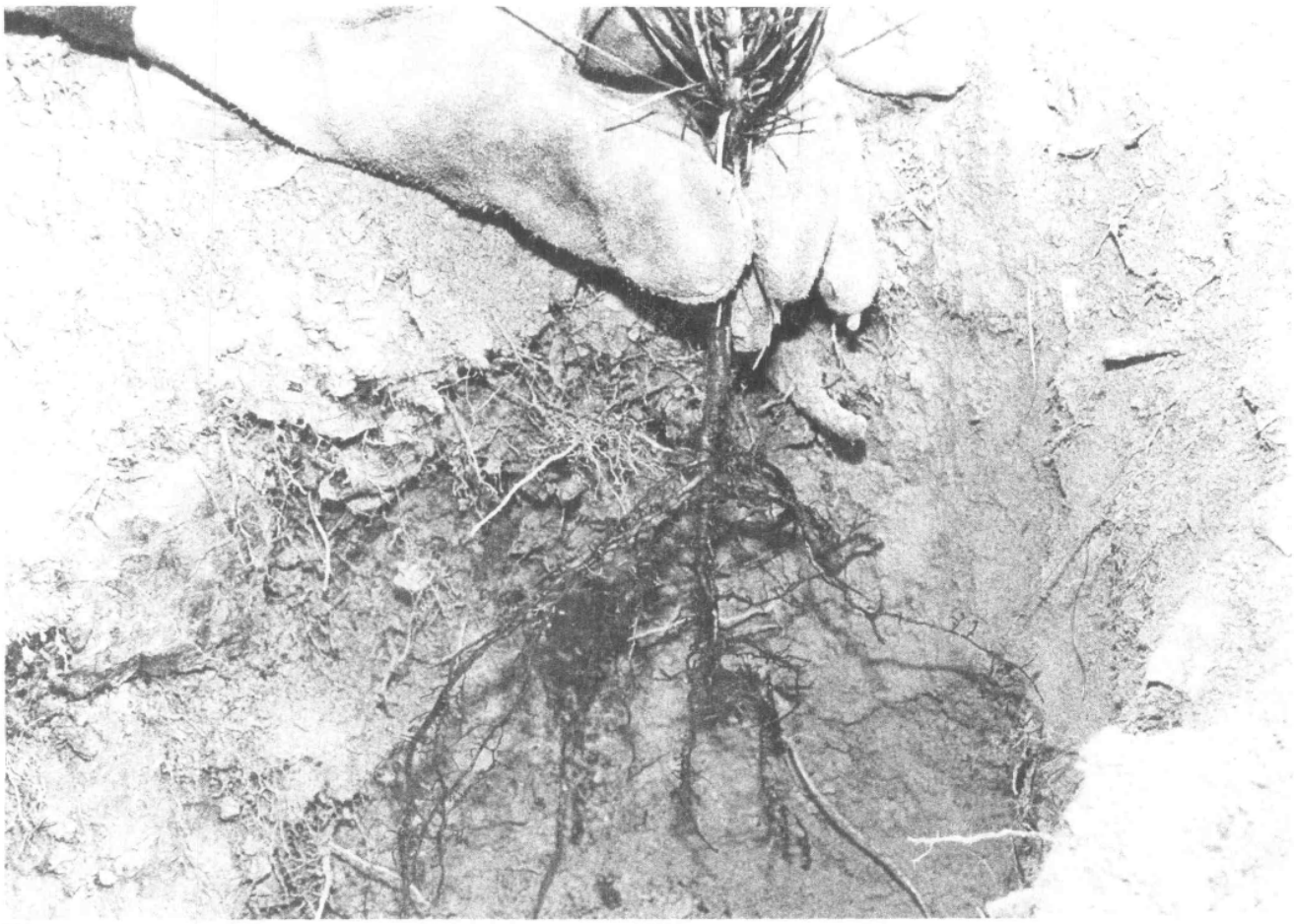

Figure 75.—Bareroot seedlings

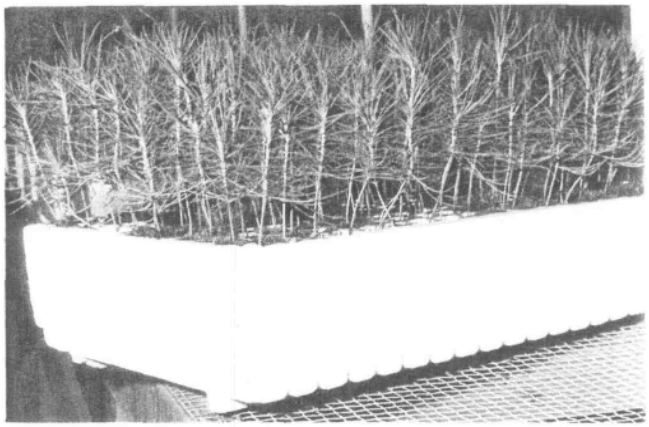

Figure 76.—Containerized seedlings

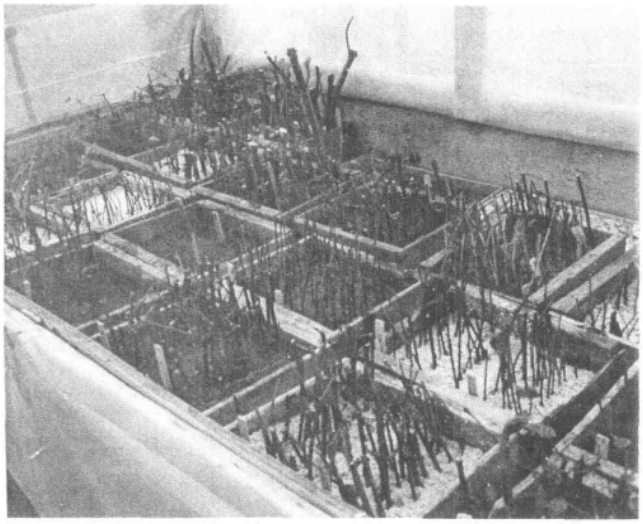

Figure 78.—Cuttings placed in soil

Cuttings. —Cuttings are pieces of plants that can root and grow into a complete plant. Stems of shrubs, clumps of grasses or forbs, rhizomes, or chunks of root mats can all produce complete plants of some species (Fig. 77). Cuttings are obtained from natural stands near the site to be revegetated. The cuttings may be rooted and grown in a nursery or greenhouse (Fig. 78) or may be transplanted immediately to the revegetation site (Fig. 79). Many cuttings are included in topsoil that is moved directly from unmined areas to mine spoils.

Figure 77.—Cutting stems of sprouting shrubs

Figure 79.—Cuttings to be incorporated into spoil

Native Plants.-Native plants are mature plants that occur naturally on the mine site or the surrounding area. These plants are moved as whole plants from unmined areas to mine spoils (Fig. 80). They are adapted to the site because they are living and reproducing on the site. They are ready to move at any time, without any handling or storage problems prior to replanting.

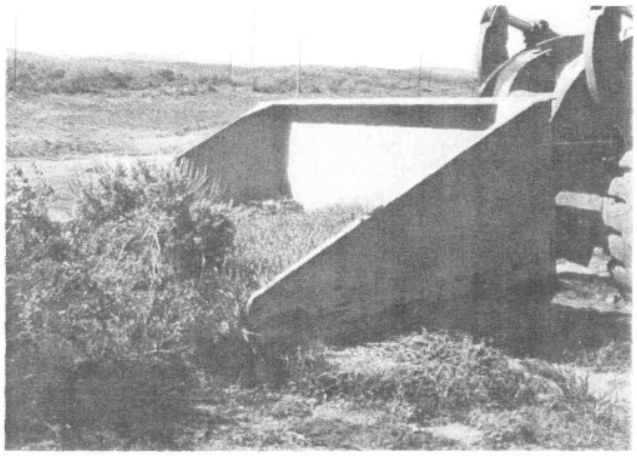

Figure 80.—Root mat on mine site

Seeding and Planting Methods

The purpose of seeding or planting is to place the seed or plant in the soil at the correct time and place to improve chances for successful establishment and growth. The species to be grown and the type of propagule used to vegetate the site will affect the method of seeding or planting. The method will also depend on the climate, soil conditions, and topography of the site. Economic factors also play a part in determining appropriate methods.

Successful planting or seeding depends on proper timing, proper technique, and an understanding of the relationship between plant establishment and planting environment. This section describes and discusses seeding and planting techniques and equipment.

General Principles

General principles for planting and seeding apply regardless of the planting technique or the equipment used. These principles deal with the fundamental plant requirements for establishment and growth and with major factors involving all planting and seeding techniques.

Timing.—Timing the planting or seeding operation is vital to revegetation success. Timing involves the time of year that planting is done, the order in which successive planting operations are carried out, and the relation of planting to other mining and reclamation operations. Planting must be done with seasonal climatic conditions in mind. Packer and Aldon (1978) divide the West into two sections: 1) semiarid region, the Northern Great Plains, and; 2) an arid region, the Southwestern deserts. The optimum planting season for both regions is just before the longest period of favorable growingconditions. This period is the longest period of sufficient moisture, when the soil temperature is high enough to promote germination and not high enough to inhibit growth.

