USE OF SHRUBS ON MINE SPOILS Stephen

B. Monsen

ABSTRACT: Mine disturbances can often be revegetated through natural plant succession. Plants that spread well by natural seeding can be used to seed mine spoils. Transplanting shrubs and herbs on mine sites hastens plant establishment and improves productivity and species diversity. However, shrub species differ in their ability to establish and survive as transplant stock. Therefore, planting sites must be prepared to accommodate direct seeding or transplanting. Environmental conditions of the planting site dictate the type of material and methods of planting. Existing herbaceous vegetation must be controlled to allow shrub seedlings to become established.

INTRODUCTION

Rehabilitation of mined land normally requires planting a combination of herbs and woody species. Natural invasion of native plants onto mined sites usually occurs too slowly to acceptably restore the site (McKell and Van Epps 1981). Planting is required to provide soil protection (Packer and others 1981), reduce the spread of weeds, and provide herbage and habitat to animals (Monsen and Plummer 1978).

Plantings also serve to establish a desirable and compatible array of species that will provide initial cover and ultimately develop a stable community (Laycock 1980).

Mined lands are generally harsh sites and plantings are not always successful. Seeding or transplanting may fail even when adapted species are used. Considerable differences exist between the microsites and soil conditions of mine spoils compared to undisturbed locations (Sindelar 1980). Consequently, it is difficult to determine the adaptability of individual species to mined land environments.

Species that are climax plants of undisturbed communities often are planted on mine spoils. Unfortunately, not all species that are regarded as climax, and usually considered desirable plants, are able to grow on disturbances (Eberly and Dueholum 1979; McGinnies and Nicholas 1980). Usually climax plants become established after the site has been modified by pioneer species. Many species that are initially adapted to mine spoils are considered weedy plants. These may persist for only a short time, but are useful to initiate plant succession (Stark 1966).

Species that are adapted to a wide range of soils, temperature extremes, and moisture conditions are the most successful species for harsh sites (Stark 1966). However, ecotypic differences occur within most species. Each ecotype is adapted to a particular range of conditions, and if planted within its natural range the selection will do well. If moved to unnatural conditions specific ecotypes often do not always survive (Plummer 1977).

Few plants have been specifically selected for their adaptability to mine disturbances. Only a limited number have been fully evaluated for their performance and survival on mine spoils. Most species that are currently used are native or introduced species that have been used mostly for other purposes. However, research has determined that certain species are adapted to infertile soils, and can be used on mined and associated disturbances (Stark 1966; Aldon and Pase 1981).

NATURAL, INVASION OF PLANTS

Weedy annuals and short-lived perennial herbs are the principal species that invade most mined lands (Howard and Samuel 1979). However, some important woody plants also spread rapidly onto abandoned mines (Butterfield and Tueller 1980). Many plants are adapted to mine disturbances but spread very slowly by natural means. Invasion by plants is often hindered by factors related to seed production (Plummer 1977), seed germination, and seedling survival (Sabo and others 1979). The quality and quantity of seed produced on wildlands varies greatly and can be influenced by unpredictable climatic conditions and insects (U.S. Department of Agriculture 1974).

Winds, overland flow of water, and rodents are agents that carry seeds onto mine sites. Under wildland conditions rodents not only distribute but plant many seeds (West 1968). A high proportion of seed produced in wildland stands is consumed by animals including rodents (Bradley 1968). The excess is all that remains to perpetuate the species.

Rodents usually collect and store seeds of large fruited species and seed that consists of an edible endosperm. Usually, seeds that remain viable for an extended period are stored as caches in the soil surface by rodents for later consumption (Sherman and Chilcote 1972). Seeds planted as rodent caches frequently are not eaten but germinate later to form a cluster of new seedlings. Shrub seeds that are

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Stephen B. Monsen is Botanist/Biologist, Intermountain Forest and Range Experiment Station, Forest Service, U.S. Department of Agriculture, located at the Intermountain Station's Shrub Sciences Laboratory, Provo, Utah.

normally gathered and stored in caches include: antelope bitterbrush _(Purshia tridentata),_ desert peachbrush _(Prunus fasciculata),_ green ephedra _(Ephedra viridis),_ Martin ceanothus _(Ceanothus martinii),_ Saskatoon serviceberry _(Amelanchier alnifolia),_ and Woods rose _(Rosa woodsi)._

Rodent activity is usually confined to areas offering overstory protection. However, rodent populations and habitat are not always decreased by clearing the vegetation (Turkowski and Reynolds 1970). Yet, small animals usually do not venture onto barren mine wastes or exposed sites. As sites become vegetated, rodents inhabit the area. Once plants that are established on the mine begin to bear seeds, rodents gather the fruits and help further the species and progress of successional stages in plant development.

