SHRUB ESTABLISHMENT ON DISTURBED ARID AND SEMI-ARID LANDS

WYOMING GAME AND FISH DEPARTMENT

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February 10, 1982

Lavern H. Stelter
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Sincerely,

Janette Petty

Janette Petty
Technical Information Specialist

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March 5, 1982

Janette Petty
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Dear Ms. Petty:

Enclosed please find your letter showing approval to reprint Shrub Establishment on Disturbed Arid and Semi-Arid Lands soley for BLM field distribution. The Department does ask, though, that you indicate in the reprint copy that the Wyoming Game and Fish Department has given permission for the reprint at your expense.

Also, a bit of clarification on the status of this publication at this time. It is not out of print. There are approximately 100 copies still available at $1.00 per copy by writing Wyoming Game and Fish Department, Special Publications, Cheyenne, WY 82002.

If you have any further questions, please feel free to contact me.

Sincerely,

Judy Hosafros

(Mrs.) Judy Hosafros
Publications Assistant in
Special Publications

jh
encl.
cc: Dr. E. J. DePuit
Vern Stelter

SHRUB ESTABLISHMENT ON DISTURBED ARID AND SEMI-ARID LANDS

Proceedings of the symposium held at Laramie, Wyoming
December 2-3, 1980

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Wyoming Game and Fish Department
1981

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Financial support was through the Wyoming Game and Fish Department and the Wyoming Department of Environmental Quality. Administrative support from Harry Harju, Dale Strickland, Francis Petera, Chester Anderson, Bill Hepworth, Neal Blair, and Judy Hosafros of the Wyoming Game and Fish Department and Gary Beach, Walter Ackerman, and Robert Sundin of the Wyoming Department of Environmental Quality made this publication possible.

INTRODUCTION

Within the last decade, the mining industry in Wyoming has grown dramatically. The major hard mineral products in Wyoming are coal, uranium, bentonite, trona, and iron. For these minerals, a total of 716,007 acres are currently under state mining permits, of which 74,386 acres have been disturbed to date. The rate of mineral development in Wyoming is still increasing, thus many more thousands of acres will be affected in the years to come.

The Wyoming Environmental Quality Act of 1973 and the Rules and Regulations stemming from the Act are enforced by the Wyoming Department of Environmental Quality (DEQ). Under this Act, reclamation is required on all lands disturbed by hard mineral mining. Revegetation is the last major step in the reclamation process. Current DEQ Land Quality Rules and Regulations specifically outline revegetation requirements. Chapter 4, Section 2.d.(6) states that "Revegetation shall be deemed to be complete when (1) the vegetation cover of the affected land is shown to be capable of renewing itself under natural conditions prevailing at the site, and is at least equal to the cover on the area before mining, (2) the productivity is at least equal to the productivity on the area before mining, (3) the species diversity and composition are suitable for the approved postmining land use and the revegetation area is capable of withstanding grazing pressure at least comparable to that which the land could have sustained prior to mining... and (4) the requirements of (1), (2), and (3) are met for 2 consecutive years." In addition, Chapter 4, Section 2.a.(2) states that "Operators are required to restore wildlife habitat, whenever possible, on affected land in a manner commensurate with or superior to habitat conditions which existed before the land became affected...." Thus a self-sustaining, productive, diverse vegetative cover similar to pre-mining conditions must be re-established, and this vegetation must include those components necessary for wildlife. These requirements make shrub establishment an essential part of the reclamation process. Though a statewide total of 20,682 acres have been revegetated with grasses, mine personnel have had limited success with shrub plantings, and many have expressed concern about their ability to meet the shrub establishment requirement.

These proceedings are an effort by the Wyoming Game and Fish Department and the Wyoming DEQ to provide mining companies with a summary of shrub establishment research, and are intended to be an aid in reclamation efforts. The proceedings describe successes and failures for a variety of species under a variety of environmental conditions, and cover virtually every step in the shrub establishment process.

The authors represent a large sample of those with experience in shrub reclamation in the West. Although their knowledge represents the state of the art at this time, much work still needs to be done, and many questions remain unanswered. Thus, the information presented herein is not meant to be treated as a panacea to reclamation problems. It is provided with the intent that it be studied, absorbed, put to use, and built upon. Free interchange of ideas and methodologies is encouraged among all who work with shrub establishment, in order that we might further advance the state of the art in this very important field. Adequate reclamation of hundreds of thousands of acres throughout the West, now and in the future, will depend on this advancement.

Lavern H. Stelter
Sharon A. Mikol

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SHRUB SELECTION AND ADAPTATION FOR REHABILITATION PLANTINGS

by

E. Durant McArthur[1]

ABSTRACT

Wyoming is richly endowed with mineral resources that are being mined at an accelerated rate. Land disturbed by this mining activity must, by law, be returned to productive use. Wyoming's environment makes much of the state shrubland. Many naturally occurring shrubs are of use in rehabilitating the disturbed lands. Shrub improvement and selection can play an increasingly important role in the land rehabilitation process.

[1]Author is Principal Research Geneticist, USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, stationed at the Shrub Sciences Laboratory, Provo, Utah; and is Adjunct Associate Professor of Botany and Range Science at Brigham Young University. He acknowledges assistance from Pittman-Robertson Wildlife Restoration Project W82-R in work that lead to this publication.

INTRODUCTION

The Interior West, including Wyoming, is endowed with vast deposits of fuels and minerals. These resources are being exploited at an increasingly rapid rate as the nation's mineral and energy needs expand. Many of these fuel and mineral resources are amenable to surface mining, which disturbs large land areas. The most prominent resources that are presently surface mined or have the potential for such in Wyoming and proximate states are coal, oil shale, phosphate, and uranium. Other mineral resources of the area include copper, lead, zinc, molybdenum, gold, nickel, iron, silver, gypsum, clays, vermiculite, pearlite, talc, flagstone, flourspar, sands, and gravel (Copeland and Packer 1972).

Once minerals are removed, the challenge is to put the land back into productive use. Difficulties in so doing stem mainly from unfavorable climatic conditions of the area and from the shallow mineralized soils that often remain after the mining process. The challenge, however, can and must be met (Wright 1978). Legislation mandates that the challenge be met. Such laws as the National Environmental Protection Act of 1969 (Carter 1973), the National Forest Management Act of 1976 (USDA 1976), and the Surface Mining Control and Reclamation Act of 1977 (USDI 1977) require a productive postmining life for reclaimed mine sites. For example, the last act listed requires that:

> "the permittee shall establish on all land that has been disturbed a diverse, effective, and permanent vegetative cover of species native to the disturbed land or species that will support the planned postmining uses of the land...." (USDI 1977).

SHRUBS AS COMPONENTS OF WYOMING'S VEGETATION

Wyoming is, in general, a high, dry place. It has a continental, semiarid climate. Except for higher mountain areas, Wyoming precipitation is less than 50 cm/year--in some locations, much less (Bailey 1976, 1978). These conditions make Wyoming essentially shrub country (Weaver 1980). Nearly half (45.8% or 11,560,000 hectares) of Wyoming's land area is, under natural conditions, dominated by shrubby vegetation (Küchler 1964, Table 1). Four of the 16 potential natural vegetation types Küchler (1964) assigns to Wyoming are shrubby vegetation types. (Ten of the 12 vegetation types not classified by Küchler as primarily shrubby have shrubs as a principal component of the vegetation). Many of the 16 vegetation types include several different shrub species (Table 1).

Küchler's (1964) map may be conservative in its treatment of shrubs because of its continental scale. For example, from Küchler's map, I calculated that 10,500,000 hectares are dominated by big sagebrush (*Artemisia tridentata*) in Wyoming. In contrast, Beetle (1960) listed a figure of 15,080,000 hectares of sagebrush (subgenus *Tridentatae* of *Artemisia*) for the state. Beetle's figure for *A. tridentata* alone was 9,335,000 hectares.

Table 1.--Wyoming vegetative types (calculated from Küchler's [1964] map).

Vegetative type	Wyoming land area	Disjunct Wyoming areas	Shrub species as principal component
	%	No.	No.
Douglas-fir forest	10.3	8	1
Western spruce/fir forest	5.9	16	4
Eastern ponderosa pine forest	.8	5	0
Black Hills pine forest	2.0	1	11
Pine/Douglas-fir forest	2.9	2	6
Juniper/pinyon woodland	.2	1	6
Mountain mahogany/oak scrub	.5[1]	2	11
Saltbush/greasewood	3.9[1]	5	11
Alpine meadow/barren	1.3	8	3
Sagebrush steppe	30.4[1]	6	4
Wheatgrass/needlegrass/wheatgrass	11.0[1]	7	7
Foothills prairie	.7	4	1
Grama/needlegrass/wheatgrass	19.0	3	2
Grama/buffalograss	4.4	1	2
Wheatgrass/needlegrass	6.6	1	1
Nebraska sand hills prairie	.0[2]	1	0
	99.9[3]	71	51[4]

[1]Shrubby vegetation types.
[2]Actually .026%.
[3]Does not equal 100.0 because of rounding.
[4]Several shrub species occurred in more than one type but were counted only once for the total.

Wyoming's shrublands have been in place for several thousand years (Axelrod 1950; McArthur and Plummer 1978; McArthur et al. 1981). Before then, the climate was more mesic; coniferous forests, grasslands, and woodlands occupied larger areas. Now and for the foreseeable future, however, shrubs are and will be a dominant form of vegetation.

SHRUB VALUES

In an article titled "Shrubs - Neglected Resource of Arid Lands", McKell (1975) listed several misconceptions about shrubs:

Shrubs are worthless invaders.
Shrubs are generally unpalatable to livestock other than goats.
Large tracts of valuable land are occupied by worthless shrubs.
Shrubs are low in feed value.

Most shrubs are spiny and harsh in nature and therefore a menace. Shrub eradication is essential to a range improvement program.

McKell rebutted each of these misconceptions. Actually, wildland shrubs have many values. Principal among these values in Wyoming are (1) providing soil stability especially in areas where some shrub species grow better than any other plant species; (2) providing habitat for small, upland, and big game animals; (3) providing wildlife and livestock feed; and (4) maintaining ecosystem function by providing nutrient pools for associated plants (McKell 1975; McArthur et al. 1978a; Klemmedson 1979).

Some adaptations that various Wyoming shrubs have that make them more efficient in arid land environments include drought tolerance, extensive dual surface and deep root systems, a heat efficient photosynthetic pathway (C_4), salt tolerance, rapid regrowth after defoliation, resistance to prolonged environmental stress, and the ability to enhance the soil nitrogen economy by symbiotic nitrogen fixation (McKell 1975; Klemmedson 1979).

SHRUB SELECTION AND ADAPTATION

Available Plant Materials

Shrubs are the dominant vegetative life form on nearly one-half of Wyoming's landscape and an important component over much of the rest of the state (Table 1). Most revegetation efforts should be used to create a productive, versatile, and esthetically pleasing vegetative cover. Used in combination with other growth forms (grasses, forbs, and trees), shrubs provide a diverse habitat for many kinds of animals. For esthetic purposes, revegetation mixtures including several shrub species can be manipulated to give sites variety in color and form and over seasons.

Much of western and central Wyoming can be referred to as the Cold Desert (Shreve 1942; McArthur et al. 1978a). The Cold Desert is generally further divided into two principal subdivisions, the salt desert shrub type (=Küchler's [1964] saltbush/greasewood vegetative type) and the sagebrush type (=Küchler's [1964] sagebrush steppe and wheatgrass/needlegrass/shrub types). The salt desert lands differ from sagebrush lands in that they occur in zones of lesser precipitation (<25 cm/year), occur generally at lower elevations (usually below 1,680 m), and generally contain salt concentrations of > 4 millimhos/cm (Gates et al. 1956; Branson et al. 1967, 1976). Salt desert lands are dominated for the most part by chenopod shrubs of the genera Atriplex, Ceratoides, and Sarcobatus, whereas sagebrush lands contain mostly big sagebrush (Artemisia tridentata) and its allies as the woody dominants.

The particular shrub species chosen for revegetation will, of course, depend on the site to be rehabilitated. Plummer and his colleagues have compiled a number of planting guidelines and species attributes and have listed species that are adapted to various plant communities (Plummer et al. 1968; McArthur et al. 1974, 1978a; Monsen 1976; Plummer 1977; Monsen and Plummer 1978). Keller (1979) provided an extensive review for species and

and methods of seeding in sagebrush types. Hull (1963) and Bleak et al. (1965) reviewed revegetation efforts in the salt desert shrub type. In some of the literature, little emphasis is given to the value of sagebrush (*Artemisia* spp.) and rabbitbrush (*Chrysothamnus* spp.). Both genera have been underrated. They both include fast growing, widely adapted species that effectively bind soil and provide wildlife habitat and feed (McArthur et al. 1979; Welch and McArthur 1979).

Salt desert shrub and sagebrush lands are extensive and concentrated enough to be marked off on continental-scale maps. Ranges and adaption of component species, however, extend over larger areas (McArthur et al. 1978a). Within and adjacent to the Cold Desert are localized areas of both salt desert and sagebrush types that do not show on vegetation maps. Often mosaics and other intertwining patterns of vegetation occur among salt desert and sagebrush types and other vegetation types. These ecotonal areas often provide good wildlife habitat and increase animal species diversity. So it can also be with reclaimed mine lands. Various spoil areas may be better suited to a salt desert type, a sagebrush type, or another vegetational type. Analysis of the properties of the reconstructed soil could be used in deciding which suite of potentially adapted species to plant. For variety on some sites reconstructed soils could be put back to preserve or create mosaic vegetation patterns.

Shrub Improvement and Selection

The West's shrublands have a vast array of naturally evolved and adapted taxa that can be used for revegetation efforts (Plummer et al. 1968; McArthur et al. 1974, 1979; Blauer et al. 1975, 1976; Monsen and Christensen 1975; Tiedemann et al. 1976; Plummer 1977). We are now beginning efforts to produce improved and selected materials for revegetation uses.

Variation in western wildland shrub species is abundant and potentially exploitable for human purposes (McArthur and Plummer 1974; Stutz 1974; Welch and McArthur 1979). Selection and breeding produced our agronomic crops, horticultural plants, and some silvicultural strains. The same kind of progress can be made on wildland shrubs. With the wildland shrubs, however, a different emphasis needs to be taken. These shrubs will not be cultivated. So while we seek improvements in certain directions--nutritive quality, growth rates, disease resistance, adaptation--retention of competitiveness and natural variation are also goals. With these latter two characteristics, the improved shrubs will be able to maintain a competitive position in wildland and semiwildland settings. Our work with fourwing saltbush (*Atriplex canescens*) (McArthur et al. 1978b; unpublished data on file at Shrub Sciences Laboratory, Provo, Utah) and big sagebrush (*Artemisia tridentata*) (McArthur and Plummer 1978; McArthur et al. 1979; Welch and McArthur 1979) has shown there is ample exploitable variation in these two large plant groups. We have begun the selective process that will lead, we hope, to new strains useful for reclamation of disturbed lands.

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NUTRITIVE VALUE OF BIG SAGEBRUSH AND OTHER SHRUBS

by

Bruce L. Welch[1]

ABSTRACT

This paper is divided into three parts. First, a section titled "Nutrient Needs of Animals" is presented as an aid in judging the nutritive value of range plants. Next, a section is presented to explain the contribution that shrubs can make toward meeting the nutrient needs of wintering animals. Last, a detailed discussion is given concerning the feasibility of improving big sagebrush for use on mule deer winter ranges.

[1]Author is Research Plant Physiologist, USDA Forest Service, Intermountain Forest and Range Experiment Station, Ogden, stationed at the Shrub Sciences Laboratory, Provo, Utah.

NUTRIENT NEEDS OF ANIMALS

The nutritive value of any plant should be measured in terms of the plant's ability to supply the nutrients needed to meet the physiological requirement of the consuming animal. The nutrient needs of animals can be broken down into four classes. These classes are: protein, energy-producing compounds, minerals, and vitamins.

Protein

Protein in animal bodies makes up a large heterogeneous group of compounds. All proteins are made from building blocks known as amino acids. It is the arrangement of these amino acids that gives a particular protein its character which in turn determines its function.. Many body structures are composed chiefly of protein, such as: 1) Skeleton muscle for external movement; 2) smooth muscle for internal movement (including the passage of food through the digestive tract, breathing, etc.); 3) cardiac muscle for the movement of blood; 4) tendons and ligaments for tying together body parts such as bones, muscles, organs; 5) organs and glands such as the stomach, eye, pituitary, and skin (with its covering of hair), and 6) other structures including hemoglobin, cytochromes, and membrane. Another important group of protein compounds are the enzymes. Enzymes provide the framework in which the chemical reactions of the body take place.

Because of the involvement of proteins in so many bodily functions, the animal body needs a liberal and continuous supply of protein. Protein requirement for an animal depends on species, age, size, and activity. Wintering mule deer and sheep need to extract from their food 0.12 to 0.20 pounds of protein per day (National Academy of Sciences 1964, Welch and McArthur 1979a).

Energy

Energy-producing compoundsmake up the single largest class of nutrients needed by animals (Dietz 1972). Energy is the driving force in the animal body. The animal body is so structured that it can obtain needed energy from a variety of compounds including sugars, fats, pectins, starches, proteins, and indirectly from cellulose and hemicellulose. Some plant products including monoterpenoids and lignin do not furnish energy to the animal (Cook 1972, Short et al. 1972). As with protein, energy requirements of animals depends on species, age, size, and activity. Wintering sheep need from 1.3 to 2.3 pounds of total digestible nutrients per day. This energy requirement is about 10 to 12 times higher than that needed for protein (National Academy of Sciences 1964).

Minerals

Minerals perform many vital functions in the body. They are: major constituents of bones, teeth, the body buffer system, soft tissues, and body fluids and they are regulators of enzymatic systems and muscular contraction. They are also important in energy transfer (Ensminger and Olentine 1978).

Calcium and phosphorus are the minerals of major concern, although other minerals (copper, cobalt, magnesium, sulfur, zinc, molybdenum) may be locally in short supply. Wintering sheep need from 2.9 to 4.8 g of calcium per day and 2.6 to 3.7 g of phosphorus (National Academy of Sciences 1964).

Vitamins

Vitamins are organic compounds needed by the body in relatively small amounts. Vitamins are unrelated chemically, but all are metabolic regulators (Maynard and Loosli 1962). For ruminants, only vitamin A is of major concern. Vitamin A needs are usually expressed in terms of milligrams of carotene, a plant precursor for vitamin A. Wintering sheep need from 1.0 to 7.9 mg of carotene per day (National Academy of Sciences 1964).

Digestibility

Digestibility is a major point that must be kept in mind when attempting to judge the ability of a food to meet the nutrient needs of an animal. For example, two shrub species may be equal in amount of crude protein[2], but differ in the amount of protein that is available for physiological use (Welch and McArthur 1979a). This important principle is illustrated in Table 1. Here, a comparison is made between the actual crude protein content of various shrubs and the amount of crude protein needed to meet the needs of wintering mule deer. We used the midvalue of 5.2% digestible protein as the requirement for wintering mule deer (National Academy of Sciences 1964, Welch and McArthur 1979a). This means that wintering mule deer need to extract 2.6 kg of protein out of each 50 kg of dry matter eaten.

