Richard Stevens
Stephen B. Monsen

Chapter 17

Guidelines for Restoration and Rehabilitation of Principal Plant Communities

Introduction

Range and wildland improvement projects conducted throughout the Intermountain region normally occur within specific plant communities. Each plant community has unique features that require different equipment, planting techniques, and plant materials to conduct improvement projects. Plant communities or associations discussed in this chapter are: (1) subalpine herblands and upper elevation aspen openings, (2) wet and semiwet meadows, (3) inland saltgrass, (4) riparian, (5) aspen-conifer, (6) mountain brush-ponderosa pine, (7) juniper-pinyon, (8) sagebrush, (9) salt desert shrub, (10) blackbrush, (11) annual weedy grasses—cheatgrass brome, red brome, and medusahead, and (12) lowland annual weeds.

Following is a description of each community, equipment and techniques recommended to control competition, a description of methods to prepare sites for planting, and a list of adapted species suggested for seeding. Additional information related to competition removal and site preparation is found in chapters 8, 9, 10, and 11; seeding procedures in chapter 12; and species descriptions, ecological relationships and distribution, plant culture, uses and management, and improved varieties and ecotypes in chapters 18 through 23.

Species selected for seeding depend on the objectives of the project. In general, planting projects fall into two categories: (1) If the principal objective is to restore plant communities, then treatments would be conducted to reestablish native species; this practice is referred to as "Restoration." (2) If the objective is to establish plants on a disturbance or change the species composition, then a combination of introduced and native species could be used and the practice would be considered "Rehabilitation" or "Revegetation." Few, if any, introduced species would be planted in restoration projects because the primary objective is to enhance the ultimate development of native communities. To date, restoration of some native communities may be somewhat limited by the availability of native seeds and planting stock. In addition, techniques and procedures to restore entire native communities are not fully understood. However, considerable information has been developed to restore certain communities and native species. In addition, studies have been directed to investigate ecotypic variability and ecology of selected native species. The studies have been designed to define the range of occurrence of specific ecotypes and the ecological and biotic factors regulating the presence of individual ecotypes. This information has been used to develop specific guidelines for restoration.

Successful restoration plantings are based on the selection of adapted ecotypes and seeding compatible species at appropriate rates with appropriate techniques. Establishment of species that may have existed in a natural community is often difficult to achieve, especially if all species are planted at one time. In most situations, planting should be designed to initiate or promote plant successional changes that would ultimately develop the desired community.

Restoration of depleted plant communities is becoming an increasingly important objective. Reestablishment of resource values is often achieved through recovery of native communities. In many instances, revegetation programs have failed to provide the desired objectives that would be achieved through restoration.

To date, many seeding or planting projects would be classified as revegetation programs. Sites that have been disturbed and support an undesirable array of plants, including some weeds, are frequently planted with a number of introduced and native species. Numerous introduced grasses and broadleaf herbs have proven adapted to western plant communities. Many advanced cultivars have been developed to revegetate disturbed and depleted areas, and these are widely seeded in revegetation projects. Various introduced species are commonly used as substitutes for native species. Many introduced species are widely used because they possess excellent establishment traits and furnish high quality forage. Although these are important characteristics, a few introduced species have, unfortunately, dominated many seeding programs. Too often, areas seeded to a few introduced species are assumed to restore or provide all of the original resources of a native community. Careful evaluation of such plantings does not confirm these assumptions.

Many introductions possess desirable features and can be seeded for specific purposes. As mentioned, various species provide productive, high quality herbage. Others are extremely valuable in the control of noxious weeds, and many have the ability to stabilize and colonize harsh disturbances. If planted for these specific purposes, the plants are quite valuable. Unfortunately, introduced species have often been sown in an attempt to restore disturbed sites and improve natural conditions. In many situations, the seeded plants have adversely affected subsequent development of entire communities. Misuse of a few widely adapted grasses including smooth brome, intermediate and pubesent wheatgrass, hard sheep fescue, Kentucky bluegrass, and crested and desert wheatgrass has occurred. In general, these species attain dominance and prevent recovery of native species and the ultimate recovery of desired communities. Smooth brome has commonly been seeded throughout mountain brush, aspen, and subalpine communities. This grass has suppressed and replaced many herbaceous species on these sites. Similarly, intermediate, pubesent, crested, and desert wheatgrass have gained dominance when seeded in the pinyon-juniper, big sagebrush, and mountain brush types. Desert wheatgrass has gained control in low elevation regions occupied by big sagebrush and, to a lesser extent, salt desert shrubs. These species prevent the establishment of understory herbs and the natural regeneration of important native shrubs. Consequently, the use of such widely adapted introductions to restore native communities should be avoided. The use of many introductions will likely continue until native plant materials become more widely available. In addition,

introductions will continue to be used for specific purposes. Of particular importance is their usefulness to control the spread of some undesirable weeds and to stabilize severely disturbed watersheds.

Native species can also be misused, resulting in disruption of community development or weak stands. In various situations, certain natives have been used in an effort to replace less desirable species without adequate consideration of the adaptability of the planted species. For example, bluebunch wheatgrass has been planted with limited success as a replacement for Sandberg bluegrass. Fourwing saltbush, winterfat, and antelope bitterbrush have been unsuccessfully planted as replacements for big sagebrush. Palmer penstemon and Lewis flax have been widely seeded, often in areas where they are marginally adapted. These practices should be avoided.

Sites that have been altered and are no longer capable of supporting some native species are usually revegetated with the most adapted and available species that would provide needed ground cover or habitat. In these situations, combinations of native or introduced species are commonly used and should be encouraged.

Plantings are often designed to allow for changes in species compositions. For example, many shrublands within the Intermountain region have been converted to grass for livestock benefits. In addition, certain wildlands have been disrupted by municipal or agricultural development. Mitigation programs have been employed to convert the remaining wildlands to a more productive status. Interseeding of additional species accompanied by fertilization, irrigation, or other site improvement techniques are used to support changes in the vegetation. These specific practices would be considered revegetation measures.

In some situations, weed presence has altered many sites, preventing natural recovery. Introductions are often used to control and eliminate weeds, restore site productivity, and provide seedbed conditions that favor the establishment of more diverse species. Revegetation plantings are widely employed to stabilize watersheds, roadways, mining, and other serious disturbances. Some introduced species have proven well adapted to these harsh sites, and are capable of persisting on infertile soils. In addition, they may be able to provide excellent ground cover and soil protection.

Various species are listed in this section that are adapted to major vegetative communities and can be used for different planting purposes (tables 1 to 28; all tables are grouped at the end of the chapter). Appropriate seed mixtures should be used to restore native communities or revegetative sites for specific purposes. Misuse of species can adversely affect community development.

Seeding normally involves the use of more than one species. When combinations of plants with different germination and establishment traits are seeded together, competition among species can regulate seedling survival. Many grass species that are commonly sown have excellent seedling vigor and establishment traits. These plants have been selected for their ease of establishment, uniform stand development, and seedling survival. Many perennial native herbs also possess good establishment features, and generally develop acceptable stands when seeded under most conditions. Many species that normally invade disturbances are able to colonize harsh, open sites. When possible, these pioneering species are commonly used as part of a seed mixture to better assure plant establishment.

When species with different establishment characteristics are seeded together, considerable seedling mortality can be expected unless special provisions are made to separate seeds in the furrow or seedbed. Seeds with different establishment traits can be seeded in separate rows, and the amount of seed sown can be adjusted to reduce competition or compensate for some natural thinning. Broadcast seeding can lessen seedling competition as seeds of different species are more widely distributed and less concentrated compared with row seedings.

The ability of individual species to become established is, of course, dependent on: (1) whether a species is sown alone, (2) the establishment features of the companion species, (3) the amount of seed planted, (4) the composition and density of onsite species, (5) climatic conditions, and (6) seedbed conditions.

It is essential that the compatibility of individual species and seeding requirements are understood before complex seed mixtures are developed. The establishment features of species recommended for seeding specific sites are summarized in tables 1 through 28. The present abundance and composition of remnant plants that exist on a proposed planting site also strongly influence the success of a seeding. Normally, weed control measures are used to eliminate undesirable competition. However, many improvement projects are designed to retain existing native plants. These plants can and do compete with new seedlings. Seeding techniques can be used to interseed or selectively plant areas without significantly eliminating remnant plants.

Subalpine Herblands and Upper Elevation Aspen Openings

Subalpine herblands and aspen openings are usually very productive and important sites. They provide

Figure 1—Subalpine herblands provide summer forage, furnish watershed protection, and provide recreational opportunities.

forage and cover, serve as important watersheds, and provide recreation opportunities (fig. 1). However, many subalpine herblands, with their parklike openings, have been so degraded (fig. 2) that they only support weeds or low-value plants. Natural openings scattered among aspen and conifer forests have been degraded by heavy grazing (Ellison and others 1951; Meeuwig 1960). These areas often support undesirable plants including starwort, goosefoot violet, cluster tarweed, flixweed tansymustard, and Douglas knotweed. Sites within some conifer forests often lack an acceptable understory, and when timber is harvested, the areas are extremely barren and frequently invaded by undesirable weeds (Ellison 1954; Ellison and others 1951). Successful rehabilitation can markedly increase the value of these ranges for wildlife, livestock, and watershed protection (Brown and Johnston 1978b; Brown and others 1978; Heede 1981; Meeuwig 1960; Plummer 1976; Turner and Paulsen 1976).

Figure 2—A subalpine area that has been seriously depleted by grazing lacks essential cover and is a source of erosion.

Some subalpine areas are relatively small, but they can be very productive (fig. 1). These areas are important summer ranges for sheep and cattle, mule deer, elk, moose, bear, and several species of grouse (fig. 3a, b). Elevation of subalpine herblands varies between 7,000 and 12,000 ft (2,150 and 3,600 m). Most sites occur above 7,800 ft (2,400 m). Because these high elevation areas receive 20 to 60 inches (500 to 1,500 mm) of precipitation annually, they are important watersheds. Sites requiring restoration often occur on steep, inaccessible terrain. Within the subalpine communities of the Intermountain West, common grasses include Letterman needlegrass, slender wheatgrass, mountain brome, and spike trisetum. Some important forbs are Louisiana sage, western yarrow, penstemons, geraniums, ligusticum, asters, lupine, and bluebell. Principal shrubs include currants, snowberry, low rabbitbrush, and subalpine big sagebrush. Widespread tree species are Engelmann spruce, subalpine fir, and aspen. Soils can be shallow and rocky; however, deep fertile soils are most common.

Removal of Competition

On level to moderate slopes supporting low-value perennials, plowing or disking is an effective procedure for reducing competition. Plowing eliminates most existing plants, including some highly desirable and sparse species. This procedure should not be used if desirable natives exist; such aggressive treatment should be confined to sites supporting a dominance of weeds. Destruction of the soil structure can also result from plowing. Soil compaction and loss of protective litter may also occur. Plowing should be restricted to only the most disrupted sites. Plowing can be done from late spring through summer, but should not be completed when soils are wet, as this may produce compacted soil and surface crusts. The use of brushland plows, offset disks, moldboard plows, or disk-chains that dig to depths of 4 to 6 inches (10 to 15 cm) are recommended. Plow furrows made at right angles to the slope can help control erosion and retain water. Plowing compacted soils can improve seedbed conditions.

Interseeding can be used where it is desirable to reestablish additional species within the existing community. Scalping and seeding can be accomplished with the browse seeder-scalper or related implements. This type of machine can be equipped with 12- to

Figure 3—Subalpine herblands, including aspen and conifer openings, are important summer ranges for livestock and wildlife.

16-inches (30- to 40-cm) wide scalpers that remove existing competition and plant seed simultaneously. The browse seeder treatment has been especially useful on slopes of up to 30 percent. Scalps should always be aligned at right angles to the slope and may be constructed to control erosion from seriously gullied slopes. Scalping or removing soil to create small terraces can be destructive and leave scars for many years. Clearings to accommodate interseeding should be carefully designed. Interseeding can also be accomplished by using herbicides to remove or reduce competition. Spraying strips with herbicides, and transplanting or seeding following the treatment, is a practical approach. This system is most useful on steep slopes where soil protection is critical and soil disturbance should be avoided.

Surface cultivators can be used to reduce annuals such as cluster tarweed, Douglas knotweed, or flixweed tansymustard. The soil should be cultivated to a depth of 2 to 4 inches (5 to 10 cm) in early spring and summer with duckfoot-weeders, spring-tooth harrows, or similar equipment. Cluster tarweed, the most competitive mountain annual, can be eliminated only if all plants are removed. Most seeds of this plant germinate each year so there is slight year-to-year carryover of seed in the soil. By taking advantage of this characteristic, tarweed can often be eliminated with one thorough treatment, although followup treatments are generally required. Annual species that retain considerable seed dormancy usually cannot be eliminated in one operation. Sufficient seed may accumulate as a seedbank, producing many competitive seedlings following spraying or mechanical tillage.

Cluster tarweed produces a toxic chemical that accumulates in the soil and reduces seed germination of other species or causes abnormal seedlings to develop (Carnahan and Hull 1962). Leachate from cluster tarweed field sites has reduced germination and establishment of introduced grasses and some native herbs. The chemical diminishes within a few months, particularly if sites are disked or plowed. Sites treated by tillage or with a herbicide in late spring or early summer can be fall seeded without adverse effects to new seedlings.

Cluster tarweed should be treated after all plants have emerged, but before flowers appear. To prevent seeds from developing, it is essential that treatments not be delayed. Once flowers appear, seeds ripen quickly and a host of new seedlings is inevitable. If larger areas are treated, it is essential that equipment be available to conduct the work on schedule. Fallowing for two growing seasons may be required to treat some areas to assure complete control. Normally, sites supporting large patches of cluster tarweed have very compact and crusted soils. Disking or tillage may be required before sites can be seeded with most conventional drills. Disking can effectively loosen the seedbed. Drill seeding should be done when surfaces are moist but not wet. Surface-type drills or broadcast seeding lessens the chance of soil compaction that can prevent seedling emergence. Competitive stands of cluster tarweed, goosefoot violet, and various annuals can be eliminated with an application of low-volatile 2,4-D at 1.1 to 1.6 lb per acre (1.25 to 1.85 k per ha) (0.5 to 0.75 lb active ingredient per acre; 0.56 to 0.85 kg per ha). The herbicide glyphosphate (Roundup) is also effective in controlling annual and perennial weeds on high elevation rangelands. Ground spray equipment is best for applying herbicides on most high mountain areas because the herbicide can be more directly applied to a precise area. Spraying should be done early in the spring. Annuals are generally most sensitive to herbicides in the two-leaf stage, and certainly should be sprayed before the four-leaf stage.

Herbicides also eliminate the necessity for soil tillage that tends to dry the seedbed. Surface soils that are disked or tilled in spring dry quickly. Sufficient rainfall must be received following tillage to initiate seed germination and sustain small seedlings.

Clumps or patches of skunk cabbage can occur in open parks intermixed with subalpine herblands and aspen openings. Grazing has eliminated many of the understory broadleaf herbs and grasses, allowing skunk cabbage plants to dominate their area of occupation. Recovery of desirable native understory species occurs slowly once sites are protected from grazing. Some reduction of this weed is required to ensure establishment of seeded species. Effective measures have not been adequately developed to control this plant, but recent studies conducted on the Manti-LaSal National Forest reveal that density of skunk cabbage can be reduced with application of various herbicides, tillage, or mowing. Applying Roundup just prior to flowering killed most plants and prevented any regrowth for 3 years after treatment. Mowing or tilling in early July when plants were less than 15 inches (38 cm) tall removed all current vegetative growth and prevented any resprouting during the remaining growing season. Plants regained about two-thirds of their pretreatment density and growth stature the following summer. Treated patches were able to completely recover in 3 to 5 years. Seeding into mowed, tilled or sprayed plots was equally successful. One-year control, attained by any of these treatments, allowed seeded grasses and broadleaf herbs to become fully established.

Skunk cabbage plants develop robust, erect stems with large, fleshy leaves that form a dense canopy. Plants are usually much taller than other associated herbs. Consequently, Roundup herbicide can be applied with ground spray equipment or roller type applicators with little damage to understory herbs. Rollers are used to simply rub or swab the herbicide on the foliage. The roller bar is suspended on a wheel tractor and the height of the applicator is regulated as the unit is passed over the plant. Commercial applicators used in farming operations work effectively on range sites, and are available through most equipment companies. This practice can be used in most situations, even where retention of understory herbs is a primary objective.

Tall larkspur is a troublesome, poisonous plant throughout this vegetative zone. Although certain herbicides are somewhat effective, Vallentine (1989) stated that repeated treatments are required. This is often costly and difficult to accomplish. Sites infested with this weed are often not suitable for cattle grazing, and are best managed for other uses. Many sites in subalpine and aspen park communities were seriously impacted by heavy grazing that occurred near the turn of the last century. Native species were eliminated and serious erosion resulted. Many sites have not fully recovered, even when protected from grazing for many years. Less desirable species, including Letterman needlegrass, western yarrow, Louisiana sagebrush, dandelion, and Rydberg penstemon have persisted and spread to dominate some areas. These sites are often considered for seeding. Direct seeding may be required to reintroduce desirable plants that can eventually produce seed and increase in importance. However, to accomplish seeding, the existing species must be significantly reduced to lessen competition to new seedlings. Unless the plants are controlled, seeding cannot be recommended. However, disturbance to the site is not always advisable. Natural improvement may occur if a sufficient seed source is available. Although the process may be slow, protection and careful management may be the best alternative to improve inaccessible, steep, or harsh sites. Interseeding of desirable species can be successful, and is an effective technique to stimulate and speed up successional changes. This can be accomplished by seeding strips, spots, or selected patches where natural spread is expected to occur. Many areas that were earlier disturbed have now recovered, and soil loss has diminished. Treatment of these sites should be carefully considered to assure that the best procedures are used—seeding or management. Introducing foreign species to a site that is improving naturally is not advisable.

Planting Season

The planting season for mountainous sites extends from early spring until mid-July. Late fall planting is also acceptable, and can be done from September until snow and frost make planting impossible. In subalpine regions the fall planting season may close in early October or even late September. Planting in areas that have been disturbed by logging or road construction should also be confined to these dates. Seeding is often done throughout the summer as logging progresses. This is not advisable because seedlings are vulnerable and can succumb to climatic extremes. Seeds planted in early summer often germinate precociously, and many of the seedlings die as the soil dries. Seedlings that emerge from mid or late summer plantings are often too small and poorly rooted to overwinter. Unless planting can be conducted in the early spring, work should be delayed until late fall to ensure germination the following spring. Because of lingering snow fields and wet areas in the spring, late fall planting is the most practical.

Planting Procedures

Aerial and ground broadcast seeding in the fall are satisfactory methods of planting large tracts of prepared ground. Soil sloughing resulting from freezing and thawing usually covers the seed adequately on plowed or disked land. Pulling a light anchor chain, chain link fence, or harrow across the treated area assures good coverage. If light chaining is used, scarce and expensive seeds can be dropped into tractor cleat marks from seed dribblers that are mounted on the crawler tractors used to pull the chain.

Drilling is recommended for spring planting and may also be used in the fall. Some risk is involved with drilling in the fall if the seeding is done too early. Most drilled seeds are placed directly in the soil and can germinate if soil temperatures warm up even for short intervals, an undesirable situation. Since this hazard is often present on high mountain ranges, it is important to delay drilling until late fall. Broadcast planting can also be used to seed small isolated tracts. Planting in the late spring and summer should be avoided, as soil moisture may not be available for a long enough period to assure seedling establishment.

Seeds of certain species require a cold stratification period to germinate, and if planted in the late spring and summer, will not be adequately stratified to germinate. Although some seeds will likely remain in the soil to germinate at a later date, many seeds will be lost, and emergence will not occur uniformly with all species planted. Weeds and less desirable plants may likely appear if the seeded species do not develop as planned.

Mixed seedings, including many costly, native, broadleaf herbs, are used to improve these rangelands and watersheds. Seeds vary in size and shape. Mixing all seeds together and planting at a similar depth frequently results in poor or erratic success. A number of commercial drills are now available that facilitate planting seeds of different sizes in separate rows or furrows. Also, seeds of different sizes can be planted at different depths. Improper seeding should be avoided on these important rangelands.

Rodents can quickly and effectively gather certain seeds that are either drilled or broadcast planted. If seeding is delayed until late in the season, small rodents are less active and seed losses can be significantly reduced.

The browse seeder-scalper equipped with 12- to 16-inch (30- to 40-cm) scalpers is an excellent unit for planting weedy sites. Browse seeders and some drills can be used to plant seed of shrubs in alternate rows with herbs. Seeding individual species separately in alternate rows is a practical procedure to reduce competition among seeded species.

Shrubs and herbs can be spring transplanted into mountainous sites. Several adapted herbs, especially rhizomatous species, have been transplanted with good success. Treated areas usually receive sufficient moisture to sustain young transplant stock. Sites should be planted before existing native species initiate growth.

Adapted Species and Mixtures

The features of grasses and broadleaf herbs that are seeded on these sites should be considered before disturbances are planted (chapters 18 and 19). Within this broad community type are various plant associations. Selecting and seeding the most adapted species requires careful inspection of the particular sites under consideration. A combination of species is normally required to restore diverse plant associations. A number of introduced grasses have been selected and widely used to stabilize watershed disturbances and provide forage for livestock and wildlife (Forsling and Dayton 1931; Frischknecht 1983; Hull 1974; Keck 1972; Laycock 1982; Plummer 1976; Plummer and others 1955, 1968). The primary species previously planted through most high-elevation revegetation projects include smooth brome, both southern and northern strains; meadow foxtail; orchardgrass, tall oatgrass, Kentucky bluegrass, hard sheep fescue, timothy, and intermediate wheatgrass. Creeping foxtail was commonly seeded at one time, but currently is only planted in restricted situations. Regar brome is a recent development that is gaining increased use. These plants have been used to protect soils and stabilize disturbances including deteriorated rangelands. However, smooth brome, intermediate wheatgrass, Kentucky bluegrass, and hard sheep fescue are serious competitors with native herbs, and prevent the recovery and persistence of many native species (Monsen and Anderson 1993). Although these introduced species are adapted to subalpine and aspen communities, they should not be used where restoration of native communities is a primary objective.

Smooth brome is well adapted to the subalpine and aspen openings. Planting about equal amounts of northern and southern strains, along with other species, has been recommended and widely used. Although smooth brome has demonstrated adaptation to high-elevation sites, its presence has created serious problems. Plants are moderately slow to establish, but increase in density and ground cover by root proliferation and seed production. This species slowly suppresses the presence of most other species. Mixed seedings established throughout the Intermountain region have developed to nearly pure stands of smooth brome, although the time required to attain complete

dominance has varied between 10 and 30 years. The loss of forbs and shrubs due to competition from smooth brome is a serious consideration. Few, if any, native grasses, broadleaf herbs, or shrubs have demonstrated the competitive ability to control the spread or persistence of this grass. In addition, few practical methods are available to remove smooth brome and reestablish other species. Consequently, smooth brome is not recommended for planting many mountainous sites. Unfortunately, this has been a primary grass recommended for seeding high-elevation ranges, as highly erodible sites and harsh disturbances can be quickly and effectively stabilized with this grass. Further use should be carefully regulated.

Meadow foxtail is an excellent companion species to most seedings. Creeping foxtail is also well adapted to mixed seedings, and both plants furnish excellent ground cover. Big bluegrass is moderately productive, particularly on moist areas. Orchardgrass is equally productive, but better adapted to well-drained soils. Slender wheatgrass, mountain brome, timothy, and tall oatgrass are also well adapted to these areas. These latter four species develop rapidly, but diminish within 15 to 25 years. Subalpine and Regar brome are also well adapted to mountainous conditions. Sulcata sheep fescue, intermediate wheatgrass, and bearded wheatgrass are adapted to more arid situations. These three species can gain dominance and exclude native herbs in some situations. Their use should be restricted to sites where the recovery of less competitive natives is not desirable. Tufted hairgrass and Canada bluegrass are well suited to the less fertile sites and exposed outcrops.

Not all introduced species have become serious competitors with native species. Tall oatgrass and timothy are relatively short-lived species, persisting for less than 20 years. Orchardgrass and alfalfa persist much longer, but generally are not highly competitive. Both mountain brome and slender wheatgrass are native perennials that can be used with excellent results. Although seed of both species is less available, supplies are generally adequate to meet most demands.

It is important that site-adapted native species are planted. Considerable variability exists among populations or ecotypes of many natives including mountain brome and slender wheatgrass. Planting nontested sources should be avoided.

Many useful broadleaf forbs occur throughout these sites, and are recommended for seeding (table 1). However, not all species common to undisturbed communities have been able to reestablish from direct seeding on seriously altered sites. Ellison (1951) reported that certain species were capable of invading exposed disturbances as pioneer plants, but others appeared in much later stages. Selecting species based on their ecological status is important in restoring these communities. Many broadleaf herbs establish quite well and are able to compete with other species if seeded at appropriate rates. Most important are showy goldeneye, Porter ligusticum, silky lupine, Rydberg penstemon, low goldenrod, and edible valerian. Seeds of other native broadleaf herbs are becoming available and should be included in seedings. As seeds become more available and less costly, seeding rates can be further adjusted. Usually it is desirable to reestablish a complex of native herbs in most disturbances in high mountain ranges. Successful seedings can be better attained in this climatic zone than in most other areas of the Intermountain region.

Mountain snowberry, mountain big sagebrush, subalpine big sagebrush, low rabbitbrush, and adapted forms of rubber rabbitbrush are useful for direct seeding. Transplanting of any or all of these shrubs is recommended where it is desirable to create immediate browse or cover. Certain rhizomatous and fleshy rooted species are selectively grazed by pocket gophers, and new seedings can be seriously impacted by gophers (Ellison and Aldous 1952). Native fescues and meadow foxtail have been shown to discourage these animals and could be seeded where rodents are numerous.

Adapted species are presented in table 1. Seeding rates are somewhat determined by the number and type of species planted.

Wet and Semiwet Meadow Communities

Wet (fig. 4) and semiwet (fig. 5) freshwater meadows can be found in lowland valleys, but are more frequently

Figure 4—Wet meadows interspaced with willows align a stream in southern Idaho.

Figure 5—Big sagebrush communities often surround small but important meadows.

encountered on mountain rangelands where water concentrates and spreads. While the total area occupied by wet and semiwet meadows is relatively small, these meadows are important to grazing animals and upland game birds (Eckert 1983; Oakleaf 1971; Patton and Judd 1970; Ratliff 1985). They produce succulent herbage throughout the growing season for all classes of game and livestock. Many meadows have been seriously depleted of valuable sedges, rushes, grasses, forbs, and shrubs that once were abundant (Eckert 1983). However, disturbed meadows can be made more productive (Eckert 1975; Eckert and others 1973a). Planting native sedges, broadleaf herbs, and shrubs may be desirable, yet is not always practical because of the lack of sufficient seed or planting stock. Exotic grasses have been used to restore cover and herbage production. In some cases, introduced plants have exceeded the herbage production of some native grasses. Commercial seed production of native herbs is necessary to facilitate planting of desirable species. Consequently, species diversity and structure of seedings are sometimes limited.

Availability of moisture in meadows ameliorates the extremes of climate and tends to create a comparatively uniform environment through all vegetal zones. Some species can often be planted throughout both lowland and mountain ranges. The important factors that favor high production on meadow lands are the moisture availability and high soil fertility.

Removal of Competition

Essential to successful seeding is the control of weedy species (Eckert 1975, 1983). Summer fallow treatments have been used to control weeds in wet and semiwet meadows (Cornelius and Talbot 1955; Eckert 1983; Eckert and others 1973b; Plummer and others 1955). Usually, moldboard plowing is required to eliminate tough, sod-forming, weedy species that may invade disturbed wetlands. Heavy offset disks or brushland plows can be used to control competition and aid in seedbed preparation. Plowing can eliminate most species, including desirable plants. However, existing species must be reduced in order to establish desirable plants. Some species such as Baltic rush provide excellent cover and stability, yet are highly competitive and must be controlled if sites are to be successfully seeded. Where the soil may be too wet for plowing or disking, shallow ripping using a crawler tractor can be employed to break up the existing sod.

Herbicides can be used to control broadleaf weeds and grasses, although streams and waterways must be protected. Noxious weeds, including Canada thistle, have invaded many semiwet areas and must be controlled to assure establishment of seeded species. Repeated treatments are required to reduce competition from this plant. In some situations, Canada thistle may be reduced by spraying, but not completely eliminated.

Removal of competitive perennial grasses, including Kentucky bluegrass, is also necessary to establish more desirable species. Extensive treatments, including mechanical tillage or application of herbicides, are required. These treatments usually eliminate other species, restricting their use to the most critical disturbances.

Planting Season

Early spring to early summer is the most effective planting period. If water does not accumulate and remain on the soil surface, fall or late winter plantings can be successful. However, spring flooding can destroy seedbeds prepared in the fall. Seeds planted in the fall will rot if inundated by water for extended periods. Consequently, areas that are subjected to flooding cannot be planted until the water level recedes. This may delay planting until late spring or summer. Shrubs should be transplanted early in the spring after water recedes but before the soil dries out. Young transplants can usually withstand wet soil conditions for a limited period, yet planting into flooded sites is not practical or desirable.

Planting Procedures

Broadcast seeding on prepared seedbeds is usually recommended on wet sites, especially for fall or early winter seeding. Plowed or disked sites usually leave a rough surface that can be broadcast planted. Drills can be used for spring and fall planting, yet particular care must be taken to avoid planting seeds too deep. Seeding can also be accomplished using the Brillion seeder

or surface-type seeders. These units distribute the seed on the soil surface. Seeds are then punched into small depressions within the soil. The depressions are created by these machines, and the planting depth is determined by the rollers or imprinters. Surface seeders do not plant seeds too deep even when seeding on a loose seedbed.

Adapted Species and Mixtures

The most often used introductions for seeding wet and semiwet meadows to increase herbage production have been Reed canarygrass and meadow foxtail. Both grow well in wet and semiwet conditions, although "Garrison" creeping foxtail is better adapted to wet areas. These plants persist even on sites where water may stand for short periods. Alsike clover and strawberry clover are good supporting legumes, although they can survive only short periods of submergence. Black medick grows well except at high elevations. Redtop, smooth brome, timothy, and alpine timothy are also well adapted to semiwet soils and are useful forage plants, although redtop is less palatable than the latter three species. Reed canarygrass and smooth brome are extremely competitive and suppress other plants. These grasses are not recommended if natives or other species are desired on the site.

Species recommended for wet and semiwet conditions differ (table 2). Many native sedges are extremely desirable species, but seed supplies are currently very limited. Attempts to restore these sites will require development of the native seed industry. Sufficient seed cannot be harvested from wildland stands, and field rearing will be required.

A list of shrubs useful for transplanting is presented in table 3. Willows are well suited to a variety of conditions found in meadows. Willows can be established from fresh cuttings placed in the ground in early spring; however, rooted cuttings are preferred. Survival of rooted cuttings is much better, particularly on sites that may dry early in the season.

Planted meadows tend to attract grazing animals. Sites that are seeded to productive and palatable grasses and herbs should be managed to prevent excessive use. Animals will concentrate in treated areas throughout the entire growing season; consequently, sites must be protected or grazed properly to maintain site productivity.

Inland Saltgrass Communities

Inland saltgrass has gained control on many dry to semiwet meadows in upland and lowland areas (fig. 6) where alkalinity is appreciable and where the early-growing grasses, sedges, forbs, and shrubs have been depleted by grazing. Soils are generally heavy with high water tables at least during some period of the year. Some areas may have standing or running water for short periods. While these meadows are relatively small, they usually have a much higher potential for livestock forage production and as wildlife habitat than when dominated by saltgrass (Lesperance and others 1978; Roundy and others 1983). This is particularly evident on sites that remain fairly moist throughout the growing season. Saltgrass produces a dense sod, so vigorous methods must be used to eliminate competition and allow establishment of other species. Not all saltgrass sites should be converted to other species. Some sites have been converted to more desirable and productive forage plants for livestock grazing, but this can be a costly effort. Improvements may benefit wildlife and allow for grazing at different and longer seasons, but revegetation projects should be carefully evaluated before treatments begin.

Removal of Competition

Saltgrass can be difficult to eradicate by plowing or mechanical tillage. McGinnies (1974) reported that saltgrass can be successfully removed by spraying with Roundup. Sites that are treated with this herbicide can be plowed or tilled to aid in seedbed preparation. Saltgrass meadows are commonly located on soils with a high concentration of salt in the C horizon and possess an impermeable B horizon. These soils may be susceptible to soil crusting and exhibit low fertility, but benefit from plowing (Ludwick 1976). Plowing may improve water infiltration and increase the availability of nutrients (McGinnies and Ludwig 1977). However, care should be taken to avoid plowing

Figure 6—Inland saltgrass communities usually remain green and productive throughout the summer.

the C horizon to prevent mixing of the surface horizons with the zone of high salt concentration.

Sodic soils are often impermeable to water and may develop a surface crust when dry. Tillage or deep ripping when soils are dry can improve permeability. If soils are wet at the time of treatment, crusting and surface packing can occur. Disking litter and vegetation into the surface soil can reduce soil crusting. Drilling with heavy equipment can compact the soil and prevent the emergence of small seedlings. Broadcast planting and drilling with light equipment can reduce surface compaction.

Treatment of saltgrass sites usually requires a fallow period. Sites can be plowed in late summer, winter fallowed, and seeded in the spring. Plowed areas usually require disking to kill the roots or sod and prepare the seedbed. Some sites may require two to three diskings to reduce the sod. Sites may also be sprayed with Roundup in the summer, fall plowed, and spring planted. Where complete control is desired, planting an interim annual crop such as yellow sweetclover is suggested. After the annual crop is harvested, the site can again be plowed and disked to control any regrowth of the saltgrass. The area can then be planted to perennials. If satisfactory control of saltgrass is evident, final plowing and seeding of perennials is recommended 1 to 3 years after the initial treatment. By this time most of the saltgrass should have been eliminated.

Planting Season

Best results are obtained with late fall, winter, and early spring plantings. Where land frequently remains wet, spring planting is advised because fall planted seeds can be adversely affected by prolonged flooding.

Planting Procedures

Deep-furrow drills with drops spaced 12 inches (30 cm) apart have performed satisfactorily on tilled soils. No-till drills have been used to drill “Garrison” creeping foxtail directly into saltgrass. The browse seeder, equipped with 16-inch (40-cm) wide scalpers, can be used to interseed species into thin stands of saltgrass. Broadcasting on plowed land in late fall or early winter has been successful for some sites. Plowed soil will slough during the winter and usually covers the seed. These soils sometimes crust, restricting seedling emergence. To avoid crusting caused by surface packing from drills and tractors, broadcast seeding is often advised. The Brillion seeder is also useful in planting into the prepared seedbed and in reducing soil crusting.

Adapted Species and Mixtures

Species adapted to the inland saltgrass type (table 4) must be salt tolerant. Growth of some species occurs primarily in the spring when the salt is diluted by soil moisture. Introduced species that have been seeded successfully in areas with high water tables or running or standing water are: meadow and creeping foxtail, tall fescue, tall wheatgrass, and strawberry clover. Areas that dry out during periods of the year have been seeded successfully to alkali sacaton, crested wheatgrass, streambank wheatgrass, Russian wildrye, black medick, yellow sweetclover, fourwing saltbush, Gardner saltbush, and winterfat. Species’ establishment and stand development can be somewhat slow. Planting native species is recommended, but is currently limited to only a few species because seeds are not available.

Riparian Communities

Riparian sites often occur as narrow corridors traversing many different plant zones. Streams and drainages often occupy very small but important sites within major land types. The vegetation and habitat provided by the riparian zone is extremely important to the management of associated lands (Thomas and others 1979b). Different riparian communities have been identified throughout the Intermountain area (Youngblood and others 1985). Riparian sites usually attract and sustain livestock and wildlife. These sites are particularly important during the midsummer months. Riparian communities often provide diversity to otherwise rather barren and exposed wildlands. Aquatic wildlife are dependent upon a continued supply of high quality water. The vegetation along a stream provides shade that greatly influences water temperature, protects soils and streambanks, and furnishes food for aquatic organisms. Vegetative debris falling into the stream is a highly important food supply for aquatic life. Insects harbored by the vegetation also serve as an important part of the food chain.

Timber harvesting, road construction, agricultural cropping, mining, and recreational uses have all destroyed riparian areas (Council of Agriculture Sciences and Technology 1974). Riparian zones have also been degraded extensively by livestock grazing and trampling (fig. 7). Woody or herbaceous vegetation or both have been eliminated or seriously stunted in many areas. On many sites the understory species have also been replaced by weedy annuals and perennials, including noxious weeds. Frequently, dense stands of sod-forming grasses or forbs gain dominance. Unpalatable and undesirable species are easily spread along waterways.

Figure 7—Improper grazing has disrupted many riparian sites in the Intermountain region.

The woody plants that occur along streambanks have often been destroyed by repeated browsing and trampling. It is critical that woody species are reestablished. Some species can recover and grow if protected from grazing. Willows, aspen, alder, and dogwood normally recover if some live plants remain. If grazing has completely destroyed the woody species, transplanting or seeding will be required. Destruction of stream habitats and associated watersheds has often resulted in serious erosion and damage to the streambank and floodplain. Erosion and flooding often remove topsoil and alter the site, hindering natural or artificial revegetation (Monsen 1983). Structures are often required before vegetation can be reintroduced (fig. 8). Reintroduction of beaver, when managed to fit the food supply, can significantly aid in stabilization of many streams and waterways. Entire watersheds may require treatment before streambanks can be improved. Controlling grazing on riparian sites is not easy (Platts 1981a,b) because the use of adjacent lands is dependent upon access to the stream.

Figure 8—Channel reshaping and construction of impoundments may be required to stabilize stream channels prior to seeding and planting.

A distinct and abrupt ecotone may separate mesic from xeric plant communities that align a stream. Different plant communities must be planted with separate, adapted, species. Seasonal changes in soil moisture affect the occurrence of different plant communities. Since most riparian zones support a mixed array of plant communities, mixed plantings are required. A more extensive plan is required to restore and stabilize riparian communities than for most other sites. Monsen, in Platts and others (1987), discusses the following considerations that influence rehabilitation practices:

1. Alteration of the riparian vegetation and soil may result from onsite impacts, or as a result of poor management of other portions of the watershed (Megahan and Kidd 1972). Proper management of the entire watershed is essential prior to initiation of rehabilitation measures in riparian communities. Restoration of riparian sites may be conducted simultaneously with treatment of other portions of the watershed. Unless adjoining areas are reasonably stable, repair of riparian disturbances will not be effective.
2. Riparian sites usually are extremely heterogeneous, containing different plant communities, topographic conditions, parent materials, and soils within a short distance (Odum 1971). Remedial treatments must be applicable to the different conditions encountered. For example, steep, unstable banks may occur immediately adjacent to wet and boggy meadows, requiring different site preparation practices, planting techniques, and plant materials.
3. Different treatments are often required to correct separate problems, such as controlling surface erosion, eliminating bank slumping, shading the stream, controlling weeds, and providing concealment for wildlife.
4. Riparian sites are often narrow, irregularly shaped corridors that are not accessible to conventional planting equipment. Although only small areas may require treatment, extensive erosion, sedimentation, and plant community alteration may have occurred, thus requiring special equipment for rehabilitation.
5. The dense and frequently storied assembly of many plant species is required to maintain riparian site stability. Grazing and other impacts have often reduced plant density or resulted in the removal of specific species. The loss of key species may seriously affect the persistence of other plants. To be successful,

rehabilitation may require reestablishment of a complex array of plants. Reestablishing woody plants is often essential.

6. Many sites are so seriously altered that extensive rehabilitation measures will be required to restrict further losses of soil and vegetation and reestablish a desirable plant cover (fig. 9).

7. Stabilization of the streambank with vegetation is often the principal concern in rehabilitation. Vegetation is also required to provide shade for the stream and improve wildlife habitat.

8. Some riparian sites have often been so seriously altered that the original vegetation can no longer survive. Thus, attempts to restore the original complement of plants may not be practical. However, unless a grouping of plants similar to the original community can be established, aquatic and terrestrial resources may not be improved.

9. Noxious weeds and other less desirable species have often invaded riparian disturbances. Weeds must be removed to improve the site and allow for planting. These plants do not always provide adequate soil protection or enhance aquatic habitat. Weeds may be spread by the stream to occupy downstream disturbances and interfere with the establishment of more desirable species.

10. Site preparation is usually required to accommodate planting. Some reduction of the existing plant cover may be necessary to eliminate competition with newly seeded or planted species. However, reduction of streambank stability by plowing or similar methods of plant removal is hazardous. Thus, treatments normally include interseeding or planting small strips or sections over a period of 2 to 3 years. By such procedures, small areas can be treated in sequential intervals to retain existing plant cover and encourage natural recovery.