Some species, especially cool season plants, will not germinate at high temperatures. Eddleman (1978) found that temperatures above 59˚F markedly reduced germination of western wheatgrass *(Agropyron Smithii');* he also found that optimum Indian ricegrass germination occurred at 39˚F. Warm season species must have higher soil temperatures than cool season species to optimize germination. Little bluestem *(Schizachyrium scoparium)* and alkali sacaton *(Sporobolus airoides]* showed virtually no germination at temperatures below 68˚F (Eddleman, 1978). When planting, it is obvious that temperature requirements must be considered.

In the Northern Great Plains, precipitation is heaviest from April to September (Packer and Aldon, 1978). Summer rains are mostly short intense thunderstorms that provide relatively small amounts of moisture for plant use. The Southwestern deserts receive 50 percent of their precipitation during the summer months, July through September.

In the Northern Great Plains, with the cold winters, cool springs and falls, and hot summers, cool season plants dominate much of the area. Seeding cool season plants should be done early in the spring before the rainy season begins or late in the fall after the soil has cooled enough to prevent germination. In both cases the seed is intended to germinate in the spring. Seeding in late fall puts seed in the soil where it will germinate as the soil warms in the spring. If seeding is done too early in the fall and germination occurs before winter, the seedlings will not have enough time to harden and will seldom survive until spring. Seeding too late will prevent access to some sites due to snow cover or frozen soils. In southern portions of the region, however, seeding can be done from late fall until February or March. Seeding in the spring is often unpredictable because the time between snow melt and the arrival of spring rains is often quite short. Hodder (1976) states that seedlings must emerge before spring rains begin (Fig. 81). Seeding between snow melt and spring rains severely limits the time available for seeding in some years. Seeding cool season species in the fall is becoming a well-accepted practice in the semi-arid region.

Seeding in the Southwest deserts is more appropriate in early summer just prior to the July and August rains. Warm season plants dominate in this region, where the soil temperatures will be high enough for their germination during the summer. Seeding at other times of the year is seldom successful, due to reduced germination rates or insufficient moisture for the seedling to become well established. Rainfall is unpredictable in this region and moisture is virtually always limiting. Any seeding or planting should be timed to take advantage of periods of moisture.

Time to plant, Northern Great Plains timing matrix

	Spring		Summer		Fall[1]		Winter	
Activity	**Advantages**	**Disadvantages**	**Advantages**	**Disadvantages**	**Advantages**	**Disadvantages**	**Advantages**	**Disadvantages**
Direct seeding[2]	Most optimum conditions probable between early March and late April. Seedlings must emerge start of spring rains. Topsoil receives best protection at this time	Access can be a problem		Optimum planting conditions have passed—would require irrigation. Postpone seeding to fall	Provides best access and weather for planting. Stratification important to and shrub seed. More time available to plant	Topsoil and seedbed protection a problem		Seeding on snow is possible but wind may destroy seedling. Seedbed preparation and access are difficult
Bareroot	Essential to plant early between frosts and snowstorms so that roots will develop before buds break dormancy. Plant immediately prior to maximum soil moisture season	Timing is very critical		Storage a problem. Seed dormancy broken. Soil too dry. Plants will burn. Lack of necessary moisture	Plants can be planted when dormant and become better acclimated to site if planted after frost	Some species not adapted to fall planting	Not recommended	
Containerized	Most optimum conditions exist very early in spring between frosts and snowstorms	Disadvantage is that stock is usually not ready or available. Access sometimes a problem	Not recommended		Same as above	Same as above	Not recommended	

Provided by R.C. Hodder

Climate Summary: Considered a continental climate, with warm summers and cold winters. Temperatures can range from -40°F to +105°F. Average precipitation about 12 inches, but can vary from 4 to 18 inches annually in various localities. Precipitation dependent on snowmelt and spring rains that fall between April and mid-June. High wind and high evaporation rates common.

[1] Fall season implies terminal season of the year and that seeds and plants will remain dormant until spring.

[2] Direct seeding involves the use of machinery to place seed in a shallow furrow and cover it with soil. Firming of soil around seeds and placement of fertilizer near to seeds may be accomplished on sites where required. If seeds are broadcast rather than drill seeded, some action to cover them with soil is essential unless it is on freshly graded spoils where natural sloughing will cover the seed.

Figure 81 .—Planting schedule (Packer,1979)

Time to plant, Great Basin Range and Foothills, and Colorado Plateau timing matrix

	Spring		Summer		Fall[1]		Winter
Activity	**Advantages**	**Disadvantages**	**Advantages**	**Disadvantages**	**Advantages**	**Disadvantages**	**recommended**
Direct seeding[2]	Favorable temperature/ precipitation for seedling establishment	Late winter may reduce time available for seeding. Late frost or a short spring may reduce seedling establishment or growth	Not recommended		Seeds may receive needed cold treatment and germinate in late winter	Early winter may prevent completion of seeding operations	Not recommended
Bareroot planting	Plant can establish if planted before summer drought	A short spring season may reduce survival	Not recommended		Plant mid-fall. Avoid late fall planting	Frost heaving in heavy soils. Open winters	Not recommended
Transplanting container-grown plants	Best results for establishment are in spring. Hazards of seed germination and establishment are bypassed	Weather may be a problem in scheduling field work	Possible if can be in moist soil. Long period of planting is possible	High temperatures and drought can be detrimental	Best results for establishment. Plant early to mid-fall	Frost heaving. Open winters	Not recommended

Provided by Cy McKell

Climate Summary: An area of isolated mountain ranges and extensive level valleys where a highly variable frost-free growing season may be from 120-180 days in the valleys and less than 110 days in the foothills. Spring and fall temperatures are generally moderate (50°F), but high summer temperatures may reach in excess of about 98°F. Warm season precipitation from erratic thunder-showers is less than half of the total precipitation of about 6-16 inches annually.

[1]Fall season implies terminal season of the year and that seeds and plants will remain dormant until spring.

[2]Direct seeding involves the use of machinery to place seed in a shallow furrow and cover it with soil. Firming of soil around seeds and placement of fertilizer near to seeds may be accomplished on sites where required. If seeds are broadcast rather than drill seeded, some action to cover them with soil is essential unless it is on freshly graded spoils where natural sloughing will cover the seed.

Time to plant, semiarid timing matrix

	Spring		Summer		Fall[1]		Winter	
Activity	**Advantages**	**Disadvantages**	**Advantages**	**Disadvantages**	**Advantages**	**Disadvantages**	**Advantages**	**Disadvantages**
Direct seeding[2] (grasses)	Cool season species only	Winter moisture variable	Warm season species. More reliable precipitation. Plant prior to July-Aug. rains	None	None	Frost heaving. Limited fall growth	None	Unsuitable for germination and growth
Bareroot (shrubs)	Not recommended		Plant after initiation of summer rains. Soil moisture must be near saturation	Timing critical. Variable precipitation	If summer rains are late, early fall plantings are possible	Frost heaving	Not recommended	
Containerized seedlings (shrubs)	Not recommended		Soil moisture must be near saturation	Variable precipitation	If summer rains are late, early fall plantings are possible	Frost heaving	Not recommended	

Provided by Earl Aldon

Climate Summary: Semiarid mesas and valleys of northwestern New Mexico and northeastern Arizona are characterized by low, highly variable rainfall and high summer temperatures. Highest rainfall months are July and August with occasional late summer storms extending into September. Driest months are May and June. Rainfall varies with elevation, but in lower areas averages 7-10 inches annually. Snowfall light most years and seldom remains on ground. Growing season ranges from 140-180 days.

[1]Fall season implies terminal season of the year and that seeds and plants will remain dormant until spring.

[2]Direct seeding involves the use of machinery to place seed in a shallow furrow and cover it with soil. Firming of soil around seeds and placement of fertilizer near to seeds may be accomplished on sites where required. If seeds are broadcast rather than drill seeded, some action to cover them with soil is essential unless it is on freshly graded spoils where natural sloughing will cover the seed.

Figure 81 .—Planting schedule (Packer, 1979), cont.

On sites where both warm and cool season plants are desired for reclamation, timing planting is very important. One method is to seed warm season plants one year, allow them to become established for a year or two, and then seed again with cool season plants. Competition from the cool season plants may inhibit establishing warm season species. This method is expensive because the area must be seeded twice. Also, seeding into an established stand of plants is more difficult than seeding into a well prepared seedbed.

Seeding warm and cool season species at the same time is a more common practice. Often, however, the climate in the seeding year will favor one type of plant to the detriment of another. Early spring rains without summer moisture will favor cool season plants and reduce the establishment of warm season plants. Seldom will conditions favorable to both types of plants occur. A more intensive method of establishing both warm and cool season species is being used on at least one mine in the Northern Great Plains. A wide range of native shrubs, grasses, and forbs that are difficult to establish are planted and seeded along with a sterile, annual grass cover crop. One to 3 years later, after the difficult-to-establish species have had an opportunity to grow without aggressive competition, a selection of desired grasses specifically chosen for the site are seeded. Small areas within the revegetation site are patch seeded with warm season grasses to simulate small native warm season grass communities within the cool season grass stand. The resultant stand is designed to be ecologically similar to the original premining stand. A diversity of warm and cool season plants, stand variation, in both species and percent composition, on various aspects and slopes, and diversity of plant lifeforms, produce small cornmunities that combine to make the entire stand. Homogeniety is not a normal situation in nature. By intensively seeding and planting, noting differences in site conditions and the species most adapted to the condition, homogeneity is avoided.