The amount of crude protein needed in the shrub forage to meet the protein needs of wintering mule deer is calculated by dividing 0.052 (the requirement) by the coefficient of digestion, and multiplying the result by 100. Table 1 shows that only big sagebrush and curlleaf mahogany, of the forages listed, meet or exceed the protein needs of wintering mule deer. Other shrubs and dormant grass do not provide sufficient amounts of crude protein.

NUTRITIVE VALUE OF BIG SAGEBRUSH AND OTHER SHRUBS

The nutrient content of range plants is cyclic (Cook 1972, Urness 1980). Nutrient content peaks during the spring then gradually decreases, reaching a low level in winter. Some of the plants supply certain winter-level nutrients below that required by the consuming animal. Generally speaking, protein, energy (total digestible nutrients), and phosphorus are deficient in winter forages (Dietz 1965). The following discussion will demonstrate how big sagebrush and other shrubs can supply some of these nutrients for wintering wildlife and livestock.

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[2]Crude protein is the product of the total concentration of all nitrogen-containing compounds in the plant multiplied by 6.25 (Ensminger and Olentine 1978).

Table 1. Importance of shrub crude protein digestibility in meeting the protein requirements of wintering mule deer.

Shrub	Actual* crude protein	Coefficient* of digestion	Protein** needed in shrubs	Meets or exceeds the requirement
	%		%	
Big sagebrush	12.4[g]	0.533[a,b,c]	9.7	Exceeds
Curlleaf mahogany	10.6[d]	.543[d]	9.6	Exceeds
Chokecherry	9.1[e]	.484[e]	10.7	Deficient
True mahogany	7.7[a,e]	.457[a,e]	11.4	Deficient
Bitterbrush	8.3[a,b,d]	.411[a,b,d]	12.7	Deficient
Cliffrose	8.4[e]	.398[e]	13.1	Deficient
Dormant grass	3.7[f]	.316[f]	16.5	Deficient
Juniper	6.2[d]	.102[d]	50.9	Deficient
Gambel oak	5.4[e]	.197[e]	48.6	Deficient

*Actual content of crude protein and coefficient of digestion represent the mean of several studies or a value from a single study.

**The winter mule deer requirement for crude protein may be taken as 5.2% digestible protein. This means that the animal needs to digest 2.6 kg of protein out of every 50.0 kg of dry matter (d.m.). The amount of crude protein needed to meet this requirement is calculated by dividing 0.052 (the requirement) by the coefficient of digestion and multiplying the result by 100. A comparison between the amount of crude protein, needed and actual, determines whether the shrub meets or exceeds the protein requirement or is protein deficient.

a = Dietz et al. 1962
b = Bissell et al. 1955
c = Smith 1950
d = Smith 1952
e = Smith 1957
f = Nat. Academy of Sci. 1964
g = Welch and McArthur 1979b

Digestible Protein

According to the National Academy of Sciences (1964), the digestible protein requirement for small ruminants like sheep and deer range from 4.4 to 5.2% of the dry matter consumed. Table 2 lists the winter content of digestible protein (DP) of shrubs and grasses. As can be seen, four of the evergreen shrubs exceed the upper range for DP (fourwing saltbush, winterfat, big sagebrush, and curlleaf mahogany). Black sagebrush and perhaps shadscale supply enough DP for the low range. Semi-evergreen Nuttal saltbush[3] (*Atriplex gardneri*) and deciduous shrubs, such as bitterbrush (*Purshia tridentata*) and mountain mahogany (*Cercocarpus montanus*), would not supply enough DP. Dormant grasses,

[3]The term Nuttal saltbush used in the Literature Cited is probably better referred to as Gardner saltbush (Stutz et al. 1979).

such as sand dropseed (*Sporobolus cryptandrus*), needle-and-thread (*Stipa comata*) western wheatgrass (*Agropyron smithii*), and Indian ricegrass (*Oryzopsis hymenoides*), do not supply enough DP to meet lower DP requirements. In general, shrubs are higher in winter levels of DP than grasses (Cook 1972).

Table 2. The amount of digestible protein in winter forages. Data expressed as percent of dry matter

Forage	Digestible protein*	Reference**
	%	
Fourwing saltbush	8.2	1
Winterfat	6.7	1,3,8,9
Big sagebrush	6.0	2,3,4,5,6,9
Curlleaf mahogany	5.9	5,7
Black sagebrush	4.5	3,9
Shadscale	4.3	3,9
Nuttal saltbush	3.4	3
Bitterbrush	3.4	2,4,5,7
Mountain mahogany	3.4	2,5
Sand dropseed grass	1.9	3
Needle-and-thread grass	1.2	3,9
Western wheatgrass	.5	1,3,9
Indian ricegrass	.2	3,9

*The digestible protein requirement for small ruminants (sheep and deer) range from 4.4 to 5.2% (National Academy of Sciences 1964).

** 1 = Otsyina et al. 1980
2 = Dietz et al. 1962
3 = Nat. Academy of Sci. 1964
4 = Bissell et al. 1955
5 = Smith 1957
6 = Smith 1950
7 = Smith 1952
8 = Morrison 1961
9 = Cook et al. 1954

Total Digestible Nutrients

Total digestible nutrient (TDN) requirements for small ruminants (sheep and deer) range from 50 to 55% of the dry matter consumed (National Academy of Sciences 1964). Table 3 lists the amount of winter TDN of shrubs and grasses. Evergreen shrubs, such as curlleaf mahogany, big sagebrush, juniper, and two grasses (sand dropseed and western wheat), supply enough TDN to exceed the upper limits of the requirement. The remaining plants do not supply enough TDN to meet the lower range of the requirement. In general, grasses are higher in winter levels of TDN than shrubs (Cook 1972), although it is evident from the data in Table 3 that certain evergreen shrubs supply as much or more winter level of TDN as grass.

Table 3. The amount of total digestible nutrients in winter forages. Data expressed as percent of dry matter

Forages	Total Digestible nutrients (%)*	Reference**
Curlleaf mahogany	64.8	1,2,3
Big sagebrush	61.3 (56.8)***	1,2,3,4,5,6,7
Juniper	60.8 (52.9)***	2,3
Sand dropseed grass	59.0	6,9
Western wheatgrass	57.6	6,8,9
True mahogany	48.4	1,2,4
Indian ricegrass	48.2	6,9
Cliffrose	47.2	2
Black sage	47.0	6,9
Bitterbrush	46.0	1,2,3,5
Needle-and-thread grass	45.1	6,8,9
Winterfat	40.0	6,8,9
Chokecherry	38.9	2
Gambel oak	36.2	2
Nuttal saltbrush	36.0	9
Shadscale	31.0	9

*The total digestible nutrients requirement for small ruminants (sheep and deer) range from 50 to 55% (National Academy of Sciences 1964).

**1 = Urness et al. 1977
2 = Smith 1957
3 = Smith 1952
4 = Dietz et al. 1962
5 = Bissell et al. 1955
6 = Cook et al. 1954
7 = Smith 1950
8 = Morrison 1961
9 = National Academy of Sciences 1964

***Values in () corrected for presence of monoterpenoids (Welch and McArthur 1979a).

Phosphorus and Calcium

The phosphorus and calcium requirement for small ruminants (sheep and deer) range from 0.14 to 0.21% and 0.18 to 0.27%, respectively, of dry matter consumed (National Academy of Sciences 1964). A quick glance over Table 4 shows why calcium is not a problem on winter ranges. All forages listed exceed the upper requirement for calcium. Phosphorus is another thing. None of the forages listed meet the upper requirement. Only five of the forages (all shrubs) exceed the lower range of the phosphorus requirement. In general, shrubs are higher in winter levels of phosphorus than grasses (Cook 1972).

Table 4. The amount of calcium and phosphorus in winter forages. Data expressed as percent of dry matter

Forage	Phosphorus (%)*	Calcium (%)*	Reference**
Big sagebrush	0.20	0.65	1,2,3,4
Juniper	.19	1.20	1,4
Black sage	.17	.62	2,3,4
Fourwing saltbush	.15	1.19	4
Nuttal saltbush	.15	2.56	2,3,4
Bitterbrush	.13	.68	1,4
Winterfat	.12	2.10	2,3,4
Mountain mahogany	.12	.73	1
Shadscale	.11	2.44	2,3,4
Needle-and-thread grass	.07	.67	2,3,4
Western wheatgrass	.07	.67	2,3,4
Sand dropseed grass	.07	.48	2,3,4
Indian ricegrass	.06	.54	2,3,4

*The phosphorus and calcium requirement for small ruminants (sheep and deer) range from 0.14 to 0.21% and 0.18 to 0.27%, respectively (National Academy of Sciences 1964).

**1 = Dietz et al. 1962
2 = National Academy of Sciences 1964
3 = Cook et al. 1954
4 = National Academy of Sciences 1958

Carotene

The winter diets of range animals are not usually listed as being deficient in carotene, a precursor of vitamin A. It is apparent, however, from the data in Table 5 that range animals consuming large amounts of dormant grass could easily develop a vitamin A deficiency. All the shrubs listed in Table 5 supply carotene at a level many times above the upper limits of the carotene requirement (1.8 mg/lb) (National Academy of Sciences 1964). In general, shrubs supply higher winter levels of carotene than grasses (Cook 1972).

SELECTING FOR NUTRITIONALLY SUPERIOR BIG SAGEBRUSH

At the Shrub Sciences Laboratory, Provo, Utah, an attempt is being made to develop nutritionally superior strains of shrubs for use on mule deer and livestock winter ranges. Following is a report on the progress made in developing a nutritionally superior strain of big sagebrush. Welch and McArthur(1979b) reported that accessions and subspecies of big sagebrush grown in a uniform garden varied significantly in the level of winter crude protein (also see Welch and McArthur 1979a). Results of the Welch and McArthur (1979b) study are given in Table 6.

Table 5. The amount of carotene in winter forages. Data expressed as milligrams per pound of dry matter

Forage	Carotene (mg/lb)*	Reference **
Shadscale	10.0	1,2
Nuttal saltbush	8.6	1
Big sagebrush	8.2	1,2
Black sage	8.0	1,2
Winterfat	7.6	1,2
Sand dropseed grass	.3	1,2
Western wheatgrass	.2	1,2
Needle-and-thread grass	.2	1
Indian ricegrass	.2	1,2

*The carotene requirement for small ruminants (sheep and deer) range from 0.4 to 1.8 mg/lb (National Academy of Sciences 1964).

**1 = National Academy of Sciences 1964
2 = National Academy of Sciences 1958

Accessional means ranged from 10 to 16% crude protein on a dry matter basis. This is evidence that crude protein is under genetic control. Welch and McArthur (1979b) also reported that subpsecies tridentata (14.5%) contained significantly higher winter levels of crude protein than wyomingensis (11.8%) and vaseyana (11.1%).

Welch and McArthur (1979a) found that wintering mule deer differentially preferred some accessions of big sagebrush over others grown in a uniform garden. The results of this study are given in Table 7.

Table 6. Midwinter crude protein content of 21 accessions of big sagebrush grown in a uniform garden. Data expressed as percent of dry matter.

Accessions	% Crude Protein
Benmore (v)*	10.0**
Durkee Springs (v)	10.0
Sardine Canyon (v)	10.5
Pinto Canyon (v)	11.0
Trough Springs (w)	11.0
Indian Peak (v)	11.2
Petty Bishop's Log (v)	11.2
Milford (w)	11.2
Alton (v)	11.3
Salina Canyon (v)	11.7
Clear Creek Canyon (v)	11.7
Kaibab (w)	11.9
Colton (v)	12.0
Wingate Mesa (t)	12.8
Evanston (w)	12.9
Big Brush Creek (t)	13.1
Loa (t)	14.5
Dog Valley (t)	14.5
Evanston (t)	15.2
Clear Creek Canyon (t)	15.3
Dove Creek (t)	16.0

* w = subspecies *wyomingensis*, v = subspecies *vaseyana*, t = subspecies *tridentata*.

** Any two means not connected by the same line are significantly different at the 95% level.

Table 7. Variation of palatability among 10 accessions of big sagebrush grown in a uniform garden as determined by browsing wild mule deer (% utilization)

Accession	% Utilized
Marysvale (t)*	25**
Trough Spring (w)	29
Loa (t)	33
Dove Creek (t)	46
Indianola (t)	47
Milford (t)	58
Indian Peak (v)	59
Monticello (v)	63
Spanish Valley (v)	73
Hobble Creek (v)	84

*w = subspecies wyomingensis, v = subspecies vaseyana, t = subspecies tridentata

**Any two means not connected by the same line are significantly different at the 95% level.

A big sagebrush accession collected from the Hobble Creek area east of Springville, Utah, appears to be the most preferred accession studied. Because of the uniform conditions of the Welch and McArthur (1979a) study, genetic factors play an important role in the selectivity of an accession by wintering mule deer (also see Welch et al. 1982).

In vitro dry matter digestibility also varies significantly among accessions of big sagebrush. Welch and Pederson (1981) reported that the *in vitro* digestibility of two accessions of big sagebrush (Clear Creek and Dove Creek) were more readily digested than seven other big sagebrush accessions and considerably more digestible than four native forages (bitterbrush, mountain mahogany, curlleaf mahogany, and rose hips) (Table 8). Again genetic factors seem to play an important role in determining digestibility.

Table 8. *In vitro* dry matter digestibility among nine accessions of big sagebrush and four other browse species

Big sagebrush accession or browse species	% digested dry matter
Bitterbrush	19.8**
Mountain mahogany	20.0
Trough Springs (w)*	44.6
Curlleaf mahogany	44.7
Sardine (v)	48.7
Rose hips	49.1
Milford (w)	54.6
Kaibab (w)	54.9
Benmore (v)	55.2
Indian Peak (v)	55.8
Loa (t)	57.0
Dove Creek (t)	64.6
Clear Creek (t)	64.8

*Subspecies of *Artemisia tridentata*: w = *wyomingensis*, v = *vaseyana*, t = *tridentata*

**Any two means not connected by the same line are significantly different at the 95% level.

There is some evidence in the literature that big sagebrush monoterpenoids may cause digestive problems in mule deer (Nagy et al. 1964, Nagy and Tengerdy 1968). Recent studies, however, show that big sagebrush is a highly digestible browse and that through three or four of the deer's physiological processes, the monoterpenoid level in the rumen is reduced about 80% (Welch and Pederson 1981, Cluff et al. 1982).

McArthur and Welch (1981), studying the growth rates (a measurement of production) among big sagebrush accessions, reported large differences among the accessions studies (also see Welch and McArthur 1979a). The Dove Creek accession was among the most productive (Table 9). Because these data (like those given earlier) were generated on even-aged plants grown in a uniform garden, differences are due mainly to genetic factors.

It is apparent that some accessions of big sagebrush are higher in winter protein than others; and that some are more palatable, some more digestible, and some more productive. Our plan is to combine accessions in an attempt to develop nutritionally superior strains of big sagebrush for use on winter ranges. It is noteworthy that the Dove Creek accession contained the highest level of protein, digestibility, and productivity. We hope to develop a nutritionally superior strain of big sagebrush by crossing the Dove Creek accession with the most palatable accession--Hobble Creek.

Table 9. Growth rate of 21 accessions of big sagebrush grown in a uniform garden

Accession	Mean annual leader growth rate (cm)
Colton (v) *	5.8**
Trough Springs (w)	7.3
Alton (v)	7.5
Sardine Pass (v)	7.5
Kaibab (w)	8.1
Evanston (w)	9.0
Benmore (v)	9.0
Big Brush Creek (t)	9.5
Petty Bishop's Log (v)	10.1
Salina Canyon (v)	10.5
Indian Peak (v)	11.3
Pinto Canyon (v)	11.3
Clear Creek Canyon (v)	11.6
Wingate Mesa (t)	12.3
Durkee Springs (v)	12.3
Milford (w)	12.8
Dog Valley (t)	15.7
Evanston (t)	17.4
Clear Creek Canyon (t)	18.0
Loa (t)	21.1
Dove Creek (t)	21.4

* w = subspecies wyomingensis, v = subspecies vaseyana
t = subspecies tridentata

**Any two means not connected by the same line are significantly different at the 95% level.

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SHRUB ESTABLISHMENT, DOMINANCE, AND ECOLOGY ON THE JUNIPER AND SAGEBRUSH-GRASS TYPES IN WYOMING

by

Herbert G. Fisser[1]

ABSTRACT

Game range improvement studies were initiated within the juniper zone in the Big Horn Basin of north central Wyoming in 1964. Juniper control was accomplished with chemical, mechanical and burning, both controlled and at some natural burn sites. Most acceptable juniper control was selective burning in most cases. Fall seed application of species with small seeds often resulted in good plant establishment. Species with large seeds often were not successfully established unless seeds were planted. With viable seeds big, black and silver sagebrush were readily established on properly prepared sites, i.e., those from which the controlling biological component such as juniper had been removed. Because of their relatively slow growth, establishment of shrubs usually requires several years protection from grazing by wildlife or livestock.

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INTRODUCTION

Intensive management of our range resources requires comprehensive and accurate biological and environmental information. The need for plant response data in recent years has been greatly intensified in view of multiple use concepts and legislation associated especially with vegetation reestablishment requirements on surface mined lands, as well as others.

Vegetation establishment, and especially that of shrubs, requires specific conditions for insured plant establishment success. This presentation will address some of those conditions, physical and biological, which have been found to be important. The general theme of research activities has been to study techniques for game range improvement, primarily in the juniper type of northwestern Wyoming. The study was initiated in 1966 by cooperative efforts of the Wyoming Game and Fish Department, the Bureau of Land Management, and the Range Management Division, University of Wyoming. During the development and initiation of the program, and through subsequent years, many individuals have contributed. These include Bill Hepworth and Calvin King of the Wyoming Game and Fish Department, Laramie and Thermopolis; and Dr. Harold Alley of the Plant Science Division, University of Wyoming. A host of graduate students have assisted with data collection over the years. Those whose graduate research was directly related to the program were Dr. Carl Wambolt, Larry Robinson, Leslie Burrough, Clinton Hanson, William Gerhart and most recently Kenneth Spaeth.

Essential components of big game winter range are food production and available cover. These are dependent upon the relationships of overstory and understory plant species. In the juniper areas of Wyoming we characterize sagebrushes as understory species, although they often do provide cover. Overstory species in the Wyoming juniper type may include either Utah juniper (*Juniperus osteosperma*) or Rocky Mountain juniper (*J. scopulorum*) associated with limber pine (*Pinus flexilis*). Understory production is greatly suppressed by juniper abundance as low as 80 trees per acre -- a spacing of 25' between trees. That being the case then, the development of our program was initiated with the study of juniper control techniques.

Results of deer behavior monitoring and fecal analyses of the program have shown that juniper is a common diet component, but most preferred during moderate winters are other shrubs such as sagebrushes, mountain mahogany, skunkbush, serviceberry, and bitterbrush. During severe winters deer actively hedge selected juniper trees till all available green leaf material is removed. Differential diet quality and palatability of individual trees is probable but has not been investigated as yet.

Specific objectives of the program discussed here were:

1. Evaluate juniper control techniques -- chemical, burn, mechanical doze and sawing.
2. Evaluate plant seeding techniques (broadcast and furrow planting): Season of year (spring and fall) and seedling adaptability under 3 juniper control techniques (spray, burn, doze).