11. Seasonal runoff and flooding influence planting dates as well as establishment and survival of new seedlings or transplants (Aldon 1970b). Sites may be covered with water in the spring for a few days or for weeks. Planting is frequently delayed by flooding until a time when air temperatures and precipitation patterns may no longer be conducive to seedling survival. Disturbances may be seeded in the late summer or fall. However, fall-germinated seedlings may not be able to survive spring runoff. Many riparian species survive or are propagated by flooding (Kozlowski 1984). However, small seedlings usually are not as tenacious as larger plants. Seasonal runoff also disrupts and seriously damages prepared seedbeds. Transplanting large stock is often required to resist the effects of flooding and scouring.

12. Protection of young plants is essential for establishment and survival. Protection from grazing may be required for a number of years to allow plants to attain a reasonable size and furnish soil protection. Transplanting large stock may be necessary to overcome the influences of grazing and flooding.

Figure 9—Transplanting is frequently required to reestablish willows and other shrubs along streams.

Artificial plantings are not the only means to restore and improve riparian communities. Because of the inherent problems associated with revegetation of these areas, consideration should be given to natural improvement whenever possible. Protection from grazing (Meehan and Platts 1978; Vallentine 1980) can be used to improve many situations. If a satisfactory number of remnant plants exist, natural recovery can often occur. Some native herbs, particularly species of sedges and rushes, are extremely vital to streambank stability and herbage productivity. Most species of sedges and rushes have not been investigated for use in artificial seeding programs, but their utility is well known. Where possible, management and revegetation programs should be tailored to promote their recovery. The growth habits and utility of most of the principal sedge and rush species in the Intermountain area are summarized by Monsen (in Platts and others 1987) (table 5).

Removal of Competition

Sites requiring transplanting to reestablish woody shrubs and trees may first require removal of herbaceous species to allow shrubs to establish (Nieland and others 1981). If shrubs or trees are to be transplanted along the edge of a stream, plantings should be selectively located in open sites free of herbaceous competition. Planting directly into dense stands of sod-forming grasses and herbs often requires removal of understory competition. A clearing of approximately

30 inches square (75 cm square) should be created. The vegetation can be removed by hand scalping or by spraying with a herbicide. Scalping is not very successful in controlling sod-forming grasses, sedges, or shrubs, but competition need not be controlled beyond the first growing season in many situations. Scalps may also be created using various herbicides. If Roundup is applied, spots can be transplanted immediately without damage to the transplant. Meadow vegetation is killed with this herbicide; however, sprayed sites actually collapse as their root mass deteriorates. Even small sprayed areas must be carefully located before sites are treated with a herbicide. Care must be taken to ensure that herbicide use complies with all State and Federal laws, and contamination of streams and waterways does not occur.

Noxious weeds commonly invade wet and semiwet meadows occurring within the riparian zone. Canada thistle and whitetop are often encountered in such areas. Noxious weeds must be eliminated or controlled before sites are planted. Plowing or repeated disking is often necessary to remove established sod forming weeds. Plowing is usually not recommended along the edge of the streambank. This area should be protected if possible.

Most meadows adjacent to streams are small irregular tracts. Often they are not accessible to large equipment. Small tractors and implements can be used in these situations. Usually, treatment is delayed until after seasonal water levels have receded. Sites where streambanks are reconstructed or where structures including dams or impoundments are erected are planted to prevent the establishment and spread of undesirable weeds (fig. 8). Often, large acreages surrounding streams should also be treated to prevent the spread of weeds. In addition, these adjacent areas should be planted with useful forage species to better control livestock distribution and use. Control of weeds and maintenance of seeded species is directly dependent on the management of grazing animals. Improperly grazed sites will not retain a suitable plant cover.

Planting Season

Seeding in late fall or early spring may be applicable. Some seeds should not be flooded or left covered with water for extended periods, although some willow seeds benefit from flooding. Consequently, areas that are subject to flooding should be spring planted after the water level recedes. Transplanting should be done as early in the spring as possible. As areas become bare of snow or as the stream flow decreases (fig. 10), the sites should be transplanted immediately. Sites along a stream dry out in irregular patterns. Transplanting and seeding should not be delayed until the soils are dry or existing plants have initiated growth.

Figure 10—Willow cuttings planted as rooted stock grow quickly, furnish cover and protection on highly erosive sites.

Planting Procedures

Areas that are large enough to be plowed or disked can be drill seeded. Meadows can be planted in the same manner as recommended for the inland saltgrass or mountain meadow sites. Small tracts may be broadcast planted, followed by dragging a harrow, chain link fencing, or other small implements over the site to cover the seed. Wet soils frequently crust, settle, or slump when tilled. These soils should not be "overworked" because a poor seedbed may develop. Planting using a culti-packer seeder often prevents or eliminates problems associated with crusting, compaction, and settling. Hand seeding and raking can be used in many small inaccessible sites. Most transplanting should be accomplished using hand-planting bars, shovels, or augers.

Interseeding and intertransplanting are useful techniques to improve portions of riparian areas without

extensively disturbing the soil. Transplanting rooted stock is a very effective technique for establishing shrubs and trees. Various drills, disks, scalpers, or spray units can be modified to treat small strips or areas while leaving adjacent sites intact. Transplanting and selected seeding can then occur with the treated strip and areas where competition has been eliminated. Once treated areas become stabilized, the remaining sites can be planted if necessary.

Transplanting both shrubs and herbs on disturbed sites is advised. Transplanting large stock, including poles and rooted stock, is recommended. Large woody transplants can compete satisfactorily with understory competition, and are better able to survive, as stems are placed deep in the soil where a more persistent water table exists. Transplants provide an effective ground cover and can stabilize erosive sites rather quickly. Once a site has been treated, seeded, and transplanted it must be protected from grazing until sufficient establishment has occurred.

Adapted Species and Mixtures

Plants growing along the edge of a stream usually are able to exist throughout a wide elevational range. Consequently, individual species are found growing throughout a number of major vegetative types. Plants not growing immediately adjacent to the stream are not influenced as much by the moderating effect of the stream. Consequently, in selecting species for riparian plantings, separate groupings must be utilized.

Areas requiring treatment that are not directly influenced by the stream can be planted with species adapted to the prevailing plant community. Plantings should include species that provide streambank stability. Only a few herbs produce root or vegetative biomass and structure equal to the amounts furnished by native sedges or rushes. These dense, sod-forming species are vitally important. Transplanting wilding root segments of the native herbaceous plants along the eroding sections of the streambank is an effective method for stabilizing the site.

In addition to the herbs that exist within most native plant communities, Doran (1957), Horton (1949), and Plummer and others (1968) discussed the utility of introduced species for riparian sites. Ree (1976) discussed the rooting features required to provide streambank stability, and identified species that can be used for erosion control. Various introduced species can be used to treat riparian disturbances, but these are generally not compatible with existing natives, and if planted may not allow natural improvement to occur. The species listed in tables 5 through 11 designate those plants that, to date, appear best adapted to various riparian situations.

Numerous species of willow are widely planted in riparian areas (fig. 10, table 11). Propagation requirements and planting techniques differ among these species (Chemelar 1974). Carlson (1950) and Haissig (1970) reported that species with preformed root primordials root freely. Those without preformed root primordials root poorly or not at all.

Small transplants are often difficult to establish on adverse sites, including flooded areas. Consequently, small or poor quality stock is not recommended for riparian plantings. Rooted cuttings (Holloway and Zasada 1979) and large healthy stock should be transplanted, especially when using species that root poorly.

Aspen and Associated Conifer Communities

Aspen is the most widely distributed native tree in North America. In the Intermountain area, there are over 20 million acres (8.1 million ha) of aspen scattered from upper foothill ranges to mountaintops and high plateaus. In Utah, aspen occupies more forested lands than does any other tree species. The majority of the aspen occurs at middle elevations and is associated with, and scattered within, conifer forests (fig. 11). Aspen forests span a broad range of environmental conditions (Warner and Harper 1972). Annual precipitation within the Intermountain aspen zone ranges from 16 to 40 inches (400 to 1,000 mm). The species thrives at a variety of elevations and under a wide range of moisture and soil conditions. (Mueggler 1988; Mueggler and Campbell 1986).

Aspen is found in a number of mountain vegetative zones, ranging from the subalpine to the foothills. Mueggler (1988) lists 14 major, 12 minor, and 35 incidental aspen community types in the Intermountain

Figure 11—Conversion of aspen stands to conifers has been hastened by grazing of understory species.

region. Shepperd (1990) classified aspen communities based on growth and stand characteristics. Aspen can be found growing in association with tall forbs, ponderosa pine, lodgepole pine, spruce-fir, mountain brush, open parks of mountain big sagebrush, snowberry and chokecherry, and on the margin of grasslands. Aspen trees are found along moist streams as well as on dry ridges and southerly exposures, on talus slopes, and in deep to shallow soils of various origins.

Aspen forests are dynamic and in a constant state of change. As change occurs, resource values change. Although some aspen stands are considered climax communities, a majority of aspen forests are probably seral to other vegetative types. Many aspen stands will eventually be replaced by conifers. Seral stands are generally regarded as fire-induced successional communities able to dominate a site until replaced by less fire-enduring, but more shade-tolerant, conifers (DeByle and Winokur 1985; Mueggler 1988). Cryer and Murray (1992) found that stable aspen stands in Colorado are found only on soils with a mollic horizon.

Succession of aspen to conifers can greatly increase the likelihood that an area will experience a devastating fire (Gifford and others 1983, 1984; Jaynes 1978; Kaufmann 1985). As aspen stands convert to spruce-fir, potential surface water runoff is reduced by 33 to 65 percent. White fir uses about 4 inches (10 cm) more water per year than does aspen, and blue and Engelmann spruce may use 8 to 10 inches (20 to 25 cm) more water per year (Gifford and others 1983, 1984; Jaynes 1978; Kaufmann 1985).

With the invasion of conifers into aspen stands, understory carrying capacity for livestock and big game is reduced. In the early seral stages, an aspen forest may produce 1,400 lb (640 kg) of forage per acre. Forage production is reduced to about 500 lb (225 kg) per acre in the early stages of conifer invasion and to only 100 lb (45 kg) per acre in the later conifer seral stages (Gifford and others 1983, 1984; Jaynes 1978; Kaufmann 1985). In the Intermountain region, aspen stands mature in about 80 years; they deteriorate rather rapidly, often in 120 years, and rarely attain ages over 200 years (Mueggler 1994). On the Manti-LaSal National Forest, it is estimated that 1,600 acres (650 ha) per year are being lost to conifer invasion.

Aspen-dominated forests have a wide range of values and are truly multiple-use communities. Forage production and cover for livestock and a wide variety of wildlife species are of high value and priority. Wood fiber is abundant; however, it is grossly underutilized. In the West, aspen is the only upland hardwood tree. High quality water yields develop from aspen forests. In some areas, the aspen type yields more quality water than any other forest type. Aspen is appealing aesthetically throughout all seasons of the year. Recreation values are especially high. Aspen forests also act as a firebreak for the more flammable coniferous types (DeByle 1985c).

Most disturbances that have occurred in aspen communities have resulted from grazing impacts. Past grazing abuses have removed many desirable species, causing a shift in understory species composition. In some situations, conifers have invaded these sites, shifting the aspen stands to conifer forests. Many aspen communities have been so seriously damaged by livestock grazing that soils have been eroded. Recovery of native species has been slow to occur, and many have been seeded with introduced grasses to stabilize watershed conditions and restore herbage productivity.

Aspen reproduction in the West is almost completely dependent upon vegetative propagation by root suckering. Most aspen communities require a major disturbance such as burning or clearcutting to alter competitive relationships and to stimulate root suckering (Bartos and others 1991; Brown and DeByle 1989; DeByle 1985c; Shepperd 1990; Shepperd and Smith 1993). In the past, fire played a prominent role in perpetuation of aspen forests. Today, however, the existence of seral aspen is threatened by suppression of fire in western forests (Bartos and Mueggler 1981; Bradley and others 1992a,b; Cartwright and Burns 1994; DeByle and Winokur 1985). Prescribed burning is widely used to simulate the effect of wildfire that rejuvenates aspen forests. Prescribed burning of mid- to late-seral aspen/conifer stands can be an economical and environmentally acceptable way of rejuvenating aspen, and has proven to be an effective tool for increasing productivity of understory species that provide quality forage for large herbivores, specifically deer, elk, cattle, and sheep (Bartos and Mueggler 1981; Brown and DeByle 1989; DeByle 1985c; Walker 1993).

Extensive plantings have been conducted in the aspen type. Seedings are normally successful as sufficient moisture is available to sustain young seedlings. In addition, various native species are available for treating these areas. With proper planning, both revegetation and restoration plantings can be successfully conducted.

Removal of Competition

Aspen stands that are in an overmature and decadent condition (Schier 1975), or have been depleted of understory herbaceous species, do not require understory plant control measures. The understory plant density has usually been reduced by grazing or suppressed by shading of trees and overstory shrubs. Few weedy species invade or gain dominance within these forested communities. However, serious weed problems

can develop on extremely deteriorated sites, particularly areas subjected to prolonged grazing.

The procedure for removing competition in aspen openings or associated conifer forests is similar to those described for the mountain brush and subalpine sites. Where overstory conifers and aspen should be eliminated, prescribed burns, timber harvest, or firewood harvest are appropriate treatments.

Planting Season

Aerial and ground broadcasting are generally the most desirable methods of seeding. Planting in nondisturbed aspen and associated conifer types extends from early September to leaf drop. Seeding should be completed before leaf fall and permanent snow covers the ground. As fallen aspen leaves become wet and stick together, they can form a satisfactory cover for planted seed. If seeds are fall planted within aspen stands immediately prior to leaf drop, no other seedbed preparation is required. Where aspen has been burned, aerial broadcasting should occur from fall to early winter. Seeding on top of early snow, following burns, has the potential to produce desirable results.

Planting Procedures

Broadcasting from a fixed-wing aircraft can be economical and effective for planting large areas. Broadcast seeding from helicopters is best suited for seeding scattered and small patches, especially in deep canyons and on steep hillsides. Many sites are too rough or steep to allow the use of ground equipment. Seeds cannot be distributed as uniformly by hand as from aircraft, yet small areas can be seeded satisfactorily from horseback or on foot. Livestock can often be beneficial in covering broadcast seed if animals are temporarily concentrated on the seeded areas.

Adapted Species and Mixtures

Because the intensity of shade differs among aspen stands, species selected for seeding should be shade tolerant as well as adapted to the specific sites being seeded within the aspen and conifer zone (table 12). Because some shrubs are usually present, it may not be necessary to include these shrubs in the seeding mixture. Many plants that occur within the aspen and conifer forests are very productive and nutritious. Many will withstand heavy grazing and recover well under a rest rotation grazing system. These species are selectively used by both game and livestock; consequently, treated areas usually attract grazing animals and upland game birds, and serve as highly useful pastures and wildlife habitat.

Smooth brome and intermediate wheatgrass have been widely seeded through the aspen type. Kentucky bluegrass has also been seeded and has spread to occupy many adjoining sites. All have established well and provide good herbage. These three species, however, exhibit very aggressive spreading traits, and develop a closed sod that eliminates many important tall forb species. Smooth brome and intermediate wheatgrass have been shown to diminish aspen regeneration (fig. 12). Open parks with interspersed aspen stands have also been seeded with smooth brome and intermediate wheatgrass. This has resulted in the elimination of many native forbs, grasses, and shrubs (fig. 13). Mountain big sagebrush and other shrubs that frequently grow in open areas have been eliminated by competition from these two seeded grasses. Seedling recruitment of serviceberry, snowberry, chokecherry, and curlleaf and mountain mahogany has also been prevented. Once these grasses are established, methods of control or conversion to other species are very limited. These grasses, therefore, should not be seeded where a diverse composition of species is desired because they do not promote recovery of native plants or community restoration.

Regar brome is an introduced species that is now being seeded more extensively. This species does not appear to be as aggressive and dominating as smooth brome, but long-term ecological studies are not available. Timothy and tall oatgrass are introduced species that are well adapted to aspen and conifer areas. They are not as aggressive as smooth brome, yet they

Figure 12—Closed stands of smooth brome often develop within 10 to 20 years following seeding of aspen sites. The dense sod frequently eliminates native grasses and forbs, and diminishes aspen reproduction.

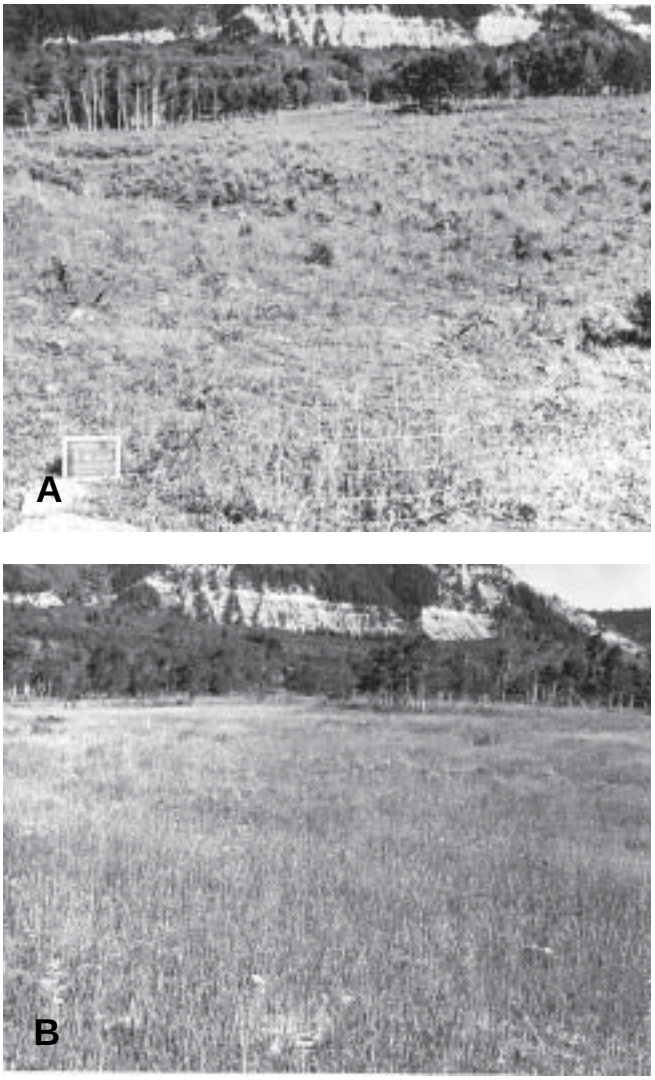

Figure 13—(A) This site was a heavily grazed aspen opening prior to seeding with intermediate wheatgrass and smooth brome in 1959; (B) Same area 30 years later showing displacement of the native shrubs, grasses and broadleaf forbs by the seeded perennials.

establish well, provide good forage and ground cover, and provide for development of the native community in 5 to 20 years. Orchardgrass is also widely planted and is well adapted. It can also suppress recovery of native species, but not to the extent of smooth brome or intermediate wheatgrass.

The natives, slender wheatgrass and mountain brome, can generally be planted in place of the commonly seeded, introduced perennial grasses. Additional native grasses with good potential that should be considered are subalpine needlegrass, alpine timothy, Canadian wildrye, and thurber fescue. Alfalfa has been seeded successfully, especially in open parks. This introduced forb establishes well, provides excellent forage, enhances soil nitrogen, and is compatible with native species. It can be planted to restore severe disturbances, but use of native forbs is recommended. Native forbs that are being seeded successfully include showy goldeneye, tall bluebell, cowparsnip, goldenrod, butterweed groundsel, oneflower helianthella, Porter ligusticum, lomatium, and sweetanise.

Broadcast seeding of most native herbs is not as successful as broadcast planting of grasses. Usually, native forb seeds are more costly and less available. Drilling or some means of placing these seeds in the soil is advised. Small seeded species, including penstemon, meadowrue, and cinquefoil, establish well by broadcast seeding, but drill seeding of expensive seeds is advised.

It is important that species and mixtures planted are site adapted. Attempting to seed extensive areas with a general mixture is not advised. Sites should be inspected and planted with a diverse mixture to assure that different plant associations are able to develop. As native species become more available, more complete and site-specific mixtures can be planted.

Many native herbs are currently being collected from wildland sites and can be used in restoration plantings. Within the Intermountain region, native species are being harvested with greater frequency from the aspen communities than from many other vegetative types. However, seed supplies are not currently adequate to facilitate all planting needs, and cultivated fields must be developed to supply demands.

Many important native grasses and broadleaf herbs that exist in these communities can be successfully planted in mixtures. Natural recovery of depleted and disturbed sites depends upon the degree of soil loss that has occurred and the amount and source of native seeds. Some aspen areas will recover quickly if livestock grazing is controlled, and seeding is not necessary. Seeding to protect exposed soils may be achieved by planting a few species, principally native grasses. Through protection, additional species will likely recover.

Mountain Brush Communities

In the Intermountain West, the mountain brush type occupies considerable acreage. The chief components are Gambel oak, bigtooth maple, Rocky Mountain maple, mountain big sagebrush, Saskatoon serviceberry (fig. 14), and Utah serviceberry. Associated

Figure 14—Mountain brush communities support Gambel oak, mountain big sagebrush, and serviceberry.

with the above species, in various geographic areas, are ninebark, chokecherry, bitter cherry, skunkbush sumac, antelope bitterbrush, cliffrose, true mountain mahogany, and curlleaf mountain mahogany. The type is rich in diversity of forbs and associated grasses. Gambel oak dominates from north-central Utah to northern Arizona, western Colorado, and on scattered mountain ranges in Nevada. Big tooth maple is dominant in northern Utah, northern Nevada, and southern Idaho. Scattered stands of serviceberry and antelope bitterbrush occur over the full range of the mountain brush type. Gambel oak, serviceberry, and maple communities normally occur above the pinyon-juniper zone and below the aspen-fir zone. Gambel oak communities also integrade into ponderosa pine and lodgepole pine forests. Ponderosa pine, in many respects, is a counterpart to the mountain brush type.

Extensive stands of curlleaf mountain mahogany occur intermixed throughout the region with other mountain brush species. Curlleaf mountain mahogany normally grows on shallow, more rocky soils than other associated shrubs. Mature stands often support less diversity of understory herbs than other mountain brush shrub associations. This plant association provides important habitat to big game animals, and stands have frequently been heavily grazed by game and livestock. Mature and taller plants often grow out of the reach of grazing animals, yet smaller or younger plants are often hedged and maintained in a stunted form. Seedling recruitment of the shrub is seriously impacted by grazing, limiting natural regeneration. Extensive areas now exist where reproduction is prevented by grazing and invasion of annual weeds.

Mountain brush communities occur between 5,000 and 9,000 ft (1,524 and 2,743 m). Annual precipitation varies from a low of 15 inches (380 mm) to 26 inches (660 mm). A linear increase in precipitation of 4.94 inches (126 mm) per 1,000 ft (350 m) rise in elevation has been demonstrated for this type (Lull and Ellison 1950). Seasonal moisture distribution shows a crest from February to April and a low from July to September.

Mountain brush communities have been recognized as important, highly productive spring-summer-fall ranges for cattle and sheep (Harper and others 1985; Sampson 1925). Deer, elk (fig. 15), bear, grouse, and Merriams turkeys also make considerable use of the type (Harper and others 1985; Julander and Robinette 1950; Kufeld 1973; Kufeld and others 1973).

Gambel oak grows in clumps that vary in height and density. The foliage of many taller plants can be out of reach of grazing animals. Some stands are thick and impenetrable to livestock and wildlife. Density and size of Gambel oak clumps have increased in many areas due to grazing and fire control measures. Understory forage production has generally decreased due to livestock grazing and competition from the oak.

Serviceberry and maple-dominated communities generally occur in quite open stands. Serviceberry and mountain big sagebrush often occur intermixed, with a number of grasses and forbs filling the large interspaces. Tall, robust plants of serviceberry and maple may become unavailable to livestock and game animals as the plants mature. The desirable understory species that occupy the interspaces are often subjected to misuse by improper grazing. The primary objective in treating most mountain brush communities is to reestablish the understory herbs. Most shrub species still occupy the sites, and shrub replanting is not usually required.

Figure 15—Mountain brush communities are important spring and summer ranges for elk and deer.

Removal of Competition

Reduction of shrub competition is often required to create a suitable seedbed and allow seeded herbs to establish (Engle and others 1983; Marquiss 1973; Plummer and others 1968; Stevens 1983b; Stevens and Davis 1985; Tew 1969). Shrub competition can be reduced using fires, herbicides, and mechanical treatment. Treatment of brush fields should be designed to retain the shrubs, but allow reintroduction of understory herbs. Sites supporting an adequate understory would not necessitate seeding. Control of wildfires has prevented natural burning of some brush fields, which tends to allow formation of closed stands of shrubs and suppression of understory plants. Some sites would benefit from burning, but may or may not require seeding.

Gambel oak is an important plant throughout many watersheds. It exists on steep slopes where ground cover is essential. Following burning, oak recovers well and provides needed ground cover. Gambel oak clumps that are burned and then chained or railed to improve seedbed conditions can be aerial seeded with good success.

An efficient means to suppress Gambel oak is twice-over anchor chaining, preferably with heavy links or with a Dixie or Ely chain. Chaining will break down both erect and short-growing shrubs. In addition, the density of shrubs can be reduced if desired. If single chained, seeding should precede chaining. With double chaining, seeding should occur between chainings to ensure proper seed coverage. Interspaces can be seeded and chained at the same time the brush is treated.

Offset disks, heavy pipe harrows, and brushland plows can be used to reduce some brush thickets. These methods of mechanical control are expensive, however, and the equipment can only be operated on level to moderately sloping sites, in open stands, or in short-statured oak. Excellent seedbeds are prepared, and small areas can usually be treated with these types of equipment.

Reestablishment of understory herbs is essential within Gambel oak stands. When competitive species are established, and grazing pressure is applied to Gambel oak thickets, the growth of new sprouts may be held in check (fig. 16) (Frischknecht and Plummer 1955; Harper and others 1985; Plummer and others 1970b; Stevens and Davis 1985). Treated oak stands that are not seeded with herbaceous plants readily resprout and regain dominance. In addition, the sprouts grow rapidly and become unavailable, and the stand may become impenetrable within a short time.

Understory species that are seeded in oak thickets must be shade tolerant because oak can resprout and form a dense canopy. Establishment of adapted understory species may reduce shrub regrowth, decrease the density of sprouting, and enable oak stands to remain

Figure 16—A stand of Gambel oak that was chained and seeded to smooth brome, intermediate wheatgrass, and tall oatgrass in 1954. Photo taken in 1993 demonstrating the ability of the seeded grasses to suppress or retard recovery of oak shoots.

open, supporting a better quality herbaceous understory. Forage production within oak clumps can be as much as three times greater than between clumps. Forage within clumps begins growth later in the spring but remains green longer into the fall than the same species growing between clumps (fig. 17). Soil moisture depletion has been found to be significantly reduced by removing oak top growth and introducing grasses (Tew 1966, 1967, 1969).

Clary and Tiedemann (1986) reported that more woody material is produced underground by Gambel

Figure 17—Grasses seeded with oak clumps are more productive and retain greenness later into the season than similar plants established in openings.

oak than is produced above ground. Various types of mechanical treatments, fire, and herbicides have been used to kill or reduce oak. However, regardless of treatment, resprouting occurs from the massive root system.

Not all woody plants that dominate the mountain brush communities recover after fires. In addition, certain ecotypes of shrub species differ significantly in their response to fires. Gambel oak, serviceberry, maple, and sumac normally resprout after mechanical treatment and burning. However, duration and timing of the fire affects plant regrowth, particularly maple and sumac.

Antelope bitterbrush, cliffrose, and mountain snowberry may or may not recover after burning. These shrubs may show sprouting the first and second year after a burn, after which most die. Layering forms of antelope bitterbrush usually recover to some extent. Erect or upright growth forms are usually killed by burning. Some plants may resprout, but succumb by the second growing season. Ecotypes of antelope bitterbrush that naturally layer or grow with ponderosa pine and lodgepole pine are most likely to resprout and live after fires.

Mountain big sagebrush and curlleaf mountain mahogany are often killed by fire. New plants may develop from natural reproduction or from artificial seeding. Establishment of shrub seedlings is regulated by the presence and recovery of the understory herbs. If these two shrubs and other nonsprouting species are to be reestablished through natural seed dispersal, sites should not be planted with a dense understory of competitive herbs. Cliffrose, curlleaf mountain mahogany, chokecherry, and to a lesser extent, antelope bitterbrush, true mountain mahogany, and serviceberry respond well to chaining.

Planting Season

Seeding in the mountain brush zone should be conducted in late fall (October and November). Planting can be conducted even after snowfall and until snow becomes too deep to effectively operate equipment. In some seasons and on some sites, treatment can continue into January; however, the season often closes by mid-November or December. Spring plantings with rapidly germinating species can be successful if done immediately after snowmelt, but this is usually a very short period. Consequently, spring seeding is not recommended because of the unpredictability of moisture required to germinate and sustain new seedlings.

Planting Procedures

When treating large areas, aerial seeding has proven to be the most successful method. Chaining or pipe harrowing should follow seeding in order to cover the seed, scatter debris, and to create small water-collection and holding depressions. Seed dribblers and thimble seeders attached to crawler tractors can be used to seed selected species into the cleat marks. Grasses and forbs can usually be established on favorable sites by broadcasting seed just before leaf fall. Hand seeding small disturbed areas is practical. Drill seeding is often impractical because of heavy debris and steep terrain.

On bare, eroding hillsides, which frequently occur on southern exposures, furrowing and seeding with sidehill furrowers attached to a tractor is appropriate where slopes permit tractor operation. On slopes over 30 percent, broadcasting onto furrows, made on the contour by reversible moldboard plows or specially designed plows, is effective. Slopes cut by large gullies may require deeper and wider contour trenches. These must be spaced sufficiently close together to retain runoff from high-intensity storms. Deep furrowing or trenching is only recommended to control serious erosion problems.

Adapted Species and Mixtures

Mountain brush communities are located between aspen and juniper-pinyon communities, hence, many species common to higher and lower elevations mingle in this zone. Also, considerable variations occur in the amount of precipitation, slope, aspect, and soil to create a variety of sites for a large number of species. Mountain brush communities are potentially one of the most productive plant types. This type is a counterpart, in many respects, of ponderosa pine sites; consequently, similar treatment practices can often be used.

Species adapted to mountain brush communities are listed in table 13. Attempts to restore the diverse plant communities require use of a wide array of species. A considerable number of shrubs that occur in the mountain brush type are quite resilient and persist with intense grazing pressure. However, mountain big sagebrush, rubber rabbitbrush, antelope bitterbrush, cliffrose, mountain snowberry, Martin ceanothus, birchleaf mountain mahogany, and curlleaf mountain mahogany have been reduced and eliminated in some areas. These shrubs can normally be seeded with drills or single-row seeders. With the exception of big sagebrush and rabbitbrush, seeds of most shrubs must be placed into the soil. Broadcast seeding of big sagebrush and rubber rabbitbrush is recommended on open or bare surfaces. Direct seeding into herbaceous competition is not recommended for any shrub. Most sites receive sufficient moisture to assure shrub establishment if seed is properly planted.

Many native grasses and broadleaf herbs occur in this plant type and can be used to restore depleted sites. Seed availability may somewhat limit large restoration plantings, but seeds of many native species are

becoming more available. Seeds of bluebunch wheatgrass, western wheatgrass, muttongrass, thickspike wheatgrass, streambank wheatgrass, big bluegrass, green needlegrass, needle-and-thread, Lewis flax, showy goldeneye, and Rocky Mountain penstemon are now more available and can be used in place of commonly used introductions. Intermediate wheatgrass, smooth brome, orchardgrass, hard sheep fescue, and crested wheatgrass have been widely planted throughout this type. These species are well adapted to this entire zone and have stabilized watershed disturbances and provided excellent forage. Intermediate wheatgrass and smooth brome are extremely competitive and have been used to stunt regrowth of Gambel oak and provide more accessible forage to grazing animals. Alfalfa, cicer milkvetch, and small burnet have been widely planted throughout this zone. All provide abundant high quality forage and have been used to stabilize livestock grazing and provide seasonal grazing to big game. Seeding of some introduced grasses, especially smooth brome, hard sheep fescue, and intermediate wheatgrass, has disrupted recovery of many understory herbs and has suppressed recruitment of big sagebrush and antelope bitterbrush (Monsen and others 1996).

Sites protected from livestock grazing normally recover if some residual species occur. Studies by Monsen and Harper (1988) demonstrate that native understory shrubs and herbs can be competitive, and are effective in suppressing invasion of juniper and pinyon and regulating density of Gambel oak.

Weedy species have not invaded the mountain brush type to any great extent, although poverty weed, various species of thistle, and a few other weeds occur. To date, they have not caused serious problems requiring intensive control measures.

Ponderosa Pine Communities

Ponderosa pine is the most widely distributed pine in North America (Fowells 1965) (fig. 18). In the Intermountain West, ponderosa pine occurs at approximately the same elevation and on sites with the same annual precipitation as does the mountain brush type. Mountain brush types are found on heavier soils than ponderosa pine, which prefers well-drained, coarser textured soils, with soil pH close to neutral, and more summer precipitation.

Twenty-two different plant associations occupied by ponderosa pine have been described by Steele and others (1981) for areas in central Idaho. These plant associations represent the primary ponderosa pine communities throughout the Intermountain region. Grazing, logging, weed invasion, and fires have created problems requiring restoration or revegetation. Logging activities have changed the composition of these plant communities. Road construction and logging disturbances have also created erosion, sedimentation, and runoff, causing degradation of downstream resources. Roads and related disturbances have also facilitated the spread of weeds that alter plant communities and interfere with restoration measures. Grazing has impacted many ponderosa pine/bunchgrass and shrub communities. Desirable understory species have been removed by grazing, which has also allowed invasion and expansion of weeds. Cheatgrass has spread throughout many of the ponderosa pine/bunchgrass associations and gained control of many disturbances. Yellow star thistle, rush skeletonweed, and medusahead also occupy sites once dominated by ponderosa pine/bunchgrass.

Invasion and spread of cheatgrass has increased fire frequency and size of wildfires throughout various ponderosa pine communities. More frequent burning has eliminated nonfire-tolerant trees, shrubs, and herbs, and further perpetuated the spread of cheatgrass and other undesirable annuals. Control measures are required to eliminate the annual grass, restore a competitive cover, and reestablish species eliminated by weed competition and burning.

Not all ponderosa pine disturbances have been invaded by weeds. In many situations understory shrubs and herbs have been eliminated or seriously weakened by grazing. Woody species important for winter grazing have been lost and must be restored. Grasses and broadleaf herbs have also been removed and require restoration to stabilize soil erosion and maintain a balance in species composition. Shrub and tree recruitment is dependent on seedbed conditions and composition of understory species.

Figure 18—A young stand of ponderosa pine with a mixture of understory species.

In many situations, disturbances within ponderosa pine sites occur on steep inaccessible sites, limiting treatment practices. Natural recovery is the most practical means of restoration. Natural recovery does occur throughout most areas where native herbs remain and have not been replaced by weeds. Protection and limited seeding should be utilized to restore these sites.

Removal of Competition

Many shrubs and herbs that occur with ponderosa pine are able to recover following burning, logging, or grazing unless the site seriously degraded. In these situations, seeding may be required. Cheatgrass, medusahead, and other weeds have invaded many lower elevation communities supporting ponderosa pine. These weedy species present serious management problems. They increase the incidence of wildfires and reduce establishment of natural and artificial seedlings. Annual weeds must be controlled to allow seedlings of other species to establish. On steep slopes, burning is the most practical method used to reduce weedy competition. Sites burned by wildfires or controlled burns should be seeded in the fall to control reinvasion of annual weeds. Adequate moisture is usually received to support new seedings if plantings are conducted the first year after burning when cheatgrass competition has been suppressed.

Recent invasion of rush skeletonweed in south-central Idaho in ponderosa pine/bunchgrass communities appears to be capable of upsetting natural successional changes. Its ecology is not well-understood, but control of this weed has become a major problem.

Plowing, disking, or spraying can be used to control dominant stands of annual grasses on large accessible areas. Seeding directly into annual grasses is not advisable. Cheatgrass sites can usually be successfully seeded following burns or during periods of drought that may diminish weeds. Burning does not reduce competition of medusahead, and additional control measures are required to assure planting success.

Broadcast seeding weed-infested sites following burning can be successful if seeds are covered by harrowing or chaining methods. Failure to cover seeds often results in spotty, irregular stands, although successful stands may occur in some years. Mechanical coverage is not always possible in many areas, and seeding on or before snowfall is advised.

Cheatgrass and medusahead occupy many ponderosa pine and associated shrub/bunchgrass sites. Many weedy areas once occupied by antelope bitterbrush have been interseeded or intertransplanted with this shrub. Plantings have been made into small scalps or clearings that are 30 x 30 inches (76 x 76 cm) in size. Weeds and weed seeds are removed by scalping and sidecasting the surface soil. Bitterbrush has been transplanted or planted into the small clearings. Many antelope bitterbrush interseedings were established using this technique amid weedy sites in central Idaho and Utah during the 1940s and 1950s. Mature stands of shrubs developed, but failed to persist. Individual shrubs reached maturity but slowly senesced. Although the antelope bitterbrush shrubs produced adequate seed crops during most years, natural recruitment failed to perpetuate shrub stands. Annual weeds were initially removed from portions of the area at the time antelope bitterbrush was seeded, but the weeds regained dominance of the understory. Competition from the understory prevented shrub seedling recruitment during the 40- to 50-year period since the sites were initially planted. Attempts to restore antelope bitterbrush in sites occupied by annual grasses must include replacement of the weeds with native understory herbs. If cheatgrass and medusahead are left as the understory, their presence will eliminate natural shrub seedling recruitment that is required to maintain the stand.

It is essential that native understory grasses and broadleaf herbs are reestablished to facilitate the natural recruitment of important shrubs. Large and extensive areas that once supported antelope bitterbrush and ponderosa pine are currently occupied with mixed stands of annual and perennial grasses. These sites should be managed or treated to restore the native understory species. As native plants are reestablished, interseeding with shrubs can be accomplished. Interseeding with shrubs into perennial native grasses will be required in many areas as the principal shrubs have been eliminated and a satisfactory seed source is not available. Once the understory is established, shrubs can be interseeded in narrow strips created by surface tillage, scalping, or following herbicide treatment. Reducing understory competition is normally required to establish uniform stands of antelope bitterbrush, snowberry, and most other shrubs. Although these species are able to establish by natural seeding into native herbs, planting large areas without some attempt to reduce understory competition is not advisable. It is essential to reestablish understory species prior to or as shrubs are planted. Planting or managing sites to establish and maintain a complete assembly of herbaceous and woody species is necessary. Attempts to establish only the shrub component of ponderosa pine associations have often been unsuccessful.

Weedy sites have commonly been seeded with perennial grasses including crested wheatgrass, intermediate wheatgrass, hard sheep fescue, and smooth brome. These species compete well and replace cheatgrass, medusahead, and other weeds; but they

also prevent recovery of native herbs, and establishment and recruitment of most shrubs.

Reestablishment of antelope bitterbrush, big sagebrush, chokecherry, bitter cherry, and mountain mahogany is required on many disturbances. Sites occupied by these and other shrubs are important wintering areas and support concentrated wildlife populations. Animal browsing can and has prevented establishment and normal growth of small plantings. To be successful, shrub plantings must be large enough to limit browsing and allow plants to attain normal stature. In some special situations, populations of game animals may have to be reduced to allow establishment of seeded species.

Planting Season

Following burns or other treatments, seeds are usually fall sown. If seeds can be covered by chaining or using lightweight drags, planting should be conducted in late fall (October and November). Broadcast seeding on steep surfaces without any followup method used to cover the seed should be delayed until a snow cover has developed. Spring plantings are not advised because many sites, particularly south and west slopes, dry quickly. Early spring is the most preferred time to transplant.

Planting Procedures

Many tree-dominated sites occur on extremely steep slopes where machinery cannot be used. Typical areas usually requiring treatment are old-stock driveways, roads, logging disturbances, burns, or other areas where these practices have seriously impacted the vegetation. Most steep slopes can be aerially seeded with herbs, big sagebrush, and rubber rabbitbrush. Where possible, seed should be covered by harrowing or chaining.

In many situations, antelope bitterbrush and big sagebrush have been eliminated from areas as a result of natural fire and grazing. These and other shrubs can be interseeded into native bunchgrass stands if herbaceous competition is controlled for 1 to 2 years. Various interseeders can be operated on sites accessible to tractor-drawn equipment. Steep slopes normally require hand seeding.

Both big sagebrush and rubber rabbitbrush can be broadcast seeded in midwinter on native bunchgrass sites with excellent success. Seeds planted on or before snowfall germinate and establish amid grass competition. Many areas subjected to frequent burning lack a shrub cover, and these sites can be aerial seeded with big sagebrush or rubber rabbitbrush (Monsen and Pellant 1995).