Seeding and planting should be done as soon as seedbed preparation is completed. By beginning revegetation immediately, competitive pioneer species will not be given an advantage and the seedbed will not degrade physically or biologically. Quick establishment of a vegetation cover protects the soil from erosion and moderates the soil surface environment, which aids species difficult to establish.

Mining operations usually dictate the timing of soil movement. Often spoils are graded and topsoil spread at times when seeding or planting is not advisable. In these cases, the soil should be seeded to a cover crop or should be stabilized with a mulch. Seeding or planting at inappropriate times, unless the seeding or plantings can be artificially cultured until they are permanently established, is usually an ineffective and costly practice. Seedings made after the period of adequate moisture can be successful if they are irrigated, however the expense of irrigation may be more than that of stabilizing the soil and then seeding at the recommended time. Whenever possible, however, topsoil should be spread on graded spoils at the optimum time for seeding. This will give the best chance of success.

Patterns.—Seeding and planting patterns should be designed to best provide the desired post-mining use. Native range is seldom in symmetrical, well-defined communities with abrupt boundaries between the communities, Native range is a heterogeneous mix of small communities that blend into each other gradually and have few distinct boundaries. The communities are differentiated according to microsite conditions. The heterogeniety of stands is often accented by differences in lifeforms; for example, timber on high slopes, bunchgrass on ridges, shrubs on lower slopes, and rhizomatous grasses in draws. Reconstructing the natural variety and diversity includes seeding and planting species at different rates in various areas. The species and rates chosen are based on site conditions. Trees and shrubs are planted only on sites that would naturally produce them; for example, they are bunched on concave slopes that have increased moisture available. Straight rows and even spacing are avoided. Grasses and forbs are seeded on areas where they naturally occur. For example, western wheatgrass might be seeded in lower areas, on sideslopes, and on ridges. However, mountain brome *(Bromus margmaius]* would be seeded only on low affias, green needle grass *(Stipa viridula)* on sideslopes and ridges, and side-oats grama *(Bouteloua curtipendula)* only on ridges.

Patch seeding, seeding a small area within a relatively homogeneous stand to species different than the majority of the diversity. Patch seeding shrubs into small draws or warm season grasses onto hot exposed slopes are examples of patch seeding that recreate natural conditions found in the Northern Great Plains.

Seeding Principles

Agricultural seeding methods and techniques are well researched and documented. These, however, do not always apply to reclamation of native range. Seeding in straight, well-spaced rows does not duplicate natural conditions. Even so, sometimes the most successful stands are seeded using common agricultural technique modified to reflect the unique characteristics of native seed and mine spoils. Such particulars as seeding rates, seeding depth, seed inoculation, and seed covering must all be determined experimentally for each species. Federal agencies, state agencies, university personnel, and extension services are all currently conducting studies involving various plant species and seeding methods. Requirements for some species may not be available and must be discovered by the reclamation specialist.

Depth.— Seeding depths are controllable only when drill seeding, In general, small seed should be seeded closer to the soil surface than large seed. Valentine (1980) states that ideal seeding depths range from 1/16-inch for winterfat to 1 inch for smooth brome *(Bromus inermis).* Most seeds should be planted from ¼- to ½-inch deep. "Seeding too deeply delays emergence and reduces total emergence. Seeding too shallowly increases desiccation, depredation, and faulty rooting of seedlings" (Vallentine, 1980). Precise seeding depths are determined experimentally.

Covering seed is important in the arid and semi-arid West. Some seeds will not germinate when uncovered; birds and rodents feed heavily on the available seed, and uncovered seed may wash or blow away before it germinates and roots. Drill seeding, by definition, places seed into the soil, with soil over the seed. Broadcast seeding spreads seed on the surface of the soil. Because of this, broadcast seeding has been considered to be inferior to drill seeding (Vallentine, 1980; Packer and Aldon, 1978). Since covering the seed is the important factor, any technique that results in seed incorporation into the soil is satisfactory. Broadcast seeding onto a fluffy, loose, well-broken seedbed often allows seeds to fall into soil cracks, under small clods of soil, or between soil particles. Weather conditions such as frost heaving can sometimes cover seed of equipment such as disk harrows or chains can be used to cover the seed.

Rates.—Seeding rates depend on a number of factors, including soil productivity, available moisture, seeding technique, species being seeded, and desired plant community conditions. Seeding rates that are too low may result in sparse stands that are subject to invasion by undesirable weedy species or may fail to stabilize the site. Excessive rates waste seed and may result in stagnant, overly dense stands with reduced plant vigor (DePuit and others, 1980; Stoddart and Smith, 1955).

Rates must be based on pure live seed (PLS) percentages. Any other method of evaluating seeding rates give rates that do not compare from species to species nor from seed lot to seed lot. Figure 64 on page 49 shows computations to derive and use PLS percentages. The amount of PLS seeded is usually determined experimentally. Depuit and others (1980) report there is little research on seeding rates applicable to revegetating mined lands. Much of the literature recommends rates for species seeded individually, while most mined areas are seeded with mixtures of seed. Cook and others (1974) state that mined sites may require heavier seeding rates than do sites that have not been disturbed.

In a seed mixture, the amount of seed from each species is affected by the intensity of the overall seeding program. If the program calls for a single mixture for the entire area, seed amounts must ensure sufficient seed to establish an adequate stand on all the sites seeded. By including enough seed of species adapted to drainage ways and other low areas, some of the seed will be wasted on dry ridges and steeper slopes. When several seeding mixtures are used, each mixture with species adapted te different specific sites in the area being reclaimed, less total seed is required. Relative amounts of each species will vary depending on the site each mixture is designed to seed. For example, in lowlands in the Northern Great Plains western wheatgrass will often dominate the seed mixture; on ridges, western wheat grass will be a minor component in the mix.

In many areas cool season species are easier to establish than warm season species. To counteract the competitive advantage enjoyed by cool season species, warm season species seeding rates are increased in proportion to the amount of warm season plants desired. Since the seeding rates are computed using PLS percentages, germination advantages are compensated for automatically. Competitive advantages must be accounted for with the proportions of each species in the seed mix.

Scarification.—Some seeds require special treatment to germinate. Scarification of the seed coat, stratitification (subjecting seed to termperatures between 32˚F and 40˚F for 6 to 20 weeks in moist sand, peat moss, or moist newspaper (Plummer and others, 1368)), or both are sometimes required before seeding. Individual species have specific requirements that can only be determined through experimenting. Researchers have published the requirements for some species (Eddleman, 1978; Plummer and others, 1968; Vallentine, 1980).

Inoculation.— Inoculation of legume seeds is important to ensure successful establishment and production in revegetation seedings. Inoculation provides bacteria for nodulation and nitrogen fixation (Valientine, 1980). This is particularly important when dealing with mine spoils. Disruption of the soil, even though the topsojl has been segregated and replaced on the spoil, can result in a reduction or elimination of the specific bacteria needed by each legume. Most commercially available legume seeds have been inoculated; if there is any doubt, inoculate the seeds. The Interagency Forage, Conservation, and Wildlife Handbook Committee (1977) recommends reinoculating any legume seed that has been inoculated more than 48 hours before seeding. Inoculation of native legume seeds is often difficult since many have no commercial inoculant available and the necessary bacteria often differ between species of legume. Hodder (1976) collected topsoil from under undisturbed native stands of the desired legume and spread it on the plots to be seeded. This technique provided adequate inoculant for legume establishment and nodulation for native species with no commercially available inoculant.

Mycorrhizae are fungal mycellium that have a symbiotic relationship with plant roots. They increase the uptake of various soil nutrienis by the roots, In turn, the mycorrhizae absorb carbohydrates from the plant roots. Growth of mycorrhizae-infected plants is superior to that of uninfected plants, especially on low fertility soils (Buckman and Brady, 1969; Black, 1968). Mycorrhizae increased both growth and survival of fourwing saltbush *(Atrip/ex canescens)* on mine spoils (Aldon, 1975). At least 14 shrubs native to the arid and semi-arid West have mycorrhizae associated with them (Aldon, 1976). Assuring that mycorrhizae associated with the seeded species are available on the reclamation site will improve productivity and survival on reclaimed lands. Use of topsoil with the necessary mycorrhizae is usually sufficient, but if the topsoil has lost the mycorrhizae or, if an otherwise acceptable subsoil is used as topsoil, the mycorrhizae should be added to the soil or the seed mixture. Mycorrhizae is seldom available commercially for species other than nursery grown trees. The most practical method of spreading noncommercial mycorrhizae is gathering the puffballs or other fruiting bodies, grinding them and mixing the ground spore with seeds or spraying them on the site in a water solution.

Planting Principles

Planting is moving a plant propagule (other than a seed) or a complete plant to a new site and placing it in the ground to grow. The propagule can be a cutting, sprig, rhizome, or bulb. A complete plant has both roots and above-ground parts, although it can be immature or mature.

Acceptable planting techniques vary by species being planted, time of planting, soil types, and competition present on the planting site. Rhizomatous species generally can be well planted using any techniques. Some shrubs will sprout roots if their stems are cut and placed in a moist soil medium; some trees will die when they are moved, but saplings will sprout from the root mass; some plants must be moved with a massive root ball in order to survive. Planting methods must be matched with the species being planted.