A substantial amount of seed is produced by certain plants. Clean seed yields have exceeded 300 pounds per acre (338 kg/ha) for antelope bitterbrush grown on a planted site near Boise, Idaho. During years of high seed production many species increase dramatically due to the planting efforts of small rodents. Adapted shrubs and herbs can be selectively located on mined sites to provide rodent habitat, regulate their distribution, and thus advance the spread of select species.

Small seeded species and appendaged seeds are widely distributed by wind (Mirov and Kraebel 1939). Although a high proportion of weedy species is spread by the wind, many useful species are also dispersed by this method. Wind-carried seeds often spread plant species quickly, and populate otherwise inaccessible sites. Species that are successfully spread by wind include: Apache-plume _(Fallugia paradoxa),_ sagebrush _(Artemisia_ spp.), penstemon _(Penstemon_ spp.), and rabbitbrush _(Chrysothamnus_ spp.).

CONDITIONS INFLUENCING ARTIFICIAL SEEDING

Mined lands are usually planted soon after mining is completed. Disturbances primarily consist of overburden material or tailings composed of unconsolidated soil materials. Although topsoil and fertilizer may be added, mine spoils usually lack soil structure and particle aggregation that contribute to a optimum seedbed condition. Soil drainage, aeration, microorganism content, nutrient balance, and organic matter are all poorly developed for supporting a combination of plants (Frischknecht and Ferguson 1979).

Although fresh mine spoils are usually less productive than undisturbed sites, cultural practices often are not employed to improve tilth and productivity before planting. Therefore, planted species must he adapted to infertile sites, and capable of developing concurrently as young seedlings.

Grasses, broadleaf herbs, and woody species are often planted together. Assembly of a mixture of plants with different growth forms creates serious problems of competition among young seedlings. Mixed plantings favor herbs over shrubs and trees (Jensen 1980).

Grasses that are currently seeded on most mined sites are derivatives formulated for high germinability and seedling vigor. These highly competitive grasses develop much faster than do most native shrubs or trees. Grasses and many forbs not only germinate earlier than most shrubs, but attain a mature status much sooner. Most seeded grasses reach maturity in 1 to 3 years. In contrast, shrubs may require 5 to 10 years to attain a sufficient size to be fully competitive (Plummer and others 1968). During this interim, the developing shrubs are subjected to extensive competition, and plant losses are common (Booth and Schuman 1981). To be fully competitive with grasses, seeded shrubs and trees must possess the following traits: (1) seeds must germinate readily, (2) seedlings must develop rapidly, (3) seasonal growth periods should be compatible with the seeded herbs, and (4) developing plants must remain competitive.

Shrubs that can survive and develop satisfactorily by direct seeding are species that would not usually be grown as transplant stock. Some plants can justifiably be transplanted or direct seeded. Seeding is usually much cheaper and easier to accomplish. Some useful shrubs that can be successfully seeded include: basin big sagebrush _(Artemisia tridentata tridentata),_ low sagebrush _(Artemisia arbuscula),_ fourwing saltbush _(Atriplex canescens),_ winterfat _(Ceratoides lanata),_ snowbrush ceanothus _(Ceanothus velutinus),_ rubber rabbitbrush _(Chrysothamnus nauseosus),_ Wyeth eriogonum _(Eriogonum umbellatum),_ prostrate summer cypress _(Kochia prostrata),_ antelope bitterbrush, and thinleaf alder _(Alnus tenuifolia)._

Natural plant succession and edaphic changes that occur after mined sites are initially planted change the growing conditions and productivity of the disturbance. Some species that have been difficult to establish initially on fresh mine spoils by direct seeding or transplanting have been successfully established at a later date. New shrub and tree seedlings are frequently encountered as a result of natural reproduction, beginning 5 to 10 years after a site has been reclaimed. The encroachment often occurs on sites dominated by a competitive understory of herbs. However, the environment of some disturbances is so harsh that only a limited number of species establish and persist. Little improvement can be expected for a considerable period of time on these areas.