Broadcast seeding beneath ponderosa pine is not as successful as planting amid aspen trees. Pine needles provide poor cover for the seeds. Seed germination and seedling establishment are quite erratic in these areas. However, most ponderosa pine and lodgepole pine types receive sufficient moisture each year to assure seedling establishment. Broadcast seedings on bare, well-drained, steep slopes normally result in poor stands. Many species simply cannot be established by broadcast planting on barren surfaces.

Anchor chaining can be used to cover seed on steep, long slopes by experienced operators (Monsen and Pellant 1995). Chains of various weights can be used with attached swivels to control the amount of soil disturbance. Contrary to some objections, chaining does not create small continuous depressions where water may collect and cause rilling or erosion. Chaining up and down long slopes is possible. Contour chaining is not necessary, even on bare or burned sites to control runoff. If properly used, chaining does not uproot or impact recovery of existing species. Chaining can be effectively used to till soils where water repellent soils form following burning. This is a major problem contributing to erosion on forested communities and open parks. The amount of soil tillage required to prepare a seedbed and cover seeds is usually helpful to "break up" water repellent soils and improve amount of infiltration.

In many situations, shrubs and trees must be established by transplanting. Seeding success with Woods rose, mountain snowberry, bitter cherry, maple, mountain ash, and chokecherry has been erratic. Yet, good success can be attained by seeding antelope bitterbrush, snowbrush ceanothus, redstem ceanothus, Martin ceanothus, mountain big sagebrush, and birchleaf mountain mahogany. These shrubs establish if good quality seed is fall sown, and the new seedlings are not subjected to excessive grazing and competition from herbaceous plants.

Adapted Species and Mixtures

Steele and others (1981) have identified various habitat types where ponderosa pine, lodgepole pine, and Douglas-fir exist with different components of understory shrubs and herbs. The distribution and occurrence of each habitat type has also been delineated. Species occurring in each habitat type or plant association should be included in any revegetation project. Since considerable differences in site conditions and plant composition occur among these types, it is not always advisable to plant species from one habitat type into another. Some grasses and shrubs occur in more than one habitat type and are more widely adapted than others. Also, certain species recover as pioneer plants and establish initially after a disturbance. Plantings of ninebark, redstem ceanothus, Utah honeysuckle, mountain lover, and cascara buckthorn do not survive well when planted on disturbed

soils. These species grow better on soils that have not been degraded by erosion. Plantings of russet buffaloberry and most species of blueberry and manzanita fail to develop when planted in openings devoid of any overstory cover. These species should not be planted in open sites or areas that have lost the topsoil.

Although species of big sagebrush and rabbitbrush are well adapted throughout the mountain brush zone, they are restricted to specific sites. Mountain big sagebrush and rubber rabbitbrush should only be planted on sites where they naturally occur. Species suggested for planting are in table 13.

Juniper-Pinyon Communities

Distribution

Mitchell and Roberts (1999) stated that there are approximately 55.6 million acres (22.2 million ha) of pinyon and juniper in the Western United States. Substantial portions of the Intermountain region are occupied by juniper-pinyon and associated species (fig. 19). Acreage estimates vary considerably. West and others (1975) listed 15.5 million acres (6.2 million ha) in Utah, 13.1 million acres (5.2 million ha) in Nevada, and 1.4 million acres (0.6 million ha) in Idaho. In the Great Basin, data grid analysis from Lansat-1 satellite photography (Tueller and others 1979) indicated there are about 17.6 million acres (7.1 million ha) of juniper-pinyon. O'Brien and Woudenberg (1999) stated that there are more than 45.3 million acres (18.1 million ha) of forests composed mostly of pinyon and/or juniper in the Intermountain West.

Singleleaf pinyon occurs throughout Nevada to central Utah where pinyon takes over and extends into Colorado. Utah juniper is found in association with both singleleaf pinyon and pinyon. On drier sites where conditions are too arid for the pinyons, Utah juniper occurs in pure stands covering vast areas. Rocky Mountain juniper occurs at the upper edge of the singleleaf pinyon occupying small scattered areas. Western juniper dominates the low foothills in eastern Oregon and Washington, existing on sites similar to those occupied by Utah juniper in the Intermountain region.

Juniper-pinyon ranges from 10,000 ft (3,280 m) elevation on the crest of the Sierras (West and others 1975) to a low of 3,200 ft (1,050 m) along the Utah-Arizona border (Woodbury 1947). Pinyon tends to favor higher elevations, and Utah juniper becomes more dominant at lower elevations. Annual precipitation in the juniper-pinyon type ranges from 8 to 22 inches (200 to 560 mm), with the best stand development occurring between 12 and 17 inches (300 and 430 mm).

Figure 19—Numerous areas in central Utah support similar age stands of pinyon and juniper, growing with only scattered amounts of understory species.

Ecological Changes and Status

From the late 1800s to the present, distribution and density of many pinyon and juniper communities have been significantly altered. A majority of the juniper-pinyon stands in the Great Basin prior to settlement were confined to specific areas, and supported a diverse understory of perennial grasses, forbs, and shrubs. Fire, combined with perennial understory competition, controlled the spread and thickening of existing juniper-pinyon stands. The understory vegetation controlled or regulated the incidence and spread of fires, which, in turn, regulated the presence and distribution of juniper and pinyon. Heavy grazing by livestock over many years resulted in community changes and the eventual loss of the perennial understory (fig. 20) and, in some locations, establishment of exotic annuals that now dominate the understory (Gruell 1999). Grazing and a lack of fire have resulted in an extensive increase in tree density and expansion into new areas. O'Brien and Woudenberg (1999) reported that 53 percent of the pinyon and juniper trees in Utah and 67 percent in Nevada are between 40 and 120 years old, and only 20 percent in Utah and 9 percent in Nevada are older than 200 years. This data dramatically demonstrates the great increase in trees following the introduction of livestock and reduction of fire incidence. Adjoining semiarid grass and shrublands underwent similar changes as desirable species were eliminated or reduced in density and vigor by grazing. The absence of fire and the loss of dominant grasses and other understory species by livestock allowed for an increase in juniper and pinyon trees, and substantial tree invasion into many adjoining grass and shrublands (Aro 1971; West 1984b, 1999; Woodbury 1947).

Figure 20—Stands of pinyon and juniper frequently provide cover for wildlife, but lack suitable seasonal herbage.

Increase or invasion of trees combined with significant changes in the understory from perennial to annual communities resulted in unstable soil conditions and erosion (Farmer and others 1995; Roundy and Vernon 1999). Grass and shrub communities use and transpire considerably less moisture than juniper and pinyon, which are active all year (Roundy and Vernon 1999). This unchecked water use has the potential to dry up springs and reduce quantity and quality of water in streams. Archaeological sites have been lost or damaged by erosion in depleted juniper-pinyon sites (Chong 1993). In addition, critical fall, winter, and spring livestock and wildlife ranges have been seriously degraded. Deer and elk numbers have been shown to decline as tree density increases (Short and others 1977). Suminski (1985) reported that declines in deer numbers were highly correlated to closing canopy cover of juniper and pinyon expansion into areas formerly devoid of trees, and the corresponding decline in understory production. Sage-grouse (Commons and others 1999) respond adversely to increased density and invasions of pinyon and juniper. Loss or alteration of riparian areas through community changes, erosion, and lowering of water tables has occurred, affecting the productivity and stability of these sites.

Not all juniper-pinyon sites support similar compositions of understory species (Rust 1999; Thompson 1999). A variety of herbaceous and woody plants exist in different amounts, depending on site and climatic conditions (Goodrich 1999). In addition, the composition and age structure is regulated by changes in climatic and biotic events including wildfires.

Over the past 45 years, some depleted juniper-pinyon stands have been artificially seeded to enhance species composition, improve habitat, and correct watershed conditions. However, not all juniper-pinyon stands merit treatment and artificial seeding. Sites that are ecologically stable and have not been so dramatically altered that natural successional changes may occur, should not be candidates for artificial treatment. In some situations, stable tree communities may be altered to satisfy high-value resource needs, but few situations would justify converting stable communities to support other species. Some juniper-pinyon woodlands have been converted to pasture lands for livestock foraging. In some situations, these practices have been used to stabilize livestock grazing problems. Although conversion from woodlands to herblands is attainable, careful management is required to maintain the desirable herbs. Introduced grasses have been successfully established throughout many juniper-pinyon woodlands and provide substantial forage for grazing animals. Introduced species generally provide considerable competition to limit tree reinvasion, but tree reincroachment is not prevented on all sites seeded to introduced herbs. Grazing practices, in conjunction with site conditions, will influence recovery of native species, including woody plants.

Species composition of juniper-pinyon communities may be altered to a different seral status with or without the introduction of a new complex of species attained by seeding. In some situations, juniper-pinyon woodlands can be converted by burning (Goodrich and Reid 1999; Greenwood and others 1999) or chaining to reduce tree density. This is possible if sufficient native understory exists, and is capable of recovery following treatment (Stevens 1999a).

To date, most juniper-pinyon conversion projects have utilized artificial seeding to ensure the rapid reestablishment of understory shrubs and herbs. If treated sites lack the desired understory species, seeding is normally used to ensure their establishment. To date, substitute species are commonly used to seed many sites because seed of many native species is not consistently available.

Juniper-pinyon sites that have been altered by extensive grazing and exclusion of wildfires must be examined to determine the restoration measures that can be used to reestablish desired vegetation, leading to the creation of a more natural system. Most sites that have been heavily grazed for long periods no longer support even minor amounts of understory perennial species (Poulsen and others 1999). On these sites, either juniper or pinyon trees, or both, have increased and dominate (Madany and West 1983). Trees provide extensive competition and preclude the invasion or establishment of small seedlings of most desirable understory species (Naillon and others 1999).

It is essential that some trees be removed to allow for the establishment of other species. Trees offer so much competition that seed germination and seedling emergence and establishment is prevented. Removal of all trees is not essential, but tree competition must be sufficiently diminished to allow many slower developing species time to fully establish. Interseeding into existing vegetation has proven successful in some community types, but not in juniper-pinyon.

Juniper-pinyon sites that have been void of understory species for many years will most likely lack a sufficient seedbank (Naillon and others 1999; Poulsen and others 1999). On these sites, natural seeding will not occur even if trees are removed. Understory shrub and herbaceous species that are weakened by heavy grazing and competition and from tree encroachment normally do not bear seed, but may persist for years before eventually succumbing. Under these conditions, undisturbed stands of juniper-pinyon may exist for many years with little seed being added to the natural seedbank. Removal of competitive trees can, in very specific situations, result in a slow, erratic recovery of associated native species. Unless sites are artificially seeded, natural recovery is often ineffective.

Many juniper-pinyon sites support scattered, but important, amounts of annual weeds including cheatgrass, bur buttercup, red brome, and various mustards. If trees are removed and sites are allowed to recover naturally, annual and perennial weeds will flourish and quickly assume dominance (Gruell 1999). Weeds can be highly competitive and restrict the reestablishment of desirable natives. Because conversion to annual weeds will occur rapidly, seeding must not be delayed beyond the year of tree removal.

Juniper-pinyon restoration programs should be designed to allow for restoring native vegetation and creating stable communities. Converting juniper-pinyon communities to assemblages of introduced species is not advisable (Stevens 1999a; Walker 1999). The seeded community should be able to respond to wildfires and sustain some grazing. In many situations, juniper-pinyon sites must be managed to allow wildfires to occur and thereby regulate species composition. In some situations, wildfires may not be acceptable or cannot be managed without extensive damage to shrubs and other adjacent resources. In these situations, chaining or other artificial treatment may be used as a substitute to regulate plant composition.

Removal or controlled use of livestock from many depleted juniper-pinyon-dominated areas will not facilitate the recovery of native vegetation, stabilize the soil, and return these areas to their presettlement conditions (Goodloe 1993, 1999). Severely depleted juniper-pinyon sites recover very slowly with the removal of grazing. In some other vegetative types, improvements can be expected by removing livestock grazing, but desired responses are slow to occur in many juniper-pinyon stands. Principal reasons are the absence of a seed source and the competition exerted by pinyon and juniper. To return most juniper-pinyon areas to a more natural state, tree competition should be reduced, a suitable seedbed created, and sites properly seeded.

Chaining or other mechanical treatments used to reduce tree density are substitutes for natural tree control most frequently attained by wildfires. The objective of most improvement projects is not to remove all trees, but to allow recovery of the understory species and to facilitate artificial seeding (Stevens 1999a). Creation of a diverse understory is normally required to enhance resource values and help control the spread and growth of trees and annual weeds. Tree removal, by whatever means, is simply a technique used to change the seral status of many sites (Stevens 1999b).

Removal of Competition

There is a need to enhance watershed conditions and water quality, increase spring flow, improve understories, and improve big game, nongame, and livestock habitat in the juniper-pinyon woodlands (Roundy and Vernon 1999). A large number of acres of juniper-pinyon woodlands have been treated by chaining and railing. When comparing results from early projects with today's plant materials, equipment, techniques, standards, and results, some mistakes were made in the past. However, most older chainings and seedings are now exhibiting desirable improvements in watershed stability (Roundy and Vernon 1999) provided by more natural plant associations. Results from poorly designed and managed projects should not prevent further treatment projects. Decisions should be based on recovery and stability of native plant communities and the use of today's plant materials, equipment, and techniques. Guidelines have been developed for chaining and seeding (Fairchild 1999; Nelson and others 1999).

Removal of competing trees can be accomplished in a number of ways. Prescribed fire can be an effective practice in some areas. Twice-over anchor chaining, with 90-lb (41-kg) links, in opposite directions have been used extensively in juniper-pinyon control and thinning (Plummer and others 1968; Stevens 1999b). Use of cable or a chain of lighter links is satisfactory where it is desired to leave more trees and shrubs. Once-over chaining may be adequate when sufficient understory remains, trees are sparse and mature, and seeding is not required. Cabling is less effective than chaining in removing trees and creating a seedbed.

Anchor chains are pulled behind two crawler tractors traveling parallel to each other. For maximum tree removal, chains cannot be dragged while stretched taut, but must be dragged in loose, J-shaped, U-shaped, or half-circle patterns. The half-circle configuration provides the greatest swath width and lowest percentage tree kill. It is primarily used in mature, even-age stands and when a low percent tree kill is desired. Tree kill increases as the width of the J- or U-shaped pattern decreases. As the proportion of young trees increases, chaining width should decrease to remove the greatest number of young trees, if this is the objective (Stevens 1999b).

Success in removing trees varies with species composition, tree age structure, and density. Trees in mature, even-age stands can be uprooted more effectively and efficiently than in uneven-age stands (Van Pelt and others 1990). Young trees less than 4 ft (1.2 m) tall generally are not killed with single or double chaining because the chain rides over the plants without causing damage (fig. 21). Young pinyon are much more flexible than are young juniper, resulting in less kill of small pinyon.

Chaining has commonly been confined to slopes of less than 50 percent (Vallentine 1989). In Utah, successful chaining has been accomplished on slopes up to 65 percent with both chainings being downhill. First and second chainings can be done in the fall, with seeding taking place between the two chainings. Another technique is to chain once during the summer months. Trees are then allowed to dry out before seeding, and the second chaining is done in the fall. Dry trees break up easily and are scattered over the area when this technique is used.

Figure 21—Young pinyon and juniper trees normally are not uprooted with chaining, and can recover quickly as older trees are removed.

It is advantageous to leave downed trees in place and not pile or burn them. Some advantages include: (1) retention and detention of surface water, preventing erosion and increasing infiltration; (2) increased ground cover; (3) improved wildlife habitat; (4) inceased big game and livestock movement onto the treated areas; (5) decreased livestock trailing; (6) more even distribution of livestock and big game which, in turn, provides for more even use; (7) improved seeded and natural seedling establishment (fig. 22); and (8) no cost for piling and burning.

Planting Season

Late fall until midwinter (October through January) is the preferred planting period. Seedings should only occur when seed can be properly covered. Delaying seeding until late fall or midwinter reduces seed depredation by rodents and birds. Fall and winter plantings provide adequate time for stratification of planted

Figure 22—Tree limbs provide ideal microsites for seedling establishment of: (A) grasses and (B) shrubs.

seeds, and ensures that seeds are in the ground when temperature and soil moisture conditions are most favorable (early spring) for germination and seedling establishment.

Planting Procedures

Seeders attached to fixed-wing aircraft and helicopters are designed to broadcast seed uniformly. The majority of juniper-pinyon chainings and burns in the Intermountain West have been aerially seeded. Most grasses, forbs, and small seeded shrubs such as sagebrush and rabbitbrush can be seeded successfully with both fixed-wing aircraft and helicopters. Helicopters generally are better adapted to seed small or irregular areas. Downdraft from helicopters can somewhat separate seed by size and weight. There is a tendency for lighter seed to drift beyond the strip or zone where heavier seeds concentrate. Chaining has proven to be the most effective practice available to prepare a seedbed and cover seed following fire or chaining. If double cabling or chaining is employed, seeding should occur before the final treatment. Seeding prior to the first chaining is not recommended. The final chaining normally provides good seed coverage. Interseeding should occur prior to chaining when one-way chaining is employed.

When downed trees do not interfere, seed can also be covered using drags or a pipe harrow. Single disk harrows, or similar light-weight machinery, can be used to cover seeds in open, debris-free areas. Care must be taken to ensure that seeds are not covered too deep and seedbeds are not too loose. Chaining, or equivalent treatments, are required to cover seed when burned sites are broadcast seeded. If mechanical coverage is not used, seeding is best done by placing seed on top of a blanket of snow.

Rangeland drills can be used to seed many species on large open areas. Again, care should be taken to ensure that seeds are properly covered. As a general rule, most seed should be covered no more than three times their own thickness, or to a depth of about ¼ to ⅜ inch (0.6 to 1 cm). Some species do, however, benefit from seeding on a disturbed soil surface.

Seeds that are in short supply or those that require a firm seedbed can be seeded with a Hansen Seed Dribbler or thimble seeder mounted on the deck of a crawler tractor. Seed is metered onto the crawler tracks, then embedded in the soil by the tractor's tracks.

Planting Adapted Species and Mixtures

Tremendous variation exists in soils and biotic condition within the juniper-pinyon type and in any given area. Consequently, a number of species adapted to specific sites and conditions should be used (fig. 23). The primary objective in any restoration project should be to restore ecologically adapted communities. This objective is currently more attainable as native seeds become increasingly more available. Planting practices have been developed to seed diverse species. Table 14 lists species adapted to pinyon-juniper communities that receive less than 11 inches (280 mm) annual precipitation. Table 15 lists species adapted to sites that received 11 to 15 inches (280 to 380 mm) of precipitation, and table 16 lists species that are adapted to sites that receive over 15 inches (380 mm) of annual precipitation. Within the juniper and pinyon vegetative type, small to rather large stands of fourwing saltbush and other salt desert species can be found. These areas generally have soils that contain more clay, may have a hardpan, and have a slightly higher pH. Species adapted to juniper-pinyon sites with considerable fourwing saltbush (salt desert shrublands)

Figure 23—(A) A depleted stand of pinyon and juniper prior to chaining and seeding. (B) Similar area eight years after treatment.

are listed in table 17. Care must be taken to ensure that aggressive species do not dominate the mixture, and once established, do not dominate the seeded and indigenous communities. Crested, desert, intermediate, and pubescent wheatgrass, smooth brome, and hard sheep fescue will outcompete most seeded and native species, thereby attaining dominance.

Numerous native species have and are being developed for restoration of juniper-pinyon communities (McArthur and Young 1999). Sufficient amounts of seed are available from wildland collections and cultivated fields to provide adapted ecotypes of a number of species. Sufficient seed can usually be obtained during a 1- to 2-year period. Seed of bluebunch wheatgrass, western wheatgrass, thickspike wheatgrass, streambank wheatgrass, basin wildrye, bottlebrush squirreltail, Indian ricegrass, Sandberg bluegrass, big bluegrass, green needlegrass, needle-and-thread, Lewis flax, various species of penstemon, western yarrow, globemallow, and other herbs are normally available. Seed lots of big sagebrush, black sagebrush, rubber rabbitbrush, antelope bitterbrush, cliffrose, mountain mahogany, ephedra, fourwing saltbush, shadscale, and winterfat are commonly collected and marketed in sufficient amounts to seed large tracts. Additional grasses and broadleaf herbs are being reared under cultivation and will become more available at cheaper prices in the future.

Benefits and Features of Chaining

Because of the controversy that has developed regarding rehabilitation or restoration projects, the following information about the proper use of chaining in juniper-pinyon communities is provided.

Juniper-pinyon communities are unique and important sites. These areas normally support big game and other wildlife during critical spring, fall, and winter months. Often the sites are important watersheds. Although they may not store and discharge large amounts of water, unstable areas often contribute sediment and affect downstream water quality. Restoration procedures, currently employed to treat unstable sites, have been developed to restore wildlife habitat, provide livestock forage, and stabilize watershed conditions. Most restoration projects are designed to improve or stabilize a number of resource values. For this reason, restoration measures must be carefully developed for each situation.

Restoration of most disturbances should be designed to regain the original composition of species and allow the communities to function naturally. Treatments should allow the recovery of suppressed understory species, and reintroduction of species that have been displaced. Designing treatments to restore only a specific resource, such as soil protection, livestock forage, or wildlife habitat, may not be ecologically sound or advisable. Following is a description of some features of anchor chaining:

1. Chaining is an effective method for restoring juniper-pinyon communities.

It is apparent that trees must be removed to reduce competition and allow new understory seedlings to establish. Various practices have been evaluated as methods to reduce or control trees. Fires, hand cutting, herbicides, hula-dozing, and railing have all been used, but chaining is most functional. It provides adequate tree control, creates desired seedbeds, and accommodates seeding.

Chaining can be effectively used to regulate or manipulate plant composition without destruction of understory species. Chain link size, modifications to links, and operation of the crawler tractor will determine the number and size of trees that are removed and the effects on understory species. Types and size of chains and chaining practices can be regulated to retain most existing understory species, yet sufficiently reduce tree competition to facilitate seeding and promote natural recovery of understory species.

Through extensive testing and development of alternate techniques and equipment, chaining has proven to be the least destructive technique to existing vegetation and soil. Compared with other methods of mechanical treatment (plowing, disking) or use of herbicides or fire, this practice can be selectively used to reduce tree density in desired locations without disruption of understory plants and nontarget areas.

Soil conditions, including watershed stability, can be improved with chaining. Many treatment practices, including burning, leave bare soil, and sites are subjected to erosion for a number of years following treatment. Chaining leaves considerable litter on the surface, which improves watershed protection by retaining and detaining surface runoff and increasing infiltration. Debris is also deposited in gullies, draws, and waterways, thereby reducing erosion and sedimentation within drainages.

Chaining improves watershed and vegetative conditions. Its primary advantage is that the practice can be used at almost any season of the year. Plowing, spraying, and burning must be conducted at specific times, depending on soil moisture, stage of plant growth, and access. Treatment by these methods is often completed at a time when sites are subjected to erosion or when unfavorable seedbed conditions occur. In many situations, burning or other methods of plant control require followup treatments to reduce erosion or limit weed invasion. Chaining can be conducted at the most appropriate season to benefit soil stability, create a desirable seedbed, plant seed, and reduce invasion of weeds. Currently, no other treatment provides the flexibility afforded by chaining.

Chaining can be used to help control weeds that normally exist within depleted juniper-pinyon stands. Since chaining does not disrupt existing perennial understory species, desirable perennials recover quickly following reduction in tree competition and provide immediate competition to potential weeds. Adding species by seeding also increases competition to weedy plants. Soil nutrients and site productivity can be maintained by chaining. Surface litter and plant debris are maintained onsite, whereas burning removes nutrients, litter, and debris. Soil profiles are not disrupted with chaining as they would be with plowing or disking.

2. Chaining can selectively reduce desired density and most age classes of trees.

Chaining is a technique that can be used to retain selected trees, if desired. The amount or number of trees removed can be regulated by widening or narrowing the operating distance between the tractors, or changing speed or direction of operation. The weight or size of the chain used and the number and position of swivels located in the chain can also be used to regulate the extent of tree removal. However, operational procedures can be simply modified by positioning and regulating the speed of the crawler tractors.

Different types of equipment are not required to treat highly variable sites. Prior to chaining, the area can be inventoried, and a chain of appropriate size and length can be selected. Once a chain size is selected, operation of the tractors can be used to regulate the number of trees that are removed. Hula dozing or cutting of individual trees also provides considerable flexibility, but costs and treatment time are normally prohibitive. The practice of chaining can be very site specific, and can be easily regulated to affect specific community types, aspects, or acreage. Compared with burning, this practice can be specifically targeted to small, irregular tracts. The degree of tree removal using chemical sprays or burning is difficult to control. Areas treated with either of these practices often results in complete removal of all vegetation, although stands or patches may be left that are untreated. However, it is much more difficult to remove only a certain fraction of the trees by burning or chemical spraying without also affecting the understory.

Since chaining can be conducted during almost any season, the extent of trees or understory removed can be determined by treating on different dates based on plant growth and soil moisture conditions. Chaining, during early winter when trees are brittle and snow covers the understory, generally results in removal of most trees and some shrubs, including big sagebrush, without damage to understory herbs. Chaining during the growing season, when woody species are more flexible, normally leaves more shrubs undamaged. Chaining late in the growing season, when soil moisture has been depleted, results in more complete uprooting of trees and shrubs than if sites are chained in early spring.

Chains with attached swivels and couplings are available to most public agencies and private users. Transportation and setup costs are not prohibitive. Individual chains require little maintenance and repairs are infrequent. Compared with other machinery, repair costs are minimal and little investment is needed for tools or repairs.

3. Chaining can provide suitable seedbeds for many species and can be used to cover seed on diverse sites.

Various practices used to control trees—spraying, burning, hula dozing, and hand-cutting—do not prepare a seedbed or aid in actual seeding. Chaining can, however, provide satisfactory seedbeds on even, steep, and irregular, terrain, and on critical watersheds. Under normal chaining conditions, suitable seedbeds are created to plant seeds of a number of species with different seedbed requirements. Chaining scarifies the soil, creating numerous microsites where seeds are planted at various depths. Seeds can be broadcast before or after chaining to take advantage of the different planting depths, surface compaction, and soil mixing that occurs. Planting before or after chaining determines which species may initially establish and become prominent in the plant community.

Natural seeding of native species can be enhanced by chaining, especially when chaining occurs after seeds mature. Chaining can also promote sprouting of some species, and if done at the correct season, favors their recovery and spread. Chaining can also be used to diminish or control weeds.

Chaining and seeding can be conducted at the most appropriate season for enhancing establishment of the planted species. Within most of the Great Basin, fall seedings have proven to be the most ideal time to plant. Spring seedings should only occur prior to mid-March and only with species that germinate and establish quickly. In southern Utah, southern Nevada, and northern Arizona, seeding just prior to the mid-July summer storms has resulted in good success if the storms come.

Satisfactory seedbeds can be prepared with chaining on rough, steep, and irregular sites. Attaining uniform and competitive stands on irregular terrain and variable soil conditions is extremely difficult with most conventional seeding practices. Chaining produces the most uniform stands on poorly accessible sites of any technique now available.

Although burning or spraying can be used to control tree competition, an additional technique is needed to prepare a seedbed and to plant seeds. Seeds may be broadcast on fresh burns or sprayed sites; however, many species require some degree of seed coverage.

Chaining provides all degrees of soil coverage, resulting in the establishment of a diversity of species. Chaining favors soil moisture accumulation, and can be conducted when conditions are most favorable for seed germination and seedling establishment. Chaining and seeding can be accomplished when sites are bare or covered with snow, without accelerating runoff and loss of soil moisture. Although some land managers fail to recognize the importance of seeding at specified periods when soil moisture is most favorable, this is one of the most critical issues determining planting success. Chaining offers an option to quickly and effectively treat small and large diverse sites.

4. Chaining does not destroy resource values. Any plant conversion or regulation practice can impact a number of wildland resources. Most revegetation or restoration measures are designed to remove existing weedy, woody, and herb species, and to reestablish natural plant succession. Removal of existing trees creates an abrupt and often dramatic change in plant density, structure, and age class. Recovery of the native species can frequently take many years to provide a visible, mature assembly of plants. During the recovery period, the impacts can be quite apparent. When properly done, chaining will not degrade or destroy soil or watershed resources. It is a practice designed to modify plant composition, stabilize erosion, provide suitable seedbeds, and cover seed. Selection of appropriate treatment practices should be based on restoration objectives.

Basic Guidelines for Juniper-Pinyon Chaining Projects

Site Considerations

Selection of treatable areas: Treat only problem sites where the opportunity for success exist. Base decisions on ecological status of the community.

Areas to be treated: No more than 50 percent of the total area should be treated at one time. Natural travel lanes, resting and thermal cover areas, snags, older chronological record trees, archeological sites, corridors that connect nonchained areas, and areas with high visual values should not be treated.

Design of chained area: Chaining should be designed to provide maximum mosaic of treated and nontreated sites that fit within topographic conditions and provide maximum aesthetic and edge effect. Treatments should match natural community zones. Almost all nonchained areas should interconnect with continuous, live, mature tree corridors at least 30 ft (9.2 m) wide.

Accessible slopes: Areas with slopes as steep as 60 percent can be effectively and safely chained. First and second chaining can be in the same direction, which may be downhill.

Maximum size of openings: Size of clearing should not exceed 100 yards (91 m) at its widest points.

Vegetative Considerations

Age class and stand structure: Highest tree removal success will occur within even-age mature tree stands. A large percent of trees will survive chaining in young and uneven-age communities. Presence of large trees usually indicates high site potential.

Tree density: Tree density and size of trees will, in part, determine link size, length of chain, and tractor requirement costs of treatment.

Treatment of downed trees: Uprooted trees should be left in place. Debris should not be concentrated in windrows or pushed into piles. Dry trees should not be burned.

Selection of seeded species: Species and accessions that are planted must be site adapted and provide an ecologically compatible community. Species selection and seeding rates will depend on presence and composition of existing species and seedbank. Seed mixtures should consist of a diverse number of species, including a majority of native species. Restraint should be used in seeding competitive, exotic grasses.

Methodology

Timing: Reduction of tree competition, preparation of a seedbed, and seeding generally requires two chainings. The first chaining may be conducted anytime during summer or fall. The second chaining should occur at the most advantageous time for seeding, which, in most cases, will be late fall or early winter.

Chain type: Smooth chains provide good control of mature trees, moderate soil and understory species disturbance, and seed coverage. Trees that are uprooted are normally left in place. Ely chains provide good control of mature and intermediate-aged trees and can be operated to remove some shrubs and other understory species. Uprooted trees often are accumulated in piles. The Dixie chain is not recommended for treatment of dense tree stands. This chain performs best in open scattered stands and can be used to uproot small trees and understory shrubs. This modified chain eliminates more

plants and provides greater soil scarification than other types of chains.

Weight of chain: Chains with individual links that weigh 40 to 60 lb (18 to 27 kg) should be used where the objective is to minimize disturbance of understory species. Heavier links of 60 to 90 lb (27 to 41 kg) are used when trees are dense and larger, and where little understory exists and maximum soil tillage is desired.

Length of chain: Chains 300 to 350 ft (91 to 107 m) long are the most commonly used lengths. Chains can be up to 450 ft (138 m) long. Size of crawler tractor, weight of chain, density and size of trees, and topography will determine chain length.

Swivels: Swivels are used to allow the chain to turn freely and prevent chain twisting and balling. One swivel is required at either end of the chain and it is recommended that one or more be placed within the chain, especially when using a Dixie or Ely chain. Swivels also regulate the amount of digging or soil tillage.

Size of crawler tractor: Crawler tractors that are rated D8 or larger should be used. Weight and length of chain, density and size of trees, percent slope, and amount and size of rocks will affect tractor power requirements. Properly powered tractors are a must.

Field operations: Trees are most effectively uprooted when tractors are not directly parallel to each other, but rather operated in a J shape, with one tractor ahead of the other. Tree removal and soil tillage increases as tractors are positioned closer together. The further the tractors are spread apart the lower the percent of tree kill and the less understory vegetation and soil is disturbed.

Seeding techniques: Seed is most effectively distributed by broadcasting from fixed-wing aircraft and helicopters between the first and second chainings. Drills can only be used on more level areas with few downed trees, shrubs, or rocks. Seed dribblers or thimble seeders can be mounted on each crawler tractor, and seeds can be planted during the first or both chaining operations.

Summary

Where seeding is to occur, competition from existing trees must be reduced to allow the new seedlings to establish. Twice-over anchor chaining in opposite directions with 60 to 90 lb (27 to 41 kg) links is usually the most satisfactory treatment (Plummer and others 1968). Use of a cable or a chain with lighter links is satisfactory where it is desirous to leave more trees. Once-over chaining may be adequate when sufficient understory exists, tree competition removal is attainable, and seeding is not planned. Cabling is less effective than chaining in removing trees and covering seed. It also disturbs less understory.

Anchor chains are pulled behind two crawler tractors traveling parallel to each other. Chains cannot be dragged stretched taut, but must be dragged in a loose J-shaped, U-shaped, or half-circle pattern. The half-circle configuration provides the greatest swath width and lowest percentage of tree kill, and should only be used in mature, even-age stands. Tree kill increases as the width of the J- or U-shaped pattern decreases. The J-shaped pattern is the most desirable. As the proportion of young trees increases, chaining width is usually decreased to achieve satisfactory thinning.

Success in removing trees varies with species composition, age structure, and density of trees. Mature trees can be killed more effectively and efficiently than trees in uneven-age stands. Young trees, less than 4 ft (1.2 m) tall, generally are not killed with single or even double chaining, (fig. 21) because the chain rides over them. Small junipers are uprooted and killed more effectively than are small pinyons that are more flexible. Chaining is commonly conducted on slopes of up to 50 to 60 percent (Vallentine 1989). In Utah, successful chaining has been accomplished on 65-percent slopes.

First and second chaining can follow each other in the fall with seeding occurring between chainings. Another technique is to chain once during the summer. Trees are allowed to dry before seeding, and the second chaining is done in the fall. The dry trees break up easily and are scattered over the area in a uniform pattern. It is advantageous to leave downed trees in place and not pile or burn them. Leaving trees in place: (1) reduces surface runoff, (2) increases ground cover, (3) provides cover for wildlife, (4) encourages big game movement onto the treated area, (5) provides shade for livestock, (6) decreases livestock trailing, (7) improves seedling establishment (fig. 22), and (8) eliminates cost of piling and burning.

Late fall or winter (October through February) is the preferred planting period. Seeding should not be attempted in frozen soil. Seedings should occur when it is possible to plant and cover the seed properly. Late fall and winter seedings can result in reduced rodent depredation, yet provide adequate stratification of planted seeds. Fall-planted seeds remain in the ground until conditions are the most ideal (early spring) for germination and establishment.

With double cabling, seeding should occur between the two chainings. Fixed-wing aircraft and helicopters

can broadcast seed uniformly. Helicopters generally do a better job of distributing seed over small or irregular areas. Where downed trees do not interfere, seed can also be covered successfully using drags or a pipe harrow. Single disk harrows or similar light machinery can also be used to cover the seed. Care must be taken to ensure that seeds are not covered too deep and seedbeds are not too loose. Chaining or equivalent treatment is required to cover seed after burning.

On large, somewhat even, open areas that are relatively free of debris and large rocks, drills can be used to plant many species. Care should be taken to ensure that seeds of most species are properly covered. As a general rule, seed should be covered at least but not much more than three times their own thickness or to a depth of ¼ to ⅜ inch (0.6 to 1 cm). There are, however, species that require surface seeding on disturbed soils and a few that require deep seeding.

Seeds of shrubs and forbs that are in short supply or those that require a firm seedbed can be successfully seeded with a Hansen seed dribbler or thimble seeder that is mounted on the deck of a crawler tractor. Seed is metered out on the crawler tracks, then pushed by the weight of the crawler into the cleat marks. Excellent stands can be obtained with this procedure.

The tremendous variation in edaphic and climatic condition in the pinyon-juniper type and within a site requires that species and accessions adapted to specific sites be seeded (fig. 23). Tables 14 through 17 list adapted species and suggested mixtures.

Sagebrush Communities

Sagebrush is one of the most widespread shrub genera in the Intermountain West. Extensive stands of sagebrush grow on low foothill ranges, adjacent valley slopes, within stands of mountain brush and aspen, and in subalpine zones above 10,000 ft (3,048 m). Sagebrush is also an important component of the southern desert shrub type where it grows in association with blackbrush and spreading creosotebush. This wide range of occurrence in differing climates and soils necessitates the use of varied treatments to improve disturbances. Treatment depends on how much sagebrush is to be retained or reestablished. Big sagebrush is a natural component in many communities and is desirable on most big game and livestock ranges within its area of distribution (fig. 24). Sage-grouse rely on sagebrush year around for food and shelter (fig. 25). However, where understory species have been removed by grazing and where big sagebrush has usurped the site and excluded understory species, stands should be thinned to permit reestablishment of understory grasses and forbs.

Figure 24—Wyoming big sagebrush communities are essential to pronghorn antelope and other wildlife.

Eight major sagebrush communities are encountered in the Intermountain region. The big sagebrush complex occupies one of the largest areas and produces perhaps the greatest amount of forage of any shrub. Three big sagebrush subspecies are generally recognized (Shultz 1986; Stevens 1987a): basin big sagebrush, mountain big sagebrush, and Wyoming big sagebrush. Other major sagebrush types are black sagebrush, low sagebrush, threetip sagebrush, silver sagebrush, and alkali or early sagebrush. Of minor importance are foothill big sagebrush, subalpine sagebrush, pygmy sagebrush, Bigelow sagebrush, stiff sagebrush, and bud sage (Shultz 1986; Stevens 1987a).

Figure 25—Big sagebrush provides sage-grouse with cover, forage, and brood-rearing areas.

Other shrubs usually occur within most sagebrush communities.

Previously, most site improvement practices conducted in the sagebrush communities have been designed to reduce shrub density and reestablish herbaceous understory. In many situations, extensive wildfires have eliminated species of sagebrush. Extensive and prolonged grazing has also reduced both understory species and shrub cover, which has allowed weeds to establish. Sagebrush seedling recruitment has subsequently been halted, and stands have slowly declined as individual plants succumb with age. In many situations, planting sagebrush is now required.

Big sagebrush communities are easily disturbed, especially on drier sites. Few understory species occur in the drier regions, and disturbances recover slowly. Annual weeds have invaded and now dominate many big sagebrush communities (Billings 1990; Young 1994). The occurrence of cheatgrass has dramatically altered species composition and restoration methods (Monsen 1994). Cheatgrass is so competitive that it prevents natural recovery of most native herbs and shrubs (Billings 1994). Cheatgrass competition must be reduced to allow other species to reestablish. In addition, cheatgrass produces a dry, highly flammable fuel that results in more frequent wildfires than are generated from native plant communities. Repeated fires further degrade the sites, eliminating nonfire-tolerant species, such as sagebrush, and perpetuate annual grass. The fire cycle must be broken to stabilize conditions and allow species to establish and recover from seedings or natural improvement. Aggressive control measures coupled with well-designed seedings are required to improve weed infested sites.

Many sagebrush sites currently support some annual weeds including cheatgrass. Inappropriate grazing practices cause continued decline of native perennials, allowing expansion of weeds. Transition may occur slowly, depending on climatic conditions and degree of grazing pressure. Natural recovery usually cannot occur unless grazing is completely discontinued. Certain species may recover with some carefully managed grazing practices, but sites that contain only scattered remnant native plants are not able to recover even with minimal use. Where there is some perennial understory in place, removal of grazing may be the most effective and economical means of restoring sites occupied by different species of sagebrush. Many sites may require an extended period of time for all species to fully recover. Consequently, it is often advisable to protect many arid and semiarid shrublands to prevent further degredation, control weed invasion, and effectively restore diverse communities. Allowing sites to deteriorate to the point that artificial seeding is required is not advisable.

Methods and techniques used to treat different species of sagebrush are quite similar, although some differences in control and seeding measures among different sagebrush communities are recommended.

Removal of Competition: Control of Sagebrush

Many stands of big sagebrush have been depleted of almost all understory herbs, which allows shrub density to increase beyond desirable levels. Where this has occurred, the shrub overstory must be reduced to faciliatate seeding and allow establishment of reintroduced herbs. Complete removal of shrub overstory is not required or recommended, but competition must be diminished to facilitate seedling establishment. In some situations, complete removal of shrubs has been advocated to accomplish conversion to stands of introduced or native grasses, with the objective of enhancing seasonal grazing for livestock. This practice is not recommended in most situations.

Anchor chaining is a useful practice where it is desirable to release suppressed understory species. Anchor chaining is the least expensive mechanical treatment to reduce thick stands of sagebrush. This treatment ensures that enough sagebrush can be left to satisfy most game requirements and maintain species diversity. Chaining can be used on a variety of sites including rocky surfaces and terrain with 60-percent slopes. The Dixie chain was designed especially for treating sagebrush stands. Eighteen-inch lengths of 40-lb (18 kg) rails welded across the chain links greatly increase elimination of sagebrush and create a better seedbed. The Dixie chain removes sagebrush more effectively than a smooth or Ely chain.