Planting, especially planting young trees or shrubs, must be done so competition from other species on the site is minimized. Special methods for eliminating competition or for increasing the trees' or shrubs' competitive capabilities are often required.

Planting techniques are more expensive than seeding in virtually all cases. Costs of planting vary widely between methods. Therefore, any planting must being considered should be the most inexpensive to produce the desired results. Planting bareroot tree seedlings is much cheaper than using a tree spade to transplant 20-foot high trees. However, if the objective is to have a clump of 20-foot high trees on a site, the long-range costs may dictate use of the tree spade. If establishment of a specific density of trees per acre, regardless of size, is the objective, then planting seedlings would be least costly.

Jensen and Hodder (1979) found that bareroot seedlings and containerized seedlings planted in southeast Montana resulted in significantly different survival rates for some species, depending on the planting method. While bareroot stock is virtually always less expensive to grow and plant, the differences in survival rates justify using container seedlings to establish some species. For other species bareroot stock survive as well or better than container stock, so use of bareroot stock is more cost-effective. The relationships carry through when comparing all planting methods; the most cost-effective method for establishing the desired species in adequate numbers and of adequate size should be used. Care should be used in extrapolating cost figures and plant survival and growth figures from one area to another. Changes in soil, climate, topography, and planting costs can affect the relationships among the various methods.

Seeding Techniques

There are two basic seeding techniques for reclamation sites, drill seeding and broadcast seeding. Broadcast seeding can be divided into ground seeding, aerial seeding, and hydroseeding.

Drill Seeding.—Drill seeding is placing seed in a soil furrow and covering it with a relatively precise amount of soil. This technique is considered by many authors to be the best method of seeding (Packer, 1979; Packer and Aldon, 1978; Larson, 1980; Vallentine, 1980). Drill seeding allows a minimum amount of seed; the seed is well distributed; seeding depth is controlled; and the seed is well covered. Seed germination is more dependable when the seeding depth is precise and the seed is well covered. Drill seeding equipment is common, handles many types of seed, and can drill fertilizer or herbicide while seeding.

Drill seeding is more limited than the broadcast seeding techniques. Seedbed preparation must leave a relatively loose surface for conventional drain drills. Steep slopes cannot be seeded with drills. Drills may not be able to handle small seeds or seeds with awns, plumes, or wings. Seeds of varying sizes and shapes may be unevenly distributed. Drills may need a carrier such as grit, sawdust, or rice hulls to keep small or trashy seed flowing. Seeds should be placed in the bottom of the furrow; if seeds are drilled into the sides or ridges of the furrow, the seedlings will be less likely to survive.

Drill seeding is more expensive than broadcast seeding in most cases. An exception is when seed costs are high; because of the accurate, precise placement and even distribution of seed, less seed is used for drill

seeding than for broadcast seeding. This is an important factor when native seed that is difficult or expensive to obtain is being seeded. Drill seeding increases the area a given amount of seed will cover.

Broadcast Seeding.—In most cases, broadcast seeding is an inexpensive, rapid method of seeding land. Inaccessible areas can be seeded by planes, helicopters, or hydroseeders. Any mixture of seed can be seeded; fertilizer can be applied at the same time as the seed.

Ground seeding is the most common type of broadcast seeding. It is done with hand-held or tractor-driven equipment that spreads the seed on the ground. Often a mechanism such as a drag chain covers the seed with soil: Aerial seeding is rarely used for broadcast seeding on mined lands. Results from past aerial seedings have been disappointing. A main reason for seeding failures stems from the inability to cover the seed with soil. Hydroseeders blow seed on the ground in a slurry or water; fertilizers, herbicides, and mulches can be blown at the same time. Hydroseeders are relatively expensive and require large amounts of water. They are used mainly for steep slopes, rough terrain, or other area where access is a problem. Covering the seed is accomplished by spraying mulch in a separate operation after seeding.

Seed expenses are often high with broadcast methods when compared to drilling methods. Various authors suggest using up to twice the recommended PLS amounts for broadcast seeding than for drill seeding (Packer and Aldon, 1978; Plummer and others, 1968; Packer, 1979; Valllentine, 1980; DePuit and others, 1980). Seed distribution is often patchy, especially if a seed mixture of different sizes and weights is broadcast. Broadcast seed, even when pressed or dragged to provide a cover of soil, is susceptible to depredation by birds, insects, and rodents. Broadcast seed is not covered as well as drilled seed.

Planting Techniques

Planting is moving whole plants or pieces of growing plants onto a site and putting them in the soil so they will grow. The plants can be seedlings or mature pieces of roots, pieces of stems, a clump of a root mat, or an entire shrub, with numerous stems and suckers. Techniques range from hand planting to sprigging to transplanting.

Hand Planting. —Hand planting is a common method of planting seedlings and cuttings. Hand planting is by definition a labor-intensive technique. The plants are placed individually, with the planter controlling location of the planting holes. The quality of planting often depends on the competence and concern of the individual planters.

Seedlings are carried onto the revegetation site and are placed in holes dug with handtools, using either manual labor or motorized augers. Bareroot seedlings are planted so that their roots extend downward, roots that are J- or L-shaped will not survive (Fig. 82). Soil is packed in the hole around the roots. Packing must be firm, leaving no airholes (Fig. 83), but care must be exercised so that the roots are not torn or ripped. Containerized seedlings are easier to plant because the roots are extended downward and are protected by the soil in which they were grown. The plug must be well packed in the planting hold. All hand-planted seedlings should be placed so their root crown is at or slightly below the soil surface. The USDA Forest Service (1981) describes general hand planting principles that can be applied to planting on mined lands.

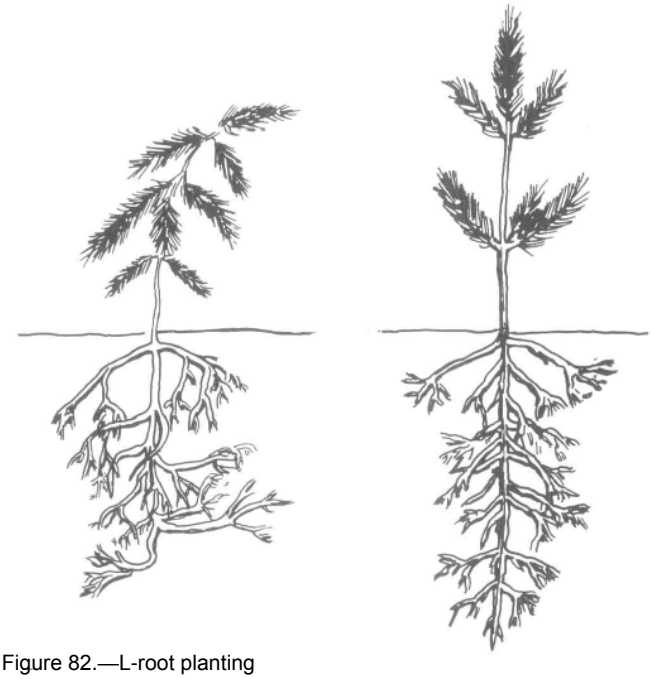

Figure 82.—L-root planting

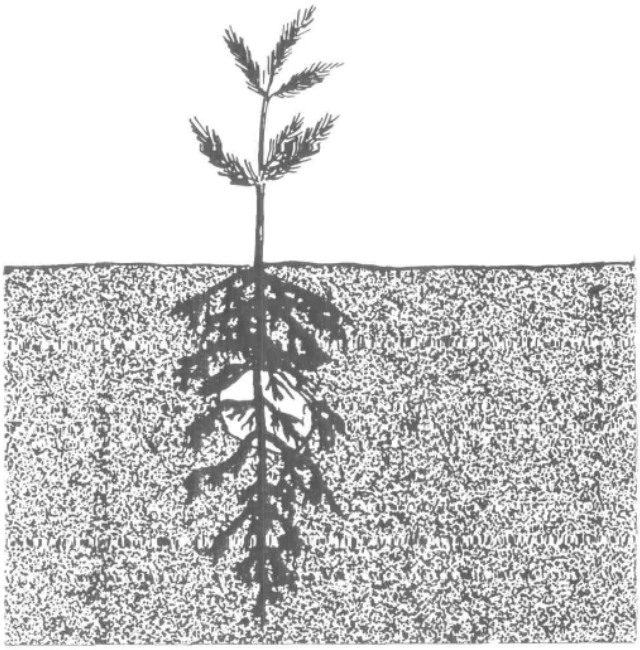

Figure 83.—Airpockets in hand-planting holes

Cuttings, especially stem cuttings of sprouting shrubs, are often hand planted. The cuttings are simply stuck into moist loose soil. They will root from the cut end of the stem and either begin growth by sprouting from the roots or will continue growth with the stem.

Wild seedlings can be hand planted by digging them out of areas that have not been stripped and planting them on top-soiled spoils. The technique is the same as that used for bare-root seedlings. Wild seedlings are sure to be adapted to the area, but are often not as vigorous as seedlings grown in nurseries or greenhouses. Wild seedlings are less expensive than cultured seedlings, but are often not as successful as cultured seedlings grown from seed adapted to the reclamation area.