3. Plot successional trends on treated areas, of native and introduced species including shrubs, forbs and grasses.

METHODS

Field activities and procedures involved several specific locations in western Wyoming in the Wind River Basin and primarily in the Big Horn Basin. Three deer proof exclosures were constructed in 1968 and treated with juniper control by chemical (Tordon @ 2 lbs/A A.I. August application), burn and mechanical doze. An earlier exclosure also included chemical control and juniper removal by chain saw. A large fortuitous natural burn area was utilized in addition to the three exclosures for trials of broadcast and furrow plantings, at fall and spring 1968-69 (29 species); fall and spring 1970-71 (35 species). Vegetation responses to control treatments were monitored with permanent quadrats 20' x 50' and 1' x 10'. Herbage production and cover of understory species including sagebrushes were monitored annually with herbaceous species clippings and weight unit computation of shrubs and mat form species. Precipitation, soil and site data were recorded.

RESULTS

Juniper Control

Results of juniper control techniques showed that two-way application of tordon (2 lbs/A A.I.) during late August was lethal to Utah juniper, big sagebrush and curlleaf mountain mahogany. Black sagebrush, a root sprouter, exhibited a significant growth during the next two years following treatment and Rocky Mountain juniper was not significantly affected.

Mechanical dozing of juniper was effective but not acceptable because of soil disturbance and subsequent erosion. Sawing juniper near ground level allowed them to begin re-invasion, which is currently very apparent (15 years post treatment), but understory establishment of half shrubs, grasses, forbs, and shrubs was evident within two years.

Burn treatment to control juniper was effective both in the tree by tree control in the exclosures and in the natural wildfire area.

Controlled burn is the most satisfactory method of juniper removal. Tordon residual effects limit revegetation, dozing promotes erosion, and sawing allows juniper trees to reestablish.

Seeding Methods and Seedbed Treatments

Results of planting technique trials showed that furrow planted seed usually, but not always, resulted in better stands of seedlings than broadcast seed. Broadcast plantings were most successful with small seeded species such as sagebrushes, penstemon, milkvetch, and winterfat. Fall season application of seed was much more acceptable than that during spring. Seed application on chemically treated areas was successful with some grasses when planted three years after spraying. Forbs and shrubs were still suppressed although some species exhibited ability to establish.

Seedling establishment on the burn and doze treatment areas was about equally successful. Limitation to establishment of planted species was very specifically related to competition for moisture. Stable native stands of juniper and of sagebrush-grass communities are often intermixed. Successful seedling establishment of any species is dependent upon removal of competing plants, which are generally assumed to be perennial long lived species such as juniper, sagebrush, and grasses such as bluebunch wheatgrass and threadleaf sedge. Competition with annual species, including cheatgrass brome and halogeton, may also be so severe that establishment is impossible.

Species Responses and Trends

Successful plant establishment was obtained with big sagebrush, silver sagebrush, black sagebrush, winterfat, four-wing saltbush, bitterbrush, mexican cliffrose, cicer milkvetch and palmer penstemon. Best results occurred in general from fall application into the burn areas, within which the juniper had virtually excluded other vegetation, including cheatgrass, prior to removal of the tree overstory. The over-riding competitive ability for utilization of moisture by mature stands of trees and shrubs offers an explosive capability for establishment of introduced plants including new stands of preferred shrubs for game range improvement.

Broom snakeweed responded strongly on the burn, doze and saw areas as compared to the spray and native sites. Soil disturbance obviously provides an environment suitable for immediate expansion of population of this non-palatable, short-lived, half-shrub.

Results of data analyses of information from permanent quadrats is useful for identification of successional trends being exhibited by native and introduced species. Untreated juniper in 20' x 50' plots showed no significant change in density, height, diameter, or age class of the trees. Because of the ecological dominance of this tree, and its long term stability under natural conditions, associated species, including shrubs, exhibit little variation, even in areas protected from game and livestock use.

Big and black sagebrush are commonly associated with juniper. On sites with black sagebrush a highly signficant increase in density was observed following juniper removal, even on those subjected to tordon spray. On sites specifically adapted to growth of big sagebrush but not black sagebrush, all shrubs were removed by the chemical treatment.

Secondary succession by the tenth year from treatment showed juniper invasion well established on the doze and saw areas. Some juniper plants were noted in the burned and chemically treated areas, but fewer than on the doze and saw sites.

Perennial grasses demonstrated a marked increase on the burn and spray areas, but not so much so on the doze sites. The latter condition a reflection of soil surface disturbance associated with greater early successional competitive ability of forbs, shrubs, and annuals.

Big sagebrush was notably abundant on doze sites by the tenth year. Where both it and black sagebrush were indigenous both increased significantly on doze and burn treatments.

Skunkbush sumac, plains cottonwood and serviceberry appeared inside the exclosure by the tenth year following treatment. These species were present along nearby streams but not on the upland juniper areas near the exclosures. Protection from game and livestock use thus indicates a history of relatively intensive utilization of these shrubs, as well as the very palatable curlleaf mountain mahogany,a very important vegetation component on the Big Horn Mountains.

CONCLUSIONS

The following conclusions became evident from long-term results of this research program:

1. Most acceptable juniper control is selective burning in most cases. Chemical (Tordon) control can be effective and on sites with strong black sagebrush understory may be acceptable.

2. Juniper is of secondary preference to deer, thus increased game food production can be realized by control of this tree.

3. Fall season broadcasting of small seeded species including sagebrushes and others can be utilized if juniper or other dominant stable shrub competition is removed.

4. Juniper and sagebrush-grass vegetation types are essentially closed communities, into which addition of new and/or different species can be accomplished only by removal of the tree and shrub dominants.

5. Big, black, and silver sagebrush are easily established with viable seed application to properly prepared sites; that is those from which the controlling biological component such as juniper has been removed.

6. Long term establishment of shrub species requires protection from game as well as livestock use for several years. Either fencing or management of the animals is necessary to give the young plants adequate time to attain a stature able to withstand foraging.

A number of M.S. theses and Ph.D. dissertations have been completed which address the ecology of juniper, sagebrush, and limber pine as well as game range improvement topics in western Wyoming. Citations for these are provided on the following page in chronological order. They may be obtained through the University of Wyoming Library.

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TECHNIQUES FOR PLANTING SHRUBS
ON WILDLAND DISTURBANCES

by

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ABSTRACT

The most important technique in revegetating disturbed sites is that of selecting adapted plants. Three criteria for selecting adapted plants are: (1) observe which species naturally invade or occur on similar sites, (2) past experience, and (3) research results. Two means of establishing desirable species that have worked well are direct seeding and transplanting.

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INTRODUCTION

The most important technique in revegetating disturbed sites is that of selecting adapted plants. Following proper selection, seed and/or plants need to be placed on the site with techniques and practices that give them every possible advantage to become established, followed by management practices that will insure perpetuation.

Selected plants must be able to establish and maintain themselves on the disturbed site. Over the years, our best results have been obtained when the species planted were adapted to the site, rather than when attempts were made to force a plant to adapt to a site or force a site to meet the requirements of a particular species by temporary manipulation of the site.

Besides selecting appropriate species, one must make sure that adapted subspecies, strains, and sources are used. Plant materials that usually perform best in rehabilitation are those obtained from areas with climatic and edaphic conditions similar to the disturbed site. Good success has, however, been obtained in planting a number of species outside their present native range. Generally most shrubs have a wider range of adaptation than their natural distribution. Greater revegetation success can be expected from species with wide environmental tolerance than those with narrow tolerance.

Rehabilitation success generally increases as the number of adapted plant taxa seeded and/or planted increases. Rapidly developing shrubs like mountain big sagebrush (*Artemisia tridentata vaseyana*), basin big sagebrush (*A. tridentata tridentata*), black sagebrush (*A. nova*), rubber rabbitbrush (*Chrysothamnus nauseosus*), prostrate kochia (*Kochia prostrata*), fourwing saltbush (*Atriplex canescens*), and many other *Atriplex* species should be selected in addition to some slower developing species such as bitterbrush (*Purshia tridentata*), cliffrose (*Cowania mexicana stansburiana*), serviceberry (*Amelanchier alnifolia*), and the mahoganies (*Cercocarpus* spp.). The rapid developing species will provide soil stabilization, cover, and herbage quickly. The slower developing species will gradually gain their place in the communities.

Other important shrub attributes that should be evaluated are water requirements, soil pH tolerance, seed and plant material availability, ability to establish, exhibit acceptable growth, and persistance. Additional attributes to be considered are tolerance to grazing, potential for soil building qualities, and value as soil cover. In areas with less than 45 cm of annual precipitation, precipitation becomes the most important site factor to consider (Stevens et al. 1974), followed closely by the soil pH. Percent slope, aspect, and the physical and chemical properties of the soil should also receive consideration and will influence species selection.

Three good criteria for selecting adapted plants are: (1) to observe which species naturally invade or occur on similar sites, (2) past experience, and (3) research results.

Shrub species that naturally invade disturbed sites should be prime candidates for artificial revegetation. Many of the Atriplex species can be found naturally occurring on disturbed sites along with black greasewood (Sarcobatus vermiculatus), the sagebrushes, rubber rabbitbrush and low rabbitbrush (C. viscidiflorus), prostrate kochia, broom snakeweed (Xanthocephalum sarothrae), virginsbower (Clematis spp.), buckwheats (Eriogonum spp.), winterfat (Ceratoides lanata), hopsage (Grayia spp.), goldenweed (Haplopappus spp.), pricklypear (Opuntia spp.), desert peachbush (Prunus fasciculata), Rocky Mountain sumac (Rhus glabra cismontana), woods rose (Rosa woodsii), tamarisk (Tamarix spp.), horsebrush (Tetradymia spp.), and matrimony vine (Lycium spp.). In more moist areas, a number of cottonwoods (Populus spp.), black chokecherry (Prunus virginiana melanocarpa), currant (Ribes spp.), willow (Salix spp.), and blueberry elder (Sambucus cerulea) can be found invading.

Knowledge gained from firsthand experience or the experience of others, relative to species performance under specific soil qualities and climatic conditions, is most helpful in making selection decisions. No revegetation project is complete without proper evaluation of species techniques and procedures employed. Tiedemann et al. (1976) and Stevens et al. (1981b) describe some good techniques for evaluating the effectiveness of transplanting and interseeding. Success of direct seeding efforts can be measured using variations of the line intercept method.

Information on capabilities, adaptability, and requirements of many shrubs is available (Plummer et al. 1966, 1968; McArthur et al. 1974, 1978b, 1979; Monsen 1974; Blauer et al. 1975, 1976; Croft and Van Epps 1975; Monsen and Christensen 1975; Plummer 1977; Stevens et al. 1977; Giunta et al. 1978). Considerable research on plant materials and ways and means of revegetating disturbed sites is taking place.

TECHNIQUES FOR ESTABLISHING SHRUBS

After proper species selection, there are two means of establishing desirable species in disturbed areas: direct seeding and transplanting.

Direct Seeding

Important factors that need to be considered when undertaking direct seeding are: (1) reducing competition, (2) obtaining and using sufficient seed with acceptable purity and viability (Plummer and Jorgensen 1978), (3) seeding during the season that provides the optimum conditions for establishment, and (4) proper seed covering.

When competitive vegetation has become established, its removal is necessary before seeding occurs. Elimination of competing plants can be done with a scalper preceding the seeder (Giunta et al. 1975; Stevens 1978, 1979; Monsen 1980), with herbicides, and with summer fallowing. Shrubs that are slow developing or have weak seedlings are likely to die if weedy species are not removed before seeding. Seedlings of most shrubs, whether aggressive or not, are not capable of establishing in stands of dominant annuals such as cheatgrass brome (Bromus tectorum), halogeton (Halogeton glomeratus), bur buttercup (Ranunculus testiculatus), and Russian thistle (Salsola pestifer). Prostrate kochia and low rabbitbrush (McArthur et al. 1978a) are perhaps two of the more aggressive establishing perennial shrubs available. Fourwing saltbush, Wyoming big sagebrush (A. tridentata wyomingensis), basin big, mountain big, and black sagebrushes, rubber rabbitbrush, antelope bitterbrush, cliffrose, and most of the Prunus species all have aggressive seedlings.

When seed is broadcast, 11 to 20 kg (grass, forbs, and shrubs) of seed mix per hectare is sufficient. With drilling, less seed is required, generally 9 to 16 kg per hectare. Grass seed should not make up more than one-half the total seed mixture. Use of too much seed is expensive and may result in seeded species competing with each other, especially in the critical seedling stage. Skimpy seeding will provide opportunity for annuals to become established, and will result in poor stands. Seeding rate will depend on species, terrain, quality of seed, and seed size. Plummer et al. (1968) gave the number of seeds per pound of most western shrubs. Additional information is also available in USDA Agricultural Handbook 450 (1974). Stevens et al. (1981a) list the expected germination for many native species over extended periods of storage.

Direct seeding should occur in the late fall and winter. Winterfat and fourwing saltbush can be seeded in the very early spring. Fall and winter seedings help to overcome the inherent dormancy of many species, and to insure that seeds are in the ground when adequate moisture is available for germination and strong seedling establishment. Fall and early winter seeding helps reduce loss to seed-eating mammals, insects, and birds. Winter seedings are preferred over early fall seedings because they avoid the danger of precocious germination resulting from moist periods followed by unseasonable warm temperatures.

Seed must be covered to insure establishment. Generally seeds should not be covered more than three times their own thickness. Most natural reproduction occurs with very shallow seed covering. Reproduction of sagebrush, rabbitbrush, fourwing saltbush, and many other shrubs occurs in disturbed areas next to soil clods and in small soil cracks where natural soil sloughing or wind action cover the seed lightly. If a drill is used to seed, depth rings should always be used. Following broadcast seeding, use of a chain or pipe harrow is unlikely to cover seed too deeply. Seed metered out with a Hansen seed dribbler and pushed into the soil by the track of a crawler tractor generally results in proper seed covering. Hydroseeding does not place the seed where it can be covered with soil and take advantage of available soil moisture. Hydroseeding is not recommended in arid land seedings.

Compaction is generally not needed in seedbed preparation with fall and winter seeding. Some compaction helps to improve stands when seeded in the spring.

Direct seeding can be performed mechanically with various types of drills, hydroseeders, thimble seeder (Stevens 1978, 1979), seed dribblers (Plummer et al. 1968), and with seeder-scalpers (Monsen 1980; Stevens et al. 1981b). Seed can also be broadcast by hand, aerially or with cyclone seeders.

Use of a mulch is often desirable. Proper mulching can help to conserve moisture, reduce wind and water erosion, and provide a blanket of protection for seedlings that have little resistance to spring frosts. Mulching can be detrimental to seedling establishment when it is too thick, particularly when it becomes compacted. Care should be taken to insure that the mulch does not bring quantities of annual weed seeds to the site that will germinate and compete with the seeded species.

Transplanting

Shrubs can be readily established and provide quick soil stabilization, forage, and cover by using bareroot or container-grown transplants (McArthur et al. 1974; Monsen 1974; Tiedemann et al. 1976; Stevens et al. 1981b).

Generally transplanting should be done in the spring when soil moisture is high, temperatures are low, chances of storms are high, and frost heaving has stopped. General rules that need to be followed when transplanting either bareroot or container-grown stock are: (1) never allow roots to dry, (2) keep plant cool, do not allow plants to overheat prior to planting, (3) compact soil well around the roots at planting time, and (4) plant with adequate soil moisture.

Roots of bareroot stock can dry out with only a few minutes exposure, particularly on windy days. Roots should be kept damp at all times. Roots of container stock, once out of the container, will also dry out, but will tolerate longer periods of exposure. Bareroot stock is generally transported and stored in plastic bags, whereas, container stock is generally in cardboard boxes. Plastic bags and cardboard boxes both reach temperatures destructive to plants when they are placed in direct sunlight for a short time. Care should be taken to keep transplants cool at all times. Once a transplant is put in the ground, soil should be firmly compacted around the roots. Care should be taken to insure that roots are placed vertical, with no "J" roots occurring at planting time. Transplanting needs to occur when soil moisture is high and ideally when storms may follow planting.

Bareroot stock has several advantages over container-grown stock. Bareroot stock, when properly planted, generally has a higher rate of survival, establishes quicker, and is more evident because of increased size than is container stock (Monsen 1980; Stevens 1980). Bareroot stock is generally older (1 to 3 years old) with strong woody stems and root systems. Container stock growth has generally been forced, resulting in young, weak, spindly plants. Bareroot transplants are truly hardened, having been grown in outside beds or as wildings. Lack of bulky packaging and soil makes bareroot stock much easier to handle on and off the planting site. Purchase price of container stock is generally 2 to 10 times greater than bareroot stock. Time required in handling and planting is somewhat less with bareroot stock.

Container-grown stock has two advantages over bareroot stock. Roots are established in a growth medium and plants are available when needed. Bareroot stock cannot be lifted until the frost is out of the soil. The author's experience shows that a number of species cannot be lifted, packed, or stored as bareroot stock over the winter as is standard for conifers.

Very successful transplanting can be accomplished using a heavily reinforced tree transplanter that requires hand placing of the transplants (Stevens et al. 1981b). Most shrubs cannot be planted successfully using the automatic pickup and planting systems found on many tree transplanters. This is because most transplantable shrubs have multiple-branching, fibrous, and/or fairly long root systems that continually tangle in the finger and chains of the automatic planting device. Depending on soil type and condition and species planted, transplanting rate of bareroot stock can vary between 10 and 18 plants per minute.

Transplant survival can increase when a scalper is attached to the transplanter (Stevens et al. 1981b). The scalper should make a scalp wide enough to remove existing vegetation and act as a water harvester. Shrubs can be successfully transplanted into annual and perennial communities using a transplanter-scalper combination.

The sagebrush and rabbitbrush species, prostrate kochia, winterfat skunkbush sumac (*Rhus trilobata*), Rocky Mountain sumac, golden currant (*Ribes aureu* Siberian peashrub (*Caragana arborescens*), Cotoneaster (*Cotoneaster acutifolia*), honeysuckle (*Lonicera tatarica*), Russian olive (*Elaeagnus angustifolia*), matrimony vine, poplars, roses (*Rosa* spp.), willows, snowberries (*Symphoricarpos* spp.) tamarisk, and horsebrush generally all transplant well. Special care should be taken to obtain good planting stock to insure success when transplanting bitterbrush, the serviceberries, cliffrose, the mahoganies, *Atriplex* species, black greasewood, Ephedras (*Ephedra* spp.), Gambel oak (*Quercus gambelii*), hopsages, blueberry elder, and common lilac (*Syringa vulgaris*).

Transplanting is more expensive than direct seeding, but success is much greater and more evident. The more severe (edaphically and/or climatically) a site, the greater the need there is for transplanting.