Pipe harrowing accomplishes many of the same objectives as does chaining, but has the advantage of operating more economically on small areas. Disk plowing to a depth of 2 or 3 inches (5 or 7.5 cm) generally removes most shrubs, but disking is more costly and more destructive to other vegetation. Disk plowing can be used on comparatively level terrain and on less rocky sites than is practicable for chaining. Brush "beaters" and root plows also may be used on such sites.

Controlled burning can be the least expensive and most effective treatment for removing sagebrush plants on large tracts where there is enough fuel to carry fire. Burning often removes or kills all sagebrush plants. Consequently, throughout the Wyoming sagebrush communities, limiting burning, if possible, to smaller areas is often recommended. Natural recruitment and artificial seeding of sagebrush are not always successful following complete removal of all sagebrush plants over large areas. If cheatgrass occurs in the understory, burning should be done after cheatgrass seeds are ripe and the foliage has dried, but before cheatgrass

seeds fall from the plant. Most seeds left on the plant will be consumed by fire. Some cheatgrass seeds usually escape, but the resulting competition may not be severe enough to suppress establishment of seeded species.

Stands of sagebrush can be eliminated by spraying with 2,4-D in ester formulations at 1 or 2 lb (0.4 or 0.75 kg) (acid equivalent) per acre (Blaisdell and others 1982). A practice that has gained considerable favor is to spray early in the summer and then seed adapted species in fall or winter. This treatment, however, is not widely suited to use on some ranges because it often kills too much of the sagebrush stand and eliminates associated forbs. The herbicide "Spike" can be used to reduce density or remove big sagebrush without harming the understory. Spike should only be used when there is an acceptable understory because areas treated with Spike cannot be seeded for at least 3 years following treatment. Mechanical methods of eradication are usually preferred because they can be regulated to eliminate desired amounts of big sagebrush, create a good seedbed, and preserve valuable herbs that are present.

Shrub Enhancement

In many situations restoration measures are required to enhance or restore sagebrush plants and associated understory species. Many burns have eliminated all sagebrush plants. These will require seeding. If annual weeds dominate the understory, the herbaceous competition must be removed by burning, disking, or use of herbicides. Shrubs and herbs can then be seeded into the burned areas or into clearings or strips formed by mechanical tillage or chemical fallow.

Big sagebrush plants are most often capable of invading weak stands of native grasses, and forbs. Broadcast seeding sagebrush without any site preparation can be successful if weeds are not present. Broadcast seeding sagebrush directly onto sites supporting Idaho fescue, Sandberg bluegrass, and bluebunch wheatgrass following burning can be highly successful. Broadcast seeding sagebrush onto existing stands of native grasses is less successful if competition has not been reduced by burning. However, adequate stands of shrubs may establish, although timing and amount of moisture is much more important.

Planting Season

If weather permits, planting in winter is best; however, seedings may be conducted from late fall through early winter. Mid October or early November is sufficiently early to start. Planting may continue through December, January, and February, or until the ground has frozen or the weather prohibits further planting. Aerial seeding sagebrush on snow has proven highly successful. Snow cover can enhance sagebrush seed germination and seedling establishment. Sites receiving a snow cover that persists until early spring normally support sagebrush emergence. Consequently, delaying seeding until a uniform blanket of snow has accumulated is advisable.

Planting Procedures

On large areas, aerial broadcasting grasses, broadleaf herbs, and big sagebrush (fig. 26) seeds by fixed-wing plane or helicopter is recommended. Hand broadcasting is efficient on small, isolated tracts. Anchor chaining is economical and effective for covering broadcast seeded herbs and sagebrush on large disked or plowed areas, burns, or herbicide-treated range. The rangeland drill or other single-disk drills can satisfactorily plant sagebrush sites. Drilling requires one-third to one-half less seed than broadcasting. Browse seed, including sagebrush, should be planted in alternate rows from grasses and forbs, with either the rangeland drill or browse seeder. Because sagebrush seed requires very shallow to surface planting, it is best to pull the drop tubes from between the furrow openers and place it so the seed falls behind the furrow openers onto the disturbed soil.

Most species of sagebrush can be successfully seeded with good success, although special consideration must be given to control herbaceous competition. The condition and quality of sagebrush seed is of particular concern in most seeding projects. Seeds of most sagebrush taxa mature in late fall or early winter after many revegetation projects would

Figure 26—Five years after chaining treatment, a mixture of native and introduced species occupy a pinyon and juniper site.

be seeded. Consequently, fresh seed is not always used. One- or 2-year-old seed is most commonly planted. Seed lots of most sagebrush taxa may remain viable for 2 to 4 years depending upon storage conditions (Stevens and Jorgensen 1994). Older seed lots with low viability may be seeded if sufficient amounts are sown. Seeds should be properly stored and tested to assure high quality seeds are used whenever possible.

Sagebrush plants produce numerous small seeds. When harvested, seed lots usually contain a considerable amount of leaves and floral debris. During seed processing, most large sticks are removed, but small leaf and floral tissue is left with the seed. Seed lots having a purity of 8 to 18 percent are commonly sold. The condition of the seed lot can influence the way seed is planted. If the seed lot is chopped before stems are removed by cleaning, the material may not flow through some drills. If the collected material is first screened to remove sticks and then chopped or processed with a debearder, the seeds and debris can be planted much easier. The seed debris is very lightweight and, if not properly cleaned to remove stems, may not flow uniformly through most conventional drills. Consequently, a carrier or seed of other species may be added to cause the material to flow freely and uniformly. Seed lots that are cleaned to a purity exceeding 12 to 15 percent will most often flow very well. Seed lots with high purity (generally over 20 percent) consist of many small seeds. Most seeding equipment or machines are not capable of precisely metering the seed; consequently, the seed must be diluted to be uniformly planted. It is not recommended to clean seed lots above 15 to 20 percent purity for use with standard seeding equipment of if seeded alone.

Sagebrush seed is frequently mixed with seeds of other species to aid in dispensing the sagebrush seed and diluting the seeding rate. This is a useful technique, but sagebrush should not be directly sown with aggressive herbs. Sagebrush can be sown separately in alternate rows with herbs using most conventional drills if the seed is properly cleaned and seeded at the appropriate depth.

Seeds of sagebrush are almost exclusively collected from wildland stands. In many cases, the identity of the taxon is not known. More than any other wildland species, sagebrush seeds are collected and planted over a broad range of sites. Failure to correctly identify specific species, subspecies, and plant-adapted ecotypes can result in poor seeding success.

Seeds of sagebrush taxa are very small, often exceeding 1 million per pound (2.2 million per kg) (Shaw and Monsen 1990) and require light to germinate (McDonough and Harniss 1974a,b). However, the response to light varies among seed lots and with environmental conditions (Bewley and Black 1984; Meyer and others 1990b). Seeds must be planted on or near the soil surface to promote germination and ensure establishment. It is often difficult to plant sagebrush seed near the soil surface using conventional drills. Most seeding equipment is designed to place seeds at deeper depths. When seeded with other species that require deep placement in the soil, sagebrush should be planted in a separate operation or seeded in separate rows. Sagebrush seeds can be dispensed through conventional drills, but seed should not be planted at the bottom of the furrow. Seed tubes attached to the furrow opener can be removed and positioned so the end of the tubes extend behind the furrow openers, which allows the sagebrush seed to be dropped behind the furrow opener on the disturbed soil surface. A "sagebrush seeder" employing a gang of truck tires and a drill box has been developed (Boltz 1994) and is being used with good success. Seed is metered out ahead of the gang of tires and then compressed into the soil.

Sagebrush seeds require adequate moisture to germinate. Goodwin (1956) reported that the highest field germination occurred when the soil was saturated. Weldon and others (1959) found that germination of big sagebrush declined by 60 percent when water potential of the soil medium was reduced to –0.80 MPa. The soil surface of most planting sites dries quickly, adversely affecting seedling establishment. The presence of surface litter and retention of a snow cover benefit sagebrush seedling establishment. Meyer (1990) found greater numbers of big sagebrush seedlings within areas where snow collected compared to open surfaces. Sagebrush seeds were able to germinate beneath the snow in a moist environment, and were protected from spring frosts, as young seedlings have little frost tolerance. Natural seedlings of big sagebrush normally establish near mature shrubs, and around and under downed pinyon-juniper trees and litter piles. The existing shrubs and downed trees obviously entrap snow and provide more favorable seedbed conditions than exposed sites. Seeding sagebrush in large, open disturbances has usually been unsuccessful because snow does not collect or is not retained for more than a few days. Within these areas, soil surfaces dry rapidly, and favorable conditions do not exist for seed germination or seedling establishment.

Meyer and Monsen (1992) found that germination response among sagebrush collections correlated to the habitat from which the seed is produced. Seed collections of mountain big sagebrush from severe winter sites had a larger dormant seed fraction and slower germination rates than collections from mild winter sites. Collections from severe winter sites require up to 113 days to germinate, while collections from mild winter sites require as few as 6 days. Habitat-correlated variation appears to be an adaptive feature

that prevents precocious germination, and promotes germination when frost damage potential is low and when the best chance of success occurs. Planting unadapted seed lots can undoubtedly lessen the chance of seedling establishment.

Sagebrush seedling establishment is related to the presence and composition of understory grasses and broadleaf herbs. Sagebrush seedlings are generally unable to compete with annual grasses, particularly cheatgrass (Evans and Young 1987a). Dense stands of perennial native and introduced grasses have been reported to reduce sagebrush seedling establishment and growth (Blaisdell 1949; Holmgren 1954). However, sagebrush seedings have frequently been able to invade many seeded areas (Blaisdell and others 1982). In general, sagebrush seedlings are less likely to reestablish and spread throughout areas receiving less than 12 inches (30 cm) of annual moisture than sites receiving greater amounts.

The relationship of sagebrush seedling establishment to native understory grasses and broadleaf herbs is not well understood. However, natural spread of sagebrush seedlings into established stands of understory herbs is frequently observed. In addition, seeding sagebrush directly into established stands of native herbs has also been successful.

Sagebrush seedlings establish satisfactorily using surface-type seeders such as a Brillion seeder (Monsen and Meyer 1990). Seedlings also establish well by aerial or broadcast seeding on a rough surface. Aerial seeding following chaining has been highly successful through the juniper-pinyon and big sagebrush communities. Broadcast seeding onto snow over disturbed soil in early or late winter also produces good stands (fig. 27). Most species of sagebrush can be interseeded or spot seeded into some existing competition (Monsen and Stevens 1987; Stevens 1980b). Interseeding in rows or strips is a practical method of establishing shrubs and providing a seed source for further spread.

Figure 27—Big sagebrush seedlings have successfully established from midwinter aerial seeding on sites covered by snow.

Adapted Species and Mixtures: Considerations in Selecting Species To Be Seeded

Extensive areas of sagebrush, particularly species of big sagebrush, have been seeded with introduced grasses to reestablish a herbaceous understory that was eliminated by previous mismanagement. Conversion of sagebrush shrublands to introduced forage grasses has provided a stable and productive forage base for livestock, enhanced watershed conditions, and has helped to control weed invasion. Wildlife resources have been enhanced occasionally; in most cases they have been dramatically reduced. Native species and community recovery have been prevented, and multiple-use management has been reduced or eliminated by converting shrublands to stands of introduced grass.

Converting or altering sagebrush communities must be done carefully to assure that desired resource values are retained or achieved. Numerous species are available to seed sagebrush sites. However, the communities that ultimately develop from mixed seedings must be recognized and appropriate seed mixtures utilized.

Revegetation efforts in the Wyoming big sagebrush and some basin big sagebrush habitat types are often only partially successful. These sites frequently receive inadequate moisture to sustain new seedlings. If seedings are completed in years of normal precipitation, planted species usually survive.

Attempts have been made to introduce other more palatable, shrub species and convert the existing shrub composition to more preferred and palatable species to Wyoming big sagebrush and basin big sagebrush communities. Few other woody plants naturally grow with these two shrubs. Antelope bitterbrush has been extensively planted throughout these sagebrush communities with limited success. In most instances, antelope bitterbrush should not be indiscriminately planted in “offsite” circumstances.

Sources of fourwing saltbush and winterfat have been collected from native stands occurring intermixed with both Wyoming and basin big sagebrush communities. These selections have been planted on broad areas throughout the big sagebrush types. Some individual selections demonstrate good longevity, but little natural spread has been recorded. No population of fourwing saltbush has been identified that is widely adapted to the Wyoming big sagebrush communities. Numerous Intermountain collections of fourwing

saltbush have been planted in southern Idaho, Utah, and Nevada, where Wyoming big sagebrush occurs. To date, some sources have established and produced seeds but no seedling recruitment has occurred. A number of sources from southern Utah, Arizona, New Mexico, and Texas have survived for less than 10 years when seeded in the northern portion of the Intermountain region. Ecotypes of fourwing saltbush that naturally occur intermixed with basin big sagebrush have established and persisted well if planted on sites similar to the area of collection. In most situations, however, it has not been practical to seed different species of shrubs on Wyoming big sagebrush types.

In situations where the density of fourwing saltbush, winterfat, or other shrubs is being increased by artificial seeding, it is imperative that an adapted seed source is planted. A number of cultivars of different native shrubs have been developed for use in the big sagebrush type (McArthur and others 1984b; Monsen and others 1985a; Welch and McArthur 1979a). Each cultivar has regional areas of adaptation and is not universally adapted to all conditions where big sagebrush occurs. Various attempts have been made to plant "Rincon" fourwing saltbush, "Hatch" winterfat, "Lassen" antelope bitterbrush, and "Hobble Creek" and "Gordon Creek" big sagebrush throughout the big sagebrush zone. These cultivars are adapted to specific locations, and plantings should be confined to these situations.

Most big sagebrush rangelands are subjected to wildfires, particularly sites that support an understory of cheatgrass. Burning reduces the density and recruitment of many species, particularly shrubs. It is advisable that species that are seeded into sagebrush-cheatgrass rangelands are able to withstand fires and recover by natural seeding. To date, ecotypes of fourwing saltbush and winterfat that have been planted in these areas have not survived fires, particularly on sites that burn frequently.

Few native forbs are available in sufficient amounts to seed large disturbances. Seed of blue aster, Palmer penstemon, western yarrow, globemallow, and Lewis flax are available to seed moderately sized disturbances. All available sources are adapted to specific site conditions. Broadleaf forbs are essential to arid shrublands, and development of additional sources is necessary.

Selections of alfalfa and small burnet have been developed and used to improve forage diversity, extend grazing periods, and enhance forage quality throughout the big sagebrush type. Both species are well adapted to sites receiving more than 12 inches (304 mm) of annual precipitation. Mountain big sagebrush and some basin big sagebrush and Wyoming big sagebrush stands receive this amount of precipitation. Stands of highly preferred species have not been maintained when small amounts of seed have been planted. Small burnet and alfalfa have frequently been planted at only 0.5 to 1.0 lb (0.2 to 0.45 kg) per acre within the big sagebrush types. These broadleaf herbs receive heavy use by all classes of animals, which may eliminate the plants from the seeded area. When highly preferred species are planted in mixtures, enough seed (2.5 to 4 lbs [1.2 to 1.8 kg]) should be seeded to establish a large enough population to reduce damage from concentrated grazing. Sufficiently large tracts should be seeded to lessen concentration of animals and heavy browsing of the more preferred species.

Many introduced and native species that have been seeded in the sagebrush types exhibit a wide range of adaptability. Crested wheatgrass, desert wheatgrass, intermediate wheatgrass, pubescent wheatgrass, Sandberg bluegrass, and bottlebrush squirreltail are widely adapted to the different habitat types of Wyoming and to basin big sagebrush. Bluebunch wheatgrass, Indian ricegrass, streambank wheatgrass, thickspike wheatgrass, needle-and-thread grass, and Russian wildrye are more sensitive to particular soil types occupied by these two shrubs, but are still widely used. Great Basin wildrye is more restricted to particular habitat types, and should only be seeded in areas of natural occurrence.

Desert wheatgrass, crested wheatgrass, intermediate wheatgrass, pubescent wheatgrass, Canby bluegrass, streambank wheatgrass, thickspike wheatgrass, and hard sheep fescue have been widely seeded in sagebrush communities. Numerous sites have been converted from a shrub-dominated community to an exotic perennial grass type. Desert wheatgrass has proven better adapted to more arid sites. Crested, pubescent, and intermediate wheatgrass, and hard sheep fescue are more suited to upland situations with southern smooth brome being suited to sites with higher amounts of precipitation. 'Hycrest' crested wheatgrass, a cross between desert and crested wheatgrass, and 'Douglas' wheatgrass express excellent establishment traits and are able to compete well with annual weeds. These two selections are not as drought tolerant as desert or crested wheatgrass. 'Douglas' wheatgrass is the least drought tolerant. 'Hycrest' wheatgrass has been widely planted, however, extensive stands have been lost in drought years. Desert, crested, 'Hycrest', intermediate wheatgrass, smooth brome, and hard sheep fescue have not proven compatible with most native herbs. When seeded in most sagebrush communities, these species will gain dominance and restrict recovery of native herbs. The lack of species diversity adversely affects wildlife habitat, and does not provide the seasonal herbage or watershed values as mixed communities do. Dominant stands of crested, desert, pubescent, intermediate

wheatgrass, smooth brome, and hard sheep fescue have, in many situations, prevented shrub seedling recruitment. Loss of sagebrush and other woody species slowly occurs in many situations when these grasses have been planted. Wildlife habitat and other resource values have been adversely affected. Seeding crested, desert, or intermediate wheatgrass and hard sheep fescue throughout the sagebrush communities should be evaluated to be sure management objectives will be achieved. Use of native herbs is desirable where diverse communities are required.

Basin Big Sagebrush

Basin big sagebrush (fig. 26, 27) is one of the most abundant shrubs in Western North America (McArthur and others 1979a). This plant occurs on plains, valley and canyon bottoms, and foothill ranges. It is most prevalent on deep, well-drained, fertile soils with a pH ranging from slightly acidic to highly alkaline. Within the Intermountain West, basin big sagebrush can be found from 3,000 to 7,000 ft (914 to 2,140 m) elevation, with annual precipitation ranging from 9 to 16 inches (23 to 41 cm).

A majority of the irrigated farmlands, dry farms, and dryland pastures within the Intermountain West were once dominated by basin big sagebrush. A large number of native and introduced grasses and forbs do well on these lands. The productive potential of the basin big sagebrush type is reported to be higher than that of the Wyoming big sagebrush type but less than the mountain big sagebrush type (Winward 1980).

Basin big sagebrush is not readily eaten by livestock or big game when it occurs with other, more preferred species (Hanks and others 1973; Sheehy and Winward 1981; Welch and others 1981). However, it does contain high levels of protein (McArthur and others 1979a; Welch 1981). The herbage is digestible (Welch 1981), and plants withstand heavy browsing. Deer and sheep use this shrub seasonally. This species is critical on deer winter ranges, especially during extended and deep snow accumulation and cold periods. Sage-grouse also use this subspecies throughout the entire year (Call 1979).

Removal of Competition

The question arises of how much basin big sagebrush is enough. Should it be controlled, reduced, or seeded? The value of the shrub cover should be carefully evaluated before attempts are made to reduce shrub density. This subspecies occurs in differing densities, with various types and amounts of associated species, and in differing climates and soils. Various range improvement treatments are thus required for satisfactory control. Complete or near complete elimination of basin big sagebrush can be accomplished with plowing, burning, or use of herbicides. Anchor chaining can be used to reduce shrub density. The extent to which the shrubs are killed by chaining is determined by the number of times a site is chained, the type of chain used, and the method and season of treatments. Similar results can be accomplished with a pipe harrow.

Disk chains and various types of disk plows have been developed that can be used to uproot and thin or remove dense stands of sagebrush. Disks can be adjusted to regulate the percent of plants uprooted. Disking and plowing can, however, result in kill of associated, desirable vegetation. Fire can be effective in eliminating or reducing basin big sagebrush. This shrub has essentially no fire tolerance. For fire to move through basin big sagebrush stands, there must be sufficient understory to carry the fire. Density of basin big sagebrush generally must be reduced to obtain satisfactory establishment of seeded understory species (fig. 28). Once a basin big sagebrush area is disturbed, it is imperative the area is seeded the same year (during the appropriate season) so undesirable species do not establish.

Planting Season

Fall and early winter planting is recommended; however, plantings at low elevations may be extended into midwinter or until frozen ground prevents tillage. Seeding on top of snow over areas that have been disturbed has proven successful (fig. 27). Spring plantings are not advised within this shrub type.

Planting Procedures

Seeding large areas can be best accomplished by aerial seeding using either a fixed-wing aircraft or helicopter. This should be followed by some method of seed coverage. Hand broadcasting is effective in planting small, isolated tracts. The rangeland drill, and other types of heavy duty drills, can be used to seed areas where debris and rocks are absent and the ground is fairly level. Species can be interplanted into sagebrush stands using a scalper and seeder combination (Stevens and others 1981b). The Hansen seed dribbler and thimble seeder are also effective equipment that can be used to seed many forbs and shrubs.

Adapted Species and Mixtures

A number of species, accessions, and varieties are adapted to and recommended for seeding areas formerly inhabited or occupied by basin big sagebrush (table 18). Species recommended for seeding mixed fourwing saltbush-basin big sagebrush sites are listed in table 17. A number of introduced grasses and

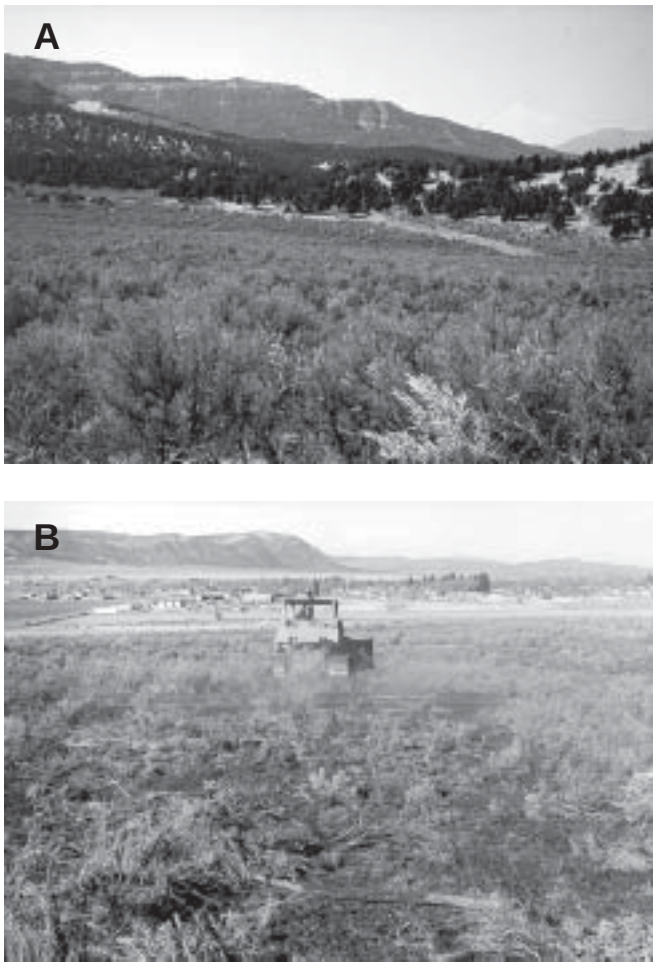

Figure 28—(A) Dense stands of basin big sagebrush often develop that lack understory species essential to wildlife. (B) Thinning stands of big sagebrush can be accomplished using a disk-chain to facilitate seeding of herbaceous species.

broadleaf herbs have been developed to revegetate these communities. In addition, some of the principal native grasses and some broadleaf herbs are available. The objectives of the project and availability of seed of adapted species will determine what is planted.

Mountain Big Sagebrush

Throughout the Intermountain West, mountain big sagebrush (fig. 29) is found at elevations from 3,500 to 9,800 ft (1,060 to 3,000 m) and occurs from foothills to subalpine zones. Annual precipitation ranges from 12 to 30 inches (300 to 760 mm). Soils on which mountain big sagebrush grows range from slightly acid to slightly alkaline (McArthur and others 1979a), and are generally well drained. Soil moisture is usually favorable throughout the growing season.

A large number of grass, forb, and shrub species grow in association with this shrub (Winward 1980), and usually produce an abundance of forage. Livestock, big and small game, and upland game birds prefer mountain big sagebrush (McArthur and others 1979a; Welch 1981). Open stands with good, diverse understory are essential to sage-grouse and must be used in treatment projects to maintain sufficient shrub density and cover for sage-grouse. It is essential that desirable understory species and woody species associated with mountain big sagebrush be retained or reestablished as part of the revegetation effort.

Removal of Competition

The use of herbicides, plowing, and disking are effective techniques in reducing competition, but often are not recommended for renovating mountain big sagebrush stands, particularly areas supporting big game and sage-grouse. These techniques usually kill most associated herbs and existing shrubs. Because mountain big sagebrush provides palatable and nutritious forage for wildlife throughout the year, it is not advisable to eliminate this shrub. Sage-grouse strutting, wintering, and chick-rearing areas can be seriously altered if mountain big sagebrush and associated native forbs are removed.

Mechanical treatments, including once- or twice-over chaining or pipe harrowing, will normally eliminate enough mountain big sagebrush to reduce competition, create a suitable seedbed, and preserve valuable forbs. If annual weeds dominate the understory and sagebrush density is extremely high, more aggressive

Figure 29—Mountain big sagebrush frequently grows in association with Gambel oak and an assembly of grasses and broadleaf herbs.

methods are required to reduce the competition. However, in many situations, thinning of mountain big sagebrush may be all that is required.

When herbicides are used, mountain big sagebrush should be treated at an earlier stage of growth than the other big sagebrush species. As leaves appear, it is especially susceptible to herbicides. It can be sprayed in early spring prior to the emergence of most understory species. If sprayed at a later date (late spring and early summer), mountain big sagebrush is less susceptible, and herbicides can be more detrimental to understory herbaceous species.

In stands where the associated herbaceous vegetation has been depleted by grazing or other causes, mountain big sagebrush can increase in density and size (Winward and Tisdale 1977). Early spring burns that occur soon after the snow starts to melt generally do not completely eliminate a stand. Burns at these dates will likely create a mosaic of shrubs and herbs. Herbicides can also be sprayed in similar patterns to create mosaics. Size and shape of areas treated must be designed to maintain or improve wildlife habitat, particularly for sage-grouse.

Planting Season

Late fall and early winter plantings are recommended. At higher elevations, plantings can be terminated by early heavy snowfall. Sites should not be spring planted. Sagebrush reduction or thinning operations in areas with healthy understory herbs may not require seeding. Areas that lack desirable herbaceous plants and those that are plowed or disked require seeding. Table 19 lists species that are adapted to the mountain big sagebrush type. The most successful seedings are those that include a mixture of species and are conducted in the fall just prior to snowfall.

Planting Procedures

Aerial broadcasting by fixed-wing plane or helicopter is recommended for seeding herbs and sagebrush seeds on large areas. Hand broadcasting or broadcasting with spreaders mounted on ground transport units are effective methods for seeding small tracts. Anchor chaining or pipe harrowing are economical and effective methods for covering broadcast seeds on depleted sites and large disked or plowed areas, burns, or herbicide-treated ranges. Mountain big sagebrush can be successfully seeded by broadcasting from aerial or ground units. This shrub can spread well by natural seeding. Chaining or other surface-manipulation practices will enhance natural spread. Seedlings of mountain sagebrush are competitive and able to establish and persist with some herbs; consequently, mixed plantings are normally successful.

Antelope bitterbrush, mountain snowberry, Stansbury cliffrose, mountain mahogany, sakatoon serviceberry, and chokecherry occur intermixed with mountain big sagebrush. These species should be drill seeded to assure seeds are placed in the soil at appropriate depths. The Hansen seed dribbler is very effective in seeding most shrub and forb species. This seeder is normally mounted on the truck or crawler tractor used to chain or pipe harrow mountain big sagebrush sites. Browse seeds can also be seeded in alternate rows with grasses and forbs with rangeland drills or modified browse seeders.

Adapted Species and Mixtures

Mountain big sagebrush communities normally support a diverse composition of species, and plantings should be designed to reestablish the entire community structure. Small but important stands of serviceberry, chokecherry, mountain mahogany, mountain snowberry, antelope bitterbrush, and Stansbury cliffrose are desirable and should be reestablished within mountain big sagebrush restoration projects where appropriate. It is important that understory herbs are reestablished along with the shrubs on depleted sites. Table 19 lists the primary species adapted to mountain big sagebrush sites.

Wyoming Big Sagebrush

This subspecies can be found throughout the Intermountain West on xeric sites, foothills, valleys, and mesas between 2,500 and 7,000 ft (760 and 2,100 m). Annual precipitation varies from 7 to 15 inches (180 to 280 mm). Soils on which Wyoming big sagebrush occurs are usually well drained, gravelly to stony, and may have low water-holding capacity. Soils are shallow, usually less than about 18 inches (46 cm) deep. Fewer herbaceous species are associated with Wyoming big sagebrush than with basin or mountain big sagebrush (Winward 1980). Native bunchgrasses are often important understory species in Wyoming big sagebrush communities. In some areas, this sagebrush may be used extensively throughout the year by livestock, big game, and upland game birds.

Removal of Competition

Following disturbance, Wyoming big sagebrush generally does not reestablish as rapidly as mountain big sagebrush. Cheatgrass has often displaced Wyoming big sagebrush and associated understory species. Control and eradication measures must be designed to replace this weed if plantings of perennial herbs and sagebrush are to be successful.

Stands of Wyoming big sagebrush normally do not produce abundant seed crops each year. Natural spread onto disturbed sites can be delayed until years when seeds are produced and favorable moisture conditions occur to support new seedlings. Attempts to seed this shrub in semiarid sites have not always been successful because of adverse climatic conditions. The amount and timing of late winter and early spring precipitation is critical for sagebrush seed germination and seedling survival, particularly on areas that receive less than 10 inches (250 mm) annual precipitation. Lack of spring and summer moisture often limit seedling survival. Wyoming big sagebrush can be successfully seeded on sites that receive 10 to 12 inches (250 to 300 mm) precipitation.

Natural spread of Wyoming big sagebrush has often been restricted by cheatgrass. This annual grass is extremely competitive and limits shrub regeneration. Seedings of crested, desert, pubescent, and intermediate wheatgrass have, in many areas, also prevented natural recovery of this shrub.

Removal of Competition

Usually sites supporting Wyoming big sagebrush receive low amounts of precipitation, and weed control is essential for the establishment of all seeded species. Where cheatgrass occurs in dense stands, plowing or spraying may be required to adequately control this weed. In many situations, cheatgrass and other annual weeds exist intermixed with Wyoming big sagebrush and perennial herbs. Under these conditions the annual weeds can provide sufficient competition to prevent natural recruitment of native plants, including Wyoming big sagebrush. Cheatgrass competition must also be reduced to assure establishment of seeded species. Control measures used should not destroy existing perennial herbs. Interseeding shrubs and/or herbs into cleared strips or spots is a satisfactory method of interplanting. This technique can be used to reintroduce desirable plants and ultimately create parental stock from which natural recruitment may occur. However, annual weeds must be controlled to allow natural spread.

Weed-infested sites can be burned after cheatgrass seeds are ripe and the foliage has dried, but before the seeds fall. Burning during this period consumes most seed; however, some seeds usually escape, but the resulting competition may be reduced enough to allow establishment of seeded species. Cheatgrass can recover quickly following burning, and sites must be planted in the fall months after the burn. Waiting to seed beyond one season allows weeds adequate time to fully recover. Seeding burned areas that remain heavily infested with annual weeds is not advised. Burning will kill existing Wyoming big sagebrush, but fires normally will not seriously impact many existing perennial herbs. If burns are relatively small, shrub recruitment by natural seeding may occur, depending on the success attained in replacing annual weeds with native perennial herbs.

Reduction in density of Wyoming big sagebrush may be required where thick stands of this shrub have developed, but the shrub can easily be controlled by disking, plowing, burning, or use of herbicides. Shrub density can also be regulated by anchor chaining or pipe harrowing. Either practice can be modified to attain different levels of control. Treating in midwinter when stems are cold and brittle results in higher kill than late fall or early spring treatments when plants are more flexible. Significant differences in kill can also be attained by using different weight chains and modifying methods of operation (operating at different speeds, adjusting width and spacing of tractors, once- or twice-over chaining). Brush beaters are also effective in removing mature shrubs, but use is restricted to level terrain and sites free of rock. Herbicides can be used to remove Wyoming big sagebrush, but the treatment often kills too much of the shrub stand and eliminates valuable forbs.

Planting Season

If possible, planting in winter is advisable, but late fall through early winter has been generally successful. Planting may continue through December, January, and February, or until the ground has frozen, preventing operation of equipment. Planting on snow over disturbed soil is acceptable. Newly disturbed sites should be seeded in the fall or winter months following disturbance.

Planting Procedures

Seeding practices described for mountain and basin big sagebrush sites apply to treatment of Wyoming big sagebrush communities. Extensive areas occupied by Wyoming big sagebrush occur on relatively level terrain where conventional drills can operate; consequently, large areas have been planted with rangeland drills coupled together in gangs of two to five drills drawn with a single tractor.

Broadcast seeding followed by anchor chaining or pipe harrowing is an appropriate practice for seeding extensive areas in a very short time. Most herbs and Wyoming big sagebrush can be seeded in this manner. In some situations, reestablishing sagebrush on large barren areas created by wildfires has been difficult to accomplish. Studies by Meyer (1994) indicate that sites receiving winter snow that persists until early spring (March) significantly favor shrub seedling establishment. Young and others (1990) reported destruction of soil surface morphology caused by various disturbances destroys seedbed conditions, diminishing

seedling establishment. Soils throughout many Wyoming sagebrush communities have been altered by grazing, weed invasion, and frequent fires. In addition, loss of shrub cover and surface litter over extensive areas results in poor seedbed conditions. Large open sites often do not receive a winter snow cover and soil surfaces dry rapidly, reducing emergence and survival of small seedlings.

Standing cover and surface litter provided by mature shrubs or perennial grasses significantly improves seedbed conditions for Wyoming big sagebrush seedlings. Attempts to modify seedbed conditions by diking, pitting, or deep furrow drilling have not improved shrub seedling success; however, use of the "sagebrush-seeder" has improved sagebrush establishment and survival over conventional drilling practices. The sagebrush-seeder deposits and firms seed onto the soil surface without further modification of the seedbed (Boltz 1994). Although this practice does not ensure planting success in all situations, it is advisable to use this equipment or other surface seeders when planting small seeds of sagebrush.

Adapted Species and Mixtures

Within Wyoming big sagebrush areas, where annual precipitation is near 10 inches (250 mm) or less and soils are light textured, Sandberg bluegrass, Indian ricegrass, bottlebush squirreltail, and Bluebunch wheatgrass may be used if plants occur naturally. Thurber needlegrass, western wheatgrass, and sand dropseed are other recommended native grasses. Not all species are universally adapted to all Wyoming big sagebrush sites. Crested and desert wheatgrass, Russian wildrye, and pubescent wheatgrass are the primary introductions adapted to this shrub type. Areas receiving more than 12 inches (300 mm) of annual precipitation will support bluebunch wheatgrass, western wheatgrass, alfalfa, small burnet, and intermediate wheatgrass. Winterfat, antelope bitterbrush, fourwing saltbush, or other shrubs seeded on Wyoming big sagebrush sites should be confined to areas where these species naturally occur. Attempting to convert Wyoming big sagebrush to other native shrub species is not advisable. Seeds of certain native broadleaf herbs, including Lewis flax, Palmer penstemon, Utah sweetvetch, and gooseberryleaf globemallow, may be sufficiently available to be included in large seedings. These species are only recommended for sites in which they naturally exist. Attempts to seed them in more arid or offsite conditions are not advised. Near pure stands of fourwing saltbush occur in some Wyoming big sagebrush areas. In some locations, the two shrubs can be intermixed. Soils in which fourwing saltbush occur are generally deeper, possess more clay, and have a slightly higher pH. Species recommended for seeding Wyoming big sagebrush sites are listed in table 20. When fourwing saltbush is intermixed with Wyoming big sagebrush, adapted species for seeding vary and are listed in table 17.

Plantings of forage kochia (fig. 30) have demonstrated adaptability to much of the Wyoming big sagebrush type (Stevens 1985b). This introduced shrub establishes well amid considerable competition from annual weeds (McArthur and others 1990a; Monsen and others 1990; Monsen and Turnipseed 1990; Stevens and McArthur 1990), provides excellent wildlife habitat, and forage, and restricts the spread of annual weeds (Monsen and others 1990). This shrub is also effective in controlling wildfires when planted as greenstrips or fuel breaks in weed infested rangelands (Pellent 1994). Currently, this low half-shrub is a useful species for planting semiarid sites where seedling establishment of other species is difficult to attain. Completely replacing sagebrush with forage kochia is not advised. Forage kochia furnishes excellent winter forage for livestock under controlled grazing conditions, but it does not provide the habitat required for sage-grouse and other wildlife.

Black Sagebrush

Black sagebrush is highly palatable to livestock, big game and sage-grouse. The species generally occurs between 4,900 and 8,000 ft (1,500 and 2,400 m), but can be encountered at lower elevations. A majority of the black sagebrush communities occur on calcareous soils, derived from limestone. There are, however, extensive areas where black sagebrush occurs on

Figure 30—Forage kochia and fourwing saltbush have been successfully seeded into weed-infested sites that once supported Wyoming big sagebrush.

volcanic soils. Black sagebrush is encountered with horsebrush, greasewood, shadscale, ephedra, pinyon-juniper, big sagebrush, and in salt desert shrub communities. In general, it grows in pinyon-juniper communities and at lower elevations; however, it is also encountered on rocky soils at higher elevations. Low sagebrush is often confused with black sagebrush. Low sagebrush, however, normally grows with pinyon-juniper, mountain brush, white fir, aspen, and spruce-fir communities.

Annual precipitation of black sagebrush sites range from 7 to 18 inches (180 to 460 mm). Because of the low moisture-holding capacity of most soils, only a small portion of the annual precipitation is available. Black sagebrush may occur on warmer and well-drained soils, and on more xeric sites than Wyoming big sagebrush. Salt desert shrub species normally occur on sites that are too xeric or saline for black sagebrush.

Removal of Competition

Generally, stand reduction should not be attempted in black sagebrush types. This is due to low precipitation, poor moisture-holding capacity of the soil, and the small number of beneficial grasses, forbs, and shrubs that can be successfully seeded. Black sagebrush is a very important forage species and should be retained, not eliminated or altered. Some black sagebrush areas have been invaded by Utah juniper, singleleaf pinyon or pinyon. Removal of the trees by anchor chaining can result in substantial recovery of residual black sagebrush plants and original understory species. Where stands of black sagebrush have been eliminated by a combination of grazing and burning, cheatgrass and red brome have frequently invaded and dominate. These annual weeds can be controlled using practices described for Wyoming big sagebrush.

Black sagebrush does recover well when sites are protected from extensive grazing. Seedlings of this shrub are extremely competitive, and natural recruitment proceeds well if disturbances are protected. Interseeding black sagebrush into disturbances can certainly speed up natural recruitment processes. Once established, black sagebrush plants compete well with annual weeds. Through protective management, weakened stands of black sagebrush can displace annual weeds and regain dominance.

Seeded grasses, including desert, crested, and Siberian wheatgrass, have not persisted well amid stands of black sagebrush. Although some native grasses and broadleaf herbs occur intermixed with this shrub, black sagebrush is extremely competitive and may not allow for the development of extensive stands of grass. Disturbances within the black sagebrush type that have been seeded to drought-tolerant grasses have reverted to a shrub cover within 10 to 20 years.

Planting Season

When seeding is attempted, every effort should be made to conserve and utilize available soil moisture. Late fall or early winter seedings are recommended. Seeding should be delayed until some winter moisture has been received. Seeding into water catchments, holding basins, or deep furrows can improve seedling establishment. Broadcast seeding black sagebrush with a mixture of native and introduced grasses has not diminished shrub seedling establishment.

Adapted Species and Mixtures

Species with potential for seeding disturbed sites in the black sage type are listed in table 21. Desert, crested, and Siberian wheatgrass, and Russian wildrye are introduced species that have established in black sagebrush sites. These species have not persisted in all areas, particularly as black sagebrush recovers. Western wheatgrass, Indian ricegrass, bluebunch wheatgrass, and needle-and-threadgrass are native species common in this shrub type. They persist better with black sagebrush than do most introduced grasses, but may occur as subdominant understory species. All can be seeded with good success. There are generally few forbs that are associated with black sagebrush. Attempts should not be made to seed shrub species that do not naturally occur with black sagebrush.