Machine Planting.—Machines can plant all types of plants, from cuttings to seedlings to mature trees. Machines that transplant bareroot seedlings, containerized seedlings, or mature trees dig a hole, place the transplant into the hole, and then pack soil around the root of the plant. Machines used to plant cuttings, sprigs, or root pads usually move both the plant and some soil to the transplant site (Fig. 80). They lay the materials on the spoils rather than placing the material in a hole.

Machine planting is faster and sometimes more economical than hand planting. Machine planting root pads or small cuttings such as sprigs or rhizomes is much more efficient than hand plantings. Moving mature trees by hand is virtually impossible; if they are to be transplanted, machines are required. Bareroot and containerized seedlings can be well planted by machines, but the cost of the machines and the time required to plant deep-rooted plants may sometimes make this economically undesirable.

Bareroot and containerized seedlings are machine planted using conventional forest tree planters or tubling planters especially designed for mined lands. Tree planters cut a furrow into which the plant is placed. The furrow is then closed around the soil plug or the roots of the plant. Straight rows of plants are planted with no variation in plant density, species diversity, or planting pattern. The result, if all the plants survive is a uniform monoculture of plants. Variations can be made by changing the distance between plants, by planting several species, or by driving the planter so that the plants are not in straight rows. Since most reclamation areas are not uniform, it is often advantageous to confine planting to areas where the species will establish and grow, rather than planting a uniform stand of plants when they will not survive on parts of the area.

Tubling planters drill individual plant holes and drop containerized seedlings into the holes. The planting sites are individually selected and can be closely controlled to optimize the use of the rather expensive seedlings.

Cutting and sprigs are dug with machines that cut under the soil surface, loosening the plant parts and the soil surrounding them. They are then lifted with some soil and carried to the area to be planted. In most cases they are simply spread over the area. Since they seldom grow unless supplied with an ample amount of water at the time they are moved, some machines have watering equipment to moisten the soil and sprigs as they are spread. Watering equipment is not necessary when the soil is wet. Sprigs and cuttings are most successful when planted just prior to the annual rainy season.

Root pads are dug out of an unmined area, carried to an area being revegetated, and laid on the surface of the soil. The pads are dug with broad, flat shovels on mechanized equipment. These shovels cut under approximately 25 inches of soil and lift a pad of sod, with the plants left intact. The root systems hold the sod together. When the pad is laid on the revegetation area, the roots are not disturbed; they continue to grow and supply nutrients to the plants.

Root pads are excellent for planting shallow-rooted plants and plants that sprout from the root crown. They are not capable of planting deep tap-rooted species. The shovel cuts tap-roots, killing the plant. Some tap-rooted plants that sprout from the root crown can be transplanted. The stem that is moved often dies, but the sprouts take over the site.

Mature trees are moved with large transplanting machines. The machines dig under the tree to loosen a large ball that contains enough roots to keep the tree alive. The ball is placed in a hole dug on the site to be reclaimed. The tree is supplied with nutrients by roots in the ball until the roots penetrate new soil. Trees up to 6 inches in diameter can be transplanted. Tall trees that might blow down can be held erect with guy wires until the roots have penetrated far enough into the spoil material to firmly anchor the tree.

Mature trees with shallow tap-roots will be more likely to survive than will plants with deep tap-roots. Although the root ball may be more than 40 inches deep, cutting the main stem of tap-rooted species will reduce their survival capacity.

Seeding and Planting Equipment

Seeders

There are two types of seeders, drill and broadcast seeders. Drill seeders place seed at a precise depth in the soil and cover the seed with soil. The seeds are placed in individual rows, with bare ground between rows. Broadcast seeders spread seed on the soil surface. The seed is distributed randomly, without rows or precise seed placement.

Grain Drills.—Grain drills (Fig. 84) are conventional farm equipment that plant grain or grass on well prepared seedbeds. They can also apply dry chemical fertilizer as they seed.

Grain drills consist of plows that open furrows, seed hoppers that carry seed and fertilizer-metering devices that control the flow of seed and fertilizer, and packers that cover and sometimes pack the furrow after it has been seeded. The drills are pulled behind a tractor. They should be pulled along slope contours so that the furrows do not create or accelerate erosion. The seedbed should be relatively smooth, free of rocks, and should be loose enough that the drill can pass easily through the soil.

Grain drills place seed quite precisely. Depth-regulating bands control planting depth, the metering devices vary the rate of seed flow, and furrow spacing can be changed. The furrows can be packed after they are covered or can be covered with loose soil.

Grain drills are not suited to rough, rocky terrain nor areas with brush or stumps. They are not rugged enough to withstand sustained rough treatment. Seedbeds must be smooth and loose for effective use of these drills.

Pasture Drills.—Pasture drills (Fig. 85) are essentially rugged grain drills. They are designed to seed into stubble, pasture, or rangeland and are therefore capable of seeding areas that are not as well prepared as those seeded with grain drills. They drill light, fluffy or chaffy seed, which is desirable when seeding many native seeds.

Pasture drills are not able to work very rough, rocky sites.

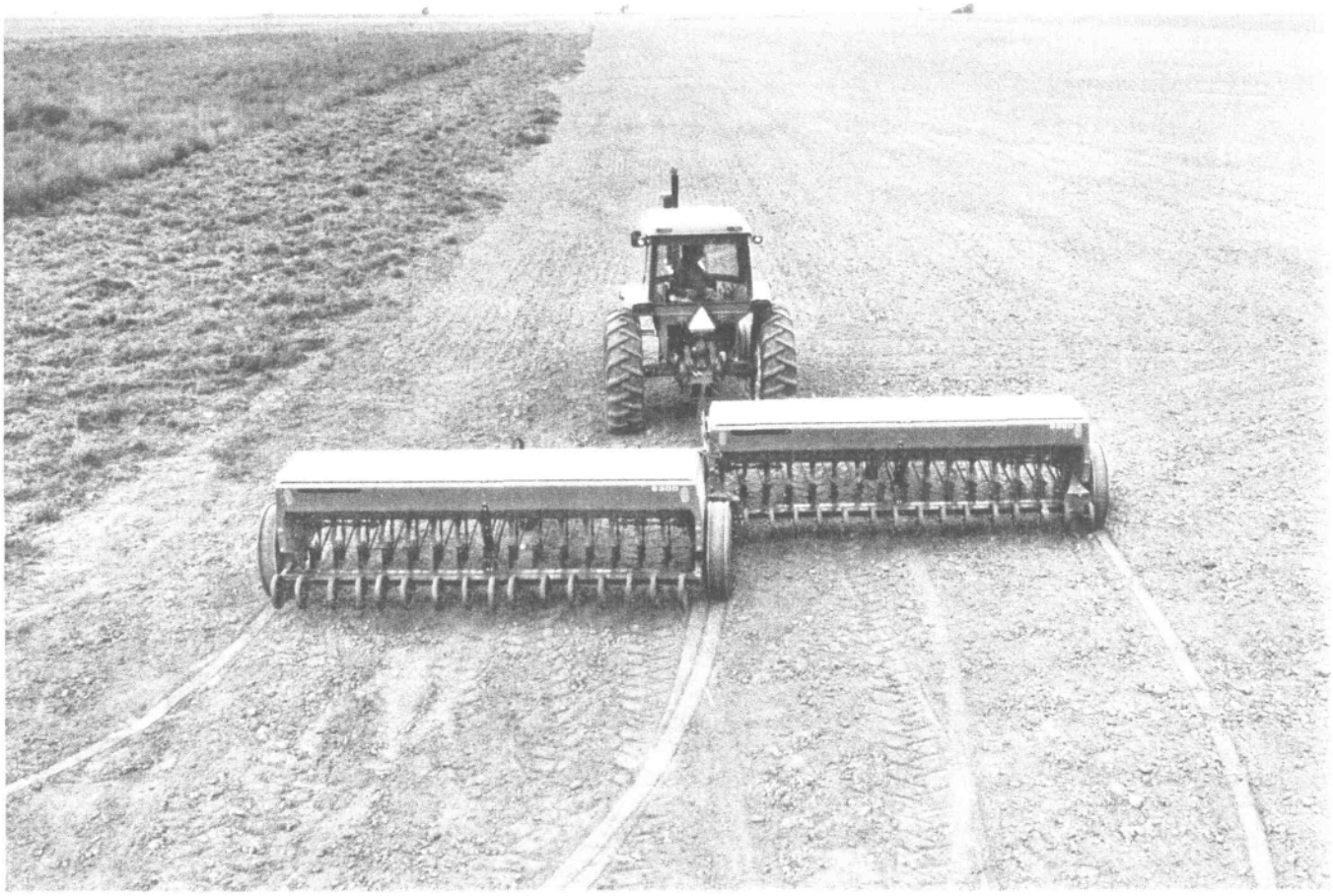

Figure 84.—Grain drill

Figure 85.—Pasture drill

Rangeland Drill.—The rangeland drill (Fig. 86) is a heavy, rugged drill especially designed to seed rough, rocky, or brushy areas. The drill has large wheels, a high clearance reinforced frame, and independently suspended furrow openers. Drag chains close the furrows after seed has been dropped in the furrow. The design of the drill is particularly adapted to very rough conditions. High clearance allows it to go over most obstructions; independently suspended arms can ride over obstructions without interrupting seeding by the other arms; rugged construction absorbs punishment from rough terrain. The drill can plant trashy or fluffy seed at a precise rate and a precise depth. Two species of seed and a fertilizer can be drilled at the same time.