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PLANTING TECHNIQUES FOR ESTABLISHMENT OF CONTAINER-GROWN OR BAREROOT PLANTS

by

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ABSTRACT

Recommendations are made to promote successful planting of container-grown and bareroot plants. Adaptability of a plant species to site specific climatic, geographic and man-induced conditions, is essential in selecting species that have a high potential for establishment. Planning should take place well in advance to allow adequate time needed for each of the many aspects of the planting project ranging from seed collection and plant production to actual planting and monitoring activities. Holding facilities are sometimes needed to protect plant materials when conditions merit. Successful planting techniques are discussed. Training of planting crew members is strongly recommended. Results of planting should be monitored and evaluated in order to improve techniques and to realize greater success in the future.

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INTRODUCTION

Successful establishment of container-grown and bareroot plants is influenced by many factors including meeting plant growth requirements and tolerance to environmental factors that affect growth. It is also influenced by procedures used in selecting, scheduling, growing, shipping, holding, planting, and protecting plant species. The use of properly selected species coupled with correct cultural procedures will result in rapid establishment of plant cover, productivity, and species diversity.

This paper focuses on the use of container-grown and bareroot plants to achieve these results. However, because of variations in local conditions, each revegetation specialist must determine which procedures are applicable to his or her situation.

SPECIES SELECTION AND PLANT MATERIALS

The selection of plant materials to be used in reclamation is determined by several factors, the most important of which is species adaptability. Adaptability (suitability) is intimately tied to the ability of a plant to complete its entire life cycle, and to reproduce itself from year to year over a long period. Plants must be adapted to soil conditions, local temperature, elevation, slope, aspect, and wind conditions. Palatability to livestock and wildlife, availability of seed, and competition among species of plants are also important considerations.

Generally, mixtures of species are desirable because they offer a greater range of adaptation, (i.e., flexibility to environmental extremes). Species to be used should be selected to match site conditions. Indigneous species usually offer an already adapted genetic background to survive the long-term climatic and other environmental rigors of the site. In some cases disturbance alters the soil or microclimatic conditions of the site such that introduced genetic material may be actually more adapted to the newly created conditions. Baseline data showing species performance at different stages of succession and on slightly different site conditions (e.g., slope, aspect, soil types, drainage characteristics, and land uses) offer valuable clues to assist in selecting species best adapted to the new site conditions.

SCHEDULING CONSIDERATIONS

Successful reclamation requires careful and timely planning. Areas requiring large quantities of container grown plant material and/or site specific seed collecting usually require long-term planning of up to one year. For example, plant material grown from site specific seed sources must be collected prior to the greenhouse cultivation/production processes, with seeds of some species requiring treatment to break dormancy and encourage germination. Time required for such treatment varies with the species of plant and may range up to 9 months and more. Suppliers should be contacted well in advance to determine if site-specific seed collections or seed treatments may pose special requirements in scheduling the availability and planting of selected species.

Since growth is not as controllable under outdoor conditions, bareroot plants require more growing time. One to two year advance orders for site-specific bareroot plants are often required to assure supply.

Under greenhouse conditions growth requires about three to four months to develop a favorable shoot-to-root ratio. Such ratios are important in reducing transpiration losses and moisture stress. Favorable ratios are encouraged using solar efficient greenhouses with the proper balance of temperature, carbon dioxide, nutrients, and light, including night lighting for some species. Growth responses are carefully controlled during the three to four months of rapid plant growth to achieve the proper shoot-to-root ratios. Ordering plants according to a well planned schedule will ensure that the plants have a favorable ratio at the time of planting.

After the rapid plant growth phase is completed, the hardening process is initiated. Hardening is the process whereby shoot growth is reduced resulting in accumulation of carbohydrates which makes the plant better able to withstand adverse conditions. It requires about two to three months or longer depending on the season of year. This process is initiated by reducing the supply of moisture, altering the nutrient balance, reducing temperature, and increasing the exposure to direct sunlight and ambient conditions that are likely to be experienced at the planting site.

If site conditions are dramatically different from climatic conditions at the nursery it may be advantageous to attempt to site harden the plants for a few weeks or months. However, it should be emphasized that moisture stress that occurs abruptly, at the planting site, before planting will do little to harden the plants. Hardening is a developmental process. Therefore, withholding water to containerized stock in an effort to rapidly adapt them to a dry environment just prior to planting may unnecessarily stress the plants and weaken them by reducing carbohydrate reserves that are essential for rapid root growth and survival.

The best establishment results for outplanting are usually obtained when the shoot is dormant when planted. It is possible for the roots to grow at their maximum rate even though the shoot is dormant. This allows for effective moisture supply, nutrition, and anchorage in the new field environment. However, when the shoot is actively flushing, it generally has first call on the food reserves of the tree or shrub and that means root growth is minimal. Therefore, outplantings on arid sites tend to be most successful when planted dormant in the late fall or early spring (after thaw), except in areas where most of the precipitation occurs in the summer. Planting should be done only when soil moisture is sufficient to maintain plant growth levels with at least some root growth. In areas where winter and spring soil moisture is not sufficient, planting should be postponed until late fall or early the next spring.

Consideration should be given to "watering-in" plants by providing 1/2 to 1 gallon of water per plant if soil moisture levels are critically low, expecially in sandy textured soils. Increases in planting labor costs required to "water-in" plants can usually be justified economically if water-in results in at least 10% to 20% increase in survival.

When possible, flexibility in the actual shipping date should be allowed when placing an order. This will allow the supplier to make the most favorable arrangements possible for finding a carrier going near your site. Carriers that have temperature controlled trailers to deliver the plants in good condition are often used as opposed to other means of transportation that may not offer such protection when bound to a more rigid delivery date.

Advantages of such protected delivery, risks associated with the time of year, and arrangements for planting (e.g., availability of labor and supervisory personnel) must be carefully weighted when stipulating when an order would be delivered.

HOLDING FACILITIES

Appropriate holding facilities such as a lath house or shelter should be constructed prior to receiving plants if the plants are not to be outplanted within a couple of days. A simple, inexpensive holding frame can be constructed using chain link fence posts with overhead railing. Shade cloth, if needed, can then be attached to the tops and/or sides using wire stays or specially designed clips. A floor for the holding facility can be constructed of gravel, wooden planks, or a closely-woven polypropylene or nylon ground cloth to reduce weeds and pests, allow for drainage, and provide for a clean walking surface.

Upon receiving a shipment, plants should be appropriately cared for. Shipping boxes should be opened and plants inspected for moisture status. Plants should be watered as soon as possible after they arrive if they have dried out during shipping. Different species of plants lose water at different rates so it is important to check, periodically, all species. Plants near the edge of the holding facilities are often exposed to more drying conditions.

Inspections to determine a need for watering can be done by feel, visual observations, or with the assistance of simple and relatively inexpensive instruments such as moisture meters or weighing scales. The rooting media should feel moist to the touch. When watered, plants should be given sufficient water to ensure that all of the root column receives moisture, not just the surface layer.

Carbohydrates in the form of sugars and starches are also important to plant establishment and growth in that they provide reserve energy. When such reserves are depleted by allowing respiration to exceed photosynthesis, the plant's vigor and potential for survival are also reduced. Depletions may occur when plants are left in darkened boxes for several days or weeks. Photosynthesis is curtailed or stopped in such cases by lack of adequate light. Depletions may also occur even with adequate lighting if moisture stress, high temperatures, strong winds or a combination of these factors blocks passage of carbon dioxide necessary for chemical reactions to occur in photosynthesis.

Temperatures of the holding facilities may be critical. Excessively high temperatures may stimulate dormant plants to break dormancy before being outplanted, rendering them more susceptible to frost damage.

To prevent excessively high temperatures plants should never be covered with plastic or canvas covers without adequate ventilation. "Shade cloth" (available from nursery supply houses) that allows different amounts of light to pass through it, or other wind resistant cloth, can be attached to a simple frame to reduce excess heat buildup or to prevent adverse moisture stress.

Plants are often severely damaged by excessive exposure to wind. Sideboards or other temporary windbreak materials can be quickly put in place should conditions require. Water stress is generally the most critical factor to monitor during windy periods.

Bareroot seedlings should be stored at between 1^{o} and $4^{o}C$ (34^{o} and $39^{o}F$) until outplanted. Field storage for these plants is best with some type of well insulated storage shed or moist cellar. Storage structures can be cooled by ice or snow. Under ideal storage conditions, some dormant bareroot seedlings can be stored for 90 days or more. However, most native shrubs can not be stored longer than about one week.

Container-grown plants can be used over longer periods of time. providing proper care is given during storage and if adequate soil moisture and climatic conditions exist at the time of out-planting.

PLANTING

Planting of bareroot and container-grown materials is perhaps one of the most important aspects of a successful revegetation effort. Success or failure of a revegetation effort is often determined by how and when planting is done. Proper planting requires prior preparation and training of planting crews.

Workers can readily form bad planting habits which are difficult to correct. In many cases, poor planting techniques may be based on good intentions by the operators and thought to be proper planting techniques; for example, firming of the soil around a plant while actually crushing the root system in rocky soils.

To avoid such problems, a short training course is useful where knowledge of good work quality in planting and objectives of planting techniques are adequately explained to each operator. Planting crew members should not only be instructed, but should also be supervised during planting.

The site should be ready for the planting. The most important considerations include proper tillage, treatment of problem soils, and control of competing species. Proper tillage should result in a soil that is loose, well aerated, and which will intercept and retain precipitation well. Problem soils, such as those with high sodium or soluble salt contents or excessively high or low soil pH (greater than 8.5 or less than 5.5) should be appropriately treated to reduce adverse effect to plants.

Competition from weeds or species seeded on the disturbed site should be controlled to provide good planting spots. Recommended techniques include reducing seedling rates, seeding in strips or mosaic patterns, using spot applications of herbicide, or scalping to remove duff, litter, competing vegetation or charred soil.

Container-grown plants or bareroot plants can be planted either by hand or by specially designed planting machines. The choice of technique will depend on the size of the area to be planted, nature of the terrain, soil moisture content, and availability of operators and equipment.

Although hand planting is labor intensive, it allows a certain degree of latitude in selecting microsites with favorable soil conditions to increase survival. Favorable planting areas and microsites are generally found where soil is relatively deep, stable, well-drained, and free of large obstructions. Hand planting is also advantageous where random planting patterns are desired.

The main disadvantages of hand planting are labor requirements and planting rates. Harsh site conditions such as rocky or hard soils reduce the planting rate. Even with high labor costs, hand planting rates appear comparable with the cost of operating many planting machines. Emphasis should always be placed on planting quality, not planting rate.

Planting by hand is accomplished by digging a hole large enough and deep enough to contain the root or root plug of the plant. The type of tool used to dig holes depends upon your soil type. Back-pack type gasoline powered augers are commonly used on large projects. One auger operator can often dig enough holes for a 3 or 4 person planting crew. However, this may not be the case in very rocky, dry or hard soil. Augers cannot be used easily where large roots are in the soil, in rocky soil (more than 30% rock), in heavy clay, or where heavy debris and slash are on the surface.

Once the hole is made a slow-release fertilizer tablet can be placed in the bottom of the hole. The root system is then inserted into the hole. Plugs should be planted immediately to prevent desiccation. Once the root tips have dried out, normal patterns of root development are altered. Therefore, proper handling of stock becomes very important.

Soil is then firmed around the plant such that the top of the root plug is 1/2 to 1 inch below the ground surface. This is important to prevent drying of the root plug by water wicking up through the rooting medium to the surface. Plants should be positioned as nearly vertical as possible.

If bareroot stock is used, caution must be exercised during planting to ensure that bending or kinking does not occur. This is especially important with tree species where instability caused initially by such bending and kinking may significantly weaken the root system over a period of 5 to 15 years, making the plants susceptible to root disease, improper nutrition, and wind damage.

Soil around the plant should be firmed to remove air pockets and to allow adequate capillary transport of water from the soil medium to the root medium, but not so dense as to prevent root penetration. In rocky soils, care should be taken not to crush the delicate root plug between rocks.

Machine planting of tubelings is becoming increasingly popular due to reduced labor requirements. Mechanized planters, however, are not yet designed for steep slope planting and make selection of microsites and random patterns difficult.

In all situations, studies have shown that careful handling and planting results in increased survival and growth regardless of the planting tool used. Thus, planting quality should be stressed for all tools in all situations. Planting rate should never be the only factor, or even the most important factor in selecting a planting tool. Rates and costs must be evaluated on a per-established-seedling basis.

SPECIAL CONSIDERATIONS

Spacing, weather, soil conditions and animal control are four categories which can affect planting and deserve special consideration. Spacing of transplants is determined by a variety of factors including species to be used; availability of soil moisture; anticipated losses; legal requirements for stocking and diversity; and objectives to be achieved in reducing visual impacts, competition, and erosion.

On very difficult sites where reduction in soil erosion is critical and losses are expected to be high due to adverse conditions (e.g., rocky, droughty, windy, or with steep slopes), 1 to 2 foot spacing intervals have been successfully used. On other sites where species diversity is of prime importance, spacing intervals of 5 to 6 or even 10 feet have been used.

Weather conditions at the time of planting can have a significant influence on plant survival particularly when planting conifers or deciduous species that have broken dormancy and leafed out. The rate of water loss from an exposed seedling is a function of the moisture gradient (graded measure of difference) between the seedling and the surrounding air.

When vapor pressure gradients are high, planting should be postponed. Stress produced under such conditions is greatest due to exposure of the tubeling to drying conditions during transportation and while handling before the seedling is planted.

Ideally air temperatures should be between 0° and $18^{\circ}C$ (32° and $64^{\circ}F$) and wind speed should be less than 20 miles per hour (disregarding occasional higher gusts) for best results. Winds may rapidly desiccate planted seedlings when soil is frozen more than one-half inch deep. Planting in powdery snow is not advisable since the snow and soil become mixed, leaving air pockets in the soil when the snow melts. Also, it is more difficult to choose the best microsite for planting when snow covers the ground.

In areas of low soil moisture, supplemental water should be added. This can be done in a variety of ways. Supplemental water can be added once the seedling has been planted. Water can be applied to each plant manually or by irrigation systems. This practice may be critically important in arid areas with low soil moisture or with soils that have low moisture holding capacity (e.g., sandy soils), especially during the first season of establishment when long gaps between rainfall events occur. If there is adequate moisture in the top 10 to 12 inches of soil, the practice of supplying supplemental water would be of little value.

In areas where supplemental water is unavailable, water harvesting of naturally occurring water is also possible. One of the most commonly used methods is the use of condensation traps consisting of square or circular sheets of plastic 2 to 3 feet in diameter. The soil around the planted tubeling is prepared by creating a basin that gradually slopes to the plant. A hole or slit is made in the center of the plastic and it is carefully fitted over the plant. The plastic is then anchored in the center near the plant and around the edges with rocks or loose soil.

Fertilizers are not recommended generally for most species of native woody plants. However, if they are used to ensure that nutrients are not a limiting factor in plant growth, then it is recommended that slow-release fertilizers be used. Such fertilizers are gradually released by the action of soil bacteria that continually feed the plant up to two years, while minimizing moisture stress produced by the soluble salts contained in the fertilizer. An equivalent amount of ammonium nitrate fertilizer would result in approximately 20 times the moisture stress produced by slow release planting tablets. Also, since they are slow to release, late applications will not force lush, frost-tender growth to form.

The use of topsoil on disturbed sites provides many important functions that will help container stock, bareroot stock, and seeds become established. Topsoil usually has a higher water and nutrient holding capacity than most subsoils. It contains more organic matter and supports a greater variety of soil organisms such as insects, bacteria, and fungi that play an important role in nutrient cycling and soil developments.

It is a well documented fact that most native shrubs in their natural habitats live in association with mycorrhizal fungi. These fungi increase the plant's disease and drought tolerance and enable them to better extract soil nutrients, particularly phosphorus which is important for proper root and shoot growth. The lack of these fungi on severely disturbed sites where infertile soils predominate appears to be one of the limiting factors in plant establishment and growth. In areas where the infection potential of the soil is low or lacking completely, inoculated container-grown plants can provide valuable sources of fungi that will serve to inoculate other individuals sprouting from seeds since many endomycorrhizal fungi are relatively non-host specific.

Animals may be attracted to newly planted or seeded areas due to the lushness and palatability of the vegetation. If animals are attracted in large numbers, serious damage to vegetation may result. Livestock, deer, elk, antelope, rabbits, and rodents are among the animals most likely to create problems.

Protection of such sites from livestock may include measures such as using less palatable species, especially if land use is for erosion control, placing salt licks and permanent water away from the area, or fencing out nearby water. Control can also be exercised by adjusting livestock numbers, time of use, or area to be used to encourage utilization of other species. Barriers such as fences, brush piles, or other devices, as well as herding, are also effective under certain circumstances to keep livestock away from revegetated areas.

State departments of wildlife resources may also provide useful insights into reducing damage by wildlife to revegetation projects.

MONITORING

Once plants have been outplanted they should be periodically observed to detect plant response to changing site conditions. If plants are to receive supplemental water, observations should be made frequently enough to detect developing moisture stress. Plants will show greatest stress (e.g., wilting or low water potential) during the late afternoon as compared to the morning hours when the plants are relatively unstressed.

In areas conducive to frost heaving, detection of heaving plants in very early spring may allow for correction by mulch application before desication can occur. Newly developing rills and gullies can also be corrected at that time before severe erosion occurs which may damage newly planted stock.

Survival and mortality counts should be made by species, and notes made periodically on vigor of transplants. Such information will be valuable in guiding future revegetation efforts. Slope, aspect, soil differences, method of planting, caliper of stock, and other variables should be noted while planting for future correlations with plant survival, vigor, or mortality.

It is just as important to know why a species dies as it is to know why one survives. Plants that have died should be dug up to determine if roots have grown into the surrounding soil and to determine the cause of death. Such causes may include moisture stress, insect damage, leaf burn, frost heaving, freeze damage, wind damage, trampling, herbivore damage, and damage due to undesirable soil characteristics such as compaction, salinity, high or low pH, or flooding.

Detection of causes of stress is best determined when the plant is still living. After the plant has died, delays in monitoring make it difficult to determine the cause of death as the symptoms or causes may have since disappeared.

Large-scale plantings should be preceded with test plots when possible to determine the most appropriate species and planting techniques to be used. This will help avoid later disappointment.

PROPAGATING AND OUTPLANTING SHRUBS ON MINE SITES

by

Nancy Shaw[1]

ABSTRACT

Bare-root stock of native shrub species may be used in areas which are difficult to revegetate with direct seeding. Representative species of major plant communities have been successfully propagated and outplanted as bare-root stock. Commercial availability of mature shrub bare-root stock has improved with increased demands. Federal and state nurseries are developing the cultural practices required to rear a wide range of native shrub species as first-year (1-0) bare-root stock. Collection or procurement of high quality seed from appropriate sources is essential to the successful production of bare-root stock. Research is needed to improve seed technology, develop nursery rearing practices, and determine characteristics of successful bare-root stock.

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INTRODUCTION

Direct seeding is a practical and inexpensive means of establishing shrubs on wildland disturbances. A wide range of sites may be treated using the appropriate combination of species, site preparation practices and seeding methods. When site characteristics or the species to be planted do not lend themselves to direct seeding, the use of bare-root transplant stock becomes a viable alternative. Bare-root transplant stock may be used to advantage in a number of situations in order to supplement direct seeding of grasses, forbs, and other shrubs or for use on sites that are inaccessible to standard seeding equipment. Such areas include steep slopes, rocky sites, and unstable surfaces. These sites provide poor seedbed conditions if broadcast or aerially seeded.