Low Sagebrush

Low sagebrush can be found growing on more moist sites, and generally at slightly higher elevations than black sagebrush. Soils in which low sagebrush occurs are dry, rocky, and often alkaline, some have shallow clay pans, and most are not well drained. Sites may be subjected to spring flooding. Areas of occurrence ranging from 2,300 to 11,500 ft (700 to 3,500 m) (McArthur and others 1979a) and receive 9 to 20 inches (230 to 510 mm) of annual precipitation.

Low sagebrush is an important and useful species, and attempts to convert this shrub type to introduced herbs is not advised. If the associated understory has been removed, the potential for herbaceous vegetation improvement through seeding is fairly good on most low sagebrush areas. Species adapted to the low sagebrush types are listed in table 22. Seeding should occur in the fall or early winter prior to snowfall. Low sagebrush has not been as widely seeded as other species of sagebrush; however, direct seedings are usually quite successful.

Some reduction of low sagebrush may be required to reestablish seedlings of displaced species, but elimination of this shrub is not recommended. If necessary, density of low sagebrush can be reduced with anchor chains and pipe harrows. These two

pieces of equipment are also useful for covering seed. Plowing, disking, fire, and herbicides are effective techniques for killing low sagebrush, but are not recommended. These techniques cause major damage and can kill existing shrubs, forbs, and grasses. Seeding should be done in the fall or early winter prior to snowfall.

Threetip Sagebrush

Within the Intermountain West, threetip sagebrush occurs in northern Utah, northern Nevada, and southern Idaho. It can be found between the lower, warmer dry sites dominated by Wyoming big sagebrush and the higher, cooler mountain big sagebrush type (Schlatterer 1973). Soils are quite variable, but are usually moderately deep, ranging from fine loam to very gravelly. Annual precipitation ranges from 10 to 20 inches (250 to 500 mm) and elevations from 3,000 to 9,000 ft (900 to 2,750 m) (Beetle 1960).

A number of forbs, grasses, and other shrubs grow in association with threetip sagebrush. The potential for reestablishing herbaceous species through seeding is fairly high, but not as great as in mountain big sagebrush areas. Threetip sagebrush may resprout from the base following fire, defoliation, or other disturbances. Practices can be used to initially reduce woody competition and allow understory species to establish, yet favoring the recovery of the sage. Threetip sagebrush sites should be seeded with adapted and available species (table 23) at the same season as described for mountain big sagebrush, using similar practices. Best seeding success has been achieved by seeding in the late fall just before snowfall .

Threetip sagebrush communities normally support a wide array of herbaceous and woody species. Sites usually are not invested with annual weeds. Areas disrupted by grazing normally recover with protection. Threetip sagebrush plants usually produce abundant seeds each year, facilitating natural recruitment. Stands of threetip disrupted by burning or extended periods of grazing can be restored by broadcast seeding. Aerial seeding of fresh burns or broadcasting prior to chaining or pipe harrowing are quite successful. Seeding threetip sagebrush with herbaceous species has also been successful.

Mountain Silver Sagebrush

Throughout the Intermountain region, mountain silver sagebrush occurs in valleys, plains, foothills, and mountains up to 10,000 ft (3,050 m). Precipitation ranges from 18 to 30 inches (460 to 760 mm) annually. Soil texture ranges from loam to sandy loam. Many sites are poorly drained, with some having seasonally high water tables. Some sites often collect a heavy snow pack that remains late into the spring. As snow melts, the soil is saturated for a period of time.

Two other silver sagebrush subspecies occur in the west: Bolander silver sagebrush occurs primarily in the Sierra-Nevada Mountains, and plains silver sagebrush occurs principally east of the Continental Divide (Shultz 1986). Timberline sagebrush grows in association with silver sagebrush, especially when there is heavy snow pack. Subalpine big sagebrush also occurs on more open areas with silver sagebrush.

Considerable variations of understory species occur among mountain silver sagebrush sites. Consequently, care should be taken when selecting species to seed within a particular mountain silver sagebrush community. Mountain silver sagebrush communities should not be altered or converted to other species. However, where disturbances have occurred, mountain silver sagebrush density can be reduced with anchor chains, pipe harrows, disks, and disk chain if necessary. Fire and herbicides are also effective means for reducing silver sagebrush. Species that are adapted to the mountain silver sagebrush, timberline sagebrush and subalpine big sagebrush areas are listed in table 24.

Ecotypes of mountain silver sagebrush demonstrate excellent establishment features. Some ecotypes compete well with annual weeds. Natural spread of mountain silver sagebrush into weed infested sites often occurs. This shrub resprouts following burning, and may be used to seed areas occupied by flammable annual weeds.

Alkali or Early Sagebrush

Alkali sagebrush occurs at elevations between 5,900 and 8,000 ft (1,800 and 2,450 m). It occupies extensive areas along the foothill ranges from south-central Montana southward into Wyoming, northern Colorado, Utah, Nevada, Idaho, and Oregon (Blaisdell and others 1982). Alkali sagebrush usually occurs on heavy textured and poorly drained soils. This shrub is unlike most other woody sagebrushes, with the exception of low sagebrush or silver sagebrush, as it is able to grow on wet sites. It is frequently mixed with antelope bitterbrush, and basin big, threetip, and low sagebrush, particularly in south-central Idaho. Yet, when growing with these shrubs, it usually occurs in separate and distinct patches.

Alkali sagebrush is useful forage for game birds, livestock, and big game animals. It is important habitat for sage-grouse and provides forage for sheep and antelope, especially as spring herbage. Rehabilitation or conversion of alkali sagebrush-dominated communities should not be initiated until the impacts on these game birds are considered.

Alkali sagebrush sites normally support a diverse understory of grasses and herbs. Sites that have been well managed support Idaho fescue, bluebunch wheatgrass, and Letterman needlegrass. It is not uncommon to encounter mixed communities of alkali sagebrush and antelope bitterbrush.

Areas that are heavily grazed usually lack a satisfactory understory of herbs. In these situations, the density of alkali sagebrush increases significantly. Once this occurs, the native herbs are slow to reestablish. Alkali sagebrush-dominated areas in south-central Idaho have been rested from grazing for over 30 years without much community change or improvement.

Removal of Competition

Improvement of alkali sagebrush ranges can be attained by artificial measures. Grasses and broadleaf herbs can be interseeded into clearings created by burning or disking. Alkali sagebrush can also be effectively controlled with chaining, disking, or spraying; however, chaining is the most effective treatment (Monsen and Shaw 1986). Complete removal of the existing shrubs is neither necessary nor desirable. A reduction of 25 to 50 percent in density of the shrubs is sufficient to allow seedling establishment of additional species. Alkali sagebrush stands exposed to burning or chaining recover quickly, often within 3 to 5 years. Consequently, it is essential to immediately seed after these treatments. However, thinning by chaining, burning, spraying, or disking can result in a rapid improvement of understory herbs (Monsen and Shaw 1986). Following burning or chaining, alkali sagebrush plants recover quickly by sprouting. This shrub normally produces a good seed crop each year. Clearing techniques, including chaining or disking, usually improve the seedbed and result in rapid recovery of new shrub seedlings.

Burning of alkali sagebrush stands is usually not difficult if conducted at the right season. Sites dominated by this shrub may lack a dense understory. If so, fires may burn erratically leaving a mosaic pattern. If an understory does exist, seeding following burning is not required. Most associated plants recover following burning and chaining.

Alkali sagebrush begins growth much earlier than either basin big sagebrush or low sagebrush. Plants normally flower a month before low sagebrush. Consequently, if herbicides are used to control alkali sagebrush, treatment should be completed much earlier than would be scheduled for basin big sagebrush.

Planting Season

Fall seeding is normally recommended, although some sites receive sufficient moisture to support early spring plantings.

Planting Procedures

Aerial seeding followed by anchor chaining is a satisfactory means of planting. Sites that are burned may be aerially seeded or drill seeded. Areas that have been burned may be drill seeded using a rangeland drill or similar type drill that is capable of operating on sites supporting considerable standing litter and debris.

Rocky outcrops often occur amid alkali sagebrush communities and can restrict the methods used to seed an area. Anchor chaining is normally the most practical and effective method of seeding rocky sites.

Adapted Species and Mixtures

Species recommended for rehabilitating alkali sagebrush sites are similar to those used for basin big sagebrush (table 18) or low sagebrush sites (table 22). Idaho fescue, bluebunch wheatgrass, and Letterman's needlegrass are also adapted to these sites.

Alkali sagebrush plants spread well by natural seeding. Attempts to improve a site by seeding understory herbs normally results in the overall recovery of the shrub. This shrub is not difficult to establish by direct seeding. Seedlings are quite competitive and can be established in combination with some herbs. Seeds are relatively large compared with those of most other sagebrushes, and are easily cleaned and planted with most equipment.

Budsage

Budsage is locally important in the Intermountain West (fig. 31). This species is found on dry, often saline,

Figure 31—Salt desert shrub communities support an important group of woody species including bud sagebrush, shadscale, winterfat, spiny hopsage, and fourwing saltbush. Maintaining these communities and preventing weed invasion is essential because these sites are difficult to restore.

plains and hills. It is well adapted to xeric conditions and is often associated with shadscale saltbush, black greasewood, and other salt-tolerant shrubs (fig. 31). In some places it can be found growing in association with black sagebrush and basin big sagebrush. Budsage sites are generally not recommended for rehabilitation because of arid conditions that prevail. If a site is disturbed, few species can be recommended for seeding. Attempts made to seed this species have not been very successful because of poor quality seed and harsh planting conditions. Seeds are small and seedlings do not grow rapidly. Stands of bud sagebrush should be protected and carefully managed to avoid loss.

Salt Desert Shrub Communities

Salt desert shrub communities occur throughout the Western United States, Canada, and Mexico. Chenopod shrubs dominate many of these communities, providing a diverse group of species (McArthur and Sanderson 1984) (fig. 31). Some species that occupy the salt desert shrublands are encountered in both cold desert and warm desert communities described by Shreve (1942). Various species of sagebrush exist in association with certain salt desert communities, but they normally grow at higher elevations and on better drained soils. Generally, salt desert species occur on heavy textured lowland soils containing some salt in the subsoil. Not all sites have a developed carbonate layer, and salt content may vary throughout the soil profile.

Salt desert communities occupy harsh and somewhat unique sites, including waste places, temperate salt marshes, deserts, and semidesert regions (Goodall 1982; McArthur and Sanderson 1984). Salt desert shrublands occur as extensive rangelands occupying broad valleys throughout southeastern Oregon and southern Idaho, southward through the Great Basin into southern California and western Arizona (Oosting 1956). Precipitation is low, normally less than 10 inches (250 mm), and erratic. Locally, physical differences in topography, soils, and aspect produce distinct patterns in the distribution of different plant communities. It is important to recognize that quite different vegetative associations occur throughout the salt desert shrublands, reflecting the effects of soil conditions, water accumulation, evaporation, and salt deposition. Accumulation of salts create zonal patterns of vegetation around playa lakes and areas where flooding or runoff may occur (Billings 1980). Where salt content is excessive, samphire glasswort and iodine bush dominate. Shadscale, greasewood, gray molly, winterfat, blackbrush, Nevada ephedra, and spiny hopsage exist on sites with less salt.

Differences in site conditions must be considered in any vegetative improvement projects. Salt desert shrublands may be difficult sites to restore or revegetate. Seasonal precipitation is not only low but very erratic, and planting success is closely regulated by availability of soil moisture in the spring and early summer. Restoration or revegetation measures must be developed to properly treat different communities and site conditions.

It is important that rehabilitation procedures selected apply to the specific plant association being treated. To date, disturbances within the salt desert shrublands have generally been seeded with crested wheatgrass, desert wheatgrass, Siberian wheatgrass, Russian wildrye, Great Basin wildrye, and bottlebrush squirreltail (Plummer and others 1968). Although attempts have been made to reestablish native shrubs and associated herbs, erratic success has resulted. Most revegetation projects have relied on the use of grasses, using species capable of developing uniform stands under adverse establishment conditions. Although native shrubs have evolved to populate these sites, natural and artificial seedings generally do not provide reliable seedling establishment each year. Recent studies with some semiarid shrubs demonstrate that by selecting adapted ecotypes (Meyer and Monsen 1990; Shaw and Haferkamp 1990), proper seedbed preparation (Stevens and others 1986), and aggressive weed control (Monsen and Pellant 1989), a number of species can be seeded with good success. Recent development of native and introduced ecotypes has also provided additional plant materials for seeding salt desert disturbances (McArthur and others 1982; Stevens and McArthur 1990; Stevens and others 1977; Welch and McArthur 1986).

Shadscale-Saltbush

Shadscale-saltbush communities occur over 50,000 square miles (129,00 km^2) ranging from Canada to Mexico, and from 1,500 to 7,000 ft (450 to 2,100 m) in elevation (Hanson 1962). These species dominate broad valley bottoms and adjacent foothills where they merge with big sagebrush and juniper-pinyon. Shadscale is the most common and abundant shrub of the salt desert shrubland (Blaisdell and Holmgren 1984). Shadscale is found in heavy soils with soluble salts ranging from 160 to 3,000 ppm and pH of 7.4 to 10.3 (Hanson 1962). On highly alkaline soils, shadscale occurs in nearly pure stands. Annual precipitation on these areas is generally less than 10 inches (250 mm), with many areas receiving from 3 to 8 inches (80 to 200 mm). Both pure and mixed stands of shadscale occur in the Colorado River drainage in western Utah

(fig. 31), and throughout Nevada, eastern Oregon, southern Idaho, and southwestern Wyoming. Community composition may be predominantly shadscale or other saltbush species. Numerous shadscale communities have been described by various investigators (Hutchings and Stewart 1953; Stewart and others 1940; Wood 1966). West and Ibrahim (1968) described four habitat types with distinctly different floristic composition and soil features in southeastern Utah. Shadscale exists as nearly pure stands with large open spaces among plants in valley bottoms. On higher slopes it exists in fairly complex mixtures with other low shrubs and some grasses (Hutchings and Stewart 1953).

Shadscale plants can be completely killed by fires. Vest (1962) reported that shadscale is more sensitive to extended periods of drought than any other of the salt desert shrubs. Extensive stands have also been killed by periods of heavy precipitation and seasonal periods of flooding or soil saturation.

Although heavy or improper seasons of grazing can diminish stands of shadscale, this species is reported to replace palatable shrubs and grasses where grazing has been excessive (Blaisdell 1958).

Most successful range improvement projects in shadscale-saltbush communities have occurred where annual precipitation exceeds 8 inches (200 mm) (Bleak and others 1965; Plummer 1966; Plummer and others 1968). Techniques and plant materials are limited at the present time to ensure consistent, acceptable, long-term success in areas that receive less than 8 inches (200 mm) of precipitation. The presence of juniper or pinyon in a shadscale community indicates that adequate precipitation is generally available to successfully seed the area.

Normally, areas with Gardner or mat saltbush are too dry or saline for successful seeding. However, treatments may be successful in shadscale or mixed shrub communities, which include fourwing saltbush, winterfat, black greasewood, blackbrush, basin big sagebrush, spiny hopsage, horsebrush, and juniper. Bud sage is often codominant or subdominant with shadscale. Disturbed shadscale areas are usually occupied by Russian thistle, cheatgrass (fig. 32), and halogeton. It is important to revegetate these disturbances to reduce erosion and to check the increase of undesirable annuals, poisonous plants, and noxious weeds, and to control wildfires.

Natural recovery of large stands of shadscale has frequently occurred following fires. In some situations, plants appeared 3 to 4 years after disturbance, indicating seeds survive in the soil and may remain viable for a number of years. Shadscale seedlings are able to compete with some herbaceous competition, but recent trials indicate seedlings are susceptible to competition.

Figure 32—Shadscale communities are often invaded by cheatgrass following wildfires, creating serious problems in restoration of this native shrub.

Removal of Competition

Disturbance of the perennial plant cover may threaten soil stability (Bleak and others 1965; Plummer 1966). Typically, perennial plant density is low with major openings existing between individual shrubs. Annual and perennial weeds have often invaded disturbances and sites where plant density is low or where shrubs have been burned by wildfires. Weeds have also established on sites where shrub density has not been diminished. Weed invasion and persistence fluctuates annually, creating the potential for large and disruptive fires.

Where cheatgrass brome (fig. 32) has become established and gained control, removal of weedy competition should follow the same general procedure as outlined in guides for seeding into cheatgrass, red brome, and medusahead types. Likewise, where halogeton and Russian thistle have established, the treatments described in this chapter for seeding into low annual weed communities would be appropriate.

If a reduction in shrub density is desired, this can be accomplished by anchor chaining, shallow plowing, and disking, or with disk-chains, pipe harrows, and scalpers of various types (McArthur and others 1978b). Shrubs within this type are generally very brittle and easily removed. Destruction of shrub cover **should not be done** unless specific objectives would justify conversion to a different community.

Control of annual weeds is a major problem throughout most of the salt desert communities. Annual weeds have invaded many sites and restrict natural recruitment of native species. The annual weeds also flourish following a wildfire or other disturbance. Once in

place, the weeds dominate and prevent establishment of artificial seedings. Cheatgrass is highly competitive and produces abundant seed crops, providing a seedbank that persists for more than one season. Any attempt to plant these disturbances requires removal of existing plants and elimination of the seedbank. Single treatments, including mechanical tillage or application of herbicides, are not always successful.

Planting Season

If soils are not frozen, midwinter seeding is recommended. Disking, drill seeding, or other disturbances when soils are wet can cause surface crusting, which prevents emergence of most seedlings. Generally, low-elevation sites can be seeded from late fall until early spring. Spring planting should be completed before winter moisture has diminished and soil surfaces are dry.

Planting Procedures

Unless weeds are present, drill seeding can usually be accomplished with little reduction of existing cover (Plummer 1966). Where the objective is to improve ground cover and increase production by leaving perennial vegetation and adding some additional species, direct seeding with the rangeland drill is especially successful. If shrubs are seeded, they should be planted in alternate rows separated from seeded grasses. Good results can be obtained when the drill makes wide furrows, permitting the maximum amount of precipitation to be collected in the depressions. However, a drill can often compact the furrow, which may interfere with seedling emergence. The use of scalpers, pitters, and land imprinters to create depressions where moisture will collect, combined with broadcast seeding, has resulted in improved establishment (Ferguson and Frischknecht 1981; Fisser and others 1974; Giunta and others 1975; Hull 1963b; Knudson 1977; Lavin and others 1981; Stevens 1980b, 1981; Wein and West 1971; Wight and White 1974). Furrows and pits are useful for collecting and conserving moisture on heavy soils with slow infiltration rates (Bleak and others 1965). Anchor chains and pipe harrows are not recommended for seed coverage where existing stands of shadscale occur, as the brittle shrubs will be seriously damaged. If shadscale shrubs have been destroyed by burning or other disturbances, chaining or harrowing can be used to cover broadcast seeds.

Adapted Species and Mixtures

Species that are adapted to the shadscale type are listed in table 25 (Bleak and others 1965; Ferguson and Frischknecht 1981; McArthur and others 1978b; McKell and VanEpps 1981; Monsen and Plummer 1978; Plummer 1966, 1977; Plummer and others 1968).

Seeding shadscale onto sites where wildfires or other disturbances have removed the shrub has frequently been attempted. Erratic stands have often developed from direct seedings, yet new shadscale plants appear over a number of years, eventually producing good stands. If a seedbank has been developed in the soil, natural recovery of shadscale has occurred following burns at a number of locations. Natural seedlings compete well with other species, and mature individuals develop in 3 to 5 years. Heavy and continuous grazing has weakened and killed existing plants. Weakened plants may fail to produce normal seed crops, slowing the recovery process. Natural recovery following extended periods of destructive grazing can be slow or may not occur. Weed invasion can also prevent shrub recruitment.

Natural recovery of shadscale can be expected on recent burns if weeds are absent and a seedbank has accumulated in the soil. Seeding shadscale or other species may not be required. If weed invasion is apparent, planting is usually necessary to ensure shrub recovery. Seeding introduced perennial grasses following wildfires is often recommended to stabilize soils and control weed invasion. However, plantings of crested wheatgrass on upland foothills and plains has prevented shadscale recovery. This practice should be avoided if conditions suggest shadscale is capable of recovery.

Seed lots of shadscale obtained from native collections often have less than 40 percent viability. A large percentage of the seed fails to develop, and many empty utricles are formed. In addition, the hard utricle prevents germination. Once the utricle is fractured or opened, seeds germinate rapidly. Procedures have not been developed to open the utricle and permit uniform germination. Seed from various native stands germinate more freely than others, and collections from north-central Nevada, southern Idaho, and eastern Utah have germinated better than collections from most other areas. This demonstrates the practicality of improving stand establishment through controlled breeding and selection.

Plantings of forage kochia (fig. 30), an introduced half-shrub, have demonstrated adaptability to and can establish in the shadscale type (McArthur and others 1990a). This plant is competitive as a seedling (Monsen and Turnipseed 1990; Stevens and McArthur 1990) and has established very well when seeded amid sites occupied by annual weeds. This introduced shrub provides useful herbage, competes well with annuals, and has significantly reduced the incident of wildfires where cheatgrass has invaded. Converting shadscale communities to forage kochia is not advised, but existing disturbances currently occupied by cheatgrass

(McArthur and others 1990a), Russian thistle, or halogeton (Stevens and McArthur 1990) can be converted to a more manageable and productive cover with forage kochia. In addition, this shrub can be used to control the further spread of weeds and restrict further decline in site productivity and erosion. Forage kochia is able to outcompete summer annuals because of its early spring growth, rapid germination, and growth of numerous small seedlings.

Black Greasewood

Black greasewood occupies considerable acreages on salty valley bottoms. This plant also occurs on salt-bearing shale outcrops in canyons and on foothills (fig. 33). Sites vary in respect to soil texture and availability of ground water. Some areas are wet with high water tables, and others are dry with well-drained soils.

Black greasewood occurs in pure or mixed stands. The plant contains oxalic acid and can cause poisoning, particularly when grazed in the spring (USDA 1968). Livestock can safely consume moderate amounts of greasewood when it is eaten in conjunction with other forage. Black greasewood is not known to be poisonous to game animals and, in fact, has some forage value. However, forage production and ground cover can often be increased by establishing additional species within greasewood stands.

Removal of Competition

Some stands of black greasewood have been converted to herbaceous species for livestock pastures or cultivated fields. Many black greasewood sites can be relatively productive areas, and increases in forage production can economically support development costs. Introduced perennial grasses are commonly seeded to provide spring/fall pastures.

Many black greasewood sites have been invaded by cheatgrass and summer annuals. These sites frequently burn, which decreases shrub density and diminishes understory herbs. Where control of annual weeds and fire suppression is a major concern, planting introduced perennial grasses has been justified. Reestablishment of the native understory is attainable in many situations, although seed availability currently limits restoration programs.

Many black greasewood sites are important for maintaining wildlife habitat and soil protection. Streams and riparian zones often align this plant type. Consequently, restoration measures are often required to restore the understory vegetation. Complete elimination of all shrubs is not necessary or advisable. Shrub density should only be decreased to facilitate planting understory species. Converting this woody community to other shrub species is not advisable in most situations.

Figure 33—Black greasewood sites often exist with a limited cover of understory herbs, and are subject to invasion by annual weeds, including cheatgrass.

Black greasewood is not very competitive with seeded herbs. However, some thinning of the shrubs is usually required to reduce competition and facilitate seeding. A heavy offset disk, disk-chain (fig. 34), pipe harrows, brushland plow, or similar equipment can be used to remove top growth and eliminate plants. Pipe harrowing, chaining, mowing, beating, or use of the land imprinter effectively reduce top growth, and leave litter on the ground as mulch. These treatments do not kill or remove all greasewood plants. Top growth of greasewood can be removed with fire when

Figure 34—Mechanical tillage is often used to reduce competition from black greasewood and establish understory species.

there is sufficient fuel to carry a fire. Greasewood can be satisfactorily controlled with 2,4-D (Cluff and others 1983b; Roundy and others 1983).

Soil crusting in the black greasewood type is a major problem. Mulching helps to reduce crusting and provides improved seedling emergence and establishment. Every effort should be made to leave mulch on the soil surface.

Planting Season

If the surface is dry or moist, February is the preferred time for planting because the soil crusts less following tillage or seeding than in late fall or early winter. However, planting from late fall (mid-October) through January can produce good stands. Seeding in March and early April is normally successful if soils are dry and firm. Spring tillage or seeding dries the soil surface and prevents seed germination and seedling establishment.

Planting Procedures

Broadcasting by aerial or hand-seeding techniques, followed by anchor chaining or pipe harrowing, are suitable and practical procedures. Anchor chaining and pipe harrowing after seeding are usually preferred treatments, as litter is scattered over the soil surface. Drilling or imprint seeding can be used unless numerous woody stems are left on the soil surface. Surface planting using a Brillon seeder often prevents surface compaction and crusting, and produces adequate stands.

Adapted Species and Mixtures

Even though few species (table 26) are adapted to the akaline soils of greasewood communities, good opportunities exist for improving forage production, ground cover, and soil stabilization. Bottlebrush squirreltail, western wheatgrass, and Great Basin wildrye are the principal native grasses adapted to this shrub type. “Fairway” and “Ephraim” crested wheatgrass, and Russian wildrye are all well-adapted introductions and useful forage species. Russian wildrye provides excellent forage during late spring and summer periods and helps control reinvasion of weeds. Although greasewood is not eliminated by the presence of seeded herbs, shrub density can be controlled by the presence of understory species and seasonal grazing practices.

Winterfat

Winterfat occurs in the pinyon-juniper, basin big sagebrush, Wyoming big sagebrush, and salt desert communities and in pure stands. It occurs from Canada to the Great Basin and Rocky Mountain States to California, Mexico, and eastward to Texas and North Dakota (Blaisdell and Holmgren 1984). This shrub is abundant on low foothill ranges, dry valley bottoms, and plains, growing on subalkaline soils (Gates and others 1956; Shantz and Piemeisel 1940). It is not uncommon to find this shrub in nearly pure stands over extensive areas (Branson and others 1967).

Winterfat may frequently dominate upland or foothill sites, normally growing with some understory grasses in these situations. Blaisdell and Holmgren (1984) conclude that winterfat appears as a dominant species in three major salt desert shrub communities: winterfat-low rabbitbrush, winterfat-low rabbitbrush-grass, and winterfat-grass. It also exists as almost pure stands or intermixed with shadscale on alluvial soils on broad valley bottoms and lower valley slopes. Indian ricegrass, galleta, and black sagebrush are frequently associated with winterfat. Throughout the salt desert communities, winterfat is second only to shadscale in importance.

Salt desert shrub communities occur on soils with extreme salinity, alkalinity, or both (West 1982) where precipitation is mostly under 6 inches (15 cm). This combination of factors creates climatically and physiologically dry soils (Billings 1945). Winterfat differs from some other salt desert shrubs in that it grows on soils relatively low in salt and sodium (Naphan 1966). Although it may occur on coarser textured soils with low water holding capacity, it also occupies fertile, moist sites.

Winterfat is highly palatable and nutritious. Its tolerance to winter grazing is remarkable. Even so, persistent and continuous overgrazing, especially in spring and summer, has reduced its density on many ranges, and in places, has completely eliminated stands. Low rabbitbrush, snakeweed, shadscale saltbush, and such annuals as Russian thistle, cheatgrass, red brome, and halogeton now occupy extensive areas that were formerly dominated by winterfat (Stevens and others 1977a). Spring and summer grazing essentially eliminates seed production.

Winterfat can survive through extensive moisture shortage. It has an extensively fibrous and deep taproot. During prolonged drought, growth is negligible and plants may even appear to be dead. However, the woody crowns often survive. With moisture, it has a remarkable ability to recover. The more successful range improvement projects have occurred where annual precipitation is in excess of 8 inches (200 mm).

Removal of Competition

Winterfat has been eliminated by grazing or other disturbances and replaced by cheatgrass, red brome,

Russian thistle, and halogeton. These sites frequently burn and further reduce shrub density and understory herbs. Techniques described in the chapter for treating these annual communities should be employed. Where control of annual weeds and fire suppression is a major concern, planting of introduced perennial grasses has been justified. However, reestablishment of natives can occur in many situations.

When winterfat stands have been invaded by or replaced with low rabbitbrush, rubber rabbitbrush, and snakeweed, the density of these species must be reduced to facilitate seeding. A Dixie chain or pipe harrow can effectively reduce competition from these species and prepare a favorable seedbed. Plowing or disking will kill and eliminate winterfat plants that may be present. Working the soil when it is damp or wet will cause soil crusting and prevent seedling emergence.

Planting Season

The most ideal time for seeding winterfat and associated species is in the fall before the soil freezes. Where summer storms occur, particularly in the southwest, seeding prior to these storms has resulted in good success.

Planting Procedures

A major factor in successful seeding is seed coverage. Winterfat seeds are encircled by two cottony, hairy bracts. Seed should not be removed from these bracts. Winterfat seed does best when it is surface seeded. The bracts, when embedded in soil, help to anchor the seed to the soil and provide for successful germination and seedling establishment. Aerial broadcasting onto disturbed sites or with slight disturbance with chaining or pipe harrowing can be successful. Drill seeding can be successful when a picker wheel or chaffy seed dispenser is incorporated in the seedbox. Seed should be deposited behind the furrow openers and in front of the drag chain. Winterfat should be seeded in alternate rows separated from grasses. The use of scalpers, pitters, and land imprinters that form depressions for moisture collection has resulted in good seedings.

Adapted Species and Mixtures

Ecotypic variations exist in winterfat. Generally, low-growing, drought-tolerant forms are found in valley bottoms with heavier soils. Tall-growing, more woody types occur on more upland sites with higher precipitation, generally associated with ponderosa pine and pinyon-juniper (Stevens and others 1977a). When seeding winterfat, it is imperative that adaptive ecotypes be selected and seeded.

Species adapted to seeding onto winterfat vary with climatic and edaphic conditions. Winterfat most often occurs in association with other species. Species recommended for seeding are listed by associated species in table 13 (mountain brush-ponderosa pine); tables 14 to 16 (juniper-pinyon); table 17 (fourwing saltbush); table 18 (basin big sagebrush); table 20 (Wyoming big sagebrush); table 25 (shadscale saltbush); and table 28 (cheatgrass, red brome, and medusahead).

Fourwing Saltbush

Fourwing saltbush is widely distributed over the west in foothills and desert ranges. It reaches well into the Great Plains on the east and nearly to the Pacific Ocean on the west, from Canada on the north and south into Mexico. It occurs from below sea level in the Mojave Desert to over 8,000 ft (3,280 m). It is found in pure stands and in scattered stands associated with shadscale saltbush, Gardner saltbush, juniper-pinyon, basin big sagebrush, and Wyoming big sagebrush.

Over its wide range of distribution, fourwing saltbush exhibits extensive variations in growth form, seed production, germination, establishment, drought tolerance, cold tolerance, grazing, palatability to livestock, and adaptability to soil type.

Removal of Competition

Fourwing saltbush has been eliminated or reduced in density on many sites by overgrazing and/or fire. Grazing has also depleted or eliminated associated understory species. Cheatgrass brome, red brome, and spring and summer annuals have invaded and occupy the understory of many fourwing saltbush areas.

The objective of most seedings has been to establish perennial understory and retain and increase fourwing saltbush density. This requires removal of grazing pressure, reduction of competitive annuals, and seeding of adapted understory species and fourwing saltbush. Treatment used to reduce competition will vary with density and composition of existing understory communites and associated perennial species. Techniques are described in the chapter for treating the various community conditions. These are listed by major species types: juniper-pinyon, basin big sagebrush, Wyoming big sagebrush, annual weedy grasses, and lowland annuals.

Planting Season

Late fall seedings are most often recommended; however, in the Southwest, when summer storms occur, seeding prior to these storms is generally recommended.

Planting Procedures

Fourwing saltbush seed requires that the seed be planted at least 1/4 inch (6 mm) deep, preferably in a firm seedbed. When drill seeding, this species does best seeded separately from grasses. Broadcast seeding will accomplish this, but provisions must be made to ensure the seed is covered. Seeding through a Hansen seed dribbler or thimble seeder mounted on a crawler tractor can result in superior establishment.

Adapted Species and Mixtures

Ecotypic variations in fourwing saltbush require that only seed sources adapted to the planting site be seeded. Sources from warmer, more southern climates cannot be moved to cooler, northern areas. Likewise, lower elevation sources cannot be moved to higher elevations. When this occurs, few seedlings generally survive.

A large majority of the fourwing saltbush seed that is produced and harvested comes from Texas, New Mexico, Arizona, southern Utah, Nevada, and California. These ecotypes should not be seeded in northern Colorado, Utah and Nevada, southern Idaho, Wyoming, or eastern Oregon. Species adapted to fourwing saltbush sites are listed by associated species. Table 17 lists species adapted to areas where fourwing saltbush occurs in assocation with juniper-pinyon, basin big sagebrush, and Wyoming big sagebrush; table 25, shadscale saltbush; table 27, blackbrush; and table 28, areas where cheatgrass, red brome, and medusahead dominate.

Blackbrush Communities

Blackbrush grows on fairly large tracts in the Colorado river drainage, Arizona, and New Mexico. In some locations, it occurs with few associated species (Bowns and West 1976). In some areas, spreading creosotebush, desert peachbrush, silver buffaloberry, Utah serviceberry, basin big sagebrush, and various cacti, yuccas, and Utah juniper grow in association with blackbrush. Annual precipitation ranges from 6 to 16 inches (150 and 400 mm). Seedings are usually not successful where annual precipitation averages less than 9 inches (220 mm). Blackbrush is a valuable shrub for livestock (fig. 35) and deer. It should not be disturbed, nor should attempts be made to convert it to another vegetative type.

Cheatgrass and red brome grow under the crowns of blackbrush plants. In wet years, these annuals may be so abundant that once they dry out, fires may burn across large acreages. Since blackbrush is not fire tolerant, these burned areas automatically become annual cheatgrass and red brome ranges and, therefore, special problem areas. Unless such disturbances are seeded, the annual grasses may persist for many years.

Removal of Competition

Control of plant competition is required only in areas where red brome and cheatgrass brome have invaded. Seeding is recommended following wildfires as a means of controlling the spread of the annual grasses. Once annuals have gained control, these plants must be significantly reduced in density to allow shrubs and native herbs to recover. Because the chief aim in improving blackbrush areas is the retention of blackbrush, and because blackbrush is not tolerant of fire, burning to control the annual grasses should be avoided. Disking or spraying with ground equipment can be used to treat specific sites, while avoiding scattered shrubs.

Planting Season

Storm patterns favor late June to early July seedings, just prior to summer storms (Jordon 1981, 1983). Fall and winter seedings can, however, be successful. Work can continue from November through February. Pendleton and others (1995) reported that natural emergence of blackbrush seedlings in southern Utah occurred between December and February. In addition, these authors found that blackbrush seeds require 4 to 6 months of stratification to break seed dormancy. Consequently, fall seeding is required to assure stratification and emergence of blackbrush seedlings. Occasional low temperatures seldom delay

Figure 35—Domestic livestock often graze blackbrush sites, but these areas are also important to big game animals.

ground treatment or planting for more than a few days. Rodents gather and feed on planted seeds and graze young sprouts, causing considerable damage and loss of a high percent of all seeds and seedlings (Longland 1994). As a precaution against undue loss of seeds to small rodents, plantings may be delayed until December when rodents are less active.

Planting Procedures

Probably the best method of seeding herbaceous species is aerial broadcasting followed by anchor chaining or pipe harrowing. This method is particularly applicable on rocky areas, where it is difficult to drill. Chaining can be detrimental to blackbrush plants and should not be used where these shrubs are present. In rock-free areas, where the rangeland drill or other disk-type drills can be used, good stands can be attained with these machines. Planting seeds of blackbrush in alternate rows with herbaceous species is recommended. Shrub seeds can also be sown using a seed dribbler or thimble seeder mounted on crawler tractors.

Adapted Species and Mixtures

Because temperatures are much warmer in this type than in more northern shrublands, a mixture of adapted species that can tolerate heat is required (table 27). Seed mixtures may be modified according to difference in climate and availability of seed. Seed of adapted native grasses is currently quite limited, and is not always sufficient for planting large acreages. Indian ricegrass and squirreltail are adapted native species for which seed is most available. In areas that have a fair amount of summer rainfall, sand dropseed can be planted.

Pendleton and others (1995) found that natural recruitment and artificial seedings are quite successful during years when sites receive adequate spring and winter moisture. Environmentally accepted methods are not currently available to control seed depredation by rodents, yet planting few seeds per spot and planting in discontinuous rows or furrows decrease seed gathering. In addition, planting open areas or sites free of cover tends to enhance seedling establishment, as rodents seek some protective cover. Seeding during periods when rodent populations are low can increase seedling survival.

Seeds of blackbrush are limited and expensive, which restricts their use on large-scale projects. Big sagebrush, desert bitterbrush, Apache plume, fourwing saltbush, and winterfat can be included in seedings in the blackbrush type where these species naturally occur.

Cheatgrass Brome, Red Brome, and Medusahead Communities

Cheatgrass brome, red brome, and medusahead dominate large areas of depleted foothill and valley rangelands (Mack 1981; Piemeisel 1938; Stewart and Young 1939; Young and Evans 1970, 1971; Young and others 1968). These grasses germinate in fall or spring and demonstrate phenomenal ability to utilize space and soil moisture to the exclusion of perennial grass and herb seedlings (Evans 1961; Hull and Hansen 1974; Robertson and Pearse 1945). The competitive influence exerted by these plants enables them to dominate vast areas for many years.

Piemeisel (1951) reported that sites in southern Idaho infested with cheatgrass and other annuals continued to support a weedy cover for over 50 years, even when protected from grazing. Natural reestablishment of desirable perennials occurs slowly on sites where annual weeds exist. On most sites, particularly arid rangelands where native seedbanks have been depleted, changes in plant composition will not occur unless aided by revegetation (Hull and Holmgren 1964; Monsen and Kitchen 1994; Monsen and McArthur 1985; Young 1983). Annual grasses, particularly cheatgrass brome, are extremely difficult to control, but must be significantly reduced in density prior to seeding other species.

Cheatgrass (fig. 36) now dominates former brush and tree types in the following approximate order of decreasing importance: big sagebrush (fig. 28, 30), juniper-pinyon (fig. 20), blackbrush, shadscale saltbush (fig. 32), and mountain brush (Monsen and McArthur 1985). Cheatgrass has recently invaded

Figure 36—Cheatgrass now dominates extensive areas previously occupied by Wyoming big sagebrush, increasing wildfire and fire suppression problems throughout the West.

southern desert shrub regions. Major areas of concern, where restoration is needed, are within the blackbrush and associated shrub types where red brome may also occur (fig. 37). Both annual grasses spread quickly and gain control soon after the perennial cover is disturbed. Wherever red brome dominates, it should be treated in much the same way as cheatgrass brome.

Different methods are required to revegetate sites infested with annual grasses than would be required if these annuals were not present. Consequently, the annual weeds have been considered as a separate major vegetative type.

Both cheatgrass and red brome provide a short grazing season for livestock and game animals. Forage production varies greatly between wet and dry years (Klemmedson and Smith 1964; Stewart and Young 1939). Seeds and new shoots provide valuable sustenance for chuckars, partridge, Gambel quail, and mourning doves. Both grasses are grazed in spring and fall by livestock and big game.

As with other annuals, production of cheatgrass, red brome, and medusahead is often negligible in dry years. All three species are serious fire hazards, particularly in wet years. Areas dominated by these two bromes and medusahead frequently burn and gradually extend their areas of dominance (Pickford 1932; Wright 1985; Wright and Klemmedson 1965; Young and Evans 1978b). Because they become a fire hazard in wet years, produce little forage in dry years, and prevent reestablishment of native species, attempts should be made to replace these annuals with adapted perennials. These two bromes can persist as minor components in perennial stands (fig. 32) (Astroth and Frischknecht 1984; Barney and Frischknecht 1974). They are, however, able to take advantage of any reduction or weakness in the perennial stand. For this reason, any major increase in establishment of either of these grasses immediately indicates damaging use, or at least a weakening of the perennials.

Medusahead has invaded many western rangelands (Major and others 1960), particularly low sagebrush sites (Young and Evans 1971). This annual grass exhibits characteristics similar to those of cheatgrass, and usually occurs in similar climatic zones. Where both occur together, medusahead has sometimes been able to replace cheatgrass. It has been able to advance into clay or heavy textured soils, particularly on sites lacking a competitive plant cover (Young and Evans 1971). Well-drained or coarse-textured soils are usually not inhabited by this grass. Plants normally occur in closed, dense patches. Medusahead (fig. 38) is a highly competitive winter annual. An abundance of seed and litter builds on the soil surface. This creates serious fire management problems, as highly flammable foliage is present every year (Bunting 1985). Medusahead seeds are not consumed by ground fires as readily as cheatgrass seeds, and intense and slow-burning fires are required to destroy accumulated seeds. Medusahead is a poor forage plant. Sites dominated by this weedy annual must be treated in a manner similar to cheatgrass sites, using competitive perennials. Once a perennial cover is established, the grass can be controlled, but not eliminated.