The rangeland drill should not be used on slopes too steep for drilling along the contour. It is more efficient when used on well prepared seedbeds even though it is rugged, rough seedbeds will increase maintenance problems. The drill is difficult to transport without special equipment.

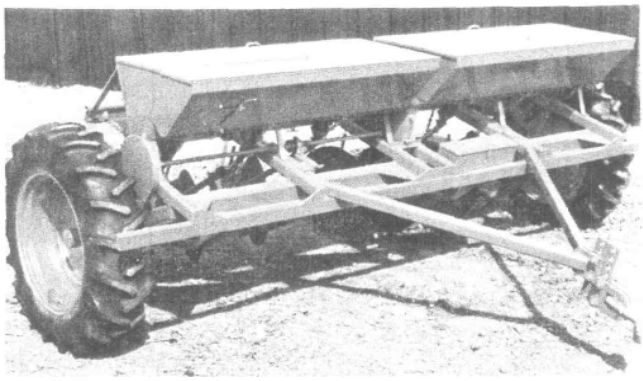

Figure 86.—Rangeland drill

Oregon Press Seeder.—The Oregon press seeder (Fig. 87) is designed to seed on a loose, prepared seedbed. Presswheels create furrows, seed tubes drop seed into the furrows, and drag chains cover the furrows with loose soil. The seeds are dropped onto a firm seedbed that is excellent for rooting, while the loose covering does not impair shoot growth. The presswheels are suspended independently, so the seeder can be used on rough, rocky soils.

The seeder is not designed for heavy, compacted soils nor for deep furrowing or plowing. It is susceptible to breakage when used on rough sites. The implement is heavy, bulky and difficult to transport.

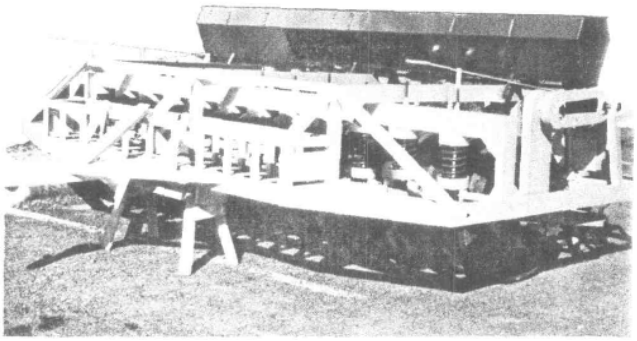

Figure 87.—Oregon press seeder

Standard Unit Planters.—Standard unit planters (Fig. 88) are separate drill seeding units that are mounted on a toolbar. Each unit opens a furrow, meters seed into the furrow, closes and packs the furrow. Seeding depths, seeding rates, and row spacing can be varied. The planters are designed to plant row crops at precise intervals. They can be used to plant shrub or tree seeds on relcamation sites. Since each unit has an individual seedbox, a variety of species can be seeded in one pass, each at its desired rate.

Unit planters are adapted to well prepared seedbeds and are not suited to rough, rocky, or steep areas. They are only needed when precise seed spacing is necessary. They are not useful for establishing a closed grass stand.

Interseeder.— Interseeders (Fig. 89) are drill seeders that scalp rows of bare ground or intermittent patches of bare ground, cut furrows in the scalped areas, seed into the furrows, and cover the seeds. They are designed to seed on vegetated lands without plowing and disturbing most of the vegetation.

Interseeders are only useful when seeding is to improve the quality and quantity of the present vegetation. They are inefficient when the entire site is to be revegetated or an entire vegetative community is being replaced.

Figure 88.—Standard unit planters

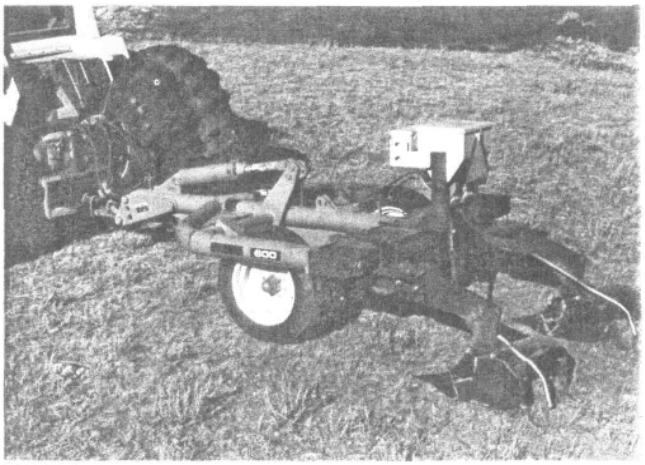

Figure 89.—Interseeders

Seed Dibbler.—Seed dibblers (Fig. 90) drop seeds onto the tracks of crawler tractors. The tracks carry the seeds to the ground and press them into the soil. Problems with wind or water movement of the seed are reduced because they are firmly in the soil. Seeding large areas is inefficient. The seeds are placed only under the tractor tracks.

Rotary Spreaders.— Rotary spreaders (Fig. 91) broadcast seed or dry fertilizers or herbicides over an area. They consist of a hopper, a fan or spinner, and a power source to turn the spinner. Seed or fertilizer falls onto the spinner and the power source turns the spinner. The seed or fertilizer is thrown out from the spreader. Spreaders usually have shields that direct the seed in a semi-circular pattern away from the spinner. The spreaders can be hand-carried, pulled behind tractors or other prime movers, attached to a prime mover, or suspended beneath an aircraft.

The spreaders have no topographical limitations. Pulled models must be used on accessible lands, but hand-operated models and aerial models can seed any area. The seed is well distributed, with no bare spots, a random distribution, and an absence of linear rows. The seeders are reliable, simple machines, with few maintenance or operational problems.

Precise seed placement is impossible with rotary spreaders. The seed should be covered after it is seeded to reduce depredation by insects, birds, and rodents, and to reduce erosion losses.

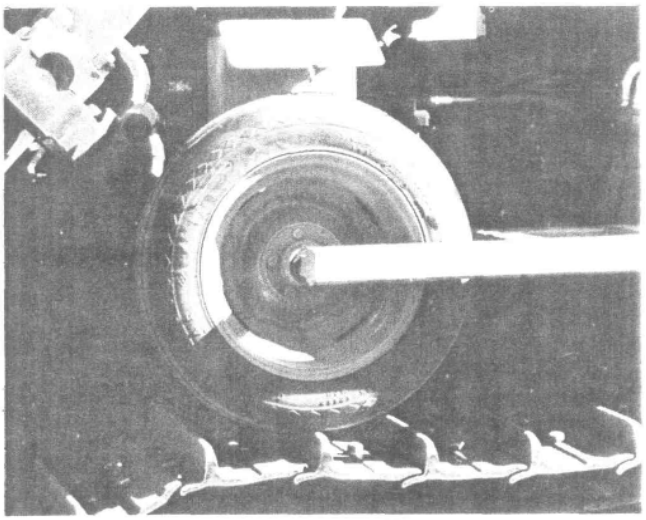

Figure 90.—Seed dibbler

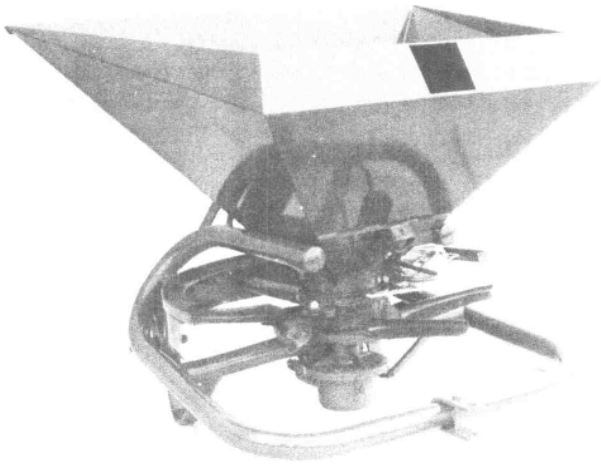

Figure 91.—Rotary spreaders

Hydraulic Seeder-Hydraulic seeders (Fig. 54, 92), or hydro-seeders, apply seed in a hydraulic spray. They consist of a large tank, a pump, and a discharge nozzle. The seed is put in the water tank, often along with fertilizer, soil inoculants, mulches, or herbicides.

Agitator paddles or centrifugal pumps keep the seeds and other substances in suspension in the water. The slurry is sprayed onto the seeding site through the discharge nozzle. The seeder operator controls the spray volume and pressure. A green dye is often included in the slurry so that the operator can be assured of completely covering the area.

Hydroseeding is most appropriate for seeding steep, inaccessible sites or trouble spots that will not be well handled by on-site vehicles. They seed large areas quickly, with good seed distribution. Covering the seed with a separate spray of wood fiber mulch protects the seed from depredation by birds, insects, and rodents.