In certain areas it may be necessary or desirable to establish a vegetation cover more rapidly than would occur following direct seeding. Plantings of bare-root conifer stock have markedly reduced erosion on unstable surfaces in the Idaho Batholith (Megahan 1974). Ceanothus velutinus Dougl. and Purshia tridentata DC are two shrub species that have been planted as bare-root stock to provide cover on roadway disturbances in the batholith (Monsen 1974). Bare-root stock has also been used to increase forage production and re-establish wildlife habitat on disturbed sites. Cluster plantings of Atriplex canescens (Pursh) Nutt. on southern Idaho rangelands provided dense cover and nesting habitat for songbirds and upland game birds within 3 years following planting. Aesthetic values in high visibility disturbed areas are immediately improved with plantings of bare-root stock.

The establishment and development of slow-growing species may be enhanced using bare-root stock. Shepherdia rotundifolia Parry, Prunus fasciculata (Torr.) A. Gray, and seedlings of other species grow very slowly. Certain accessions of Symphoricarpos oreophilus Gray and Ceanothus sanguineus Pursh. also exhibit this characteristic. These species may be unable to compete successfully if seeded with previously seeded grasses and broadleaf herbs. Those species that do become established are easily overlooked and do not become a noticeable part of the community within the first 2 or 3 years following planting. Consequently, the overlooked species are frequently omitted from seed mixtures. Slow developing species may be transplanted in established stands of grass or other vegetation by interplanting 1-0 or 2-0 nursery stock into cleared furrows or scalps (Stevens 1979).

Rodent or insect predation of seeds, soil crusting, and the difficulty in preparing an adequate seedbed on rocky or unstable soils all interfere with seed germination, emergence, and seedling development. These problems may be overcome or circumvented with the use of bare-root stock.

Seeds of some native shrubs and forbs are expensive, difficult to obtain, and available only in small quantities. The production of bare-root stock provides for effective utilization of these seeds. Many factors which contribute to seed or seedling mortality are controlled or absent in the nursery.

The use of bare-root stock adds flexibility to a planting program. For mine revegetation programs, the time of planting is dependent upon the completion of mining and site preparation activity. Although spring lifting and transplanting is preferable, bare-root shrubs can be fall lifted and planted. In addition, Purshia tridentata, Ceanothus cuneatus (Hook.) Nutt. and other species have been successfully planted in the spring following fall lifting and overwinter storage.

AVAILABILITY OF NURSERY STOCK

Many private horticultural nurseries presently produce at least a few native species. Past emphasis has been given to the propagation of plants used for landscaping, windbreaks, and landscape plantings. Large ball and burlap or containerized plants have normally been grown. However, 1-0 and 2-0 bare-root seedlings and container stock are becoming more available from commercial sources.

Forest Service and state nurseries are presently producing native shrubs as 1-0 and 2-0 bare-root stock. Transplants are grown for projects on state and federal lands. In some cases, however, state or federal nurseries have arranged to produce bare-root stock for private individuals or companies; however, an attempt is made to avoid agreements which may conflict with private businesses. Nurseries are now in the process of establishing the cultural requirements and technology necessary for the production of bare-root stock of native and introduced shrubs. Forest Service nurseries are prepared to absorb the initial costs associated with the developmental phases of this work.

Demands for transplant stock of native shrubs for use on federal lands have increased during the past decade. More than two million bare-root seedlings of approximately 50 species have been produced at the Lucky Peak Nursery in Idaho during this period (Table 1). Production at this site may be increased to 1.5 million seedlings per year in order to meet increased requests.

Table 1. Native plant production at the Lucky Peak Nursery near Boise, Idaho*

Year	Seedlings shipped (1,000s)
1971	80
1972	101
1973	250
1974	84
1975	98
1976	302
1977	160
1978	317
1979	323
1980	575
1981	375 (expected)
1982	560 (requested for sowing)

*Personal communication Richard A. Thatcher, Nurseryman at Lucky Peak Nursery

The use of 1-0 and 2-0 bare-root stock offers a number of advantages over the use of larger stock. Bare-root stock and the required planting equipment are relatively inexpensive. Planting machinery and implements designed for use with conifer stock can be readily adapted for planting shrubs. The small plants are easily handled, transported, and planted with the result that shipping and labor costs are substantially lower than for larger stock.

In developing a revegetation program it may occasionally be desirable to use larger bare-root, containerized, or ball and burlap stock or a combination of various types and sizes of transplant stock. Group plantings designed to quickly improve aesthetics, screen unsightly areas, or provide shade or windbreaks are examples of such situations.

At nurseries in the Intermountain Region, cultural practices developed for conifer production have been applied to the propagation of shrub seedlings as bare-root stock. These procedures have provided seedlings of acceptable quality for many species; however, problems currently exist which impair the production of other species and accessions (Table 2). In most cases, these difficulties are not as extreme as to eliminate the species from production.

Table 2.--Important propagation characteristics of selected shrubs.

Species	Ease in processing	Germination	Ease in planting	Cultural requirements	Lift	Storage	Transplant
Artemisia tridentata tridentata	2	4	2	4	4	2	5
Atriplex canescens	4	2	4	2	3	2	4
Cercocarpus ledifolius	3	4	4	5	3	4	3
Chrysothamnus nauseosus	2	3	1	3	3	3	5
Prunus virginiana	5	3	5	5	4	4	4
Purshia tridentata	5	5	5	5	4	5	5
Rhus trilobata	4	3	5	4	3	2	4
Rosa woodsi	4	3	5	5	5	4	5
Symphoricarpos oreophilus	4	3	5	5	5	4	4

Ratings: 1 = poor, 5 = excellent

SEQUENCE OF NURSERY STOCK PRODUCTION

Revegetation programs must be planned carefully with time being alloted for all phases of the work. The number of acres to be planted, topography, soil conditions, and the species and types of plant materials required should be determined well in advance of the actual planting dates. If bare-root stock is to be included in the planting, the time requirements for its propagation must be considered.

SEED COLLECTION

Arrangements must be made to insure that acceptable seed supplies will be received by the nursery in time for processing and planting. Most native shrub seed is presently being obtained from wildland stands. Seed crops of many native species are extremely erratic in terms of quality and quantity. Good seed crops of many species are produced only infrequently and are dependent upon weather conditions, insect predation, and other factors. Consequently, the cost and availability of seed varies greatly with the species and year. It may be advantageous for firms planning revegetation projects to identify local stands of shrubs and arrange for their employees to collect the seed as it matures. In most cases, only small quantities of seed are required to grow nursery stock. Only seed with sound and mature fruits should be collected. Failure to recognize damaged seeds, immature fruits, or fruits with low fill can result in unnecessary expenditures of time and labor.

Scheduling of seed collection is critical. The approximate date of seed maturation for each species may be determined from various reports (Plummer et al. 1968; Vories 1980; USDA 1974). Sagebrush, rabbitbrush, and saltbush species present problems because their seeds do not mature prior to the fall planting season. Seed of these species must be collected during the winter prior to the desired date of nursery planting. Seed of bitterbrush, shinyleaf ceanothus, and other shrubs may be collected only during the short period of time between maturation and dehiscence. In contrast, seed of most sagebrush and rabbitbrush species may be collected over a period of 1 or 2 months before the mature seed falls from the shrub. The collection of seed from spiny shrubs or shrubs with seeds that must be individually hand picked is difficult and time consuming. Adequate time must be allowed for making these collections.

The collection of seed from local stands can be contracted to commercial seed collectors or nurseries. Another alternative is that seeds of many of the principal shrubs can be purchased as seed from commercial seed collectors or companies. If this course is followed, it is essential that only those seed sources adapted to the planting site be purchased. Sources, quantities, and costs of seed are dependent upon past demand, location of superior collection sites, and the quality of recent seed crops. Source descriptions and results of seed tests should be provided with each seed lot purchased.

During years of poor seed production, it may become necessary to use or purchase seed collected during previous years. Seeds of most shrub species remain viable under storage for many years. However, seeds of _Artemisia_ and _Chrysothamnus_ and other species begin to lose viability within 2 or 3 years after harvesting (USDA 1974; Vories 1980). All seed lots should be tested for germination or viability prior to nursery planting.

If seed is collected by company employees or if uncleaned seed is purchased, adequate time must be allowed for drying, cleaning, and processing the seed. Proper cleaning and a high degree of purity are essential for seed lots used in nursery plantings. Trashy seed lots clog seeding equipment and prevent seeds from being spaced uniformly within the furrows. If cleaning equipment is not available, arrangements may be made to have the seed cleaned by a commercial seed company or at the nursery.

PLANTING

Seed lots received by the nursery are coded and cleaned if necessary. Techniques for cleaning fleshy fruits, appendaged fruits, and small seeded species continue to be improved. Seed lots can be tested for seed germination, purity, and quality either by the nursery or a qualified seed laboratory. Extended stratification periods are required to determine the germination of some species. The lack of standard germination tests for some native species complicates seed testing.

Seeding rates are dependent upon the number of seedlings to be reared per linear foot of seedbed, the number of seeds per pound of cleaned seed, germination and purity of the seed lot, expected seedling mortality, and the culling rate. Estimates of the optimal number of seedlings to be reared per linear foot of seedbed, seedling mortality, and the culling rate are based on limited data and experience wih conifer seedlings.

New developed seeders can be quickly and easily adjusted to sow seeds of diverse sizes and shapes at rather exact rates. Small seeded species including the sages, rabbitbrush, penstemon, and alder are hand seeded. The feasibility of incorporating seeds of these species into seed tapes at predetermined spacings is being investigated. Following sowing, nursery beds are usually covered with a layer of sand or litter to provide overwinter protection for the seed and prevent soil crusting. Fall planted seeds are field stratified throughout the winter months. If planting is delayed until spring, artificial stratification or other pregermination treatments may be required to overcome seed dormancy (USDA 1974).

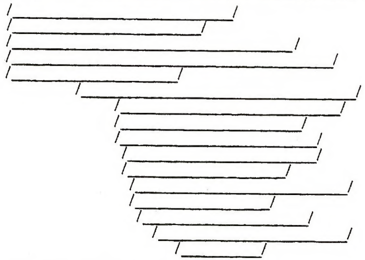
The time of germination and growth periods varies greatly among species. Germination and seedling emergence of fall planted seeds occurs from late April through early June. For most species root and shoot growth reaches maximum rates during late June or early July. Certain species including *Cupressus arizonica* (Mast.) Green and *Rosa woodsii* Lindl. continue to grow at appreciable rates through early fall (Table 3).

At the Lucky Peak Nursery shrub seedlings generally receive the same treatment as conifer seedlings. Specific cultural requirements for individual species and accessions have not been determined. Optimum spacing, root pruning, nutrient requirements, response to herbicides, and other cultural practices are being investigated for species that are in high demand.

Bare-root stock is normally spring lifted and planted on the site. Alternatively, they may also be fall lifted and planted immediately if weather conditions permit. Some species have been successfully held in storage through the winter for early spring planting. Observations and limited data indicate a wide variation in the ability of shrub species and accessions to survive long term storage.

Table 3.--Season of vegetative development for shrubs grown at the Lucky Peak Nursery

Species	Growing period		
	April	June	August
Robinia pseudoacacia			
Prunus fasciculata			
Prunus besseyi			
Prunus tomentosa			
Ceanothus velutinus			
Cupressus arizonica			
Ceanothus integerrimus			
Amelanchier alnifolia			
Amelanchier utahensis			
Purshia tridentata			
Rhus trilobata			
Caragana arborescens			
Ceanothus cuneatus			
Cornus tolonifera			
Rosa woodsii			
Prunus virginiana			



At present, grading and sorting of shrub seedlings involves only the culling of very poorly developed plants. Optimum root/shoot ratios and favorable growth characteristics for transplant survival have not been ascertained and established for individual species.

Bare-root stock can be planted at the rate of 400-600 plants per day per person. Planting rates are dependent upon the terrain, soil conditions, planting tools, and the need for preparing a scalped area around each transplant. If seedlings are to be planted on level terrain, a mechanical tree planter pulled by a tractor or vehicle may be used. A two-man crew can plant approximately 1,000 seedlings per hour with this implement.

In situations where transplant stock may be required, either bare-root or container stock may be selected. In some situations a combination of both types may be most suitable. The following items, among others, should be considered in selecting plant materials:

1. Bare-root stock can be stored more compactly and is easier to handle than container stock. A single crate of bare-root stock may contain from 500 to 2,000 seedlings. The excessive bulk of containerized seedlings results in additional transportation, handling, and planting costs.

2. Both types of stock must be maintained carefully prior to planting. Bare-root stock must be held at temperatures slightly above freezing. Bare-root may be stored in refrigerated areas, portable coolers, or snow caches. Containerized plants must be held in a lathhouse or shaded and watered periodically.

3. The cost of container stock is substantially higher than that of bare-root stock. In addition, planting costs for container stock are greater.

4. Species such as Cercocarpus ledifolius Nutt. and Cupressus arizonica have not performed well as bare-root stock. Container stock of these species has been easier to rear and is more successful when transplanted than is the bare-root stock.

5. Extremely rocky sites may require the use of container stock. On such sites it is sometimes impossible to place an adequate amount of soil around the roots of bare-root stock; however, potting media dries at a different rate than most soils thus reducing survival of container stock.

CONCLUSIONS

A large number of shrub species from most major shrub communities have been successfully propagated as bare-root stock (Table 4). Current studies should provide information which can be used to alleviate some of the problems encountered in the nursery propagation of certain species and to reduce the cost of bare-root stock. Determination of optimal root/shoot ratios and growth habits for transplant survival and establishment should also result from ongoing studies. This information will be used to provide improved guidelines for grading and sorting stock. Nursery cultural practices can then be adjusted to maximize the percent of seedlings exhibiting the desirable growth characteristics. Improvements in seed collection, handling, and germination techniques are being determined (Heit 1970; Nord 1963; Young et al. 1978). These should be reflected in improved quality of seed lots and the production of more uniform nursery stands.

Table 4.--Representatives of major plant communities which are successfully propagated as bare-root stock

Southern desert shrubs	Salt desert shrubs	Northern desert shrubs	Mountain brush
Atriplex canescens	Atriplex nutallii	Artemisia nova	Purshia tridentata
Fallugia paradoxa	Ceratoides lanata	A. tridentata ssp. tridentata	Rosa woodsii
Prunus fasciculata	Artemisia spinescens	Chrysothamnus nauseosus	Symphoricarpos oreophilus
			Rhus glabra

A major impediment to the successful propagation of native shrubs continues to be the difficulty of procuring seeds of high quality from appropriate sites or stands of superior accessions. Efforts are being made to alleviate this problem. Superior accessions which have shown adaptability to particular sites and desirable morphological or physiological traits are being released to seed growers through the Plant Materials Centers of the Soil Conservation Service. Seed orchards and seed rearing fields of superior accessions have been grown under agricultural conditions on an experimental and a production basis (McArthur et al. 1978). A program is being initiated to manage wildland stands as seed production centers (Monsen personal communication).

In the Intermountain Region, the production of native shrub plant materials to revegetate disturbed lands is a developing industry. Each year large acreages are disturbed. Mining activity in particular creates a wide range of sites that must be revegetated. Land managers must recognize the potential use and value of available plant materials and ascertain the best combinations of species and types of planting stock for each site.

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SHRUB ESTABLISHMENT ON RECONSTRUCTED SOILS IN SEMIARID AREAS

by

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ABSTRACT

Intermountain Forest and Range Experiment Station (Forest Service, USDA) personnel have been involved in research on the reclamation of surface-mined lands since the initiation of the Surface, Environment and Mining Project (SEAM), in 1973.

Since 1976, the Station's effort in Utah has been on lands considered to be in the arid and semiarid climatic zones. Our research has been on land areas that have not yet been mined inasmuch as there are no active surface coal or oil shale mines in the State of Utah. Efforts have been made to assess the relative value of different site preparation treatments and the relative success of a wide variety of plant species seeded or planted on different soil materials.

In this paper we will discuss briefly how our findings relate to the establishment of shrubby species of plants.

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DIRECT SEEDING OF GRASS-SHRUB MIXTURES

Past experience in semiarid areas such as the salt desert shrub community shows that it is risky to depend on direct seeding as a method of revegetation.

When direct seeding is contemplated as a method of establishing shrubs, it must be remembered that soil moisture is foremost in importance to success. In semiarid areas, the land manager should be prepared to utilize sprinkler irrigation early in the spring if it becomes apparent that sufficient soil moisture is unavailable to promote good seed germination. Once seedlings have become established, it may only be necessary to provide irrigation water on a few additional occasions during the first growing season to ensure plant survival. Most shrubs do not compete very successfully with grasses. A grass-shrub seed mixture should be sown in the autumn for two reasons. First, seed of many shrub species require a pregermination period of cold, moist conditions. Overwintering in the soil meets this requirement. Second, tilling and seeding operations in the spring result in considerable loss of stored soil moisture by evaporation from the loosened soil.

In our research on reconstructed soils in the salt desert shrub community, when a grass-shrub mixture was seeded in the autumn the shrubs fared best when the seedbed was harrowed following broadcast seeding. After 3 years, both shadscale (*Atriplex confertifolia*) and winterfat (*Ceratoides lanata*) were well represented in the stand despite some mortality. Broadcasting the seed simultaneously with use of the Hodder gouger or firming the seedbed with a cultipacker following broadcasting was less conducive to the establishment of the shrub species used. The pits formed by the gouger provided improved microsites for grass seedling establishment, and the grass competition was too severe for shrub seedlings.

On reconstructed soils of two sites in the pinyon-juniper zone of Kane County, Utah, shrub seedlings faced even greater competition from associated grasses. Although better soil moisture resulted in good initial establishment of winterfat, fourwing saltbush, and bitterbrush (*Purshia tridentata*), shrub numbers decreased greatly over the next 3 years. After four growing seasons, bitterbrush was the most abundant shrub followed by fourwing saltbush and winterfat. However, most of these shrubs (which have been protected from all browsing) are growing slowly among a vigorous grass stand.

DIRECT SEEDING OF SHRUBS ALONE

Shrubs can be established by direct seeding, even on semiarid sites, if the seeding job is done properly and competition from other plants is eliminated or controlled.

Land managers often hesitate to establish shrubs without associated grasses because shrubs are not as effective in preventing erosion. Shrubs, however, can be seeded or planted in strips or patches that will be surrounded by grasses or a grass-shrub mixture. By setting aside four 30- by 75-foot patches in each acre, shrubs could be the dominant vegetation on one-fifth of the area reclaimed.

Broadcasting seed of a mixture of shrub species onto a well-loosened seedbed surface should be followed by light harrowing or cultipacking. As previously mentioned, shrubs are best seeded in the autumn.

PLANTING SHRUB NURSERY STOCK

Considering the unreliability of adequate soil moisture for seed germination in semiarid areas, shrub establishment can often be better achieved by transplanting plants grown in a nursery or greenhouse. Such planting stock can be either "bare root" or "container grown." Age of transplants may be anywhere between 2 and 12 months.

Transplants are not affected as much by damaging or destructive factors of the environment as are seedlings. In effect, transplants have nearly a year's headstart on newly emerged seedlings.