The success of most plants has been based upon the response attained from plantings established on newly exposed mine spoils.

Unfortunately many useful species are often discarded due to failures from initial plantings. Growing conditions improve as soil nutrients build up or the soil microflora is established.

VALUE OF TRANSPLANT STOCK

Although plants may be successfully established by direct seeding, transplanting is also a viable revegetation technique. Some species that establish readily by seeding do not grow rapidly enough to provide initial ground cover for soil stabilization (Shaw 1981). Some species that may fail to establish or perform satisfactorily by direct seeding can be transplanted. This has been particularly evident with Woods rose and chokecherry (*Prunus virginiana melanocarpa*) planted on phosphate mines in southeastern Idaho. Seedlings of both species germinated erratically and young plants were weak and slow to develop. Although plantings have been established on topsoiled and fertilized sites, the growth performance of these small seedlings has remained unchanged. However, 2-0 transplants of both species developed rapidly.

Transplants that are properly spaced can provide an immediate and effective cover. Transplanting can be effectively used to stabilize erodible sites and promote the natural establishment of understory species. Megahan (1974) reported that over 50 percent of surface erosion from roadfills was controlled by planting 1-year-old hareroot stock of ponderosa pine (*Pinus ponderosa*).

Transplants can also be used to control the establishment and spread of weeds. In contrast, shrub and tree transplants may also promote the establishment of some understory species. Ponderosa pine transplanted along steep roadcut and fill slopes in central Idaho stabilized the sites and served as a nurse crop for understory herbs (Monsen 1974). The presence of the overstory canopy of Woods rose, blueberry elder (*Sambucus cerulea*), and redstem ceanothus (*Ceanothus sanguineus*) also aids in the establishment of other species. Shrubs and trees that may persist for only a few years can be highly useful in the development of satisfactory cover.

Some leguminous and nonleguminous shrubs and trees are beneficial in improving soil nutritive levels. Klemmedson (1979) reported that eight genera of shrubs are able to fix nitrogen through actinomycete nodulation. These species can be used as companion plants to improve the performance of various understory herbs. Species of *Ceanothus* have been successfully used for this purpose on mine spoils in Idaho (Monsen 1974). Langkamp and others (1979) reported that reestablishment of a nutrient bank would occur slowly with the use of Acacia (*Acacia pellita*), and that pasture legumes would rapidly rebuild nutrient levels.

Transplants can be used to increase the rate of plant succession. In addition, transplant stock matures quickly and community changes occur rapidly. If persistent and compatible species are planted initially, a predesigned community structure can he arranged. This is an important feature, as many planted species do not attain full prominence until a mature and stable plant composition is achieved.

FACTORS AFFFCTING TRANSPLANT SUCCESS

Factors that affect transplant survival are similar to those that influence seedling establishment. However, a significant difference is that transplanting usually eliminates the need for a prepared seedbed. The principal factors that reduce transplant survival are: (1) planting unadapted species and ecotypes; (2) carelessness in planting; (3) insufficient soil moisture resulting from inadequate site preparation and planting at the wrong time of year; and (4) use of poor quality planting stock.

Planting Adapted Species and Ecotypes

Species that are reared and planted on wildland sites in the West normally include selections that are native to the planting site. Seed and vegetative cuttings often are collected from the planting area. If this is not possible, stock is obtained from similar vegetative types growing in separate areas. In addition, various grasses, forbs, and shrubs have been developed for rangeland plantings.

However, few native or introduced species have been specifically developed for mined sites. Although numerous plants have been established on mined lands, their persistence and areas of adaptability have not been fully determined. Considerable differences have been recorded in the survival and initial growth rates of ecotypes when planted on mined sites. Different strains or ecotypes of many native shrubs could he used to select sources that have vigorous seedling adaptability to infertile soils.

Growers should be aware of the differences that occur among ecotypes of a particular species, and seek to raise stock that is adapted to specific soil and climatic conditions. Mined sites should be evaluated before planting to assure that adequate time is given to program the vegetation efforts, collect sufficient adapted seed, and rear transplant stock.