Hydroseeding has several disadvantages that inhibit its widespread use in the West. Hydroseeding uses large volumes of water, a limited resource in many areas. Various types of hydroseeders have significantly reduced grass seed viability. Kay (1977) found that hydroseeders damaged 5 to 15 percent of grass seed immediately after the seed was placed in the slurry and circulated through the seeder. More significantly, hydroseeders with centrifugal pump agitation reduced seec germination 90 percent in 1 hour when seed and water we; *t* the only components of the slurry. When seed, water, and wood fiber were in the slurry, germination was reduced 50 percent in 1 hour. A seeder with gear paddle agitation did not significantly reduce seed germination after 1 hour in the machine, either with water alone or with water and wood fiber. Kay suggests that: (1) a gear pump with paddle agitation be used for hydroseeding; (2) if a centrifugal pump is used, the time between addition of seed to the slurry until the tank is fully discharged should be less than 20 minutes; (3) wood fiber should be in the slurry if a centrifugal pump is used; and (4) seeds should be put into the slurry just before beginning seeding; they should be in the slurry for a minimum amount of time.

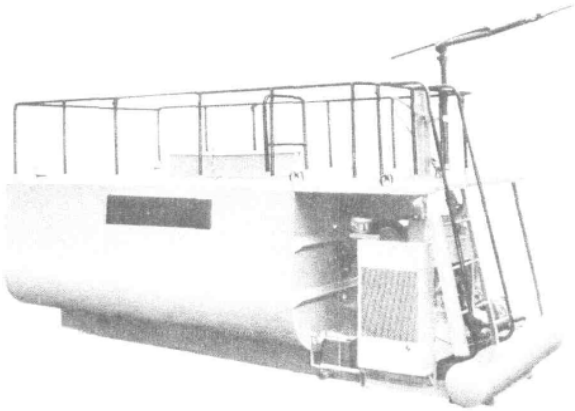

Figure 92.—Hydroseeder

Planters

Planting equipment moves entire plants or propagules other than seeds onto the revegetation site. The plants can be either precisely placed or randomly dispersed over the area.

Hand Planting Tools.—Hand planting tools are tools for planting either bareroot or containerized seedlings. Various types of tools are available. All excavate holes large enough to hold plant roots. The tools range from planting hoes to reinforced shovels, from straight bars with planting blades to specialized container planting tubes that displace soil with a foot lever and place the seedling through the hollow handle (Fig. 93a-f).

Both site conditions and the type of planting stock determine the tools used. Planting hoes and planting bars are used on most sites. Planting bars are often used on rockier sites. Planting tubes and dibbles that punch holes the size of the seedling container are used to plant containerized seedlings. Dibbles are more effective in rocky soil, planting tubes are used on the less rocky sites.

Hand planting tools allow the planter to precisely place the seedlings. Each microsite is selected individually. Seedling survival is enhanced by careful choice of planting sites. These tools allow planting on inaccessible sites or on sites where vehicle traffic is not desired.

Hand planting tools are not well suited to rocky areas. They are labor intensive and severity of the site often affects the quality of planting. Hand planting costs can be quite high if a large area is being planted.

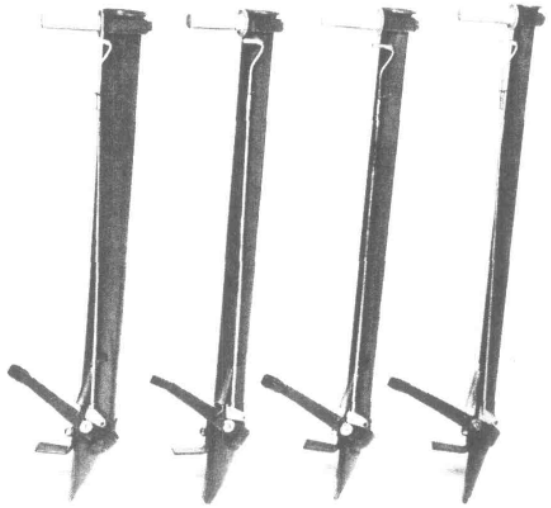

Figure 93a.—Hand-planting tools, planting tubes

Figure 93b.—Hand-planting tools. Adze hoe

Figure 93c.—Hand-planting tools, planting hoe

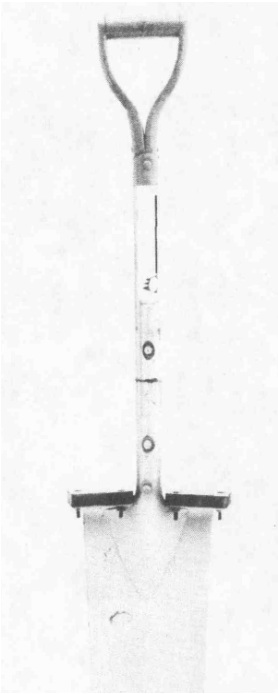

Figure 93d.—Hand-planting tools, planting spade

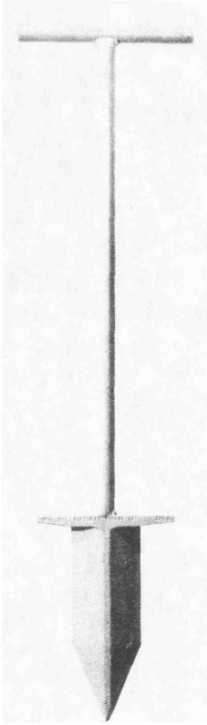

Figure 93e.—Hand-planting tools, KBC planting bar

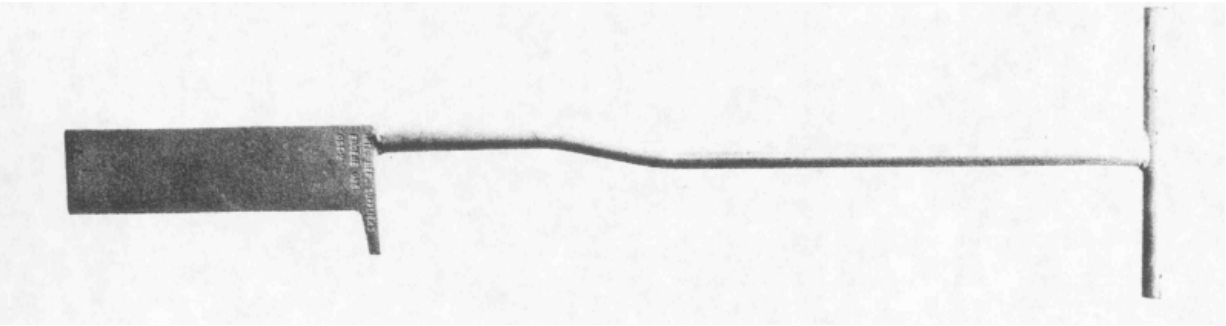

Figure 93f.—Hand-planting tools, OST planting bar

Planting Auger.—Planting augers (Fig. 94) are portable, powered augers to dig holes for planting seedlings. The augers consist of a power unit, a gear box, and an auger bit. Power units are lightweight handheld or backpack units that, through the gear box, drive the auger bits. Planting augers excavate holes into which seedlings are planted.

Figure 94.—Planting auger

Planting augers are fast, efficient tools for digging planting holes. Auger bits can be tipped with carbide chips that wear longer and dig faster than hardened steel tips. They are portable so that inaccessible areas may be planted. Planting augers drill large, deep holes that are usually more favorable for planting than holes created by hand tools. Soil excavated from the planting hole is usually heaped near the hole, where it is readily available for packing around the seedling roots. Planting augers are heavy, fatiguing tools. They are difficult to use in heavy clay soils and are not adapted to very rocky soils. All hard planting is labor-intensive, therefore auger-planting can be very costly when applied to a large area.

Seedling Planter. — Seedling planters (Fig. 95) are tractor-drawn implements that open furrows into which bareroot or containerized seedlings are placed. Packers close the furrows around the seedling roots. The seedlings are placed either manually by an operator or automatically by a mechanized arm.

The seedlings are planted in rows, usually at regular spacing. Planters are most applicable for high-speed, large-scale planting projects. The seedlings are planted deep and the soil is well packed around the roots.

Figure 96.—Tree spade

Seedling planters are limited by terrain and site conditions. They can only be used on slopes traversable by tractors, and should be pulled along slope contours. They are not well adapted to very rocky sites.

Tree Spade.—Tree spades (Fig.96) are machines designed to transplant large, mature trees. They have digging blades that excavate a tree with a root ball to minimize root damage (Fig. 97). Trees up to 10 inches in diameter can be transplanted, although the tree's root system affects the stem diameter of the trees that can be moved. The root ball must contain enough of the plant roots to enable the tree to root successfully and survive at the transplant site. The tree can be transported either individually in the tree spade or loaded on a truck or trailer (Fig. 98).

Plants are placed in holes that have been previously excavated on the reclamation site. They are transplanted with a minimum of root disturbance. Shrubs can be moved as well as trees.

Tree spades are limited to slopes less than 15 percent. Tree spades with large taproots are difficult to transplant because much of the root system must be cut off when the root ball is excavated. Tree spades are expensive to use and their use should be reserved to transplanting hard-to-establish trees or to achieve an objective of immediate stocking with mature trees. Shrubs moved with tree spades usually survive well but the cost is higher than using front-end loaders or sod mover buckets.