Several things should be remembered when planting nursery stock. Although transplants are older and larger than newly emerged seedlings, they still cannot be planted successfully without controlling competition from adjacent vegetation whether this be seeded grasses or native vegetation. This means that if shrubs are planted in a strip, the strip should be free of all vegetation to a width of at least 36 inches.

In areas receiving less than 10 inches of annual precipitation, transplants should be given about one quart of water at the time of planting whether they are bare-root or container-grown. This will aid them in getting new root growth started as soon as possible.

Planted shrubs should always have a small basin formed around them to catch natural precipitation or to hold supplemental water when it is applied. Such a basin is especially useful on clayey soils having a low infiltration rate.

Following transplanting, the need for additional supplemental water in semiarid areas will depend upon the amount and timeliness of natural precipitation. The goal should be to ensure that the plants survive the first growing season. A drip irrigation system with an emitter placed next to each shrub is an efficient way to provide supplemental water several times during the growing season. The land manager, however, may find it more practical to simply water the plants by hand, using a tank truck and one or more long hoses. The size and location of the site will dictate the best way to provide supplemental water.

Overwintered container-grown and bare-root nursery stock should be planted as early as possible (as soon as the soil has thawed sufficiently to allow planting) in the spring. Spring planting is preferable to fall planting.

Planting of container-grown plants that are only a few weeks old and not well hardened to cold temperatures should be delayed until most of the danger from hard frost has passed. As this may result in late spring planting, the need for supplemental water at the time of planting is much greater.

The size of transplants, whether bare-root or container-grown, may affect their survival following planting. Transplants that are very small may have an inadequate root system to allow new root growth to penetrate deeply enough to avoid soil drying as the growing season progresses. Very small transplants are also more susceptible to destruction by soil movement, and cutting by rodents and insects.

On the other hand, too large a transplant may require more moisture to keep it alive than its root system can obtain from the soil. For most shrub species, a transplant 4 to 8 inches in height at the time of planting should be satisfactory. There should be a good balance between the size of tops and roots of transplants. For this reason, containers used for growing shrubs should be 6 to 8 inches deep, with a volume of about 15 to 25 cubic inches.

Bare-root planting stock should be kept cool (preferably in cold storage at 34° to 40°F) until the day of planting. Roots of bare-root stock should never be allowed to dry out. Obtain the help of someone experienced in planting when planning this type of project.

Boxes or trays of container-grown plants should be kept in the shade at the field planting site. Exposure of containers to the sun while awaiting planting may result in the root system being damaged by heat.

All transplanting must be done so as to ensure that the plant's root system is in firm contact with the soil. No air pockets should be left below or adjacent to the newly planted shrub.

SPECIES ADAPTABILITY IN SEMI-ARID AREAS

Areas receiving 6 to 15 inches of precipitation annually can be considered "semiarid." Average annual precipitation alone, however, is not the sole criterion for deciding the species of shrubs that can be successfully established on disturbed sites. The potential of an area receiving 7 inches of precipitation in Idaho or Wyoming to sustain vegetative growth is different from that of an area in Arizona that receives the same annual precipitation.

Species adaptability will depend upon a number of environmental factors, among which are soil and air temperature regimes and soil properties.

Our research in Utah has been on two study areas that receive 6 to 8 inches of annual precipitation, and on one area that receives 14 inches annually. Soils at each of these areas are near neutral to basic, with pH values of 6.7 to 8.3.

In areas within the salt desert shrub type, genera of the Chenopodiaceae family are well suited for use in reclamation. The genera Atriplex, Grayia, Ceratoides, Kochia, Sarcobatus, and Camphorosma have all contributed species that have exhibited high survival and good growth on saline soils. Certain ecotypes of Artemisia should also be suitable.

In the pinyon-juniper zone, the list of adapted shrubs is long. Some chenopods, such as fourwing saltbush and prostrate summer cypress (Kochia prostrata), can be used but other shrubs and small trees are also adapted to this more moderate environment. Shrubs, such as big sagebrush (Artemisia tridentata), rubber rabbitbrush (Chrysothamnus nauseosus), skunkbush (Rhus trilobata), bitterbrush, and Woods rose (Rosa woodsii), may be easily established. Forbs, such as Penstemon and Hedysarum, and small trees such as chokecherry (Prunus virginiana), and Russian olive (Eleagnus angustifolia), are useful.

In the Appendix, plants that have shown promise on our study areas in Utah are listed in Tables 1 and 2. The lists show only plant species that we have worked with. The land manager will find others that are adapted to his specific geographic areas.

APPENDIX

Table 1. List of shrub species showing promise for reclamation use in the semiarid salt desert shrub zone of Utah

Artemisia nova	Black sagebrush
Atriplex aptera	Shortwinged saltbush*
A. bonnevillensis	Bonneville saltbush
A. canescens	Fourwing saltbush
A. idahoensis	Idaho saltbush*
A. lahontanensis	Lahontan saltbush*
A. navajoensis	Navajo saltbush*
A. obovata	Broadscale saltbush
A. tridentata	Trident saltbush
A. worlandensis	Worland saltbush*
A. canescens x A. cuneata	Natural hybrid*
A. canescens x A. dollyvardensis	Natural hybrid*
A. canescens x A. idahoensis	Natural hybrid*
A. canescens x A. navajoensis	Natural hybrid*
A. canescens x A. tridentata	Natural hybrid*
Camphorosma monspeliaca	Mediterranean camphorfume
Ceratoides lanata	Winterfat
C. papposa	Plumed white sage
Ephedra nevadensis	Nevada ephedra
Eriogonum corymbosum	Corymbed eriogonum
Grayia spinosa	Spiny hopsage
Kochia prostrata	Prostrate summercypress
Sarcobatus vermiculatus	Greasewood

* Atriplex accessions acquired through cooperative research with Dr. Howard Stutz, Brigham Young University.

Table 2. List of shrub species showing promise for reclamation use in the semiarid pinyon-juniper shrub zone of Utah

Amelanchier utahensis	Utah serviceberry
Artemisia tridentata vaseyana	Mountain big sagebrush
Atriplex canescens	Fourwing saltbush
A. tridentata	Trident saltbush
Berberis fremontii	Fremont barberry
Caragana arborescens	Siberian peashrub
Cercocarpus ledifolius	Curlleaf mountain mahogany
C. montanus	True mountain mahogany
Chrysothamnus nauseosus	Rubber rabbitbrush
Cowania mexicana	Cliffrose
Cupressus arizonica	Arizona cypress
Elaeagnus angustifolia	Russian olive
Ephedra viridis	Green ephedra
Kochia prostrata	Prostrate summercypress
Peraphyllum ramosissimum	Squawapple
Purshia tridentata	Antelope bitterbrush
Rhus trilobata	Skunkbush
Ribes aureum	Golden currant
Rosa woodsii	Woods rose

COLLECTING NATIVE SEED

by

Claire Gabriel

ABSTRACT

Seed is collected when it cannot be bought and to secure site adapted ecotypes. This paper explains contracting for seed, identifying species, locating good stands, checking the health of the germ, collecting, cleaning, storing, and testing seed.

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INTRODUCTION

New native species—especially grasses—are being put into field production every year, but most native shrub and forb seed is still hand collected. Shrub seed in particular will be hand collected for a long time.

Shrubs resist cultivation. Few shrub seed orchards have solved the problems of density, male-female ratio, irrigation, tillage, pest control in a monoculture, pollination, and timing and method of mechanical harvesting. Even some grasses do not lend themselves to cultivation. Picture the seed heads of bottlebrush squirreltail *(Sitanion hystrix)*. The long, barbed awns hook the seed together, choking combines and seed cleaning machines.

SITE ADAPTATION

Even if the species you want can be bought, you may want site-adapted seed. We know wild rose *(Rosa woodsii)* is broadly adaptable; on the other hand, Indian ricegrass *(Oryzopsis hymenoides)* is site specific—seed must be collected near the site where it is to be planted. We don't yet know, however, the range of adaptability of most species. New named varieties are usually selected for adaptability to a range of sites and to cultivation, but until more adapted varieties are released by plant research groups you may decide it is worth the expense to have seed collected near your site.

QUANTITY

Collecting enough seed to grow plants in a nursery is much easier than collecting enough seed for direct seeding onto a disturbed site. In the nursery almost every viable seed can be turned into a plant, but thousands of times more seed must be sacrificed on a harsh site to produce the same number of plants. Once you learn to distinquish healthy seeds and to clean and store them undamaged, you can successfully collect enough seed for nursery production. If you don't have the staff to spare, you may prefer to contract with an experienced collector. The Pathfinder Mine in Shirley Basin, Wyoming, for example, contracted with Native Plants, Inc., to collect five ecotypes of shrubs at their mine site. In two days we were able to collect four of the five shrubs, and to train the staff at the mine to collect seed in the future. We cleaned, tested, and stored the seed; and each year Pathfinder orders tubelings grown from their adapted seed.

Collecting large quantities of seed near the site is more difficult. You risk not getting the seed you need. Experienced collectors have located large stands, and often travel 50,000 miles a year on collection trips. Collecting seed economically requires being in the right place at the right time. For example, 100 pounds of serviceberries yield only three pounds of clean seed, so it is unlikely to have a large enough stand nearby to harvest the quantity you want. If you need the seed it is wise to contract with an experienced collector before the species flowers (6-12 months before your seeding date).

If there is a crop, the collectors will harvest it, even if they must cover three states. Keep in mind that a crop may fail. There was not 100 pounds of serviceberry collected by anyone in 1980. If the crop is short, seed companies will fill their orders, and someone trying to order late in the season will find they are sold out. Seed collected on contract will also be less expensive than collecting it yourself since the collector is operating with the benefit of years of experience.

TEST THE SEED

Whether you buy seed, contract for it, or collect it yourself, always test the seed so you know what you are planting. Since seed laws vary from state to state, and since there are no standard testing procedures for most native seed, protect yourself by requiring the following information on each tag:

1) Botanical name - request an herbarium specimen if you doubt the collector's taxonomic skills.

2) Common name

3) Collection site - state and county, or township and range.

4) Elevation

5) Pure seed (%) - the percentage by weight of seed, after inert matter, broken seeds, and other crop and weed seeds have been separated.

6) Inert matter (%)

7) Other crop seed (%)

8) Weed seed (%)

9) Noxious weed seed - prohibited or restricted by each state

10) Germination (%) - the letters "TZ" should follow if a chemical tetrazolium test for viability is used; the word "fill" or "cut test" should follow if the seed was merely inspected for fill rather than germinated.

11) Hard seed (%) - this category accounts for seed that did not germinate but is viable, due to a hard, impermeable seed coat, as in legumes, or due to another form of dormancy.

12) Date tested

13) Lot number - if an accession does well or poorly, the lot number will enable the collector to trace the handling, storage, and collection history of the seed.

14) Net weight - bulk weight. Pure Live Seed (PLS) weight, as well, if ordered PLS.

15) Name and address of collector

You may also require data such as the number of clean seed per pound, the expiration date of nitrogen-fixing bacterial inoculation, or other collection site data.

Ask for a copy of the lab test, or, when the seed is delivered, pull a random sample from each lot and mail it to a seed testing lab. The charge runs from $8.00 to $25.00 per sample. Send in a test even if you must plant the seed; the results should be returned within 30 days, in time to adjust payment of the supplier's invoice if the seed does not measure up to the label.

PURE LIVE SEED (PLS)

To get your money's worth, order Pure Live Seed. PLS is figured by the following equation:

$$\text{PLS} = \text{Purity (\%)} \times \text{Germination (\%)}$$

For example, if a seed lot of western wheatgrass is 90% pure seed, of which 80% is viable, 72% of the bag weight is Pure Live Seed. If you order 100 pounds bulk, 72 pounds has the potential to germinate. On the other hand, if you order 100 pounds PLS, you will be shipped 139 pounds bulk. Since every seed lot has a different analysis, compare price per PLS pound to determine the best value.

FIND THE RIGHT PLANT

If you decide to collect seed, the first step is to identify the plant you want. Visit an herbarium (a collection of dried plants, found at most universities and some government offices). Study all the specimens to become familiar with the range of variation, particularly leaf size, leaf color, and shape. Compare other easily confused species and learn the key characteristics. Learn to use the taxonomic key (flora) of your area, if there is one. Once you are in the field, collect specimens of the plants of interest, unearthing the entire forb or grass, or cutting a flowering or fruiting branch of a shrub. Press each numbered specimen in a piece of folded newspaper between blotters; include site data. List each specimen by number and date in a field notebook, putting the same number on the bag of seed collected. File the dried and mounted specimens in an herbarium for reference.

LOCATE GOOD STANDS

Look for large, pure stands of well-spaced plants on workable terrain. Avoid collecting from individual plants that may not be cross-pollinated. Learn the noxious weeds in the state and steer clear of infested areas. Check stands during flowering and try to predict yield and dates of maturity.

As the seed matures check the health of the germ—look for insect and fungus damage and cut the seed to check fill. Good fruit doesn't always mean good seed. Experience will tell you what good seed looks like, but don't expect to gain that experience the first season. The best reference for shrubs is Seeds of Woody Plants in the United States, 1974, USDA Forest Service handbook 450, (U.S. Government Printing Office, Washington, D.C. 20402, hardbound, 883 pages). Although most stands need to be checked more than once, some species, such as bitterbrush, need constant surveillance. I have checked an unripe bitterbrush crop one day and found the seed on the ground the next morning. Also, bitterbrush may look good until almost ripe, then blacken and shrivel the last week. Fleshy fruits are lost to birds; fluffy seed such as winterfat *(Ceratoides lanata)* might be lost to the wind.

Good seed doesn't form every year. I collected blackbrush *(Coleogyne ramosissimum)* in southern Utah in 1978, after a wet spring, the first good crop in nine years. Gambels oak *(Quercus gambelii)* was infested with weavil larvae in the Wasatch Mountains last fall, but produced so many good acorns in south-central Colorado they rained into a truck bed driven through the thickets. Even field crops may fail—unseasonable rains rotted all lupines last summer. If a collector locates many stands he is less likely to come home empty-handed.

COLLECTING SEED

Collecting is done by hand, using a hopper or a tarp and beating the seed from the plant with a paddle. The U.S. Forest Service equipment development centers are among those designing and testing new equipment, but at present, no machine can harvest faster than a good collector. Besides being slower, machines indiscriminately pick up weed seed, dirt and rocks.

Pick seed when it is dry, carry it in porous bags or boxes, and then continue to dry it by spreading it on tarps or screens, using warm forced air if the relative atmospheric humidity is high. Berries will ferment within 24 hours, and should be cleaned or spread to dry before the fruit overheats the seed. The viability of a bag of damp seed can drop overnight.

CLEANING SEED

Berries are easier to clean when fresh. Use a macerator such as the dybvig, manufactured by Melvin Dybvig, Oregon City, Oregon. Other seed should be dry. Eight major pieces of seed cleaning equipment are needed to process the commonly collected native seeds. The skill of the collector in the field determines how well the seed can be cleaned, and of course, cleaning is a highly skilled operation as well—a novice can kill a batch of seed in two minutes by bruising or overheating the germ. There is no native seed cleaner's manual, because the machinery was designed for farm commodities. My advice is to work slowly, checking the seed often for damage. The cleaning operation of Native Plants, Inc., includes a useful adjunct, a seed laboratory and trained technician who can check for damage in 24 hours using a chemical stain.

STORING SEED

A rule for safe storage: keep the sum of humidity plus temperature (°F) less than 100. Under such conditions most seed will maintain viability for a few years in cloth bags. But there are exceptions to this rule. Winterfat should not be cleaned of its fuzz, and should be used within nine months or stored sealed in 6-mil thick plastic bags at 33-41°F. Conifers should be dried to 5% moisture content, sealed, and stored at 0°F. Before placing seed in long-term storage, fumigate with an insecticide and a fungicide. We have found seed-eating pests in every lot of seed gathered from the wild. Storage buildings must also be rodent-proof. Test seed before storing, and retest every 6-18 months.

SPECIES DIVERSITY FOR WILDLIFE AS A CONSIDERATION IN REVEGETATING MINED AREAS

by

Bland Z. Richardson

and

Tamara P. Trussell[1]

ABSTRACT

Several methods were used to promote vegetation diversity at five disturbed mine sites. The spoils on all sites were amended to assist in building a soil. Initially, plant species that established ground cover promptly and provided optimum watershed protection were chosen for the revegetation. Establishing native shrubs and increasing species diversity became important after the crucial watershed protection and soil stabilization problems had been overcome.

Interseeding shrubs with grasses results in a constant ratio of shrubs to grasses over time, although the overall density declines. Planting shrubs only is not recommended in areas of extremely low or high precipitation, or on steep slopes. Seeding shrubs in strips alternately with grasses is a method that could be used in these areas.

Natural succession and increased diversity can be encouraged by spoil amelioration and the addition of organic matter.

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INTRODUCTION

The act of revegetating surface mine disturbances is no longer a point of debate; it is being done by mining companies either voluntarily or under the governing eyes of a concerned public.

Revegetation concepts and methods, however, continue to differ fundamentally among the distinct disciplines. Covering the barren terrain with vegetation that provides an instant green cover is not sufficient to the wildlife biologist. The botanist may be concerned only with the establishment of native plant species, while the watershed manager's primary concern is soil stabilization. Restoring the site to its ecological condition prior to disturbance is the sole objective of many others. The ideals are admirable and desirable. The desired result is worthy; however, it is often difficult to obtain. Controversy arises primarily out of disciplinary bias. Consequently, there has been no consistent approach to the methods and analysis of revegetation projects. The end result is that no single method or approach is seen as satisfactory to all concerned. This is not unfavorable in itself. All geographical areas require specific treatment. The controversy arises during the evaluation of what is successful or acceptable.

All disciplines must be sensitive to a collective end goal. Priorities in the approach to that end must be set. However, before any attempt can be made to set goals, communication between all the interested groups must be open. Each discipline must realize its limitations, and operate on the assumption that knowledge is gained only by further interchange of experience and founded research, not opinions. The proceedings from this symposium may help to clarify goals and acceptable standards for all disciplines.

Many physical problems, some of which appear impossible to resolve, must be overcome when revegetating surface mines. For example, in most cases, revegetation takes place using spoil material, not soils. Other problems are:

a. steepness of slope
b. aspect
c. dark color of spoils and resultant high temperatures
d. toxic properties of spoils (acidity, alkalinity, etc.)
e. infertility
f. lack of organic matter
g. texture and other physical properties of spoils that are not conducive to plant growth
h. climate (both arid and high precipitation areas may present problems)

Revegetation priorities are perceived differently by various disciplines. The priorities should, however, be the same if the ultimate goals, which often differ in a group, are to be achieved. The order of events for successful revegetation listed by priority are:

1. to establish groundcover for protection of the watershed resource, accumulation of litter, and eventual soil stabilization,

2. to establish diversity of the vegetation community,

3. to establish food, cover, and water for domestic and wildlife populations, and

4. to enhance the aesthetic qualities.

The first priority, protection of the watershed resource, must be achieved if the other priorities are to follow successfully. This is the basic premise upon which this research is founded. Site specific information is necessary for every situation instead of "cookbook" methodology. In addition, flexibility and compromise are often necessary to achieve the desired results. Above all, planning and reevaluation by all disciplines must be cooperative.