Plants that inhabit the site before mining may not be adapted to the mine spoils. Present State and Federal laws often require mining companies to restore native plant species to reclaimed areas. Although the use of adapted native plants is often advisable, many mined sites are not capable of immediately sustaining the dominant species of the undisturbed site.

Some species and ecotypes are currently available that are adapted to mined lands, and these should be promoted and used. Research is needed to develop additional plants adapted to mined sites. A classification system needs to he developed to identify plant selections for disturbed situations. The system currently used in reforestation makes use of soil types, elevation, and climatic zones in selecting adapted ecotypes for planting. These features should also be applicable in delineating plants for mined lands, although the edaphic conditions of mine spoil are not entirely comparable to undisturbed soils. However, mining does not completely alter climatic and biotic influences. Consequently, plants that are components of original sites are still candidates for initial revegetation trials. Equally important is the identification of individual species that possess inherent characteristics that contribute to the range of adaptation of the species. For example, the occurrence of different subspecies, ecotypes, and kinds of sagebrush offers a wide diversity of planting stock suited to different site conditions (McArthur and others 1974). Through careful selection, adapted ecotypes of other species can be used to revegetate mine spoils.

Site Preparation and Planting

Transplanting does not require the intensive surface preparation treatment required for direct seeding, yet most mines usually utilize both revegetation techniques. Surface tillage and fertilization are required to enhance the survival of the seeded species. Seeding is frequently done to control soil erosion and surface runoff. Transplanting may be superimposed over the existing seeding. This usually does not create serious problems if transplant needs are recognized.

Transplants can usually compete with newly sown grass. However, if the grass is heavily seeded and fertilized, shrub transplants may suffer (Jensen 1980). Therefore, to improve shrub and tree survival the seeding should not be at a high rate. Fertilization of herbaceous species should be applied at a low rate, yet the seeding can be refertilized after the shrubs are well established.

Mine spoils should be treated to aid plant survival. Compact soils should be ripped to allow infiltration, aeration, and root development. Transplants should also be fertilized. Fertilizer tablets placed in the planting hole significantly aided tree growth in an Idaho trial (Megahan 1974).

Woody species that grow slowly and require 2 or 3 years to fully establish should be interspaced in strips or clearings separate from more competitive species (Giunta and others 1975). The planting areas should be delineated according to site conditions to assure that species are planted in adapted locations. It is not necessary to plant the entire site in a grid pattern. Species can be transplanted in groups, clusters, or mixes to provide diversity.

Planting Quality Stock

The development of high-quality transplant stock is essential to plant survival on mine wastes. Specimens that are poorly developed succumb quickly to adverse conditons. Failure to acquire and plant quality stock accounts for many planting failures.

Growers frequently produce a uniform grade of planting stock. Materials are grown to 1-0 or 2-0 size classes. Container-grown stock is also produced in rather uniform grades. Plants can he grown to different age and size classes, but this is difficult to program for a mine location when only a short rearing time is available.

The size and type of transplant is vital to plant survival. Species that grow rapidly will normally survive and grow well if a healthy 1-0 transplant is used. Other species grow slowly, requiring a year or two to fully establish and begin any appreciable growth. Green ephedra, mountain snowberry (*Symphoricarpos oreophilus*), mountain-ash (*Sorbus scopulina*), roundleaf buffaloberry (*Shepherdia rotundifilia*), skunkbush sumac (*Rhus trilobata*), and spiny hopsage (*Grayia spinosa*) do poorly when planted as 1-0 stock, but perform much better when planted as 2-0 or larger stock. Survival rates improve and growth is markedly increased.

Proper maintenance and field planting of a well-conditioned transplant is essential to plant survival. Shrubs such as Wyeth eriogonum, bush penstemon (*Penstemon fruticosus*), and prostrate ceanothus (*Ceanothus prostratus*) begin growth early in the season and must be lifted and planted as dormant stock, otherwise survival is very low.

Container-grown stock or ball and burlap materials are useful in planting rocky sites. However, high-quality bareroot stock will perform satisfactorily. Planting large pads and root sections as wildlings has proven successful with species of aspen (*Populus tremuloides*), oak (*Quercus* spp.), and other plants (Crofts 1978).

Mine plantings require special attention. Sites often are rocky and planting is impared. Without particular care, plants may fail simply because of poor handling. Care must he taken to follow normal planting guides.

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