Figure 37—Red brome is a serious invader in more arid environments than those occupied by cheatgrass or other annual weeds. It is as competitive as cheatgrass and has created similar fire problems.

Cheatgrass, medusahead, and red brome possess a number of traits that must be recognized before restoration practices are initiated. Cheatgrass has spread to occupy a wide array of habitats throughout the Western United States (Mack 1981) and has quickly developed habitat-adapted populations. Although red

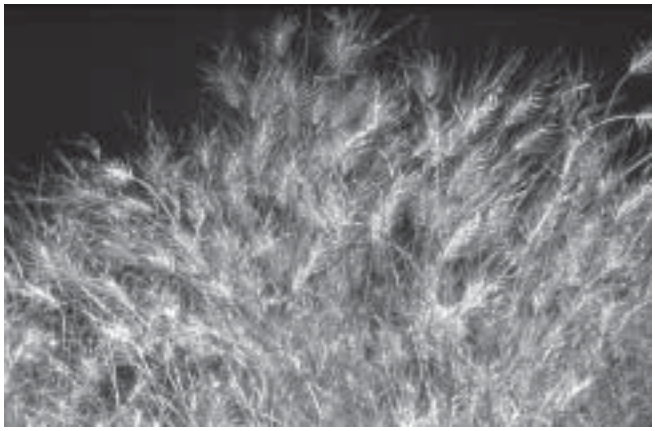

Figure 38—Medusahead is an annual grass that is rapidly expanding its area of occupation, and is now found on sites once dominated by cheatgrass.

brome and medusahead occupy less diverse habitats, populations of all three species are well suited to the variety of sites they occupy. Plants of all species are able to respond to differences in annual climatic conditions, and to mature and produce some seeds each year, even during years of relatively high stress (Rice and Mack 1991). Generally, plants produce an abundant seed crop. Seed germination patterns vary among populations of cheatgrass, although a high percent of seeds will germinate if moisture is available (Hull and Hansen 1974). Hulbert (1955) reported that recently harvested seeds of cheatgrass from eastern Washington and southern Idaho were conditionally dormant at summer incubation temperatures, but became nondormant with autumn temperatures. Young and others (1969a) reported that freshly harvested seed from western Nevada were nondormant. Beckstead and others (1993) concluded that high summer dormancy has evolved with populations growing in climates with plentiful summer rain, as opposed to nondormant populations occurring in areas with less chance of premature germination from summer rains.

Most studies demonstrate that seed of cheatgrass fully afterripens and germinates in response to fall rains. Seeds that are partially covered with litter or soil readily germinate and become established. Medusahead and red brome seeds also fall germinate at similar periods as reported for cheatgrass. Seeds that do not fall germinate are left on the soil surface and will carryover until the following spring (Evans and Young 1972b; Wicks and others 1971; Young and others 1969a). Regular spring germination is common in many regions with little carryover beyond this date (Mack and Pyke 1983). Young and Evans (1975) found that seeds from western Nevada were induced into secondary dormancy under winter conditions, which delayed germination, resulting in substantial carryover until the second year. Hull and Hansen (1974) reported similar results from seeds of northern Utah. Consequently, a sufficient reservoir, or seedbank remained from year to year (Wright 1985).

Plants of cheatgrass, red brome, and medusahead are highly competitive. The number of seedlings germinating and becoming established varies from year to year. Regardless of the number of seedlings to appear, the plants can extract all available soil moisture throughout their rooting depth. One large plant may be as competitive as a large number of small, individual plants (Monsen and McArthur 1985). Thus, reducing the density of seedlings may not significantly reduce the overall effect on soil moisture.

Cheatgrass, red brome, and medusahead are winter annuals. Seeds may germinate either in fall or spring months, depending on weather conditions (Bunting 1985). Seeds that germinate in the fall produce plants that overwinter and resume growth in the early spring (Young and Evans 1973). Seeds that germinate in the spring do so prior to most seeded or native perennials (Buman and others 1988). In addition, seedling vigor and rate of growth is superior to that of most perennials (Harris 1967); therefore, they provide serious competition to newly developing seedlings of other species. To eliminate or reduce density of these weedy annuals, any treatment must effectively control live plants and both fall- and spring-germinated seeds (Monsen 1994).

Removal of Competition

Burning before seeds shatter is an economical treatment, particularly on rocky rangelands. To be most effective, burning should be done before seeds are dispersed (Hull 1944; Pechanec and Hull 1945). Fires must burn slowly or hot enough to consume seeds left on the soil surface. Most fires destroy only a portion of the seed, particularly medusahead seed. Cheatgrass is often infested with smut (Fisher 1937), which may destroy over 95 percent of the seeds. Scheduling treatments to coincide with smut outbreaks may not always be practical, yet sites that are heavily infested can be treated to good advantage with fire.

Deep furrow drilling or other methods to control these annuals may be required to reduce competition within the seeded area. Plowing, shallow disking, or pipe harrowing young plants before seeds mature can be effective on areas that are accessible to tractor drawn equipment. Except on small tracts, disking or plowing is more costly than burning. Offset disks, disk chains, pipe harrows, and disk harrows are satisfactory implements for removing competition.

Ogg (1994) summarizes the status and potential use of herbicides to control annual grasses. More than 20 herbicides are registered for use. Cheatgrass seedlings are easily killed with herbicides. The main problem is to develop methods that selectively control the weed, but retain desirable plants. Pronamide applied late in the fall will selectively control cheatgrass without damage to slender wheatgrass, tall wheatgrass, western wheatgrass, crested wheatgrass, intermediate wheatgrass, creeping foxtail, or orchardgrass. Currently, labeling permits grazing of treated grasses (Ogg 1994). Evans and others (1967, l983) reported that Paraquat, a contact herbicide, could be applied in the spring followed by spring seeding.

Glyphosate is a foliage-active herbicide that will control cheatgrass when applied at rates as low as 0.3 kg/ha. This herbicide can be applied early in spring when cheatgrass growth is quite active, with little damage to dormant perennials. This herbicide can be effectively used where extensive stands of cheatgrass occur. Glyphosate can also be used to spray strips that are about 3 ft (1 m) wide to allow interseeding of other species. Cheatgrass plants can be fall or spring treated

if these plants are actively growing. Spraying and seeding can be done in one operation if care is given to prevent overturning soil from the seeding operation onto sprayed plants.

Drilling seeds in scalped furrows 16 to 32 inches (40 to 60 cm) wide with an interseeder eliminates competition for one or two seasons and allows sufficient time for new seedlings to establish (Monsen 1980a,b; Nyren and others 1980; Stevens 1994). The scalps create good barriers against the spread of wildfires in the same season. On hillsides too steep for machinery, shoveled scalps 3.3 ft^2 (l m^2) remove competition sufficiently for planting shrubs (Giunta and others 1975).

No single method is completely effective for eliminating live plants and seeds of annual grasses. To be most effective, disturbances should be treated before these annuals have gained dominance.

Planting Season

Late fall (mid-October) through February is recommended for seeding. Planting in winter is preferable, especially on sites in the southern desert shrub type. If herbicides are used, planting must be scheduled following recommendations for the specific herbicide. Sites should not be seeded in the summer or early fall months. Burned areas are frequently planted immediately after wildfires regardless of the date of the burn. This is a mistake and should not be done. Early seeding does not reduce the reestablishment of the annual grasses. Seeds planted too early in the season may germinate after a light rainfall, only to succumb as soils quickly dry.

Planting Procedures

Aerial broadcasting, using fixed-wing aircraft or helicopters, followed by anchor chaining or pipe harrowing, can be widely used on both rocky and rock-free sites. This treatment is especially useful on extensive burns. Selected areas referred to as “greenbelts,” or “fuel barriers,” can be planted to help contain range fires. Small areas can be broadcast seeded with a cyclone seeder or by hand, but seeds must be covered afterward. Failure to cover the seed, or planting out of season, will often result in failure of the project. Ash and litter remaining on the soil following burns cannot be expected to adequately cover seeded perennials.

Drilling is successful on plowed, machine-scalped, and burned areas. The rangeland drill, with its disks regulated to make deep, wide furrows, can satisfactorily interseed perennial grasses into cheatgrass stands. The drill can also plant forbs and shrubs on burned cheatgrass ranges. Depth bands should be used on the disks to insure that drills do not plant too deep in loose seedbeds. Both the browse seeder and the rangeland drill can be used to plant browse seeds in alternate rows with herbs. The browse seeder, equipped with wide scalpers, has been the most satisfactory planter used for seeding into cheatgrass. Recently developed drills with multiple seed boxes can plant individual species in separate drill rows. In addition, press wheels have been added that firm the seedbed and improve seedling establishment. It is important that sites are correctly seeded, as annual grass will quickly recover and occupy openings. Seeded plants must compete with the weeds, and should be established in the most optimal sites.

Adapted Species and Mixtures

Cheatgrass sites must be planted with perennials to reduce the reestablishment of the annual grass. If perennials are not established the first season after treatment, cheatgrass will regain dominance. If perennial seedlings survive the first growing season, they will usually attain dominance. The time required for seeded plants to develop a mature stand is dependent on annual climatic conditions. The perennial grasses usually require at least two growing seasons to fully establish. Seeded stands generally reach full maturity 4 to 6 years after planting. Treated areas must be carefully managed to ensure development of the seeded species.

Individual species and mixtures recommended for use in cheatgrass, red brome, and medusahead areas are essentially the same as those recommended for whatever vegetative type existed prior to invasion of the annual weeds. Some species are more competitive and have the potential to establish and spread in annual grass communities (table 28). Included in this group are Sandberg bluegrass, Lewis flax streambank wheatgrass, bottlebrush squirreltail (Stevens 1998), crested wheatgrass, desert wheatgrass, and rubber rabbitbrush (fig. 30). At higher elevations, muttongrass, sheep fescue, intermediate wheatgrass, pubescent wheatgrass, and small burnet compete and increase well with annual grasses. Other species can also compete with the annuals, but may require a longer period to attain maturity and dominate the site. Some examples are western yarrow, Pacific aster, Thurber needlegrass, bluebunch wheatgrass, and needle-and-threadgrass.

Lowland Annual Weed Communities

There are two types of lowland annual weed communities; those that prosper in the spring, and those that develop in the summer (fig. 39).

Figure 39—Interplanting and interseeding shrubs and herbs on sites infested with annual weeds have been successful methods of facilitating establishment and spread of the desired species.

Spring-Growing Annuals

Spring-growing annuals germinate early (February through April), grow rapidly, and flower before summer arrives. Major spring-growing species found on valley and foothill ranges in the Intermountain West are bur buttercup, tumble mustard, blue mustard, tansy mustard, prickly lettuce, fiddleneck, and African mustard. These annuals can be found in pure or mixed stands, mainly in the sagebrush zone. Abandoned farmlands, sheep bedgrounds, feeding areas, and sites where the native vegetation has been severely depleted are typical areas for these weeds. Annual precipitation throughout these areas varies from 9 to 16 inches (230 to 410 mm), and soils are generally basic.

Spring-growing annuals germinate early, sometimes under snow cover. To establish desirable perennials in communities of spring-growing annuals, the following should be done: (1) eliminate the annual seed source, (2) use perennial species that exhibit early germination or that have vigorous seedlings that are able to compete with the established annual seedlings, and (3) seed at the most opportunistic time.

Removal of Competition

Most spring-growing annuals can be controlled by shallow disking using offset disks, pipe harrows, disk chains, or anchor chains. Seeds of most weed species are small and germinate on or near the soil surface. Plowing or deep disking can be used to bury these seeds in areas where elimination of other species is not a concern. Weeds can be removed with broadleaf herbicides applied prior to seed maturation. Most spring-growing annuals are not as competitive as cheatgrass, and desirable species can be established by reducing competition. Some weed-infested sites can improve if livestock grazing is better regulated; however, many sites will require control measures to promote recovery.

Planting Season

Areas dominated by spring-growing annuals generally are best seeded in the fall or winter. Seeds of many perennial species exhibit dormancy, which can be overcome by fall or winter seeding. Fall, winter, and spring seedings generally require reduction or removal of weedy species and their seeds. Control measures should be designed not only to reduce competition, but to conserve soil moisture and aid in seedbed preparation and planting.

Spring seedings are not recommended. By the time soil surfaces dry enough to operate planting equipment, annuals have germinated and soil moisture has nearly been depleted. Consequently, sufficient soil moisture is not available to support germination and establishment of new seedlings.

Planting Procedures

Seedling establishment can be enhanced by seeding into scalps or furrows created to remove the annual weeds. Various types of equipment are available that make scalps or furrows and plant seeds into the cleared depression (Larson 1980). Scalps 4 to 8 inches (10 to 20 cm) wide are generally sufficient for seeding adapted grasses. Strips of this width can be created using offset disks on the rangeland drill or other commercial drills. Shrubs and perennial forbs do better with wider clearings. Scalps should be at least 12 to 24 inches (30 to 60 cm) wide for shrubs. The more competition, or potential competition (seed), that is removed, the greater chance for success.

Adapted Species and Mixtures

Species seeded into spring-growing annual communities can face considerable competition until they are well established. Seeded areas should not be grazed until there is a good, healthy stand of the seeded species. This generally requires at least 2 to 4 years of nonuse. One should not expect stand density to be exceptionally high the first 2 to 4 years. However, some sites do respond rapidly.

Species recommended for seeding are those recommended for seeding the vegetative type that existed prior to disturbance. These include juniper-pinyon (tables 14 through 16), fourwing saltbush (table 17), basin big sagebrush (table 18), Wyoming big sagebrush (table 20), black sagebrush (table 21), low sagebrush (table 22), shadscale saltbush (table 25), black greasewood (table 26), and blackbrush (table 27).

Summer-Growing Annuals

Major summer-growing annuals are Russian thistle and halogeton. Two species of Russian thistle have been identified (Welsh and others 1987). Both grow with halogeton and are widespread on lower elevation ranges (Beatley 1973; Evans and Young 1980). These plants are most abundant on abused, deteriorated areas in the salt desert shrub and basin big sagebrush types. Soils are basic, and annual precipitation usually ranges from 5 to 16 inches (130 to 410 mm). Most improvement can be gained on areas that receive more than 9 inches (230 mm) of annual precipitation. Areas that receive less than 9 inches (230 mm) of precipitation may, however, warrant treatment. Russian thistle and halogeton are early spring germinators, but do not grow much until midsummer. When both species grow rapidly (Cook and Stoddart 1953; Dwyer and Wolde-Yhannia 1972; Evans and Young 1972a, 1980).

Removal of Competition

Chaining, disk chaining, disking, scalping, or pipe harrowing generally eliminate sufficient competition so adapted perennials can be established. Deep furrow drills can also be used to clear strips adjacent to the seeded furrow to assure establishment of seeded species.

Burning is not effective in removal or control of these summer annuals. Both species generally remain green until late summer and are not easily burned. Abundant seed crops are formed each year, and primary control measures must be developed to eliminate or remove weed seeds. Broadleaf herbicides can be used to kill established plants, but sufficient seed persists in the soil to germinate the following season. To be most effective, mechanical or herbicide treatments should be conducted when weeds are young, generally each summer. However, sites cannot be seeded at this date, and planting should be delayed until the fall. Weeds quickly reinvade treated areas, and sites should be fall seeded to prevent weed invasion.

These weeds invade and increase rapidly following disturbances. It is important to seed new disturbances as soon as possible. Sites should not be allowed to remain open or occupied by these weeds because a seedbank will quickly develop. Disturbances that have been occupied by these weeds for a number of years may require 1 to 2 years of fallowing to exhaust the seedbank. Once perennial herbs or shrubs have reestablished, weeds can be controlled.

Because early season competition from these two annuals is usually not serious, perennial species that germinate early and quickly develop a root system that can be most successful. If environmental conditions are adequate and seeded species become established, Russian thistle and halogeton density can be reduced substantially.

Planting Season

Fall seedings are essential in summer-growing annual communities.

Planting Procedures

Most disturbances can be seeded with a number of methods. Sites can be aerial seeded, and seeds covered with a drag, harrow, or similar implement. Drill seeding is a primary method of planting, and deep furrow drills are commonly used to remove weeds in a narrow strip or scalp. Interseeding using the Hansen seeder or similar equipment is particularly effective in reestablishing desired species.

Many species established from interseedings will naturally spread by seedling recruitment into the weedy areas. Russian thistle density fluctuates from year to year, allowing for invasion of other species.

Adapted Species and Mixtures

Summer-growing annuals have established and become dominant over areas in a number of vegetative types. Species recommended for seeding summer-growing annual communities are essentially the same as those recommended for seeding the vegetative type that existed prior to when the annuals gained control. These include juniper-pinyon (tables 14 through 16), fourwing saltbush (table 17), basin big sagebrush (table 18), Wyoming big sagebrush (table 20), black sagebrush (table 21), low sagebrush (table 22), shadscale saltbush (table 25), black greasewood (table 26), and blackbrush (table 27).

Table 1—Ecological status, use index, competitiveness, and seeding rate for species adapted for seeding subalpine herblands and upper-elevation aspen openings.

Species	Ecological status[a]	Use index for:		Competitiveness[b] as a seedling in the presence of:		Mature plant
		Restoration plantings	Revegetation plantings	Maximum competition	Minimum competition	
Grasses and sedges						
Barley, meadow	P,E,L	X	X	EX	EX	ME
Bentgrass, redtop	P,E	X		ME	ME	PO
Bluegrass, big	E,L	X	X	ME	ME	ME
Bluegrass, Canada	P,E,L		X	ME	ME	ME
Brome, meadow	P,E		X	EX	EX	ME
Brome, mountain	P,E,L	X	X	EX	EX	EX
Brome, smooth (northern)	P,E,L		X	ME	EX	EX,NC
Brome, subalpine	E,L		X	ME	EX	EX
Fescue, sulcata sheep	P,E,L	X	X	PO	EX	ME
Fescue, tall	P,E		X	EX	EX	ME
Foxtail, creeping	P,E,L		X	ME	EX	EX
Foxtail, meadow	P,E,L		X	ME	ME	EX
Hairgrass, tufted	P,E,L	X	X	PO	ME	ME
Needlegrass, subalpine	E,L	X		ME	ME	ME
Oniongrass	P,E		X	ME	ME	PO
Orchardgrass	P,E,L		X	EX	EX	ME
Oatgrass, tall	P,E		X	ME	EX	ME
Reedgrass, chee	E,L		X	PO	PO	EX
Sedge, ovalhead	E,L	X	X	PO	ME	EX
Timothy	P,E		X	EX	EX	PO
Timothy, alpine	P,E,L	X	X	ME	ME	ME
Wheatgrass, intermediate	P		X	EX	EX	EX,NC
Wheatgrass, slender	P,E,L	X	X	EX	EX	ME
Forbs						
Alfalfa (drought tolerant)	P,E,L		X	EX	EX	ME
Aster, leafybract alpine	E,L	X		PO	PO	PO
Aster, Pacific	P,E,L	X	X	PO	ME	ME
Aster, smooth	P,E,L	X	X	PO	PO	EX
Bluebell, tall	E,L	X		PO	PO	EX
Cinquefoil, gland	E,L	X		ME	ME	ME
Columbine, Colorado	E	X		PO	ME	ME
Cowparsnip	E,L	X		ME	ME	ME
Crownvetch	P,E,L		X	ME	ME	ME
Fleabane, Bear River	E,L	X		ME	ME	ME
Fleabane, Oregon	E,L		X			
Geranium, sticky and Richardson	P,E,L	X	X	PO	PO	ME
Goldeneye, showy	P,E,L	X	X	ME	EX	ME
Goldenrod, low	E,L	X	X	ME	EX	ME
Groundsel, butterweed	E,L	X		ME	ME	ME
Helianthella, oneflower	P,E	X		ME	ME	ME
Ligusticum, Porter	P,E,L	X		ME	ME	ME
Lomatium, Nuttall	P,E,L	X		ME	ME	ME
Lupine, mountain	E,L	X		ME	ME	EX

(con.)

Table 1 (Con.)

Species	Ecological status[a]	Use index for: Restoration plantings	Use index for: Revegetation plantings	Competitiveness[b] as a seedling in the presence of: Maximum competition	Competitiveness[b] as a seedling in the presence of: Minimum competition	Mature plant
Lupine, silky	E,L	X		ME	ME	EX
Meadowrue, Fendler	L	X		PO	ME	ME
Painted-cup, sulphur	L	X		ME	ME	EX
Penstemon, Rocky Mountain	P,E,L	X	X	PO	ME	ME
Penstemon, Rydberg	P,E	X	X	PO	ME	ME
Penstemon, Wasatch	P,E	X	X	ME	ME	ME
Sage, Louisiana	P,E	X	X	PO	ME	ME
Solomon-plume, fat	E,L	X		PO	PO	ME
Sweetanise	P,E,L	X		ME	EX	ME
Valerian, edible	E,L	X		PO	PO	EX
Vetch, American	L	X	X	ME	ME	ME
Violet, Nuttall	P,E,L	X		ME	EX	ME
Yarrow, western	P,E,L	X	X	ME	EX	ME
Shrubs						
Cinquefoil, shrubby	E,L	X		PO	PO	EX
Currant, sticky	E,L	X		PO	PO	EX
Currant, wax	E,L	X		PO	PO	EX
Elderberry, red	E,L	X		PO	ME	EX
Rabbitbrush, low	P,E,L	X	X	ME	ME	EX
Rabbitbrush, mountain rubber	P,E,L	X	X	ME	ME	ME
Rabbitbrush, Parry	P,E,L	X	X	ME	ME	ME
Rose, Woods	E,L	X	X	PO	PO	EX
Sagebrush, big mountain	P,E,L	X	X	ME	ME	ME
Sagebrush, big timberline	P,E,L	X		EX	EX	EX
Sagebrush, silver	P,L	X		ME	ME	ME
Snowberry, mountain	E,L	X	X	PO	PO	EX

Growth form	Soil seeding rate: Well drained	Soil seeding rate: Moist
	Pls lb/acre[c]	
Grasses	4 to 6	4 to 6
Forbs	6 to 8	6 to 8
Shrubs	1 to 2	1 to 2

[a]Species status: P = pioneer; E = early seral; L = late seral.
[b]Competitiveness rating: PO = poor competitor; ME = medium competitor; EX = excellent competitor; NC = noncompatable with other species.
[c]Drill rate—broadcast seeding requires ¼ to ⅓ more seed.

Table 2—Ecological status, use index, competitiveness, and seeding rate for species adapted for seeding wet and semiwet meadows.

Species	Ecological status[a]	Use index for:		Competitiveness[b] as a seedling in the presence of:		Mature plant
		Restoration plantings	Revegetation plantings	Maximum competition	Minimum competition	
Grasses and sedges						
Barley, meadow	P,E,L	X	X	EX	EX	ME
Bentgrass, redtop	P,E	X	X	ME	ME	PO
Brome, mountain	P,E,L	X	X			
Brome, smooth (northern)	P,E,L		X	ME	EX	EX,NC
Foxtail, meadow	P,E,L		X	PO	ME	EX
Hairgrass, tufted	P,E,L	X	X	PO	ME	ME
Oatgrass, tall	P,E		X	ME	EX	ME
Sedge, ovalhead	E,L	X		PO	ME	EX
Timothy	P,E		X	EX	EX	PO
Wheatgrass, tall	P,L		X	EX	EX	EX
Wildrye, Great Basin	E,L	X		PO	PO	ME
Forbs						
Aster, alpine leafybract	P,E,L	X	X	PO	PO	PO
Aster, blueleaf	P,E,L	X	X	PO	PO	ME
Aster, Pacific	P,E,L	X	X	PO	ME	ME
Cinquefoil, gland	P,E,L	X		ME	ME	EX
Clover, alsike	E,L		X	ME	ME	ME
Clover, strawberry	P,E,L		X	ME	ME	ME
Geranium, sticky and Richardson	P,E,L	X		ME	ME	EX
Medick, black	P,E,L		X	EX	EX	ME
Milkvetch, cicer	P,E,L		X	ME	ME	EX
Sainfoin	E		X	ME	ME	PO
Sage, Louisiana	P,E	X	X	PO	ME	ME
Sweetanise	P,E,L	X		ME	ME	ME
Valerian, edible	E,L	X		PO	PO	EX
Yarrow, western	P,E,L	X	X	ME	ME	ME

Growth form	Soil seeding rate	
	Well drained	Moist
	Pls lb/acre[c]	
Grasses	4 to 5	3 to 4
Forbs	5 to 7	6 to 8

[a]Species status: P = pioneer; E = early seral; L = late seral.
[b]Competitiveness rating: PO = poor competitor; ME = medium competitor; EX = excellent competitor; NC = noncompatable with other species.
[c]Drill rate—broadcast seeding requires ¼ to ⅓ more seed.

Table 3—Ecological status, use index, and competitiveness for shrubs recommended for transplanting in wet meadows.

Species	Ecological status[a]	Use index for: Restoration plantings	Use index for: Revegetation plantings	Competitiveness[b] as a seedling in the presence of: Maximum competition	Competitiveness[b] as a seedling in the presence of: Minimum competition	Mature plant
Grasses and sedges						
Birch, water	P,E,L	X		ME	ME	EX
Cinquefoil, bush	E,L	X		ME	ME	EX
Dogwood, redosier	E,L	X		PO	ME	EX
Honeysuckle, Utah	E,L	X		PO	PO	EX
Rose, Woods	E,L	X	X	PO	PO	EX
Willows (see table 11)	P,E,L	X	X	PO	PO	EX

[a]Species status: P = pioneer; E = early seral; L = late seral.
[b]Competitiveness rating: PO = poor competitor; ME = medium competitor; EX = excellent competitor.

Table 4—Ecological status, use index, competitiveness, and seeding rate for species adapted for seeding inland saltgrass sites.

Species	Ecological status[a]	Use index for: Restoration plantings	Use index for: Revegetation plantings	Competitiveness[b] as a seedling in the presence of: Maximum competition	Competitiveness[b] as a seedling in the presence of: Minimum competition	Mature plant
Grasses						
Dropseed, sand	P,E,L	X	X	ME	ME	ME
Fescue, tall	P,E,L		X	EX	EX	PO
Foxtail, meadow	P,E,L		X	ME	EX	ME
Sacaton, alkali	P,E,L	X	X	PO	PO	ME
Wheatgrass, fairway crested	P,E,L		X	EX	EX	ME
Wheatgrass, 'NewHy'	P,E,L		X	ME	ME	EX
Wheatgrass, streambank	P,L	X	X	ME	ME	EX
Wheatgrass, tall	P,L		X	ME	ME	EX
Wildrye, Russian	P,E,L		X	PO	PO	EX
Wildrye, Salina	P,L	X		PO	PO	ME
Forbs						
Aster, Pacific	P,E,L	X	X	PO	ME	ME
Clover, strawberry	P,E,L		X	ME	ME	ME
Medick, black	P,E		X	EX	EX	PO
Summercypress, Belvedere	P,E		X	EX	EX	PO
Sweetclover, yellow	P		X	EX	EX	PO
Shrubs						
Buffaloberry, silver[c]	E,L	X		PO	PO	EX
Greasewood, black	E,L	X		PO	PO	EX
Honeysuckle, tatarian[c]	E,L	X		PO	PO	EX
Plum, American[c]	E,L	X		PO	PO	EX
Rabbitbrush, rubber	P,E	X	X	ME	ME	ME
Saltbush, fourwing	P,E,L	X	X	ME	ME	ME
Saltbush, Gardner	P,E,L	X	X	ME	ME	ME
Willow, purpleosier[c]	E,L		X			EX

Growth form	Soil seeding rate: Wet and dry soils
	Pls lb/acre[d]
Grasses	6 to 8
Forbs	2 to 3
Shrubs	1 to 2

[a]Species status: P = pioneer; E = early seral; L = late seral.
[b]Competitiveness rating: PO = poor competitor; ME = medium competitor; EX = excellent competitor.
[c]Established most successfully by tansplants.
[d]Drill rate—broadcast seeding requires ¼ to ⅓ more seed.

Table 5—Distribution and rooting characteristics of select native sedges and rushes for riparian sites. Information, in part, is from Lewis (1958a) and Monsen, in Platts and others (1987).

Species	Areas[a]	Habitat	Abundance	Characteristic	Comments
Bulrush, saltmarsh	Mtn. B.	Lake edge, streambank, alkali sites	Abundant	Rhizomatous	Dense patches, spreads rapidly.
Bulrush, tule	Val.-Mtn. B.	Lake edge	Abundant	Rhizomatous	Tall, rank, dense patches, restricted to water's edge.
Rush, Baltic	Val.-Asp.	Wet and semiwet meadows	Abundant	Rhizomatous	Principal species for stabilization. Use adapted ecotypes, spreads aggressively, persists with grazing.
Rush, Drummond	LPP-Alp.	Wet and dry meadows	Common	Caespitose	Spreads after disturbance, occupies infertile soil.
Rush, longstyle	Sage-SF	Wet meadows and streams	Common	Rhizomatous	Moderately palatable rush, long style.
Rush, swordleaf	Sage-SF	Streams and wet meadows	Abundant	Strongly rhizomatous	Moderately palatable, wide elevational range.
Rush, Torrey	Val.-PJ	Streams, wet meadows, seeps, alkali tolerant	Common	Strongly rhizomatous	Spreads onto disturbances.
Sedge, analogue	PP-SF	Bogs and wet meadows	Frequent	Long, creeping rootstock	Excellent cover, widely distributed, calcareous soils.
Sedge, beaked	Val.-SF	Streams, water's edge, standing water	Abundant	Culms from stout, long rhizomes	Principal species for streambank, stabilization, low palatability.
Sedge, black alpine	SF-Alp.	Well-drained meadows	Frequent	Creeping rootstock	Good cover for wet areas.
Sedge, blackroot	Alp.	Open, dry meadows	Common	Caespitose	Vigorous, abundant.
Sedge, Douglas	PF-Asp.	Dry meadows, alkali tolerant	Abundant	Creeping rootstocks, long culms, increases under grazing	Adapted to compact soils, low palatability.
Sedge, downy	Alp.	Dry and wet meadows	Abundant	Rhizomatous	Vigorous, spreads rapidly.
Sedge, golden	Val.-SF	Marsh, wet	Frequent	Caespitose, long rootstock	Widely distributed, good ground cover.
Sedge, Hepburn	Alp.	Open meadows	Abundant	Densely caespitose	Short stature, open cover.
Sedge, Hood	Mtn. B.-SF	Open parks, drainageways	Abundant	Densely caespitose	Excellent ground cover, useful forage.
Sedge, Kellogg	Mtn. B.-SF	Wet meadows, marshes	Abundant	Caespitose, long rootstock	Pioneer species, invades water's edge.
Sedge, Nebraska	Val.-Asp.	Marshes and meadows	Common	Strongly rhizomatous	Excellent soil stabilizer, palatable, widely distributed.
Sedge, rock	Alp.	Dry slopes and meadows	Abundant	Short rhizomes	Vigorous, spreads rapidly, limited distribution.
Sedge, russet	LLP-SF	Water's edge	Abundant	Culms from long, creeping rootstock	Excellent streambank cover, limited distribution.
Sedge, slim	Val.-Asp.	Dry to moist alkali bottomlands	Abundant	Long, creeping rootstock	Large, dense, persistent, moderately palatable.
Sedge, smallwing	Mtn. B.-Asp.	Meadow edges	Abundant	Densely caespitose	Good cover for streambank, palatable, spreads by seeds, widely distributed.
Sedge, soft-leaved	ASP-Alp.	Swamps, meadows	Abundant	Caespitose, long rhizomes	Shady areas, solid mat, moderate vigor.
Sedge, valley	Sage-Asp.	Dry slopes	Abundant	Caespitose	Spreads onto dry grass-sage sites.
Sedge, woolly	Val.-SF	Dry to wet meadows	Abundant	Caespitose	Very robust, good species for streambank stabilization.
Spikerush, common	Val.-SF	Wet meadows and streams, alkali tolerant	Abundant	Rhizomatous	Spreads rapidly, low palatability, wide elevational range.

[a]Areas: Alp. = alpine; SF = spruce-fir; Asp. = aspen; LPP = lodgepole pine; PP = ponderosa pine; Mtn. B. = mountain brush; PJ = pinyon-juniper; Sage = big sagebrush; Val. = valley.

Table 6—Characteristics of broadleaf herbs recommended for planting riparian sites (from Monsen in Platts and others 1987).

Species	Areas of adaptation[a]	Origin	Seeding trait	Transplant capability	Growth rate
Alfalfa	Asp.-Sage	Introduced	Excellent	Good	Rapid
Aster, Pacific	Asp.-V	Native	Poor	Excellent	Moderate
Bassia, fivehook	PJ-SDS	Native	Excellent	Good	Rapid
Checker-mallow, Oregon	Asp.-Mtn. B.	Native	Good	Good	Moderate
Clover, alsike	Asp.-Mtn. B.	Introduced	Good	Fair	Moderate
Clover, strawberry	V	Introduced	Good	Fair	Moderate
Cinquefoil, gland	Asp.-PP	Native	Good	Excellent	Moderate
Cowparsnip	Alp.-Mtn. B.	Native	Poor	Poor	Poor
Crownvetch	PJ-Mtn. B.	Introduced	Good	Excellent	Rapid
Fireweed	Asp.-Mtn. B.	Native	Excellent	Good	Rapid
Flax, Lewis	Asp.-Sage	Native	Excellent	Good	Moderate
Groundsel, butterweed	Asp.-PP	Native	Good	Excellent	Moderate
Medick, black	Asp.-Sage	Introduced	Excellent	Good	Moderate
Sage, Louisiana	Alp.-Sage	Native	Excellent	Excellent	Rapid
Solomon-seal, western	Asp.-Mtn. B.	Native	Poor	Fair	Slow
Sweetclover, yellow	Asp.-Sage	Introduced	Excellent	Poor	Rapid
Valerian, edible	Asp.-Mtn. B.	Native	Poor	Fair	Slow
Yarrow, western	Alp.-V	Native	Excellent	Excellent	Rapid

[a]Areas of adaptation: Alp. = alpine; SF = spruce-fir; Asp. = aspen; PP = ponderosa pine; Mtn. B. = mountain brush; PJ = pinyon-juniper; Sage = big sagebrush; Salp. = subalpine; SDS = salt desert shrub; V = valley bottom.

Table 7—Characteristics of grasses adapted for direct seeding and transplanting riparian sites (from Monsen in Platts and others 1987).

Species	Areas of adaptation[a]	Origin	Seeding trait	Transplant capability	Growth rate
Barley, meadow	Alp.-Asp.	Native	Excellent	Excellent	Moderate
Bentgrass, redtop	Salp.-SF	Introduced	Fair	Good	Moderate
Bluegrass, Sandberg	Mtn. B.-Sage	Native	Fair	Good	Slow
Brome, meadow	Alp.-PJ	Introduced	Excellent	Excellent	Moderate
Brome, mountain	Alp.-PJ	Native	Excellent	Excellent	Rapid
Brome, smooth	Alp.-Mtn. B.	Introduced	Good	Excellent	Moderate
Fescue, tall	Asp.-SDS	Introduced	Excellent	Excellent	Rapid
Foxtail, meadow	Alp.-Mtn. B.	Introduced	Excellent	Good	Rapid
Hairgrass, tufted	Alp.-SF	Native	Poor	Fair	Slow
Orchardgrass	Alp.-Sage	Introduced	Good	Good	Rapid
Reedgrass, bluejoint	SF-Sage	Native	Good	Excellent	Moderate
Reedgrass, chee	Alp.-PJ	Introduced	Poor	Good	Slow
Ryegrass, perennial	SF-PP	Introduced	Excellent	Good	Rapid
Sacaton, alkali	Sage-SDS	Native	Fair	Good	Slow
Saltgrass	V	Native	Poor	Excellent	Slow
Squirreltail, bottlebrush	Mtn. B.-V	Native	Good	Fair	Moderate
Timothy	Asp.-Mtn. B.	Introduced	Good	Good	Rapid
Wheatgrass, slender	SF-PJ	Native	Excellent	Excellent	Rapid
Wheatgrass, tall	Mtn. B.-V	Introduced	Excellent	Good	Rapid
Wheatgrass, western	PP-Sage	Native	Fair	Excellent	Slow
Wildrye, creeping	JP-V	Introduced	Good	Excellent	Moderate
Wildrye, Great Basin	Mtn. B.-V	Native	Good	Good	Moderate
Wildrye, mammoth	Mtn. B.-Sage	Introduced	Fair	Good	Moderate
Wildrye, Russian	Mtn. B.-V	Introduced	Fair	Good	Moderate

[a]Areas of adaptation: Alp. = alpine; SF = spruce-fir; Asp. = aspen; PP = ponderosa pine; Mtn. B. = mountain brush; PJ = pinyon-juniper; Sage = big sagebrush; Salp. = subalpine; SDS = salt desert shrub; V = valley bottom.

Table 8—Characteristics of grasses adapted for direct seeding and transplanting riparian sites (from Monsen in Platts and others 1987).

Species	Growth habit	Salinity tolerance[a]	Flooding tolerance	Palatability	Spreadability
Barley, meadow	Rhizomatous	T	Tolerant	Fair	Good
Bentgrass, redtop	Rhizomatous	MT	Moderate	Good	Rapid
Bluegrass, Sandberg	Bunch	MT	Moderate	Good	Fair
Brome, meadow	Rhizomatous	MT	Moderate	Good	Rapid
Brome, mountain	Rhizomatous	MT	Moderate	Good	Good
Brome, smooth	Rhizomatous	MT	Moderate	Good	Rapid
Fescue, tall	Rhizomatous	T	Tolerant	Good	Rapid
Foxtail, meadow	Rhizomatous	MT	Tolerant	Good	Rapid
Hairgrass, tufted	Bunch	MT	Tolerant	Fair	Poor
Orchardgrass	Bunch	MS	Sensitive	Excellent	Fair
Reedgrass, bluejoint	Rhizomatous	MT	Tolerant	Good	Rapid
Reedgrass, chee	Rhizomatous	MT	Tolerant	Good	Good
Ryegrass, perennial	Small bunch	MT	Sensitive	Good	Good
Sacaton, alkali	Bunch	MT	Moderate	Good	Rapid
Saltgrass	Rhizomatous	T	Tolerant	Fair	Rapid
Squirreltail, bottlebrush	Bunch	MT	Moderate	Good	Good
Timothy	Bunch	MS	Moderate	Good	Good
Wheatgrass, slender	Rhizomatous	MS	Sensitive	Excellent	Good
Wheatgrass, tall	Large clump	MT	Moderate	Fair	Good
Wheatgrass, western	Rhizomatous	MS	Moderate	Good	Good
Wildrye, creeping	Rhizomatous	T	Tolerant	Poor	Good
Wildrye, Great Basin	Large clump	T	Moderate	Good	Fair
Wildrye, mammoth	Rhizomatous	T	Tolerant	Good	Good

[a]Salinity tolerance: MS = moderately sensitive; MT = moderately tolerant; T = tolerant.

Table 9—Characteristics of woody species recommended for riparian disturbances (from Monsen in Platts and others 1987).