MAYBE CANYON MINE

The Maybe Canyon Mine is a phosphate mine near Soda Springs, Idaho. The natural terrain of the area is mountainous. Consequently, the waste dumps often have very steep slopes. The elevation of the mine site is approximately 7,000 feet (2,134 m) and average annual precipitation is approximately 19 inches (48 cm). The growing season is short with potential frost hazard throughout the summer at the higher elevations.

Vegetation is a complex mosaic, as vegetal types are the results of aspect, elevation, micro-site climate, and soils. Sagebrush-grass is the predominant type. Stands of aspen are interspersed with the sagebrush while a spruce-fir vegetal type occupies north-facing slopes at higher elevations.

Wildlife species include moose, elk, and mule deer. Golden eagles, bald eagles, and sandhill cranes are commonly sighted throughout the year.

Methods and Results

A Maybe Canyon demonstration area was constructed in 1976. Protection of the integrity of the steep slopes was crucial. A fast growing, complete cover that protected the dump from infiltration and saturation was required in order to prevent mass failure. Recommendations were made to the company's contractor to plant a mixture of native and introduced grasses and forbs, and to interseed simultaneously with a mixture of shrubs. The contractor used a Brillion seeder-packer[2]. The front hopper (large seed) held a mixture of native and introduced grasses, alfalfa (*Medicago sativa*), sanfoin (*Onobrychis vicaefolia*) and yellow sweetclover *Melilotus officinalis*). The back hopper (small seed) held big sagebrush (*Artemisia tridentata*), bitterbrush (*Purshia tridentata*), and rubber rabbitbrush (*Chrysothamnus nauseosus*).

No data have been collected yet for the Maybe Canyon area. However, the grass-shrub-forb seed mixture appears to have established itself well. The grasses are thriving, while the shrubs are competing moderately well.

GAY MINE

The Gay Mine is a phosphate mine located near Pocatello, Idaho. The altitude of the mine is 5,600 feet (1,707 m). Average annual precipitation is approximately

11 inches (28 cm). The area is situated in the Great Basin desert and is characterized primarily by shrub species such as big sagebrush, rubber rabbitbrush, and bitterbrush.

A wildlife survey conducted in 1978 showed that while there are no rare or endangered wildlife species in the area, the area does support a resident deer herd, upland game birds, and waterfowl.

The area is part of the Fort Hall Indian Reservation's summer rangeland and trailing area and is quite heavily utilized by both cattle and sheep.

Methods

The research plot, was planted in the fall of 1977. It was ripped to a depth of four feet (1.22 m) and fertilized at a rate of 580 pounds per acre (649.60 kg/ha, 70% NH_4, 30% NO_3). Two methods of planting shrubs and forbs were used: 1) interseeding big sagebrush, bitterbrush and flax (Linium lewisii) with a grass seed mixture, and 2) sowing shrub seed in strips between grass seed strips. A Brillion seeder-packer was used for both methods. The seed hopper was divided into two sections for the strip method. The sections were filled with the grass or shrub-forb seed mixture. This made it possible to plant in alternate strips without emptying and refilling the hopper at each turn. Figure 1 demonstrates how the seed was sown using the strip method. The single strip method ran one way and dropped a five foot (1.52 m) width of both the grass and shrub-forb seed mixtures. A "U" turn of the seeder-packer produced alternate ten foot (3.05 m) strips of both the grass and shrub-forb seed mixtures.

Results

Emergence data were collected in the spring of 1978. Species density data were collected in 1979 and 1980. The data are summarized for the interseeding and the shrub "single strip" method in Figure 2.

Interseeding with the grass-shrub-forb mixture provided adequate ground cover and species diversity. The single strip planting is preferred over the double strip method as there is a more uniform cover distribution of grass and shrub components that leaves less bare ground susceptible to wind and water erosion. Weedy forbs invade the double strip planted areas faster and more effectively since there are not enough shrubs established to provide efficient competition.

Overall, the initial results indicate that shrubs, seeded with grass at a rate of 15 pounds per acre (16.80 kg/ha), seem to compete favorably with the grass. In addition, the soil is covered sufficiently to prevent erosion and species diversity is augmented to the benefit of other users.

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[2]The use of trade, firm, or corporation names in this paper is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

Figure 1. Planting using single and double strip methods.

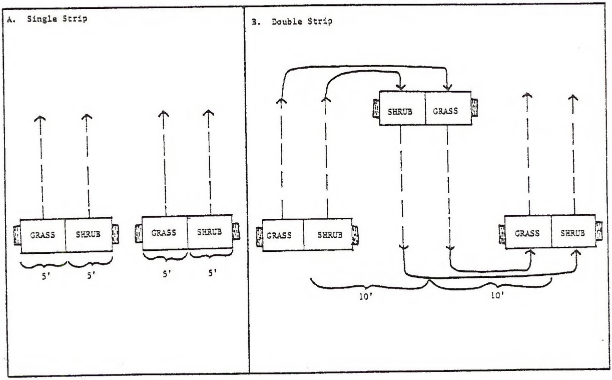
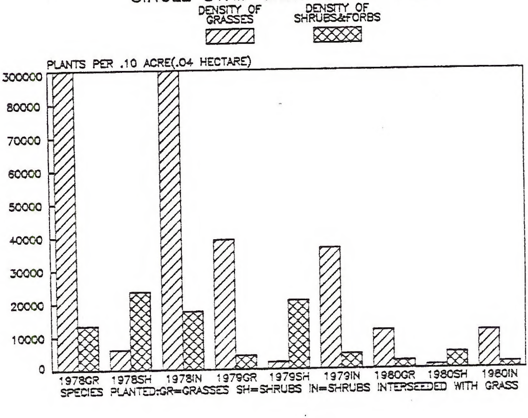


FIGURE 2:SPECIES DENSITY FOR INTERSEEDING AND SINGLE STRIP METHOD—GAY MINE



BEACON PIT MINE

The Beacon Pit Mine is a barite mine located about 15 miles (24 km) southeast of Battle Mountain, Nevada. The pit is at an altitude of about 4,600 feet (1,402 m). It, too, is part of the Great Basin Desert Complex and is characterized by big sagebrush. The average annual precipitation is only about 6 inches (15 cm). The climate is characterized by hot, dry summers and cold winters.

The area supports cold desert wildlife with a particular abundance of black-tail jackrabbits. Other small mammals are also abundant. Predators include the coyote, prairie rattlesnake, and several species of raptors. A year-round grazing season for cattle exists.

Methods

The test plot was constructed in December 1978. The spoil material required amelioration because it was alkaline, lacked plant nutrients, and had excessive concentrations of soluble salts and sodic properties. It was enhanced by: (1) ripping the spoil to improve structure characteristics; (2) adding soluble calcium salts (calcium chloride) to replace the sodium ions which lowered the sodium absorption ratio (SAR) value to one more favorable to plant growth, and (3) adding fertilizer to provide the required basic plant nutrients.

Shrub seed only was planted in six plots at a rate of 10 pounds per acre (11.20 kg/ha). Six plots were seeded with a grass-shrub-forb seed mixture using a Brillion seeder-packer at a rate of 12 pounds per acre (13.44 kg/ha). The shrub mixture was then hand broadcast at a rate of 10 pounds per acre (11.20 kg/ha), for a total rate of 22 pounds per acre (24.64 kg/ha). The plots were also: (1) hydromulched, (2) straw mulched, or (3) not mulched at all.

Results

Emergence data and species density data collected in 1979 and 1980, respectively, show no significant differences between treatments (fertilizer, mulch, CaCl) and species establishment. Cheatgrass (_Bromus tectorum_) and halogeton (_Halogetonglomeratus_) are established species in the vicinity of the plots, and were very successful in reestablishing themselves despite the planting of other species. The competition between these two undesirable species and the species planted is of primary concern. Figure 3 summarizes species density data for all treatments collected in 1980. The problem of weed invasion is by far greater on plots planted with "shrubs only." It is recommended that in areas with low precipitation and an abundant weedy species seed source, grasses should be included in the seed mixture.

ARCO'S BLACK THUNDER COAL MINE

The Black Thunder Coal Mine is located 40 miles (64 km) south of Gillette, Wyoming in the Thunder Basin National Grasslands. The topography is characterized by low rolling hills with broad valleys. Elevation of the mine site is 4,724 feet (1,440 m). Average annual precipitation ranges between 9 and 11 inches (23 and 28 cm). The area is mostly sagebrush-grass vegetation type with

FIGURE 3:SPECIES DENSITY IN TWO SEED MIXTURES BEACON PIT MINE

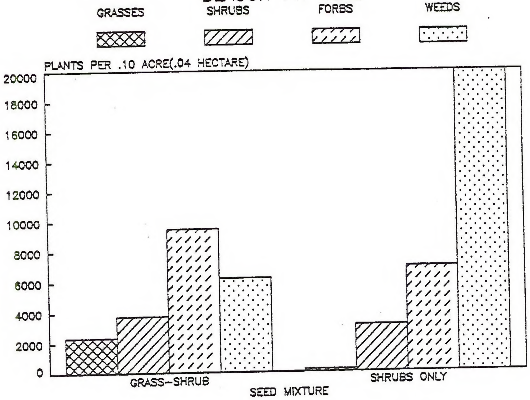
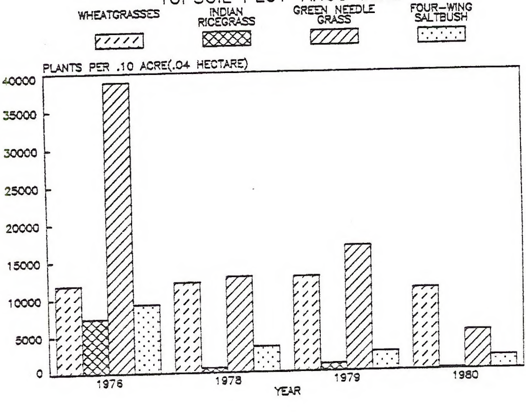


FIGURE 4:SPECIES DENSITY*-NATIVE SEED MIX TOPSOIL PLOT-ARCO MINE



some grassland types present. A variety of wildlife exists in the area: deer, pronghorn antelope, some upland game birds and waterfowl, weasels, badgers, skunk, and many species of songbirds (University of Wyoming 1976).

Methods

The research plots were topsoiled and fertilized in fall 1975. Native grasses and a single shrub species, fourwing saltbush (*Atriplex canescens*), were planted using the same method employed at Maybe Canyon. After planting, a portion of the plots were mulched with straw, and a portion mulched with a wood fiber.

Results

Emergence data were collected in June, 1976. Species density data were collected in the summers of 1978, 1979, and 1980. The data are summarized in figure 4. The density of all four species represented on the graph declined over the years. This is expected for the first few years as plants grow larger and more vigorous, increasing both intra- and interspecific competition. It is important to note, however, that the ratio of the shrub species (fourwing saltbush) to the grasses (wheatgrasses, Indian ricegrass, and green-needlegrass) remains relatively unchanged.

BLACKBIRD MINE

The Blackbird Mine is a cobalt mine located on the Salmon National Forest near Salmon, Idaho. The elevation of the mine area ranges from 6,600 to 8,200 feet (2,012 to 2,499 m). Average annual precipitation is from 25 to 40 inches (63 to 102 cm). The vegetation is predominantly lodgepole pine (*Pinus contorta*) with an understory of huckleberry (*Vaccinium* spp.), Oregon grape (*Berberis repens*), spirea (*Spirea* spp.), pinegrass (*Calamagrostis rubescens*), and various forb species. The general physiography is characterized by a rugged succession of high ridges with steep hillsides and deep, narrow draws.

Wildlife species at the Blackbird Mine include: deer, elk, black bear, mountain lion and numerous nongame species.

Methods

The Blackbird plots were constructed in 1972. Methods and equipment used are described by Farmer, et al. (1976). The Blackbird site was not prepared primarily for shrub or tree establishment. Rather, the acidic spoil material was amended by the addition of lime, topsoil, fertilizer, and mulch. It was also ripped and harrowed in order to improve infiltration, permeability, and general physical characteristics. Grasses were planted and the subsequent litter and organic matter, together with spoil ameliorations proved to provide a niche for the establishment of such native species as lodgepole pine, subalpine fir (*Abies lasiocarpa*), and Engelmann spruce (*Picea engelmannii*).

FIGURE 5:DENSITY OF NATIVE TREES
BLACKBIRD MINE

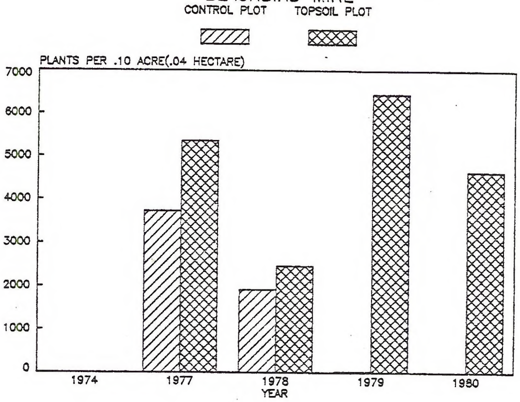
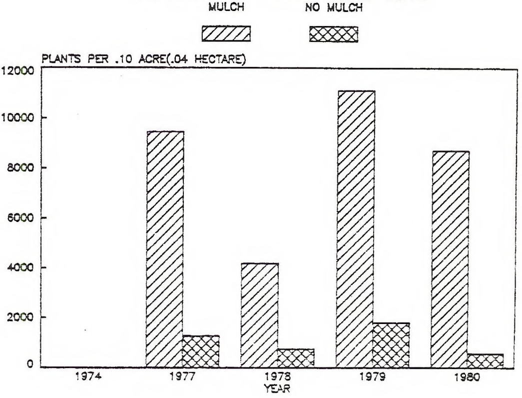


FIGURE 6:DENSITY OF NATIVE TREES
TOPSOIL PLOT—BLACKBIRD MINE



Results

Figure 5 compares average native tree density on the control plot (no topsoil) to the topsoil treatment. It is apparent that the addition of topsoil is necessary to encourage natural succession at the Blackbird. Figure 6 compares "mulch" to "no mulch" on the topsoiled plot. The addition of mulch is an important treatment for the natural establishment of tree seedlings at the Blackbird. The mulch used was a combination of sphagnum moss and jute netting.

Figures 5 and 6 represent data collected on nonfertilized plots. No trees have yet invaded fertilized plots, perhaps due to the grass competition which is high on fertilized plots.

Secondary succession on this site had been at a complete standstill for over 20 years; no vegetation at all had grown on these sterile spoils. Thus, it appears that the treatments at the Blackbird have helped promote and accelerate natural succession.

SUMMARY

Several methods were used to promote vegetation diversity at five disturbed mine sites. The spoils on all sites were amended to assist in building a soil. Benefits were derived in accelerated watershed protection and soil stabilization, which are the most crucial factors to successful revegetation. Improving vegetative diversity was a primary goal at each site. The methods used varied from site to site as the environmental and physical characteristics varied.

Interseeding shrubs with grass mixtures appears to work moderately well, provided that the grasses are not seeded too heavily. A Brillion seeder-packer can be used for this method. Density of both shrubs and grasses will decline over time, as expected. But the ratio of shrubs to grasses should remain constant.

Planting "shrubs only" did not work well in an area with low precipitation and with an abundant source of weedy species seed. In our opinion, neither would this method work in areas of moderate to heavy precipitation or in areas with steep terrain because shrubs alone do not offer the watershed sufficient erosion protection. Seeding shrubs in strips alternately with grasses (vegetative terracing) is an alternate method that could be used in these areas of greater rainfall or steeper slopes. The grass strip catches the water and it filters on down to shrubs, thus preventing accelerated soil loss. The single strip method provides more uniform cover and thus greater protection from erosion.

Spoils may be amended, and selected plants be used to build a soil from spoil, which will enhance and accelerate natural succession. At the Blackbird, topsoil and mulch--together with the organic matter (litter, dead roots, etc.) contributed to the spoil from grasses originally planted to protect the watershed--have significantly contributed to the diversity of the area by encouraging the natural "invasion" of conifers.

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SHRUB REESTABLISHMENT RESEARCH AT THE HIGH PLAINS GRASSLANDS RESEARCH STATION

by

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and

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ABSTRACT

This paper reviews shrub reestablishment research carried on by scientists at the High Plains Grasslands Research Station, Cheyenne, Wyoming. Initial work dealt with vegetative propagation of select woody plants and with their adaptation and survival at five surface-mined reclamation sites in Wyoming and one in Colorado. The sites were not irrigated.

The study showed that woody shrub plantings may survive a wide range of climatological and soil conditions but that growth of most species was slow and hindered by wildlife use. Antelope (*Antilocapra americana*) were particularly destructive of the test plants at the Shirley Basin and Hanna sites. Species showing the least amount of browse by antelope were: silver sagebrush (*Artemisia cana*), fourwing saltbush (*Atriplex canescens*), Maximowicz peashrub (*Caragana maximowicziana*), pygmy peashrub (*C. pygmaea*), Siberian salttree (*Halimodendron halodendron*), Chinese wolfberry (*Lycium chinense*), matrimonyvine (*L. halimifolium*), and trumpet gooseberry (*Ribes leptanthum*).

Current work emphasizes shrub establishment from direct seedings. Work in this area has shown the advantages of seeding in a standing stubble mulch and preliminary results are reported for seeding depth studies of fourwing saltbush (*Atriplex canescens*), fringed sagebrush (*Artemisia frigida*), and mugwort wormwood (*A. vulgaris*).

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INTRODUCTION

Research on the reestablishment of shrubs on mined land was begun by Gene Howard, Frank Rauzi, and Gerald Schuman of the High Plains Grasslands Research Station in 1975. They used plant material from the arboretum on the Station (which contains woody plant species collected from all over the world over a 46 year period) and several native species as a resource to test a variety of woody plant species for their capability to adapt to a disturbed land environment. The first part of the paper will present the results of the native and most successful non-native shrubs evaluated in that project (Howard et al., 1979). The remainder of the paper will cover the first year results of a study of techniques in seeding fringed sagebrush (*Artemisia frigida*), mugwort wormwood (*A. vulgaris*) and fourwing saltbush (*Atriplex canescens*). In the case of the seeding study, no final conclusions have been drawn, but the results are of interest and merit discussion.

METHODS

The 1975 woody plant trials were begun at three sites; additional clones of woody plant species were propagated to expand the 1975 trials and to include three additional sites in 1976. All species tested except one were successfully propagated by the use of hardwood and softwood cuttings under intermittent mist. Neither the hardwood or softwood cuttings were stored, but were placed directly into the propagating bench after the lower one-third of each cutting stem was sprayed with liquid rooting hormone composed of 1 g indole-3-butyric acid and 0.625 g 1-naphthaleneacetic acid dissolved in 125 ml of ethanol and brought to 500 ml volume with distilled water. After rooting, plants were either potted in a greenhouse potting soil mix in 15 lb tar paper containers, 2 inches square and 9 inches deep, or set in nursery rows in a lathe house. Plants propagated and set in containers in the summer of 1975 were induced to go dormant for 45 days in late fall under shade and cold temperatures in underground cellars. They were then forced into a winter growth cycle under extended day length and warm temperatures for 90 days to obtain larger plants for the field planting in 1976.