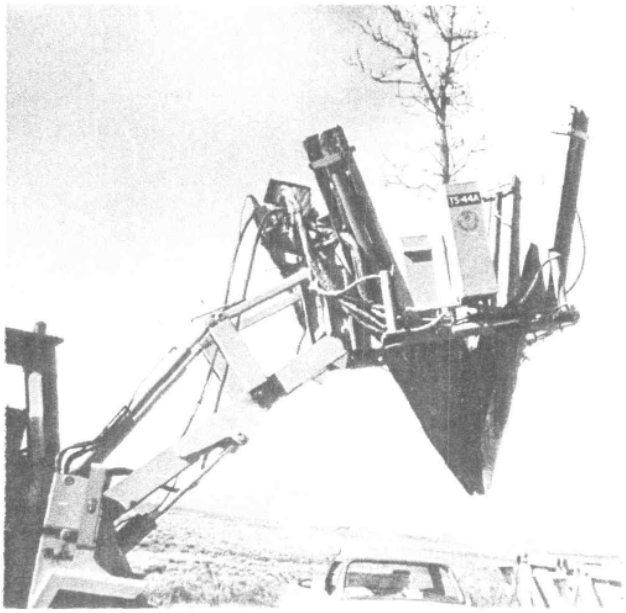

Figure 95.—Mechanized seedling planter

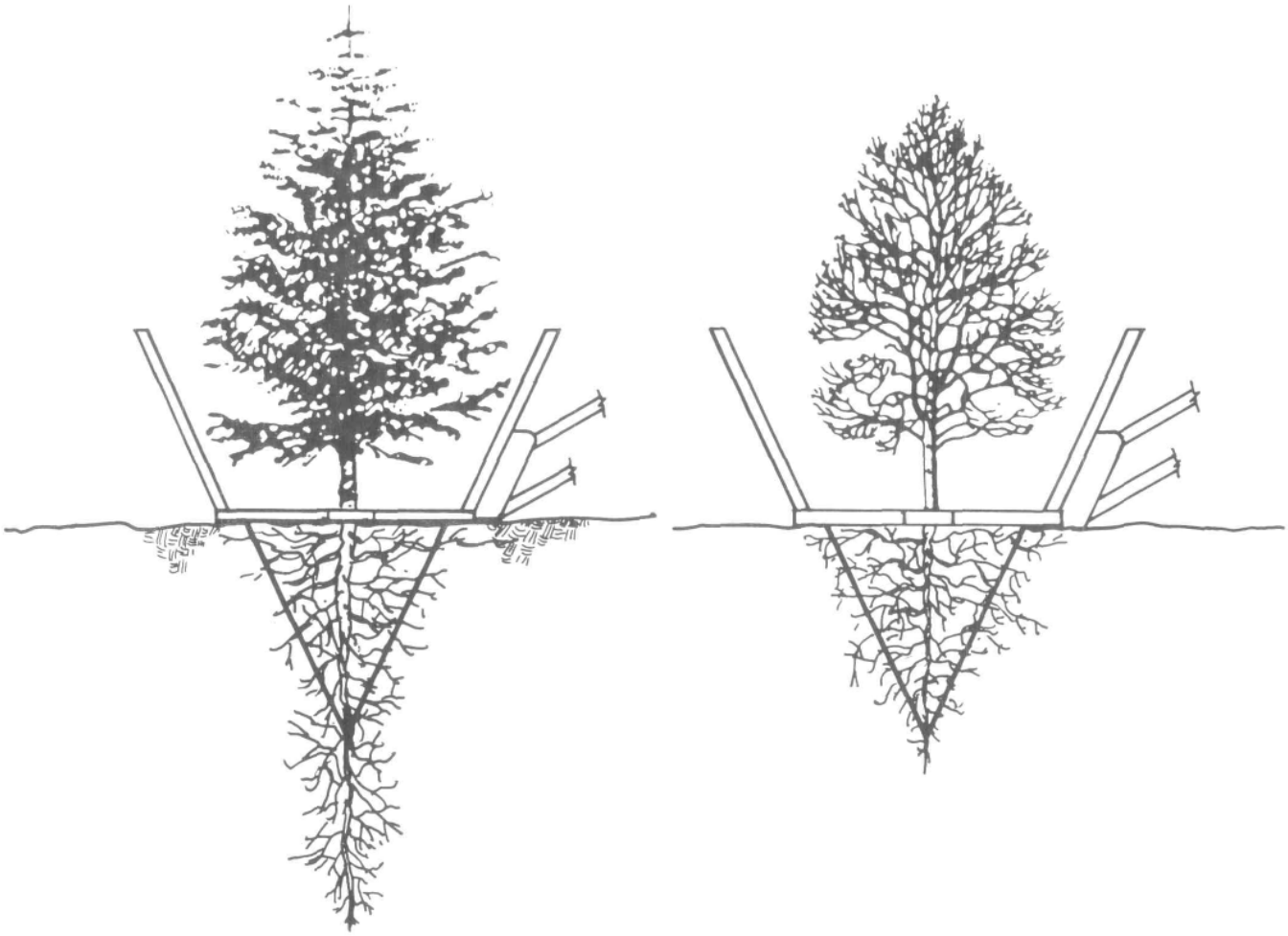

Figure 97. —Tree spade cutting a root ball

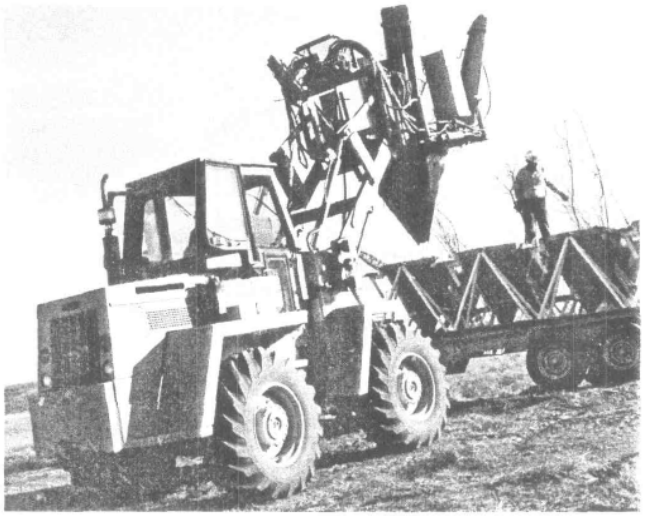

Figure 98.—Tree spade trailer

Front-end Loader.—Front-end loaders (Fig. 99) can transplant trees, shrubs, and root pads. They are common equipment on virtually all surface mines and are often readily available for part-time reclamation work. They dig, transport, and plant on the reclamation site.

Front-end loaders can move shrubs and root pads efficiently and quickly. They are well equipped to dig species with shallow roots that do not require a deep root ball. They are not suited for moving trees with tap roots. Trees that sprout from the root crown, such as quaking aspen *(Populus tremuloides),* can be moved successfully by front-end loaders. Often the original stems moved will not survive, but sprouts from the root crown will occupy the site. End loaders are limited to slopes under 20 percent because they are unstable on steep slopes.

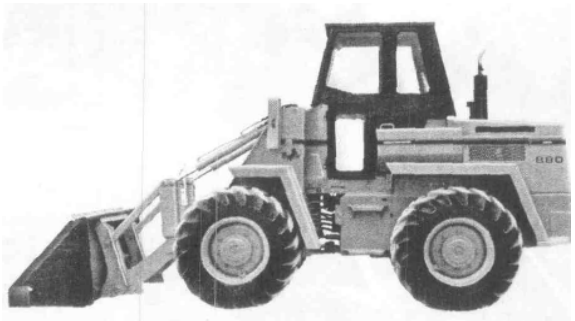

Figure 99.—Front-end loader

DrylandSodder.—The dryland sodder (Fig. 100) is a special bucket for a front-end loader. It was designed specifically for digging pads of sod on unmined land, carrying them to a reclamation site and laying them on the site. Shallow-rooted species of all types of plants are successfully transplanted. The soil horizons down to 2 feet are carried intact, eliminating mixing the topsoil and preventing destruction of the soil.

The sodder is expensive to use for large-scale operations. It is most suited to critical areas with high erosion potential.

Figure 100.—Dryland sodder

Tubling Planter.—Tubling planters (Fig. 101) are especially designed implements that automatically plant containerized seedlings. The planter is a trailer unit towed by a tractor. An auger digs a planting hole as a scarifying blade scalps competing vegetation from around the hole. A containerized seedling is automatically dropped into the hole where a packing spade firms soil around the seedling.

The planter quickly and efficiently plants large containerized seedlings. The size of the seedlings, which have 24-inch roots, and the size and quality of the auger-drilled hole increases the survival rate of the seedlings over the survival rate of smaller, hand-planted seedlings. The planter is self leveling and can be used on moderate slopes up to 30 percent grade.

The planter is an expensive implement and the seedlings which it plants are costly to grow. The planter is appropriate for planting difficult-to-establish species or for planting on critical sites.

Figure 101.—Tubling planter

Sprigger.—Spriggers (Fig. 102) are modified potato harvesters that gather rhizomatous or sprouting root material for transplanting shrubs. The harvester has an undercutting blade that loosens and cuts roots of native range. The soil that is disturbed, which includes root material, is conveyed to a truck bed or to a trailer. The soil and root material are spread on the surface of areas to be revegetated using a modified manure spreader.

The sprigger can quickly plant a large number of shrubs on a large area. Rhizomes and sprouting root materials are wetted and can begin to grow immediately.

The sprigger does not work well in heavy clay spoils. It is efficient in planting rhizomatous plants or plants that will sprout form the root crown, but does not work well for deep tap-rooted species (Larson, 1980; Brown, 1977).

Figure 102— Sprigger