Species	Areas of occurrence		Adaptation to disturbed sites	Methods of culture[b]
	Zones[a]	Habitat		
Alder, thinleaf	SF-Mtn. B.	Stream edge and well-drained soils	Excellent	NS, CS, DS
Aspen, quaking	SF-Asp.	Well-drained, moist soils, occasionally occurs at streams edges	Fair	NS, CS, RC
Birch, water	SF-Mtn. B.	Stream edges	Good	NS
Buckthorn, cascara		Frequently wet sites		
Buffaloberry, silver	Mtn. B.-V	Well-drained sites, edges of streams and ponds	Good	NS
Ceanothus, redstem	SF-PP	Moist soils, seeps, well-drained soils	Good	DS, NS, CS
Chokecherry, black	SF-PJ	Well-drained, moist soils, occasionally occurs at stream edges	Fair	NS, CS, RC
Cinquefoil, shrubby	Alp.-PP	Stream edges, wet meadows	Excellent	NS, CS
Cottonwood, Fremont	Mtn. B.-V	Moist soils, seeps, frequently wet sites	Good	NS, CS, RC
Cottonwood, narrowleaf	Asp.-Sage	Well-drained and wet sites, edges of streams, ponds, and bogs	Good	NS, CS, RC
Currant, golden	SF-PP	Moist soils	Fair	NS, CS
Dogwood, redosier	SF-Mtn. B.	Stream edges and well-drained soils	Good	DS, NS, CS, RC
Elderberry, red	Asp.-PP	Moist sites, occasional seeps and streambanks	Good	NS, CS
Greasewood, black	SDS-V	Sites with shallow water tables, occasionally flooded sites	Good	NS, CS
Hawthorn, Douglas	Asp.-Sage	Stream edges and well-drained soils	Good	NS
Honeysuckle, Tatarian	Mtn. B.-Sage	Well-drained and moist soils, occasional wet sites	Excellent	NC, CS, DS
Mountain ash, Greene's	SF-Asp.	Moist soils, occasional seeps and stream bottoms	Fair	NS, CS
Mountain lover	SF-Asp.	Moist soils and seeps, requires some shade	Fair	NS, CS
Ninebark, mallow	SF-Asp.	Moist and well-drained soils	Fair	NS, CS
Rabbitbrush, threadleaf rubber	Sage-V	Well-drained soils	Good	DS, NS, CS
Rockspirea	SF-Mtn. B.	Well-drained and moist soils, occasional seeps	Good	NC, CS
Rose, Woods	Asp.-Mtn. B.	Moist and well-drained soils, seeps, streambanks	Excellent	NS, CS, W, RC
Sagebrush, big basin	Mtn. B.-SDS	Deep, well-drained soils, occasional flooding	Excellent	DS, NS, CS
Sagebrush, big mountain	Asp.-Mtn. B.	Well-drained soils, moist sites	Excellent	DS, NS, CS
Sagebrush, silver	Asp.-Sage	Well-drained and moist soils	Fair	DS, NS, CS
Sagebrush, tall threetip	Asp.-Mtn. B.	Well-drained soils, moist sites	Excellent	DS, NS, CS
Saltbush, fourwing	Mtn. B.-V	Well-drained soils, frequent flooding	Good	DS, NS
Saltbush, Gardner	SDS-V	Semi-arid deserts, withstands seasonal flooding and alternating wet/dry periods	Fair	DS, NS, CS
Serviceberry, Saskatoon	Asp.-Mtn. B.	Well-drained soils, seeps occasionally	Good	NS, CS
Silverberry	PJ-V	Stream edges and well-drained soils	Excellent	NS, SC
Snowberry, common	SF-Asp.	Moist sites and well-drained soils	Good	NS, CS, W, RC
Snowberry, mountain	Asp.-Sage	Well-drained soils, edges of streams	Good	NS, CS, W, RC
Snowberry, western	SF-Mtn. B.	Moist sites, occasionally streambanks and valley bottoms	Good	NS, CS, W, RC
Thimbleberry	Asp.-PP	Well-drained soils, frequently wet sites	Excellent	NS, CS, W, RC
Willows (see table 11)				

[a]Areas of adaptation: Alp. = alpine; SF = spruce-fir; Asp. = aspen; PP = ponderosa pine; Mtn. B. = mountain brush; PJ = pinyon-juniper; Sage = big sagebrush; SDS = salt desert shrub; V = valley bottom.
[b]Methods of culture: DS = direct seeding; RC = rooted cuttings; NS = nursery-grown seedling; CS = container-grown seedling; W = wilding.

Table 10—Characteristics of woody species recommended for riparian disturbances (from Monsen in Platts and others 1987).

Species	Establishment traits			Comments
	Seedling establishment	Growth rates	Soil stability value	
Alder, thinleaf	Excellent	Rapid	Excellent	Easily established, adapted to harsh sites, grows rapidly.
Aspen, quaking	Good	Rapid	Good	Considerable ecotypic differences, not well-suited to highly disturbed sites.
Birch, water	Excellent	Rapid	Excellent	Establishes well by transplanting, adapted to streambanks and bogs.
Buckthorn, cascara	Fair	Moderate	Good	Limited plantings, plants perform well on disturbed sites.
Buffaloberry, silver	Good	Moderate	Good	Adapted to valley bottoms and saline soils.
Ceanothus, redstem	Excellent	Rapid	Excellent	Not adapted to saturated soils, but useful in planting disturbed streambanks.
Chokecherry, black	Good	Moderate	Good	Widely adapted, larger transplant stock establishes, and grows rapidly.
Cinquefoil, shrubby	Good	Moderate	Excellent	Valuable species for riparian disturbances, establishes well, and provides excellent site stability.
Cottonwood, Fremont	Good	Rapid	Good	Establishes easily, grows rapidly, furnishes good cover.
Cottonwood, narrowleaf	Good	Rapid	Good	Establishes easily, grows rapidly.
Currant, golden	Excellent	Excellent	Good	Widely adapted, easily established, excellent site stability.
Dogwood, redosier	Excellent	Rapid	Excellent	Easy to grow and establish, useful for disturbed sites, requires fresh aerated water.
Elderberry, red	Fair	Moderate	Good	Adapted to restricted sites, establishes slowly on disturbed sites.
Greasewood, black	Fair	Slow	Good	Difficult to establish, well adapted to valley bottoms and salty soils.
Hawthorn, Douglas	Fair	Slow	Good	Slow growing, but well-suited to disturbed streambanks.
Honeysuckle, Tatarian	Excellent	Rapid	Good	Easily established, provides immediate cover, well-adapted to different soil conditions.
Mountain ash, Greene's	Fair	Slow	Good	Not well adapted to disturbed soils, establishes slowly.
Mountain lover	Fair	Slow	Good	Common on upland slopes, not well adapted to disturbances.
Ninebark, mallow	Fair	Moderate	Good	Requires good sites.
Rabbitbrush, rubber threadleaf	Excellent	Moderate	Good	Suited to heavy, saturated soils.
Rockspirea	Fair	Moderate	Good	Erratic establishment, but suited to disturbed sites.
Rose, Woods	Excellent	Moderate	Good	Widely adapted, easily established, excellent site stability, commonly used species for riparian disturbances.
Sagebrush, big basin	Good	Rapid	Fair	Useful for planting extremely disturbed and well-drained soils.
Sagebrush, big mountain	Good	Rapid	Fair	Adapted to disturbed sites, suited to moist, but not saturated, soils.
Sagebrush, silver	Good	Rapid	Fair	Well adapted to exposed, moist soils, able to tolerate flooding for a short time.
Sagebrush, tall threetip	Excellent	Rapid	Fair	Well suited to eroded, exposed soils, spreads quickly.
Saltbush, fourwing	Excellent	Rapid	Good	Useful for well-drained and disturbed soils.
Saltbush, Gardner	Fair	Moderate	Fair	Adapted to arid sites and seasonally saturated soils.
Serviceberry, Saskatoon	Fair	Slow	Good	Slow to establish, sensitive to understory competition.
Silverberry	Excellent	Rapid	Good	Easily established, rapid rate of growth, adapted to harsh sites.
Snowberry, common	Fair	Moderate	Excellent	Not well suited to extremely disturbed soils, provides excellent stability and spreads well.
Snowberry, mountain	Fair	Slow	Excellent	Plants not well adapted to disturbed soils, provides excellent stability and spreads well.
Snowberry, western	Fair	Slow	Excellent	Plants not well adapted to disturbed soils, provides excellent stability and spreads well.
Thimbleberry	Excellent	Moderate	Good	Well adapted to eroded sites, limited range of distribution.
Willows (see table 11)				

Table 11—Areas of adaptation and selected characteristics of several willow species (from Monsen in Platts and others 1987).

Species	Areas of adaptation		Origin of roots	Prevalence of roots	Period required for:		Comments
	Zones	Habitat			Root formation	Stem formation	
					- - - - Days - - - -		
Willow, arroyo	Aspen-mountain brush	Restricted to stream edges	Callus and lower one-third of stem	Few to many	10	10	Erratic rooting habits.
Willow, barrenground	Subalpine-spruce-fir	Wet sites and well-drained soils	Roots throughout entire length of stem	Abundant	15–20	15–25	Roots freely.
Willow, Bebb	Spruce-fir-aspen	Edges of streams, occasionally well-drained soils	Roots throughout entire length of stem	Moderate	10	10–20	Roots freely.
Willow, Booth	Aspen-sagebrush	Stream edges and standing water	Roots mostly at lower one-third of stem	Abundant	10–15	10–15	Roots freely.
Willow, Drummond	Spruce-fir, upper sagebrush	Edges of streams and ponds	Roots throughout entire length of stem	Abundant	10	10	Roots freely.
Willow, Geyer's	Subalpine-aspen-upper sagebrush	Edges of streams, frequent in wet meadows	Roots throughout entire length of stem	Few to moderate	10	10–15	Fair rooting capabilities
Willow, grayleaf	Subalpine-spruce-fir	Wet and dry sites, widely distributed, occupies seeps	Roots throughout entire length of stem	Few to moderate	10	10	Requires special treatment to root.
Willow, Pacific	Aspen-upper sage-brush	Wet soils, edges of streams and ponds	Roots throughout entire length of stem	Abundant	10	10–15	Easily rooted.
Willow, peachleaf	Aspen-big sagebrush	Stream edges, pond margins, soils saturated seasonally	Callus cut	Moderate	10–20	10	Moderate rooting capabilities.
Willow, plainleaf	Subalpine-aspen	Wet sites, edges of streams, wet meadows	Roots throughout entire length of stem	Few to moderate	10	10–15	Fair rooting.
Willow, sandbar	Spruce-fir-sagebrush	Edges of streams, wet sites, some times well-drained soils	Roots throughout entire length of stem	Moderate	10–15	10	Easily rooted.
Willow, Scouler	Spruce-fir	Well-drained soils, forest understory	Callus cut	Moderate	10–15	10–15	Requires special treatment to root.
Willow, Wolf	Spruce-fir-aspen	Stream edges and ponds	Roots throughout entire length of stem	Few to moderate	10–15	10–15	Erratic rooting.
Willow, yellow	Aspen-sagebrush	Mostly along streams, may occur on sites that remain dry for short periods	Entire stem section, most abundant at lower one-third	Moderate	10	10	Roots easily.

Table 12—Ecological status, use index, competitiveness, and seeding rate for species adapted for seeding aspen and coniferous forests and associated openings.

Species	Ecological status[a]	Use index for:		Competitiveness[b] as a seedling in the presence of:		Mature plant
		Restoration plantings	Revegetation plantings	Maximum competition	Minimum competition	
Grasses						
Barley, foxtail	P,E		X	ME	ME	ME
Barley, meadow	P,E,L	X	X	EX	EX	ME
Bentgrass redtop	P,E,L		X	EX	EX	ME
Bluegrass, Canada	P,E		X	ME	ME	ME
Bluegrass, big	P,E	X	X	ME	ME	ME
Bluegrass, Kentucky	P,E,L	X	X	ME	ME	ME,NC
Brome, meadow	P,E,L		X	EX	EX	ME
Brome, mountain	P,E,L	X	X	EX	EX	EX
Brome, nodding	P,E,L	X	X	EX	EX	ME
Brome, Regar	P,E,L		X	ME	ME	ME
Brome, smooth northern	P,E,L		X	ME	EX	EX,NC
Brome, subalpine	P,E,L		X	ME	EX	EX
Fescue, alta	P,E,L		X	ME	ME	ME
Fescue, hard sheep	P,E,L		X	PO	ME	ME
Fescue, red	P,E,L	X	X	ME	ME	ME
Fescue, thurber	P,E	X		ME	ME	PO
Foxtail, meadow	P,E,L		X	ME	ME	EX
Needlegrass, green	P,E,L	X	X	PO	ME	ME
Needlegrass, Letterman	P,E,L	X	X	ME	ME	EX
Needlegrass, subalpine	P,E,L	X	X	ME	ME	ME
Oatgrass, tall	P,E		X	ME	ME	PO
Orchardgrass	P,E,L		X	EX	EX	ME
Rye, mountain	P,E		X	EX	EX	PO
Timothy	P,E		X	EX	EX	ME
Timothy, alpine	P,E,L	X		ME	ME	ME
Wheatgrass, intermediate	P,E,L		X	EX	EX	EX,NC
Wheatgrass, pubescent	P,E,L		X	EX	EX	EX,NC
Wheatgrass, slender	P,E,L	X		EX	EX	EX
Wildrye, blue	P,E,L	X	X	EX	ME	ME
Forbs						
Alfalfa (drought tolerant)	P,E,L		X	EX	EX	ME
Angelica, small leaf	P,E,L	X		EX	EX	ME
Aster, alpine leafybract	P,E,L	X		EX	EX	ME
Aster, blueleaf	P,E,L	X	X	PO	ME	ME
Aster, Engelmann	P,E,L	X	X	PO	PO	EX
Aster, Pacific	P,E,L	X	X	PO	ME	ME
Aster, smooth	P,E,L	X	X	PO	PO	EX
Bluebell, tall	E,L	X		PO	ME	EX
Columbine, Colorado	E,L	X		PO	ME	ME
Cowparsnip	P,E,L	X		ME	ME	ME
Crownvetch	P,E,L		X	ME	ME	EX
Eriogonum, cushion	P,E,L	X		ME	ME	ME
Geranium, sticky and Richardson	P,E,L	X		PO	PO	ME
Goldeneye, showy	P,E,L	X	X	ME	ME	ME
Goldenrod, Canada	P,E,L	X	X	ME	ME	ME
Goldenrod, low	P,E,L	X	X	ME	ME	ME

(con.)

Table 12 (Con.)

Species	Ecological status[a]	Use index for: Restoration plantings	Use index for: Revegetation plantings	Competitiveness[b] as a seedling in the presence of: Maximum competition	Competitiveness[b] as a seedling in the presence of: Minimum competition	Mature plant
Forbs (con.)						
Groundsel, butterweed	P,E,L	X		ME	ME	ME
Helianthella, oneflower	P,E	X	X	EX	EX	ME
Ligusticum, Porter	P,E	X		ME	ME	EX
Lomatium, Nuttall	P,E,L	X		ME	ME	ME
Lupine, mountain	E,L	X		ME	ME	EX
Lupine, silky	E,L	X		ME	ME	EX
Medick, black	P,E,L		X	ME	ME	ME
Milkvetch, cicer	P,E,L		X	ME	EX	ME
Peavine, thickleaf	P,E,L	X		PO	ME	ME
Peavine, Utah	P,E,L	X		PO	ME	EX
Penstemon, Rocky Mountain	P,E,L	X	X	ME	ME	ME
Penstemon, Rydberg	P,E	X	X	PO	ME	PO
Penstemon, Wasatch	P,E,L	X		ME	ME	ME
Sainfoin	P,E		X	ME	ME	PO
Sage, Louisiana	P,E	X	X	PO	ME	ME
Sweetanise	P,E,L	X		ME	ME	EX
Sweetroot, spreading	P,E,L	X		ME	ME	ME
Vetch, American	P,E,L	X		PO	ME	EX
Yarrow, western	P,E,L	X	X	ME	ME	ME
Shrubs						
Alder, thinleaf	P,E,L	X		ME	EX	EX
Bitterbrush, antelope	P,L	X		ME	ME	EX
Chokecherry, black	P,L	X		PO	PO	EX
Cinquefoil, shrubby	E,L	X		PO	PO	EX
Elderberry, blue	E,L	X		PO	PO	EX
Elderberry, red	E,L	X		PO	PO	EX
Maple, bigtooth	P,E,L	X		ME	ME	EX
Mountain ash, Greene's	L	X		PO	ME	EX
Oregon grape	L	X		PO	PO	EX
Rabbitbrush, rubber mountain	P,E	X		ME	ME	ME
Rabbitbrush, rubber whitestem mountain and basin	P,E	X	X	ME	EX	EX
Rose, Woods	E,L	X	X	PO	PO	EX
Sagebrush, big mountain	P,E,L	X	X	ME	ME	EX
Serviceberry, Saskatoon	E,L	X		PO	PO	EX
Snowberry, mountain	E,L	X		PO	PO	EX

Growth form	Seeding rate: Wet and dry sites
	Pls lb/acre[c]
Grasses	5 to 6
Forbs	6 to 8
Shrubs	1 to 2

[a]Species status: P = pioneer; E = early seral; L = late seral.
[b]Competitiveness rating: PO = poor competitor; ME = medium competitor; EX = excellent competitor; NC = noncompatable with other species.
[c]Drill rate—broadcast seeding requires ¼ to ⅓ more seed.

Table 13—Ecological status, use index, competitiveness, and seeding rate for species adapted for seeding mountain brush and ponderosa pine communities.

Species	Ecological status[a]	Use index for:		Competitiveness[b] as a seedling in the presence of:		Mature plant
		Restoration plantings	Revegetation plantings	Maximum competition	Minimum competition	
-Grasses						
Bluegrass, big	P,E,L	X	X	ME	ME	ME
Bluegrass, Canada	P,E,L		X	ME	ME	ME
Brome, mountain	P,E	X	X	EX	EX	ME
Brome, Regar	P,E,L		X	EX	EX	ME
Brome, smooth northern and southern	P,L		X	EX	EX	EX,NC
Fescue, sheep	P,E,L	X	X	ME	ME	ME
Fescue, hard sheep	P,E,L		X	ME	EX	EX,NC
Fescue, sulcata sheep	P,E,L	X	X	ME	EX	EX
Junegrass, prairie	P,E,L	X		ME	ME	ME
Needlegrass, green	P,E,L	X	X	ME	ME	EX
Oatgrass, tall	P,E		X	ME	ME	ME
Orchardgrass	P,E,L		X	ME	ME	EX
Orchardgrass,'Paiute'	P,E,L		X	ME	ME	EX
Squirreltail, bottlebrush	P,E,L	X	X	EX	EX	ME
Timothy	P,E		X	EX	EX	ME
Wheatgrass, bluebunch	P,E,L	X		ME	ME	EX
Wheatgrass, fairway crested	P,E,L		X	EX	EX	EX
Wheatgrass, standard crested	P,E,L		X	EX	EX	EX
Wheatgrass, intermediate	P,E,L		X	EX	EX	EX
Wheatgrass, slender	P,E,L	X	X	EX	EX	ME
Wheatgrass, streambank	P,E,L	X	X	ME	EX	EX
Wheatgrass, tall	P,E		X	EX	EX	ME
Wheatgrass, thickspike	P,E,L	X	X	ME	EX	EX
Wheatgrass, western	P,E,L	X	X	ME	ME	EX
Forbs						
Alfalfa (drought tolerant)	P,E,L		X	EX	EX	EX
Aster, blueleaf	P,E,L	X	X	PO	PO	ME
Aster, Pacific	P,E,L	X	X	PO	ME	ME
Balsamroot, arrowleaf	E,L	X		PO	PO	EX
Balsamroot, cutleaf	E,L	X		PO	PO	EX
Balsamroot, hairy	E,L	X		PO	PO	EX
Burnet, small	P,E,L		X	EX	EX	ME
Crownvetch	P,E,L		X	ME	ME	EX
Eriogonum, cushion	P,E,L	X	X	ME	ME	ME
Flax, Lewis	P,E,L	X	X	EX	EX	ME
Goldeneye, Nevada showy	P,E,L	X	X	ME	ME	ME
Goldeneye, showy	P,E,L	X	X	ME	ME	ME
Goldenrod, Canada	P,E,L	X	X	ME	ME	ME
Groundsel, butterweed	P,E,L	X		ME	ME	EX
Lomatium, Nuttall	P,E,L	X		ME	ME	ME
Lupine, Nevada	E,L	X		ME	ME	ME
Lupine, silky	E,L	X		ME	ME	ME
Milkvetch, cicer	P,E,L		X	ME	ME	ME
Penstemon, Eaton	P,E,L	X		EX	EX	ME
Penstemon, low	P,E,L	X		EX	EX	EX
Penstemon, Palmer	P,E	X	X	EX	EX	PO
Penstemon, Rocky Mountain	P,E,L	X		ME	ME	EX
Penstemon, Wasatch	P,E,L	X		EX	EX	ME
Sage, Louisiana	P,E,L	X	X	PO	ME	EX

(con.)

Table 13 (Con.)

Species	Ecological status[a]	Use index for: Restoration plantings	Use index for: Revegetation plantings	Competitiveness[b] as a seedling in the presence of: Maximum competition	Competitiveness[b] as a seedling in the presence of: Minimum competition	Mature plant
Forbs (con.)						
Sainfoin	P,E,L		X	ME	ME	ME
Sweetclover, yellow	P		X	EX	EX	PO
Sweetvetch, Utah	P,E,L	X		ME	ME	EX
Trefoil, birdsfoot	P,E		X	ME	ME	ME
Yarrow, western	P,E,L	X	X	ME	ME	ME
Shrubs						
Alder, thinleaf	P,E,L	X	X	ME	EX	EX
Bitterbrush, antelope	P,E,L	X	X	EX	EX	EX
Ceanothus, Martin	P,E,L	X		PO	ME	EX
Ceanothus, redstem	P,E,L	X	X	ME	EX	EX
Ceanothus, snowbush	P,E,L	X		ME	EX	EX
Cherry, bitter	P,E,L	X		PO	PO	EX
Chokecherry, black	E,L	X		PO	PO	EX
Cliffrose, Stansbury	P,E,L	X		ME	ME	EX
Cotoneaster, Peking	P,E		X	PO	PO	ME
Elderberry, blue	E,L	X		PO	ME	EX
Ephedra, green	P,E,L	X		ME	ME	ME
Eriogonum, sulfur	P,E,L	X	X	ME	ME	ME
Honeysuckle, Tatarian	P,E,L		X	PO	ME	ME
Honeysuckle, Utah	E,L	X		PO	ME	ME
Maple, Rocky Mountain	E,L	X	X	ME	ME	EX
Mountain ash, Greene's	E,L	X		PO	ME	EX
Mountain mahogany, true	P,L	X	X	PO	ME	EX
Mountain mahogany, curlleaf	P,L	X	X	PO	ME	EX
Penstemon, bush	P,E,L	X	X	ME	ME	ME
Rabbitbrush, mountain rubber	P,E	X	X	ME	ME	ME
Rabbitbrush, Parry	P,E	X	X	ME	ME	ME
Rabbitbrush, mountain and basin whitestem rubber	P,E	X	X	ME	ME	ME
Rose, Woods	P,E,L	X	X	PO	ME	EX
Sagebrush, mountain big	P,E,L	X	X	ME	ME	EX
Sagebrush, silver	P,E,L	X		ME	ME	EX
Sagebrush, foothills big	P,E,L	X	X	ME	ME	EX
Serviceberry, Saskatoon	E,L	X		PO	PO	EX
Serviceberry, Utah	E,L	X		PO	PO	EX
Snowberry, longleaf	E,L	X		PO	PO	EX
Snowberry, mountain	E,L	X		PO	PO	EX
Squawapple	E,L	X		PO	PO	EX
Sumac, Rocky Mountain smooth	P,E,L	X	X	PO	ME	EX
Sumac, skunkbush	P,E,L	X	X	ME	ME	EX

Growth form	Seeding rate: Exposure: North and East	Seeding rate: Exposure: South and West
	Pls lb/acre[c]	
Grasses	5 to 6	6 to 8
Forbs	5 to 6	3 to 5
Shrubs	2 to 4	2 to 4

[a]Species status: P = pioneer; E = early seral; L = late seral.
[b]Competitiveness rating: PO = poor competitor; ME = medium competitor; EX = excellent competitor; NC = noncompatable with other species.
[c]Drill rate—broadcast seeding requires ¼ to ⅓ more seed.

Table 14—Ecological status, use index, competitiveness, and seeding rates for species adapted for seeding juniper-pinyon sites that receive less than 11 inches (280 mm) of annual precipitation.

Species	Ecological status[a]	Use index for:		Competitiveness[b] as a seedling in the presence of:		Mature plant
		Restoration plantings	Revegetation plantings	Maximum competition	Minimum competition	
Grasses						
Bluegrass, Sandberg	P,E,L	X		ME	ME	ME
Dropseed, sand	P,E,L	X		PO	ME	ME
Fescue, hard sheep	P,E,L		X	ME	ME	EX,NC
Fescue, sheep	P,E,L	X		ME	ME	EX
Muttongrass	P,E,L	X		ME	ME	ME
Needle-and-thread	P,E	X		ME	ME	ME
Orchardgrass, 'Paiute'	P,E,L		X	EX	EX	EX
Ricegrass, Indian	P,E,L	X	X	ME	ME	EX
Rye, winter	P		X	EX	EX	PO
Squirreltail, bottlebrush	P,E,L	X	X	EX	EX	ME
Wheatgrass, bluebunch	P,E,L	X		ME	EX	ME
Wheatgrass, fairway crested	P,E,L		X	EX	EX	EX,NC
Wheatgrass, standard crested	P,E,L		X	EX	EX	ME,NC
Wheatgrass, intermediate	P,E,L		X	EX	EX	EX,NC
Wheatgrass, pubescent	P,E		X	EX	EX	EX,NC
Wheatgrass, Siberian	P,L		X	EX	EX	EX
Wheatgrass, streambank	P,E,L	X	X	ME	EX	EX
Wheatgrass, western	P,E,L	X	X	PO	ME	EX
Wildrye, Russian	P,E,L		X	PO	ME	EX
Forbs						
Alfalfa (drought tolerant)	P,E,L		X	EX	EX	ME
Burnet, small	P,E,L		X	EX	EX	ME
Flax, Lewis	P,E,L	X	X	EX	EX	ME
Goldeneye, Nevada showy	P,E,L	X	X	EX	EX	ME
Globemallow, gooseberryleaf	P,E,L	X	X	PO	PO	EX
Globemallow, scarlet	P,E,L	X	X	PO	PO	EX
Penstemon, Palmer	P,E	X	X	EX	EX	PO
Sweetclover, yellow	P		X	EX	EX	PO
Yarrow, western	P,E,L	X	X	ME	ME	ME
Shrubs						
Apache plume	P,L	X		PO	ME	EX
Bitterbrush, antelope	P,E,L	X	X	EX	EX	EX
Bitterbrush, desert	P,E,L	X	X	EX	EX	EX
Buffaloberry, roundleaf	L	X		PO	PO	EX
Ceanothus, Fendler	P,E,L	X		ME	ME	EX
Cliffrose, Stansbury	P,E,L	X		ME	ME	ME
Ephedra, green	P,E,L	X		ME	ME	EX
Ephedra, Nevada	P,E,L	X		ME	ME	EX
Hopsage, spineless	P,L	X		PO	ME	EX
Kochia, forage 'Immigrant'	P,E		X	EX	EX	ME

(con.)

Table 14 (Con.)

Species	Ecological status[a]	Use index for: Restoration plantings	Use index for: Revegetation plantings	Competitiveness[b] as a seedling in the presence of: Maximum competition	Competitiveness[b] as a seedling in the presence of: Minimum competition	Mature plant
Shrubs (con.)						
Mountain mahogany, littleleaf	P,L	X		PO	ME	EX
Peachbrush, desert	P,L	X		PO	PO	EX
Rabbitbrush, mountain and basin whitestem rubber	P,E,L	X	X	ME	ME	ME
Sagebrush, basin big	P,E,L	X	X	PO	ME	EX
Sagebrush, black	P,E,L	X	X	PO	ME	EX
Sagebrush, fringed	P,L	X		PO	ME	EX
Sagebrush, Wyoming big	P,E,L	X	X	PO	ME	EX
Sagebrush, foothills big	P,E,L	X	X	ME	ME	EX
Saltbush, fourwing	P,E,L	X	X	ME	ME	ME
Serviceberry, Utah	P,E,L	X	X	PO	PO	EX
Winterfat	P,E,L	X	X	ME	ME	EX

Growth form	Seeding rate
	Pls lb/acre[c]
Grasses	4 to 6
Forbs	4 to 6
Shrubs	3 to 4

[a]Species status: P = pioneer; E = early seral; L = late seral.
[b]Competitiveness rating: PO = poor competitor; ME = medium competitor; EX = excellent competitor; NC = noncompatable with other species.
[c]Drill rate—broadcast seeding requires ¼ to ⅓ more seed.

Table 15—Ecological status, use index, competitiveness, and seeding rates for species adapted for seeding juniper-pinyon sites that receive 11 to 15 inches (280 to 380 mm) of annual precipitation.

Species	Ecological status[a]	Use index for:		Competitiveness[b] as a seedling in the presence of:		Mature plant
		Restoration plantings	Revegetation plantings	Maximum competition	Minimum competition	
Grasses						
Bluegrass, big	P,E,L	X	X	ME	ME	ME
Bluegrass, Canada	P,E,L		X	ME	ME	ME
Bluegrass, Sandberg	P,E,L	X	X	ME	ME	ME
Brome, Regar	P,E,L		X	ME	ME	ME
Brome, smooth (southern)	P,L		X	EX	EX	EX,NC
Fescue, hard sheep	P,E,L		X	ME	ME	ME,NC
Fescue, sulcata sheep	P,E,L	X	X	ME	ME	EX
Junegrass, prairie	P,E,L	X		ME	ME	ME
Muttongrass	P,E,L	X		ME	ME	ME
Needle-and-thread	P,E	X		ME	ME	ME
Needlegrass, green	P,E,L	X	X	ME	ME	EX
Orchardgrass, 'Paiute'	P,E,L		X	EX	EX	EX
Ricegrass, Indian	P,E,L	X		ME	ME	EX
Rye, mountain	P,E		X	EX	EX	PO
Rye, winter	P		X	EX	EX	PO
Squirreltail, bottlebrush	P,E,L	X	X	EX	EX	ME
Wheatgrass, bluebunch	P,E,L	X	X	ME	ME	EX
Wheatgrass, fairway crested	P,E,L		X	EX	EX	EX,NC
Wheatgrass, standard crested	P,E,L		X	EX	EX	EX,NC
Wheatgrass, intermediate	P,E,L		X	EX	EX	EX,NC
Wheatgrass, pubescent	P,E,L		X	EX	EX	EX,NC
Wheatgrass, Siberian	P,E,L		X	EX	EX	EX
Wheatgrass, streambank	P,E,L	X	X	EX	EX	EX
Wheatgrass, thickspike	P,E,L	X	X	ME	EX	EX
Wheatgrass, western	P,E,L	X	X	ME	ME	EX
Wildrye, Great Basin	P,E,L	X		PO	ME	EX
Wildrye, Russian	P,E,L		X	PO	ME	EX
Forbs						
Alfalfa (drought tolerant)	P,E,L		X	EX	EX	EX
Aster, Pacific	P,E,L	X	X	PO	ME	ME
Balsamroot, arrowleaf	E,L	X		PO	PO	EX
Burnet, small	P,E,L		X	EX	EX	ME
Flax, Lewis	P,E,L	X	X	EX	EX	ME
Globemallow, gooseberryleaf	P,E,L	X	X	ME	ME	EX
Goldeneye, Nevada showy	P,E,L	X	X	ME	ME	ME
Goldeneye, showy	P,E,L	X	X	ME	ME	ME
Penstemon, Palmer	P,E	X	X	EX	EX	PO
Sainfoin	P,E,L		X	ME	ME	ME
Sweetclover, yellow	P,E		X	EX	EX	PO
Sweetvetch, Utah	P,E,L	X		ME	ME	ME
Yarrow, western	P,E,L	X	X	ME	ME	ME

(con.)

Table 15 (Con.)

Species	Ecological status[a]	Use index for: Restoration plantings	Use index for: Revegetation plantings	Competitiveness[b] as a seedling in the presence of: Maximum competition	Competitiveness[b] as a seedling in the presence of: Minimum competition	Mature plant
Shrubs						
Apache plume	P,L	X		PO	ME	EX
Ash, singleleaf	P,E,L	X		PO	PO	EX
Bitterbrush, antelope	P,E,L	X	X	EX	EX	EX
Bitterbrush, desert	P,E,L	X	X	EX	EX	EX
Ceanothus, Fendler	P,E,L	X		ME	ME	EX
Cliffrose, Stansbury	P,E,L	X		ME	ME	EX
Cypress, Arizona	P,L		X	PO	PO	ME
Elderberry, blue	E,L	X		PO	ME	EX
Ephedra, green	P,E,L	X		ME	ME	EX
Ephedra, Nevada	P,E,L	X		ME	ME	EX
Eriogonum, Wyeth	P,E,L	X	X	ME	EX	ME
Kochia, forage	P,E		X	EX	EX	ME
Mountain mahogany, curlleaf	P,L	X		ME	ME	EX
Mountain mahogany, littleleaf	P,L	X		ME	ME	EX
Mountain mahogany, true	P,L	X		ME	ME	EX
Peachbrush, desert	P,L	X		PO	PO	EX
Rabbitbrush, mountain rubber	P,E,L	X	X	ME	ME	ME
Rabbitbrush, mountain and basin whitestem rubber	P,E,L	X	X	ME	ME	ME
Sagebrush, basin big	P,E,L	X	X	ME	ME	EX
Sagebrush, black	P,E,L	X	X	ME	ME	EX
Sagebrush, mountain big	P,E,L	X	X	ME	ME	EX
Sagebrush, foothill big	P,E,L	X	X	ME	ME	EX
Saltbush, fourwing	P,E,L	X	X	ME	ME	ME
Serviceberry, Saskatoon	P,E,L	X	X	PO	PO	EX
Serviceberry, Utah	P,E,L	X	X	PO	PO	EX
Snowberry, mountain	P,E,L	X	X	PO	PO	EX
Squawapple	E,L	X		PO	PO	EX
Sumac, Rocky Mountain smooth	P,E,L	X	X	PO	ME	EX
Sumac, skunkbush	P,E,L	X	X	PO	ME	EX
Winterfat	P,E,L	X	X	ME	ME	EX

Growth form	Seeding rate
	Pls lb/acre[c]
Grasses	4 to 6
Forbs	4 to 6
Shrubs	3 to 4

[a]Species status: P = pioneer; E = early seral; L = late seral.
[b]Competitiveness rating: PO = poor competitor; ME = medium competitor; EX = excellent competitor; NC = noncompatable with other species.
[c]Drill rate—broadcast seeding requires ¼ to ⅓ more seed.

Table 16—Ecological status, use index, competitiveness, and seeding rates for species adapted for seeding juniper-pinyon sites that receive more than 15 inches (380 mm) of annual precipitation.

Species	Ecological status[a]	Use index for: Restoration plantings	Use index for: Revegetation plantings	Competitiveness[b] as a seedling in the presence of: Maximum competition	Competitiveness[b] as a seedling in the presence of: Minimum competition	Mature plant
Grasses						
Bluegrass, big	P,E,L	X	X	ME	ME	ME
Bluegrass, Canada	P,E,L		X	ME	ME	ME
Bluegrass, Sandberg	P,E,L	X	X	ME	ME	ME
Brome, Regar	P,E,L		X	EX	EX	ME
Brome, smooth (northern and southern)	P,E,L		X	EX	EX	EX,NC
Fescue, hard sheep	P,E,L		X	ME	EX	EX,NC
Fescue, sulcata sheep	P,E,L	X		ME	EX	EX
Junegrass, prairie	P,E,L	X		ME	ME	ME
Needle-and-thread	P,E	X	X	ME	ME	ME
Needlegrass, green	P,E,L	X	X	ME	ME	EX
Orchardgrass, 'Paiute'	P,E,L		X	EX	EX	EX
Ricegrass, Indian	P,E,L	X		ME	ME	EX
Rye, mountain	P,E		X	EX	EX	PO
Rye, winter	P,E		X	EX	EX	PO
Squirreltail, bottlebrush	P,E,L	X	X	EX	EX	ME
Wheatgrass, bluebunch	P,E,L	X		EX	EX	EX
Wheatgrass, fairway crested	P,E,L		X	EX	EX	EX,NC
Wheatgrass, standard crested	P,E,L		X	EX	EX	EX,NC
Wheatgrass, intermediate	P,E,L		X	EX	EX	EX,NC
Wheatgrass, slender	P,E,L	X	X	ME	ME	ME
Wheatgrass, streambank	P,E,L	X	X	ME	ME	EX
Wheatgrass, thickspike	P,E,L	X	X	ME	ME	EX
Wheatgrass, western	P,E,L	X	X	ME	ME	EX
Wildrye, Great Basin	P,E,L	X		ME	ME	EX
Forbs						
Alfalfa (drought tolerant)	P,E,L		X	EX	EX	ME
Aster, blueleaf	P,E,L	X	X	EX	EX	EX
Aster, Pacific	P,E,L	X	X	EX	EX	EX
Balsamroot, arrowleaf	E,L	X		PO	PO	EX
Balsamroot, cutleaf	E,L	X		PO	PO	EX
Balsamroot, hairy	E,L	X		PO	PO	EX
Burnet, small	P,E,L		X	EX	EX	ME
Crownvetch	P,E,L		X	ME	ME	ME
Eriogonum, cushion	P,E,L	X	X	ME	ME	ME
Flax, Lewis	P,E,L	X	X	ME	ME	ME
Goldeneye, showy	P,E,L	X	X	ME	ME	ME
Goldenrod, Parry	P,E,L	X		ME	ME	ME
Helianthella, oneflower	P,E	X		ME	ME	ME
Lupine, Nevada	E,L	X		PO	PO	EX
Lupine, silky	E,L	X		PO	PO	ME
Lomatium, Nuttall	P,E,L	X		ME	ME	ME
Milkvetch, cicer	P,E,L		X	ME	ME	ME
Penstemon, Eaton	P,E,L	X		EX	EX	ME
Penstemon, Palmer	P,E	X	X	EX	EX	PO
Penstemon, Rocky Mountain	P,E,L	X	X	ME	ME	PO
Penstemon, thickleaf	P,E,L	X		ME	ME	ME
Penstemon, toadflax	P,E,L	X		PO	ME	ME
Penstemon, Wasatch	P,E,L	X		EX	EX	ME

(con.)

Table 16 (Con.)

Species	Ecological status[a]	Use index for: Restoration plantings	Use index for: Revegetation plantings	Competitiveness[b] as a seedling in the presence of: Maximum competition	Competitiveness[b] as a seedling in the presence of: Minimum competition	Mature plant
Forbs (con.)						
Sainfoin	P,E,L		X	ME	ME	ME
Sage, Louisiana	P,E,L	X	X	PO	PO	ME
Sage, tarragon	P,E,L	X		PO	PO	ME
Sweetclover, yellow	P,E		X	EX	EX	PO
Sweetvetch, Utah	P,E	X		PO	ME	ME
Shrubs						
Ash, singleleaf	P,E,L	X		PO	PO	ME
Bitterbrush, antelope	P,E,L	X	X	ME	EX	EX
Ceanothus, Martin	P,E,L	X		ME	ME	EX
Chokecherry, black	P,L	X		PO	ME	EX
Cliffrose, Stansbury	P,E,L	X		ME	ME	EX
Cotoneaster, Peking	P,E		X	PO	ME	ME
Cypress, Arizona	P,E		X	PO	PO	ME
Elderberry, blue	P,E,L	X		PO	ME	EX
Ephedra, green	P,E,L	X		ME	ME	EX
Ephedra, Nevada	P,E,L	X		ME	ME	EX
Eriogonum, Wyeth	P,E,L	X		EX	EX	ME
Kochia, forage	P,E		X	EX	EX	ME
Mountain mahogany, curlleaf	P,E,L	X	X	PO	ME	EX
Mountain mahogany, true	P,E,L	X	X	PO	ME	EX
Maple, Rocky Mountain	E,L	X		ME	ME	EX
Rabbitbrush, mountain rubber	P,E,L	X	X	EX	EX	ME
Rabbitbrush, mountain and basin whitestem rubber	P,E,L	X	X	ME	ME	ME
Rose, Woods	P,E,L	X	X	PO	ME	EX
Sagebrush, mountain big	P,E,L	X	X	ME	EX	EX
Sagebrush, foothill big	P,E,L	X	X	ME	ME	EX
Saltbush, fourwing	P,E,L	X	X	ME	ME	ME
Serviceberry, Saskatoon	P,E,L	X	X	PO	PO	EX
Snowberry, longflower	E,L	X		PO	PO	EX
Snowberry, mountain	P,E,L	X		PO	ME	EX
Squawapple	P,E,L	X		PO	ME	EX
Sumac, Rocky Mountain smooth	P,E,L	X	X	PO	ME	EX
Sumac, skunkbush	P,E,L	X	X	PO	ME	EX
Winterfat	P,E,L	X	X	ME	ME	EX

Growth form	Seeding rate: Soils: Neutral pH	Seeding rate: Soils: Basic pH
	Pls lb/acre[c]	
Grasses	3 to 5	4 to 7
Forbs	4 to 5	5 to 6
Shrubs	3 to 4	3 to 4

[a]Species status: P = pioneer; E = early seral; L = late seral.
[b]Competitiveness rating: PO = poor competitor; ME = medium competitor; EX = excellent competitor; NC = noncompatable with other species.
[c]Drill rate—broadcast seeding requires ¼ to ⅓ more seed.

Table 17—Ecological status, use index, competitiveness, and seeding rate for species adapted for seeding fourwing saltbush sites occurring in association with juniper-pinyon, basin big sagebrush, and Wyoming big sagebrush.

Species	Ecological status[a]	Use index for:		Competitiveness[b] as a seedling in the presence of:		Mature plant
		Restoration plantings	Revegetation plantings	Maximum competition	Minimum competition	
Grasses						
Bluegrass, Sandberg	P,E,L	X	X	ME	EX	ME
Dropseed, sand	P,E,L	X	X	ME	ME	EX
Galleta	E,L	X		ME	ME	EX
Needle-and-thread	E,L	X		ME	ME	ME
Ricegrass, Indian	P,E,L	X	X	ME	ME	EX
Sacaton, alkali	P,E,L	X		ME	ME	ME
Squirreltail, bottlebrush	P,E,L	X	X	EX	EX	EX
Wheatgrass, fairway crested	P,E,L		X	EX	EX	ME,NC
Wheatgrass, standard crested	P,E,L		X	EX	EX	ME,NC
Wheatgrass, pubescent	P,E,L		X	EX	EX	EX,NC
Wheatgrass, Siberian	P,E,L		X	EX	EX	EX
Wheatgrass, streambank	P,E,L	X	X	ME	ME	EX
Wheatgrass, thickspike	P,E,L	X	X	ME	ME	EX
Wildrye, Great Basin	P,E,L	X	X	PO	PO	EX
Wildrye, Russian	P,E,L		X	PO	PO	EX
Forbs						
Burnet, small	P,E		X	ME	ME	ME
Flax, Lewis	P,E	X	X	ME	ME	ME
Globemallow, gooseberryleaf	P,E,L	X	X	PO	PO	EX
Globemallow, scarlet	P,E,L	X	X	PO	PO	EX
Penstemon, Palmer	P,E	X	X	ME	ME	PO
Sweetclover, yellow	P		X	ME	ME	ME
Yarrow, western	P,E,L	X	X	ME	ME	ME
Shrubs						
Ephedra, green	P,E,L	X	X	PO	ME	EX
Ephedra, Nevada	P,E,L	X	X	PO	ME	EX
Hopsage, spiny	P,E,L	X		PO	PO	EX
Kochia, forage	P,E		X	EX	EX	ME
Rabbitbrush, low	P,E	X	X	EX	EX	ME
Sagebrush, basin big	E,L	X	X	ME	ME	ME
Sagebrush, foothills	E,L	X	X	ME	ME	ME
Sagebrush, low	E,L	X	X	ME	EX	ME
Sagebrush, Wyoming big	E,L	X	X	ME	ME	ME
Saltbush, fourwing	P,E,L	X	X	ME	ME	EX
Saltbush, Gardner	P,E,L	X	X	ME	ME	EX
Shadscale	P,E,L	X		PO	PO	ME
Winterfat	P,E,L	X	X	ME	ME	ME

Growth form	Seeding rate
	Pls lb/acre[c]
Grasses	4 to 6
Forbs	4 to 6
Shrubs	3 to 4

[a]Species status: P = pioneer; E = early seral; L = late seral.
[b]Competitiveness rating: PO = poor competitor; ME = medium competitor; EX = excellent competitor; NC = noncompatable with other species.
[c]Drill rate—broadcast seeding requires ¼ to ⅓ more seed.

Table 18—Ecological status, use index, competitiveness, and seeding rate for species adapted for seeding basin big sagebrush sites.

Species	Ecological status[a]	Use index for: Restoration plantings	Use index for: Revegetation plantings	Competitiveness[b] as a seedling in the presence of: Maximum competition	Competitiveness[b] as a seedling in the presence of: Minimum competition	Mature plant
Grasses						
Bluegrass, Sandberg	P,E,L	X		ME	ME	ME
Dropseed, sand	P,E,L	X		PO	ME	ME
Fescue, hard sheep	P,E,L		X	ME	ME	EX,NC
Fescue, Idaho	E,L	X		PO	ME	ME
Fescue, sulcata sheep	P,E,L	X	X	ME	ME	ME,NC
Fescue, sheep	P,E,L	X		ME	ME	ME
Needle-and-thread	P,E	X		ME	ME	ME
Needlegrass, Thurber	P,E,L	X		ME	ME	EX
Orchardgrass,'Paiute'	P,E,L		X	ME	ME	ME
Ricegrass, Indian	P,E,L	X		ME	EX	EX
Rye, mountain	P,E		X	EX	EX	ME
Squirreltail, bottlebrush	P,E,L	X	X	EX	EX	ME
Wheatgrass, bluebunch	E,L	X		ME	ME	EX
Wheatgrass, fairway crested	P,E,L		X	EX	EX	EX,NC
Wheatgrass, standard crested	P,E,L		X	EX	EX	EX,NC
Wheatgrass, intermediate	P,E,L		X	EX	EX	EX,NC
Wheatgrass, pubescent	P,E,L		X	EX	EX	EX,NC
Wheatgrass, Siberian	P,E,L		X	EX	EX	EX,NC
Wheatgrass, streambank	P,E,L	X	X	ME	ME	ME
Wheatgrass, tall	P,E		X	ME	ME	ME
Wheatgrass, thickspike	P,E,L	X	X	ME	ME	EX
Wheatgrass, western	P,E,L	X	X	PO	ME	EX
Wildrye, Great Basin	P,E,L	X		PO	ME	EX
Wildrye, Russian	P,E,L		X	PO	ME	EX
Forbs						
Alfalfa (drought tolerant)	P,E,L		X	EX	EX	ME
Aster, Pacific	P,E	X	X	ME	ME	ME
Burnet, small	P,E,L		X	EX	EX	ME
Flax, Lewis	P,E,L	X	X	ME	EX	ME
Goldeneye, Nevada showy	P,E,L	X	X	ME	ME	PO
Globemallow, gooseberryleaf and scarlet	P,E,L	X	X	ME	ME	EX
Lupine, Nevada	E,L	X		ME	ME	EX
Penstemon, Eaton	P,E,L	X		EX	EX	ME
Penstemon, low	P,E,L	X		EX	EX	EX
Penstemon, Palmer	P,E	X	X	EX	EX	PO
Sweetclover, yellow	P,E		X	EX	EX	PO
Sweetvetch, Utah	E,L	X		ME	ME	ME
Yarrow, western	P,E,L	X	X	EX	EX	ME
Shrubs						
Bitterbrush, antelope	P,E,L	X		ME	EX	EX
Cliffrose, Stansbury	P,E,L	X		ME	ME	EX
Ephedra, green	P,E,L	X		PO	ME	EX

(con.)

Table 18 (Con.)

Species	Ecological status[a]	Use index for: Restoration plantings	Use index for: Revegetation plantings	Competitiveness[b] as a seedling in the presence of: Maximum competition	Competitiveness[b] as a seedling in the presence of: Minimum competition	Mature plant
Shrubs (con.)						
Ephedra, Nevada	P,E,L	X		PO	ME	EX
Hopsage, spiny	P,E,L	X		ME	ME	EX
Rabbitbrush, mountain low	P,E,L	X	X	EX	EX	ME
Rabbitbrush, mountain and basin whitestem rubber	P,E,L	X	X	EX	EX	ME
Sagebrush, basin big	P,E,L	X	X	ME	EX	EX
Sagebrush, Wyoming big	P,E,L	X		ME	EX	EX
Sagebrush, foothills big	P,E,L	X		ME	ME	EX
Sagebrush, low	P,E,L	X		ME	EX	EX
Saltbush, fourwing	P,E,L	X	X	ME	ME	ME
Winterfat	P,E,L	X	X	ME	ME	ME

Growth form	Seeding rate — Precipitation: 9 to 13 inches	Seeding rate — Precipitation: 13+ inches
	Pls lb/acre[c]	
Grasses	4 to 5	4 to 5
Forbs	4 to 5	5 to 6
Shrubs	3 to 4	4 to 5

[a]Species status: P = pioneer; E = early seral; L = late seral.
[b]Competitiveness rating: PO = poor competitor; ME = medium competitor; EX = excellent competitor; NC = noncompatable with other species.
[c]Drill rate—broadcast seeding requires ¼ to ⅓ more seed.

Table 19—Ecological status, use index, competitiveness, and seeding rate for species adapted for seeding mountain big sagebrush sites.

Species	Ecological status[a]	Use index for:		Competitiveness[b] as a seedling in the presence of:		Mature plant
		Restoration plantings	Revegetation plantings	Maximum competition	Minimum competition	
Grasses						
Bluegrass, big	P,E,L	X	X	ME	ME	ME
Bluegrass, Canada	E,L		X	ME	ME	ME
Bluegrass, Sandberg	P,E,L	X		ME	ME	ME
Brome, Regar	P,E,L		X	EX	EX	ME
Brome, smooth (southern)	P,E,L		X	EX	EX	EX,NC
Fescue, hard sheep	P,E,L		X	ME	ME	EX,NC
Fescue, Idaho	E,L	X		PO	ME	ME
Fescue, sulcata sheep	P,E,L	X	X	ME	ME	EX
Fescue, sheep	P,E,L	X	X	ME	ME	ME
Junegrass, prairie	P,E,L	X		ME	ME	ME
Muttongrass	P,E,L	X		ME	ME	ME
Needle-and-thread	P,E	X		ME	ME	ME
Needlegrass, green	P,E,L	X	X	ME	ME	ME
Needlegrass, Letterman	P,E,L	X		ME	ME	ME
Oatgrass, tall	P,E		X	ME	ME	ME
Orchardgrass, 'Paiute'	P,E,L		X	EX	EX	EX
Ricegrass, Indian	P,E,L	X		ME	EX	ME
Rye, mountain	P,E		X	EX	EX	ME
Squirreltail, bottlebrush	P,E	X	X	EX	EX	ME
Wheatgrass, bluebunch	P,E,L	X		EX	EX	ME
Wheatgrass, fairway crested	P,E,L		X	EX	EX	EX,NC
Wheatgrass, standard crested	P,E,L		X	EX	EX	EX,NC
Wheatgrass, intermediate	P,E,L		X	EX	EX	EX,NC
Wheatgrass, pubescent	P,E,L		X	EX	EX	EX,NC
Wheatgrass, slender	P,E,L	X		EX	EX	ME
Wheatgrass, streambank	P,E,L	X	X	ME	ME	ME
Wheatgrass, thickspike	P,E,L	X	X	ME	ME	EX
Wheatgrass, western	P,E,L	X	X	PO	ME	EX
Wildrye, Great Basin	P,E	X		PO	ME	ME
Forbs						
Alfalfa (drought tolerant)	P,E,L		X	EX	EX	ME
Aster, Pacific	P,E	X	X	ME	ME	ME
Balsamroot, arrowleaf	E,L	X		PO	PO	EX
Burnet, small	P,E,L		X	EX	EX	ME
Crownvetch	P,E,L		X	ME	ME	ME
Flax, Lewis	P,E,L	X	X	EX	EX	ME
Goldeneye, showy	P,E,L	X	X	ME	ME	PO
Lupine, mountain	E,L	X		PO	ME	ME
Lupine, silky	E,L	X		ME	ME	ME
Milkvetch, cicer	P,E,L		X	ME	ME	ME
Penstemon, Eaton	P,E,L	X		EX	EX	ME
Penstemon, low	P,E,L		X	EX	EX	EX
Penstemon, Palmer	P,E	X		EX	EX	PO

(con.)

Table 19 (Con.)

Species	Ecological status[a]	Use index for: Restoration plantings	Use index for: Revegetation plantings	Competitiveness[b] as a seedling in the presence of: Maximum competition	Competitiveness[b] as a seedling in the presence of: Minimum competition	Mature plant
Forbs (con.)						
Penstemon, Rocky Mountain	P,E,L	X	X	ME	ME	ME
Penstemon, Wasatch	P,E,L	X		EX	EX	ME
Sainfoin	P,E		X	ME	ME	ME
Sweetclover, yellow	P,E		X	EX	EX	PO
Sweetvetch, Utah	P,E,L	X		ME	ME	ME
Trefoil, birdsfoot	P,E		X	ME	ME	ME
Yarrow, western	P,E,L	X	X	EX	EX	ME
Shrubs						
Bitterbrush, antelope	P,E,L	X	X	ME	EX	EX
Ceanothus, Martin	P,E,L	X		PO	ME	EX
Ceanothus, snowbush	P,E,L	X		ME	ME	EX
Chokecherry, black	E,L	X		PO	PO	EX
Cliffrose, Stansbury	P,E,L	X		ME	ME	EX
Elderberry, blue	P,E,L	X		PO	ME	EX
Ephedra, green	E,L	X		ME	ME	ME
Eriogonum, sulfur	P,E,L	X	X	ME	ME	ME
Eriogonum, Wyeth	P,E,L	X	X	ME	ME	ME
Kochia, forage	P,E		X	ME	EX	ME
Mountain mahogany, curlleaf	P,E,L	X	X	PO	ME	EX
Mountain mahogany, true	P,E,L	X	X	PO	ME	EX
Rabbitbrush, mountain low	P,E,L	X	X	EX	EX	EX
Rabbitbrush, mountain rubber	P,E,L	X	X	EX	EX	EX
Rabbitbrush, mountain and basin whitestem rubber	P,E,L	X	X	EX	EX	EX
Rose, Woods	P,E,L	X	X	PO	PO	EX
Sagebrush, low	P,E,L	X		EX	EX	ME
Sagebrush, mountain big	P,E,L	X	X	EX	EX	EX
Sagebrush, silver	P,E,L	X		EX	EX	ME
Sagebrush, foothills big	P,E,L	X	X	EX	EX	EX
Saltbush, fourwing	P,E	X	X	ME	ME	ME
Serviceberry, Saskatoon	P,E,L	X		PO	PO	EX
Snowberry, mountain	P,E,L	X		PO	PO	EX
Squawapple	P,E,L	X		PO	PO	EX
Sumac, skunkbush	P,E,L	X		PO	ME	EX
Sumac, Rocky Mountain smooth	P,E,L	X		PO	ME	EX

Growth form	Seeding rate — Precipitation: 12 to 17 inches	Seeding rate — Precipitation: 17+ inches
	Pls lb/acre[c]	
Grasses	4 to 6	4 to 5
Forbs	4 to 6	3 to 5
Shrubs	3 to 4	3 to 4

[a]Species status: P = pioneer; E = early seral; L = late seral.
[b]Competitiveness rating: PO = poor competitor; ME = medium competitor; EX = excellent competitor; NC = noncompatable with other species.
[c]Drill rate—broadcast seeding requires ¼ to ⅓ more seed.

Table 20—Ecological status, use index, competitiveness, and seeding rate for species adapted for seeding Wyoming big sagebrush sites.

Species	Ecological status[a]	Use index for:		Competitiveness[b] as a seedling in the presence of:		Mature plant
		Restoration plantings	Revegetation plantings	Maximum competition	Minimum competition	
Grasses						
Bluegrass, Sandberg	P,E,L	X		ME	ME	EX
Dropseed, sand	P,E,L	X	X	PO	ME	EX
Fescue, hard sheep	P,E,L		X	ME	ME	EX
Fescue, Idaho	P,E,L	X		PO	ME	ME
Needle-and-thread	P,E	X		ME	ME	ME
Needlegrass, Thurber	P,E,L	X		ME	ME	EX
Ricegrass, Indian	P,E,L	X		ME	ME	EX
Rye, mountain	P,E		X	EX	EX	ME
Squirreltail, bottlebrush	P,E,L	X	X	EX	EX	EX
Wheatgrass, bluebunch	P,E,L		X	EX	EX	EX
Wheatgrass, fairway crested	P,E,L		X	EX	EX	EX,NC
Wheatgrass, standard crested	P,E,L		X	EX	EX	EX,NC
Wheatgrass, pubescent	P,E,L		X	EX	EX	EX,NC
Wheatgrass, Siberian	P,E,L		X	EX	EX	EX,NC
Wheatgrass, streambank	P,E,L	X		ME	ME	ME
Wheatgrass, thickspike	P,E,L	X		ME	ME	EX
Wheatgrass, western	P,E,L	X		PO	ME	EX
Wildrye, Great Basin	P,E,L	X		PO	ME	EX
Wildrye, Russian	P,E,L		X	PO	ME	EX
Forbs						
Alfalfa	P,E,L		X	ME	ME	PO
Burnet, small	P,E,L		X	ME	ME	PO
Flax, Lewis	P,E,L	X	X	ME	ME	PO
Goldeneye, Nevada showy	P,E,L	X	X	ME	ME	PO
Globemallow, gooseberryleaf	P,E,L	X	X	PO	ME	EX
Globemallow, scarlet	P,E,L	X	X	PO	ME	EX
Lupine, Nevada	E,L	X		ME	ME	ME
Penstemon, Palmer	P,E,L	X	X	ME	ME	PO
Sweetclover, yellow	P,E		X	EX	EX	PO
Shrubs						
Ephedra, green	P,E,L	X		PO	PO	PO
Ephedra, Nevada	P,E,L	X		PO	PO	ME
Hopsage, spiny	P,E,L	X		PO	ME	EX
Kochia, forage	P,E,L		X	EX	EX	ME
Peachbrush, desert	P,E,L	X		PO	PO	EX
Rabbitbrush, mountain low	P,E,L	X	X	EX	EX	ME
Rabbitbrush, mountain and basin whitestem rubber	P,E,L	X	X	EX	EX	EX
Sagebrush, foothills big	P,E,L	X	X	EX	EX	EX
Sagebrush, Wyoming big	P,E,L	X	X	ME	EX	EX
Saltbush, fourwing	P,E	X	X	ME	ME	ME
Winterfat	P,E,L	X	X	ME	ME	ME

Growth form	Seeding rate
	Pls lb/acre[c]
Grasses	5 to 6
Forbs	4 to 5
Shrubs	2 to 3

[a]Species status: P = pioneer; E = early seral; L = late seral.
[b]Competitiveness rating: PO = poor competitor; ME = medium competitor; EX = excellent competitor; NC = noncompatable with other species.
[c]Drill rate—broadcast seeding requires ¼ to ⅓ more seed.

Table 21—Ecological status, use index, competitiveness, and seeding rate for species adapted for seeding black sagebrush sites.

Species	Ecological status[a]	Use index for:		Competitiveness[b] as a seedling in the presence of:		Mature plant
		Restoration plantings	Revegetation plantings	Maximum competition	Minimum competition	
Grasses						
Bluegrass, Sandberg	P,E,L	X		ME	ME	ME
Needle-and-thread	P,E	X		ME	ME	ME
Ricegrass, Indian	P,E,L	X		ME	ME	ME
Squirreltail, bottlebrush	P,E,L	X	X	EX	EX	EX
Wheatgrass, fairway crested	P,E,L		X	EX	EX	ME,NC
Wheatgrass, standard crested	P,E,L		X	EX	EX	EX,NC
Wheatgrass, streambank	P,E,L	X	X	ME	ME	ME
Wheatgrass, western	P,E,L	X	X	PO	ME	EX
Wildrye, Russian	P,E,L		X	PO	ME	EX
Forbs						
Globemallow, gooseberryleaf	P,E,L	X	X	PO	PO	ME
Globemallow, scarlet	P,E,L	X	X	PO	PO	ME
Penstemon, Palmer	P,E	X	X	EX	EX	PO
Shrubs						
Ephedra, green	P,E,L	X		PO	ME	PO
Ephedra, Nevada	P,E,L	X		PO	ME	PO
Rabbitbrush, low	P,E,L	X	X	EX	EX	ME
Sagebrush, black	P,E,L	X	X	ME	ME	EX
Sagebrush, low	P,E,L	X		ME	ME	EX
Winterfat	P,E,L	X	X	ME	ME	ME

Growth form	Seeding rate
	Pls lb/acre[c]
Grasses	6 to 8
Forbs	2 to 3
Shrubs	2 to 4

[a]Species status: P = pioneer; E = early seral; L = late seral.
[b]Competitiveness rating: PO = poor competitor; ME = medium competitor; EX = excellent competitor; NC = noncompatable with other species.
[c]Drill rate—broadcast seeding requires ¼ to ⅓ more seed.

Table 22—Ecological status, use index, competitiveness, and seeding rate for species adapted for seeding low sagebrush sites.

Species	Ecological status[a]	Use index for:		Competitiveness[b] as a seedling in the presence of:		Mature plant
		Restoration plantings	Revegetation plantings	Maximum competition	Minimum competition	
Grasses						
Bluegrass, Sandberg	P,E,L	X	X	ME	EX	ME
Fescue, hard sheep	P,E,L	X	X	EX	EX	EX,NC
Fescue, Idaho	E,L	X	X	ME	ME	ME
Muttongrass	P,E,L	X	X	ME	ME	ME
Needle-and-thread	P,E	X		ME	EX	PO
Ricegrass, Indian	P,E,L	X	X	ME	ME	EX
Rye, mountain	P,E		X	EX	EX	PO
Squirreltail, bottlebrush	P,E	X	X	ME	EX	PO
Sacatoon, alkali	P,E,L	X		ME	ME	ME
Wheatgrass, bluebunch	P,E,L	X	X	ME	EX	ME
Wheatgrass, fairway crested	P,E,L		X	EX	EX	EX,NC
Wheatgrass, pubescent	P,E,L		X	EX	EX	EX,NC
Wheatgrass, Siberian	P,E,L		X	ME	EX	ME,NC
Wheatgrass, standard crested	P,E,L		X	EX	EX	EX,NC
Wheatgrass, streambank	P,E,L	X	X	ME	ME	ME
Wheatgrass, thickspike	P,E,L	X	X	ME	EX	ME
Wildrye, Russian	P,E,L		X	ME	EX	EX
Forbs						
Burnet, small	P,E		X	ME	ME	ME
Flax, Lewis	P,E	X	X	ME	ME	ME
Globemallow, scarlet	P,E,L	X	X	PO	PO	EX
Penstemon, Palmer	P,E	X	X	ME	ME	PO
Sweetclover, yellow	P		X	ME	ME	ME
Shrubs						
Rabbitbrush, low	P,E	X	X	ME	ME	ME
Rabbitbrush, mountain whitestem rubber	P,E	X	X	ME	ME	ME
Sagebrush, Wyoming big	P,E,L	X	X	ME	ME	EX
Sagebrush, black	P,E,L	X	X	ME	ME	EX
Saltbush, fourwing	P,E,L	X	X	PO	ME	EX

Growth form	Seeding rate
	Pls lb/acre[c]
Grasses	4 to 6
Forbs	2 to 3
Shrubs	2 to 3

[a]Species status: P = pioneer; E = early seral; L = late seral.
[b]Competitiveness rating: PO = poor competitor; ME = medium competitor; EX = excellent competitor; NC = noncompatable with other species.
[c]Drill rate—broadcast seeding requires ¼ to ⅓ more seed.

Table 23—Ecological status, use index, competitiveness, and seeding rate for species adapted for seeding threetip sagebrush sites.

Species	Ecological status[a]	Use index for:		Competitiveness[b] as a seedling in the presence of:		Mature plant
		Restoration plantings	Revegetation plantings	Maximum competition	Minimum competition	
Grasses						
Bluegrass, Sandberg	P,E,L	X	X	EX	EX	EX
Brome, Regar	P,E,L		X	ME	ME	ME
Brome, smooth (southern and northern)	P,E,L		X	EX	EX	EX,NC
Fescue, hard sheep	P,E,L		X	ME	EX	EX,NC
Fescue, Idaho	P,E,L	X	X	PO	ME	ME
Fescue, sheep	P,E,L	X	X	EX	EX	EX
Junegrass, prairie	P,E	X		PO	ME	ME
Muttongrass	P,E,L	X	X	ME	ME	ME
Needlegrass, green	E,L	X	X	ME	ME	ME
Needlegrass, Thurber	P,E,L	X		PO	EX	ME
Oatgrass, tall	P,E		X	EX	EX	ME
Orchardgrass	P,E,L		X	EX	EX	EX
Ricegrass, Indian	P,E	X	X	ME	EX	EX
Rye, mountain	P,E		X	EX	EX	PO
Squirreltail, bottlebrush	P,E,L	X	X	EX	EX	ME
Wheatgrass, bluebunch	E,L	X	X	ME	ME	EX
Wheatgrass, fairway crested	P,E,L		X	EX	EX	EX,NC
Wheatgrass, standard crested	P,E,L		X	EX	EX	EX,NC
Wheatgrass, intermediate	P,E,L		X	EX	EX	EX,NC
Wheatgrass, pubescent	P,E,L		X	EX	EX	EX,NC
Wheatgrass, Siberian	P,E,L		X	ME	EX	EX,NC
Wheatgrass, slender	E,L	X	X	ME	EX	ME
Wheatgrass, streambank	P,E,L	X	X	ME	ME	EX
Wheatgrass, thickspike	P,E,L	X	X	ME	ME	EX
Wheatgrass, western	P,E,L	X	X	ME	ME	EX
Wildrye, Great Basin	P,E,L	X	X	ME	ME	EX
Wildrye, Russian	P,E,L		X	PO	ME	EX
Forbs						
Alfalfa (drought tolerant)	P,E,L		X	ME	ME	EX
Balsamroot, arrowleaf	P,E	X	X	PO	ME	EX
Balsamroot, cutleaf	P,E	X	X	PO	ME	EX
Burnet, small	P,E		X	ME	ME	ME
Flax, Lewis	P,E	X	X	ME	ME	ME
Goldeneye, showy	P,E,L	X	X	ME	ME	EX
Globemallow, gooseberry	P,E		X	PO	ME	EX
Lupine, silky	E,L		X	PO	PO	EX
Penstemon, Eaton	P,E	X	X	ME	ME	ME
Penstemon, Palmer	P,E	X	X	ME	ME	ME
Sweetvetch, Utah	P,E,L	X	X	ME	ME	ME
Sunflower	P,E	X	X	ME	EX	ME
Yarrow, western	P,E,L	X	X	ME	EX	EX

(con.)

Table 23 (Con.)

Species	Ecological status[a]	Use index for: Restoration plantings	Use index for: Revegetation plantings	Competitiveness[b] as a seedling in the presence of: Maximum competition	Competitiveness[b] as a seedling in the presence of: Minimum competition	Mature plant
Shrubs						
Bitterbrush, antelope	P,E,L	X	X	ME	EX	EX
Ceanothus, snowbush	P,E	X	X	ME	EX	EX
Chokecherry, black	P,E,L	X	X	PO	PO	EX
Elderberry, blue	P,E	X	X	PO	PO	EX
Rabbitbrush, mountain low	P,E	X	X	ME	ME	ME
Rabbitbrush, mountain rubber	P,E	X	X	ME	ME	ME
Rabbitbrush, mountain and basin whitestem rubber	P,E	X	X	ME	ME	ME
Rose, Woods	P,E,L	X	X	PO	ME	EX
Spirea, rock	P,E	X		PO	PO	EX
Sagebrush, basin big	P,E,L	X	X	ME	ME	ME
Sagebrush, mountain big	P,E,L	X	X	ME	ME	ME
Sagebrush, threetip	P,E,L	X	X	ME	ME	EX
Sagebrush, Wyoming big	P,E,L	X	X	ME	ME	ME
Serviceberry, Saskatoon	P,E,L	X	X	PO	PO	EX
Snowberry, mountain	P,E,L	X		PO	PO	EX
Sumac, skunkbush	P,E,L	X	X	ME	ME	EX

Growth form	Seeding rate
	Pls lb/acre[c]
Grasses	4 to 5
Forbs	3 to 5
Shrubs	3 to 4

[a]Species status: P = pioneer; E = early seral; L = late seral.
[b]Competitiveness rating: PO = poor competitor; ME = medium competitor; EX = excellent competitor; NC = noncompatable with other species.
[c]Drill rate—broadcast seeding requires ¼ to ⅓ more seed.

Table 24—Ecological status, use index, competitiveness, and seeding rate for species adapted for seeding silver sagebrush, timberline sagebrush, and subalpine big sagebrush sites.

Species	Ecological status[a]	Use index for:		Competitiveness[b] as a seedling in the presence of:		Mature plant
		Restoration plantings	Revegetation plantings	Maximum competition	Minimum competition	
Grasses and sedges						
Barley, meadow	P,E,L	X	X	EX	EX	ME
Bluegrass, big	E,L	X	X	ME	ME	ME
Bluegrass, Canada	E,L		X	ME	ME	ME
Brome, meadow	P,E,L		X	ME	ME	ME
Brome, mountain	P,E,L	X	X	EX	EX	EX
Brome, smooth (northern and southern)	P,E,L		X	EX	EX	EX,NC
Brome, subalpine	E,L		X	ME	EX	EX,NC
Fescue, hard sheep	P,E,L		X	ME	ME	EX,NC
Fescue, sheep	P,E,L	X	X	ME	ME	EX,NC
Foxtail, creeping	P,E,L		X	ME	EX	EX
Foxtail, meadow	P,E,L		X	ME	ME	EX
Needlegrass, green	P,E,L	X		ME	ME	ME
Needlegrass, Letterman	P,E,L	X	X	ME	ME	ME
Oatgrass, tall	P,E		X	ME	EX	ME
Orchardgrass	P,E,L		X	EX	EX	ME
Hairgrass, tufted	P,E	X	X	PO	ME	ME
Sedge, ovalhead	P,E,L	X		PO	ME	EX
Timothy	P,E		X	EX	EX	PO
Timothy, alpine	P,E,L	X		EX	EX	ME
Wheatgrass, slender	P,E,L	X	X	EX	EX	ME
Forbs						
Alfalfa (nonirrigated type)	P,E		X	EX	EX	ME
Aster, blueleaf	P,E,L	X		ME	ME	EX
Aster, Engelmann	P,E,L	X		PO	ME	EX
Crownvetch	P,E,L		X	ME	ME	EX
Geranium, sticky and Richardson	P,E,L	X	X	ME	ME	EX
Goldeneye, showy	P,E	X		ME	EX	EX
Goldenrod, Canada	P,E,L	X		ME	ME	EX
Groundsel, butterweed	P,E	X		PO	ME	EX
Lupine, mountain	P,E	X		ME	ME	EX
Lupine, silky	P,E	X		ME	ME	EX
Milkvetch, cicer	P,E,L		X	ME	EX	ME
Penstemon, Eaton	P,E	X	X	ME	ME	ME
Penstemon, low	P,E	X	X	ME	ME	ME
Penstemon, Rocky Mountain	P,E	X	X	ME	ME	ME
Penstemon, Wasatch	P,E	X	X	ME	ME	EX
Sage, Lousiana	P,E	X	X	ME	ME	PO
Sainfoin	P,E		X	ME	EX	ME
Sweetanise	P,E,L	X	X	ME	ME	ME
Yarrow, western	P,E,L	X	X	ME	ME	ME

(con.)

Table 24 (Con.)

Species	Ecological status[a]	Use index for: Restoration plantings	Use index for: Revegetation plantings	Competitiveness[b] as a seedling in the presence of: Maximum competition	Competitiveness[b] as a seedling in the presence of: Minimum competition	Mature plant
Shrubs						
Ceanothus, Martin	P,E,L	X	X	PO	ME	EX
Ceanothus, snowbush	P,E,L	X	X	ME	ME	EX
Chokecherry, black	P,E,L	X	X	PO	PO	EX
Cinquefoil, shrubby	P,E,L	X	X	ME	ME	EX
Elderberry, blue	P,E	X	X	PO	ME	EX
Elderberry, red	P,E	X	X	PO	ME	EX
Rabbitbrush, mountain low	P,E	X	X	ME	ME	ME
Sagebrush, silver	P,E,L	X	X	ME	ME	EX
Sagebrush, subalpine big	P,E,L	X	X	ME	ME	EX
Sagebrush, timberline big	P,E,L	X	X	ME	ME	EX
Snowberry, mountain big	P,E,L	X	X	PO	PO	EX

Growth form	Seeding rate
	Pls lb/acre[c]
Grasses	4 to 5
Forbs	3 to 4
Shrubs	3 to 4

[a]Species status: P = pioneer; E = early seral; L = late seral.
[b]Competitiveness rating: PO = poor competitor; ME = medium competitor; EX = excellent competitor; NC = noncompatable with other species.
[c]Drill rate—broadcast seeding requires ¼ to ⅓ more seed.

Table 25—Ecological status, use index, competitiveness, and seeding rate for species adapted for seeding shadscale saltbush sites.

Species	Ecological status[a]	Use index for:		Competitiveness[b] as a seedling in the presence of:		Mature plant
		Restoration plantings	Revegetation plantings	Maximum competition	Minimum competition	
Grasses						
Bluegrass, Sandberg	P,E,L	X	X	ME	ME	ME
Dropseed, sand	P,E,L	X	X	ME	ME	EX
Ricegrass, Indian	P,E,L	X	X	ME	ME	EX
Squirreltail, bottlebrush	P,E,L	X	X	EX	EX	ME
Wheatgrass, standard crested	P,E,L		X	EX	EX	EX,NC
Wheatgrass, Siberian	P,E,L		X	EX	EX	EX,NC
Wheatgrass, streambank	P,E,L	X	X	ME	ME	ME
Wheatgrass, western	P,E,L	X	X	PO	ME	ME
Wildrye, Russian	P,E,L		X	PO	PO	EX
Wildrye, Salina	P,E,L	X		PO	PO	EX
Forbs						
Globemallow, gooseberryleaf	P,E,L	X	X	PO	ME	EX
Globemallow, scarlet	P,E,L	X	X	PO	ME	EX
Yarrow, western	P,E,L	X	X	ME	ME	EX
Shrubs						
Budsage	P,E,L	X		PO	PO	EX
Hopsage, spineless	P,E,L	X		PO	ME	EX
Hopsage, spiny	P,E,L	X		PO	ME	EX
Peachbrush, desert	P,E,L	X		PO	PO	EX
Rabbitbrush, spreading	P,E	X	X	ME	ME	ME
Rabbitbrush, low	P,E	X	X	ME	ME	ME
Sagebrush, black	P,E,L	X	X	ME	ME	ME
Sagebrush, Wyoming big	P,E,L	X	X	ME	ME	ME
Saltbush, fourwing	P,E	X	X	ME	ME	ME
Saltbush, Gardner	P,E,L	X	X	ME	ME	EX
Saltbush, mat	P,E	X	X	ME	ME	EX
Shadscale	P,E,L	X	X	PO	PO	EX
Winterfat	P,E,L	X	X	ME	EX	EX

Growth form	Seeding rate
	Pls lb/acre[c]
Grasses	5 to 7
Forbs	1 to 2
Shrubs	3 to 4

[a]Species status: P = pioneer; E = early seral; L = late seral.
[b]Competitiveness rating: PO = poor competitor; ME = medium competitor; EX = excellent competitor; NC = noncompatable with other species.
[c]Drill rate—broadcast seeding requires ¼ to ⅓ more seed.

Table 26—Ecological status, use index, competitiveness, and seeding rate for species adapted for seeding black greasewood sites.

Species	Ecological status[a]	Use index for:		Competitiveness[b] as a seedling in the presence of:		Mature plant
		Restoration plantings	Revegetation plantings	Maximum competition	Minimum competition	
Grasses						
Bluegrass, Sandberg	P,E,L	X	X	ME	ME	ME
Squirreltail, bottlebrush	P,E,L	X	X	EX	EX	ME
Wheatgrass, standard crested	P,E,L		X	EX	EX	EX
Wheatgrass, Siberian	P,E,L		X	ME	EX	EX
Wheatgrass, streambank	P,E,L	X	X	PO	ME	EX
Wheatgrass, tall	P,E,L		X	EX	EX	EX
Wheatgrass, western	P,E,L	X	X	ME	ME	EX
Wildrye, Great Basin	P,E,L	X	X	ME	ME	EX
Wildrye, Russian	P,E,L		X	PO	PO	EX
Forbs						
Globemallow, gooseberryleaf	P,E,L	X	X	ME	ME	ME
Shrubs						
Greasewood, black	P,E,L	X		PO	PO	EX
Kochia, forage	P,E,L		X	EX	EX	EX
Sagebrush, basin big	P,E	X	X	ME	ME	ME
Saltbush, Castle Valley clover	P,E,L	X	X	ME	ME	EX
Saltbush, fourwing	P,E	X	X	ME	ME	ME
Saltbush, Gardner	P,E	X	X	ME	ME	ME
Shadscale	P,E,L	X	X	PO	PO	ME
Winterfat	P,E,L	X	X	ME	ME	EX

Growth form	Seeding rate
	Pls lb/acre[c]
Grasses	6 to 8
Forbs	1
Shrubs	3 to 4

[a]Species status: P = pioneer; E = early seral; L = late seral.
[b]Competitiveness rating: PO = poor competitor; ME = medium competitor; EX = excellent competitor; NC = noncompatable with other species.
[c]Drill rate—broadcast seeding requires ¼ to ⅓ more seed.

Table 27—Ecological status, use index, competitiveness, and seeding rate for species adapted for seeding in the blackbrush type.

Species	Ecological status[a]	Use index for:		Competitiveness[b] as a seedling in the presence of:		Mature plant
		Restoration plantings	Revegetation plantings	Maximum competition	Minimum competition	
Grasses						
Dropseed, sand	P,E,L	X	X	ME	ME	EX
Galleta	P,E	X	X	ME	ME	ME
Needle-and-thread	P,E	X	X	ME	ME	PO
Ricegrass, Indian	P,E,L	X	X	ME	ME	EX
Squirreltail, bottlebrush	P,E	X	X	ME	EX	ME
Wheatgrass, fairway crested	P,E		X	ME	EX	ME
Wheatgrass, pubescent	P,E,L		X	EX	EX	EX
Wheatgrass, Siberian	P,E,L		X	ME	ME	EX
Wheatgrass, standard crested	P,E		X	ME	EX	ME
Wheatgrass, western	P,E,L	X	X	ME	ME	EX
Wildrye, Russian	P,E,L		X	PO	PO	EX
Forbs						
Globemallow, gooseberryleaf	P,E,L	X	X	ME	ME	ME
Globemallow, scarlet	P,E,L	X	X	ME	ME	ME
Penstemon, Palmer	P,E	X	X	PO	ME	ME
Shrubs						
Apache plume	P,E,L	X		PO	ME	EX
Bitterbrush, desert	P,E,L	X	X	ME	EX	EX
Blackbrush	P,E,L	X		ME	ME	EX
Buffaloberry, roundleaf	P,E,L	X		PO	PO	EX
Ephedra, Nevada	P,E,L	X		ME	ME	EX
Hopsage, spineless	P,E,L	X		ME	ME	EX
Hopsage, spiny	P,E,L	X		ME	ME	EX
Kochia, forage	P,E		X	EX	EX	EX
Peachbrush, desert	P,E,L	X	X	PO	PO	EX
Rabbitbrush, low	P,E	X	X	ME	ME	ME
Sagebrush, black	P,E,L	X	X	ME	ME	ME
Sagebrush, sand	P,E,L	X		ME	ME	ME
Saltbush, fourwing	P,E,L	X	X	ME	EX	ME
Winterfat	P,E,L	X	X	ME	EX	EX

Growth form	Seeding rate
	Pls lb/acre[c]
Grasses	4 to 6
Forbs	3 to 4
Shrubs	2 to 3

[a]Species status: P = pioneer; E = early seral; L = late seral.
[b]Competitiveness rating: PO = poor competitor; ME = medium competitor; EX = excellent competitor; NC = noncompatable with other species.
[c]Drill rate—broadcast seeding requires ¼ to ⅓ more seed.

Table 28—Species with the ability to establish and spread within stands of cheatgrass brome, red brome, or medusahead[a].

Species	Native	Introduced	Adapted to: Mid-elevation	Adapted to: Foothills and valleys	Spreadability[b]	Competitiveness[b] as a: Seedling	Competitiveness[b] as a: Mature plant
Grasses							
Bluegrass, Sandberg	X		X		ME	ME	ME
Fescue, hard sheep		X	X		EX	ME	EX
Fescue, Idaho	X		X		ME	ME	ME
Needle-and-thread	X			X	ME	EX	ME
Needlegrass, Thurber	X			X	EX	ME	EX
Ricegrass, Indian	X			X	PO	PO	EX
Rye, mountain		X		X	EX	EX	EX
Squirreltail, bottlebrush	X			X	EX	EX	ME
Wheatgrass, bluebunch	X		X	X	ME	EX	
Wheatgrass, fairway crested		X	X	X	ME	EX	EX
Wheatgrass, standard crested		X	X	X	ME	EX	EX
Wheatgrass, 'Hycrest'		X	X		ME	EX	EX
Wheatgrass, intermediate		X	X		ME	EX	EX
Wheatgrass, pubescent		X	X		ME	ME	EX
Wheatgrass, streambank	X		X	X	ME	ME	EX
Wheatgrass, thickspike	X		X	X	EX	ME	EX
Wheatgrass, western	X		X	X	ME	ME	EX
Forbs							
Aster, Pacific	X		X		EX	ME	EX
Burnet, small		X	X	X	EX	EX	ME
Flax, Lewis	X	X		X	EX	EX	EX
Penstemon, Palmer	X		X	X	EX	EX	EX
Yarrow, western	X		X	X	EX	EX	EX
Shrubs							
Kochia, forage		X	X	X	EX	EX	EX
Rabbitbrush, low	X		X	X	ME	ME	EX
Sagebrush, big	X			X	ME	ME	EX

[a]Individual species and mixtures recommended for use in cheatgrass, red brome, and medusahead areas are essentially the same as are recommended for seeding the vegetative type that existed prior to when the annuals gained control. These include: mountain brush-ponderosa pine (table 13), juniper-pinyon (tables 14,15,16), fourwing saltbush (table 17), basin big sagebrush (table 18), mountain big sagebrush (table 19), Wyoming big sagebrush (table 20), black sagebrush (table 21), low sagebrush (table 22), threetip sagebrush (table 23),shadscale saltbush (table 25), black greasewood (table 26), and blackbrush (table 27).

[b]Key to ability to spread and compete with annual grasses: PO = poor spreader, poor competitor; ME = medium spreadability, medium competitor; EX = excellent spreadability, excellent competitor.