This treatment was followed by a second dormant cycle of at least 6 weeks prior to field planting in May or June. The second dormant cycle was very important as it meant the first flush of new root growth occurred after transplanting rather than before, thus allowing the plant to establish below ground before the shoots began active growth. The practice of transplanting dormant stock is not followed in many cases and is one reason for large losses of containerized transplant stock.

Planting sites were located at Shirley Basin, Glenrock, Gillette, Kemmerer and Hanna in Wyoming and at Oak Creek, Colorado. These sites represented a wide range of climatological and soil characteristics (Table 1). Sites at Gillette, Glenrock, and Shirley Basin were cultivated while the other three sites were planted and left to compete with the plants of natural succession. Plantings at the Shirley Basin, Hanna, and Kemmerer sites were watered when set in the field. Trial plants at all sites were set in rows, with 3 to 8 ft between plants in the row and 20 to 25 ft between rows. Plantings were made in 1975, 1976, and 1977.

Table 1. Soil Characteristics at 6 Mine Reclamation Sites (do = ditto)

Location and Soil Association	Soil Material	pH	Texture	Electrical Conductivity	Organic Matter
				mmhos/cm	percent
Pathfinder Mines Corp.					
Formerly Lucky Mac Uranium Corp.	Topsoil	7.2	Sandy loam	0.78	1.68
Shirley Basin, Wyo.	Subsoil 1/	7.8	-- do --	0.95	0.58
(Borollic Haplargid)					
Pacific Power & Light Co.					
Dave Johnson Mine	Topsoil	6.3	-- do --	1.18	1.25 2/
Glenrock, Wyo.	Subsoil	5.2	-- do --	4.20	2.00
(Ustollic Haplargid)					
Wyodak Mine					
Gillette, Wyo.	Topsoil	6.9	Clay loam	3.98	4.32
(Ustollic Haplargid)	Subsoil	6.7	-- do --	1.60	3.30
Kemmerer Coal Co.					
Frontier, Wyo.	Topsoil	7.3	-- do --	0.40	3.00
(Ustic Torriorthent)	Subsoil	8.0	Silt loam	3.10	0.80
Rosebud Coal Sales					
Hanna, Wyo.	Topsoil 3/	---	---	---	---
(Borollic Haplargid)	Subsoil	7.4	Silt loam	7.02	2.87
Pittsburg & Midway Coal Co.					
Oak Creek, Colo.	Topsoil	7.4	-- do --	2.00	6.50
(Unnamed complex)	Subsoil	7.7	Clay loam	3.30	3.70

1/ Mixture of spoils and other subsoil material.

2/ Reclaimed soils at the coal mine sites have various amounts of coal particles, which contribute to the high organic matter readings in some samples.

3/ No topsoil replaced on this site.

Plant growth and survival notes were taken in late September of each year. Notes on wildlife use were taken in 1976 and 1977 and will be discussed in the conclusions. Only the 1977 survival data will be presented.

In addition to the species transplanted, 13 species were direct seeded at two locations in the fall of 1976 using a cone seeder. Eight species were direct seeded with a cone seeder at the same location in the spring of 1977.

RESULTS & DISCUSSION

One hundred percent rooting success (Table 2) was obtained with softwood cuttings of dwarf oldman wormwood (*Artemisia abrotanum nanum*), a non-native and with the native common snowberry (*Symphoricarpos albus*).

Table 2. Percent of Woody Plants Rooting

Species	% Rooted
Artemisia abrotanum nanum *	40
Artemisia abrotanum nanum	100
A. absinthium	80
A. tridentata	80
Symphoricarpos utahensis	84
Symphoricarpos sp.	74
S. oreophilus	63
S. vaccinoides	40
S. albus	100
Rosa laxa	62
Potentilla fruiticosa	96

* Hardwood cutting

Survival of most of the native species was very good at most locations (Table 3). Silver sagebrush (*Artemisia cana*), fourwing saltbush, rubber rabbitbrush (*Chrysothamnus nauseosus*), rose (*Rosa* sp.), skunkbush sumac (*Rhus trilobata*) and the snowberries did the best among the natives. Dwarf oldman wormwood and siberian salttree (*Halimodendron halodendron*) were the best of the non-natives.

The results of direct seeding 13 species in the fall and 8 species in the spring are shown in Table 4. Mugwort wormwood and two species of *Caragana* at Shirley Basin and six species of *Caragana* at Glenrock produced plants from direct fall seeding. Only two *Caragana* species at Glenrock produced plants from the direct spring seeding.

In addition to small numbers of rabbits (*Lepus* sp.) at all sites, wildlife browse of plant species at Gillette was by mule deer (*Odocoileus hemionus*) and antelope (*Antilocapra americana*), at Glenrock mostly by mule deer,

Table 3. 1977 Survival of Woody Plant Species by Planting Site (percent)

Year Planted	Species	Gillette	Glenrock	Shirley Basin	Hanna	Kemmerer	Topsoil Oak Creek	Overburden Oak Creek
1975	*Artemisia abrotanum nanum*	100	100	67	50	---	75	75
1976	*A. absinthium*	---	100	100	---	---	50	100
1976	*A. cana*	100	100	100	---	20	75	50
1975	*A. tridentata*	---	---	33	---	---	---	---
1976	*Atriplex canescens*	100	100	100	89	83	75	100
1975	*Ceratoides lanata*	60	92	---	13	---	50	---
1975	*Cercocarpus betuloides* (BR)	---	---	---	---	---	25	25
1975	*Chrysothamnus nauseosus*	100	67	100	42	57	75	50
1976	*Halimodendron halodendron*	100	100	100	100	---	100	100
1975	*Pinus ponderosa*	100	75	11	---	---	75	100
1975	*Rhus trilobata*	73	100	---	---	---	100	100
1976	*Rosa arkansana* (BR)	100	100	100	---	25	50	100
1976	*Symphoricarpos albus*	100	60	100	33	---	100	100
1976	*S. oreophilus*	---	80	67	---	---	25	50
1976	*S. utahensis*	---	---	---	---	---	100	100
1976	*S. vacciniodes*	---	---	---	100	---	---	---
1976	*Symphoricarpos sp.*	100	100	67	---	---	75	50

BR = Planted as bare root stock, all others planted as containerized stock.

Table 4. Data for Direct Seeding of Shrubs

Species	Shirley Basin		Pacific Power and Light (Glenrock)		
	Row length in feet	Stand in summer 1977	Row length in feet	Stand on 6-14-77	Stand on 9-22-77
	Seeded 10-22-76		Seeded 10-22-76		
Artemisia abrotanum nanum	48	None	50	None	None
A. cana	42	None	65	None	None
A. tridentata	44	None	50	None	None
A. vulgaris	45	Fair 1/	45	None	None
Caragana arborescens	38	Fair	50	Fair	Few 2/
C. aurantiaca	24	Fair	52	None	Few
C. boisii	33	None	58	Fair	Few
C. decorticans	28	None	40	Few	Fair
C. fruticosa	33	None	56	Many 3/	Many
C. microphylla	36	None	52	Many	Many
Cotoneaster acutifolia	28	None	45	None	None
C. multiflora	21	None	54	None	None
C. racemiflora soongorica	28	None	40	None	None
	Seeded 4-21-77		Seeded 4-28-77		
Artemisia vulgaris	20	None	20	None	None
Caragana arborescens	22	None	30	None	None
C. aurantiaca	20	None	24	None	None
C. boisii	24	None	25	None	Few
C. maximowicziana	22	None	20	None	None
C. pekinensis	22	None	48	Fair	Fair
Cercocarpus douglasi	24	None	42	None	None
Pinus ponderosa	22	None	78	None	None

1/ Fair, about 5 to 8 plants per 16 ft of row.
2/ Few, about 1 to 3 plants per 16 ft of row.
3/ Many, 16 or more plants per 16 ft of row.

at Shirley Basin and Hanna mostly by large populations of antelope, at Kemmerer mostly by mule deer, and at Oak Creek by mule deer and elk (*Cervus canadensis*).

This study shows that woody shrub plantings may survive climatological and soil conditions and the browse of all wildlife species except antelope when planted under the conditions tested. Antelope have severely browsed all the test species except those species with natural protective mechanisms such as thorns, volatile oils or flavor. If shrub species were planted in forage mixtures so they would be widely despersed over large acreages, wildlife use might be considerably different. Those species with natural protective mechanisms limiting antelope browse were the pygmy forms of *Caragana* [Maximowicz peashrub (*C. maximowicziana*) and pygmy peashrub (*C. pygmaea*)], fourwing saltbush, siberian salttree, matrimonyvine (*Lycium halimifolium*), Chinese wolfberry (*L. chinense*), and trumpet gooseberry (*Ribes leptanthum*). Silver sagebrush was the most browse resistant of the *Artemisia* species tested.

Caragana species and mugwort wormwood are recommended because of their capability to establish from seed. Mugwort wormwood, because of its nutritive value and ability to withstand grazing, appears particularly well adapted (Schuman and Howard, 1978).

In the current study of seeding techniques, seedling establishment as influenced by seeding depth and mulch are being evaluated for fringed sagebrush, mugwort wormwood and fourwing saltbush.

These species were seeded in March, 1980, in both barley stubble and bare soil. The use of standing stubble has been tested with regard to improved grass seedling establishment on mine spoils by Schuman, Taylor, Rauzi, and Howard (1980). When compared with the standard crimped straw mulch, the stubble mulch resulted in a seedling being less subject to extremes of diurnal temperature fluctuation and to wind; and in having better soil moisture. The improvement in soil moisture was due to increased snow entrapment by the standing stubble, increased infiltration and reduced evaporation from the soil surface -- the latter would be especially critical for small seed lying on or near the soil surface.

Seeding of the three species in the study was done by hand, using 10 seeds of each species on each of 150 plots in the standing stubble and 150 plots on the bare ground. These plots were randomly assigned to planting depths of surface, 1/4 inch deep and 1/2 inch deep. The surface seeding consisted of placing the seed in a 1/2 inch furrow and not covering it.

Seedling counts were made in late May, early June, late June and late July. Both mugwort wormwood and fourwing saltbush established best at the 1/2 inch planting depth, but the difference was not statistically significant from the other depths, The best stand of fringed sagebrush resulted from a 1/4 inch seeding depth in standing stubble, followed by a surface seeding in stubble (Table 5).

Table 5. Percent Live Seed of Fringed Sagebrush Producing a Surviving Seedling as of Mid June 1980 and End July 1980 as Related to Seeding Depth and Seedbed

Seeding Depth	Seed-Bed	Mid June	End July
1/4	stubble	46 %	29 %
surface	stubble	28 %	23 %
1/2	stubble	19 %	13 %
1/4	bare soil	14 %	9.3 %
surface	bare soil	11 %	13 %
1/2	bare soil	7.3 %	11 %

The data of this first year emphasize the importance of an improved micro-climate, such as occurs when seed is planted in a stubble mulch, and it indicates that a shallow seeding depth is best for fringed sagebrush.

In other current work, at the Station, the effect of nitrates on germination and radicle elongation of selected native shrubs, is being investigated. Also several studies are being conducted to further investigate the seed and seedbed ecology of winterfat (*Ceratoides lanata*).

In cooperation with the Plant Science Dept. at the University of Wyoming, additional projects are underway investigating germination requirements and mycorrhizal associations of native shrubs and searching for methods to enhance shrub establishment from seed.

In summary, the research program at the High Plains Grasslands Research Station will continue work with woody plants by emphasizing research in the biology, bio-chemical and physical aspects of establishing from seed woody plant species on surface mined lands.

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ANALYSIS OF DIRECT SEEDING METHODS FOR ESTABLISHMENT OF SELECTED NATIVE SHRUB SPECIES ON MINESOILS IN SOUTHEASTERN MONTANA

by

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and
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ABSTRACT

Direct seeding of shrub species has been only partially successful on mined lands to date. To overcome certain difficulties inherent to direct seeding, a study was initiated on minesoils during fall, 1978. The objective was to determine the effectiveness of high shrub seeding rates on establishment and growth with and without seeded perennial grass competition. Five native shrub and one forb species were evaluated. Vegetational and physical monitoring were conducted over the first two growing seasons. All seeded species germinated in the first spring, but ultimate survival and growth were adversely impacted by drought conditions during both seasons of study. Skunkbush sumac and cudweed sagewort exhibited complete mortality by the end of the second growing season, while Nuttall's saltbush demonstrated highest density relative to surviving shrub species. Results demonstrated positive effects of reduced perennial grass competition on initial establishment of Nuttall's saltbush and skunkbush sumac, with inconclusive results for other shrub species. Results also indicated a superiority of use of seed from local ecotypes of winterfat and Nuttall's saltbush rather than from more distantly collected ecotypes in terms of initial establishment.

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INTRODUCTION

The need for suitable and successful means of reclaiming surface mined lands is urgent. An area of particular concern involves the revegetation of such lands. The state of Montana provided strict regulations concerning revegetation in it's Strip and Underground Mine Reclamation Act of 1973. This act requires that vegetation established on mined lands provide a suitable permanent, diverse cover capable of regeneration under existing climatic conditions, and which is able to support livestock and wildlife as well as control erosion in a manner comparable to that preceding mining.

The phrase "diverse vegetative cover" is very important. A plant cover of this type should in many cases include shrubs and forbs as well as grasses. Although it is important to establish a cover of perennial grass species quickly, in order to stabilize the soil, it is equally important to establish a shrub and forb association. Such an association (grasses, forbs, and shrubs) will provide a diverse habitat for many species of wildlife as well as livestock (DePuit and Coenenberg 1979). Shrubs are important in many ways to both animal and plant communities. The various functions they provide include: 1) substantial herbage production, hence providing forage and cover for wildlife and livestock; 2) niche diversification; and 3) ground cover for effective soil stabilization (Robinette 1972; Vallentine 1971; Plummer, Monsen, and Christensen 1968).

One approach for establishing shrubs on lands disturbed through strip-mining involves direct seeding. Direct seeding may be accomplished by seeding a broad mixture of different lifeforms which may include several species of shrubs, perennial grasses and forbs. This technique has been used in seeding deteriorated rangelands and lands disturbed through strip-mining (Plummer et al., 1968; Dollhopf and Majerus 1975). However, it has often met with only limited success in terms of shrub establishment (Monsen and Christensen 1975; Plummer et al., 1968; Dollhopf and Majerus 1975; Frischknect 1978). Very few shrub species have seedlings which are sufficiently vigorous and aggressive to compete with concurrently establishing perennial grass seedlings. Differences in competition tolerance between shrubs and grasses are due to the fact that shrubs and grasses are two different lifeforms, with different seedling morphologies, physiologies and growth rates. Grasses tend to mature more rapidly than shrubs, and thus provide frequently stifling competition (Blaisdell 1949; Frischknect 1978; Anderson 1975). The growing points of shrub seedlings are usually aboveground, which exposes them to spring frost and grazing animals. Conversely, grass seedlings have growing points below ground and thus have greater tolerance for these two factors (Plummer, Christensen and Monsen 1965).

An alternative method to seeding using grass-shrub seed mixtures is to seed shrubs and grasses in alternate rows, thus reducing competition between the two (Plummmer et al., 1968; Frischknect 1978). This has proven successful to a certain degree when dealing with shrubs that possess low seedling vigor.

However, interspecific competition will not be entirely removed when shrubs are seeded alone. Seeds of annual forbs and grasses, along with other perennial and biennial species as well, may be present in the seedbed, and these will compete with seeded shrubs (Holmgren 1956). This is especially true on mined lands when the original topsoil is utilized, which may serve as a "reservoir" of seed for volunteer plant species.

Another factor which makes establishment of native shrub species difficult from direct seeding is that seeds of certain species possess low germinative characteristics (Sindelar et al., 1974). Also, in past research involving shrub direct seeding, low seeding rates of shrubs sometimes have been utilized with respect to other lifeforms, especially perenial grass species (DePuit and Dollhopf 1978; Dollhopf and Majerus 1975; Plummer et al., 1968).

The general goal of this study was to develop methods for establishment of certain shrub species on topsoiled stripmine spoils by direct seeding. Specific objectives were as follows:

1) Evaluation of effectiveness of unusally high seeding rates in promotion of shrub establishment and growth.
2) Determination of effects of presence and absence of competition from concurrently seeded perennial grasses on shrub establishment and growth.
3) Comparison of responses of five selected shrub and one forb species seeded to the above treatments in terms of establishment and growth.
4) For two of the shrub species seeded, evaluation of the performance of locally collected versus commercially purchased seed.

METHODS AND PROCEDURES

Study Area

The study area is located in southeastern Montana near the town of Colstrip, approximately 30 miles south of Forsyth, Montana. The pre-mining topography of the area comprises gently rolling hills strongly dissected by intermittent streams and sandstone outcrops (Sindelar, Hodder, and Majerus 1973). Vegetation primarily consists of a ponderosa pine savannah type, with ponderosa pine located on ridge tops grading into mixed prairie grassland below. The elevation of the area ranges between 3,000 and 5,000 feet. Average annual precipitation in the Colstrip area is 15.13 inches, most of which occurs as rain from April through July, and the frost-free growing season varies from 95 to 135 days (Sindelar et al., 1973).

This area overlies rich deposits of sub-bituminous coal of the Fort Union formation. Stripmining to reach much of this coal is practical and is being conducted by both the Peabody Coal Company and Western Energy Company.

Experimental Design

This study was conducted on topsoiled stripmine spoils located in Area E at the Western Energy Company Rosebud Mine. This company also provided the support for the project. Five xerophytic shrub and one forb species native to the Colstrip region were seeded in small (5 x 5 m) plots both alone and combined with a mixture of six native perennial grass species. Locally collected ecotypes of two of the shrub species, winterfat (Ceratoides lanata) and Nuttall's saltbush (Atriplex nuttallii), were also included to see if there were any differences in establishment between these and seed obtained commercially. The shrub species seeded as well as the grass species making up the mixture are presented in Table 1. Seeding rates are also given.

This experiment utilized a completely randomized design. There were two major treatments involved: 1) shrub species seeded alone and 2) shrub species seeded with a mixture of perennial grass species. The two major treatment effects times the six species to be evaluated provided twelve possible treatment interactions. Each treatment was replicated three times giving a total of thirty-six experimental units. The locally collected ecotypes of the two shrub species (winterfat and Nuttall's saltbush) were also replicated three times (seeded alone only) giving an overall total of forty-two experimental units (plots).

The study site was first chisel plowed (to a 10 inch depth) to provide a loose, moderately rough seedbed. Plots were then broadcast seeded and hand-raked to simulate harrowing. Seedbed preparation and subsequent seeding took place on September 29-30, 1978. Plot #30 was intended for seeding of cudweed sagewort with the grass seed mixture concurrently, but there was not enough of this shrub seed left to complete the seeding. All study plots were uniformly fertilized at 26 lb/A actual N and 14 lb/A actual P in May, 1979.

Measurements

All planned physical and vegetation measurements were conducted during the 1979 and 1980 seasons. Parameters measured were canopy cover and frequency, density growing at two sampling dates for shrubs only and at one date only for all vegetation classes and species present in each class, phenology, shrub heights, and species composition.

Aboveground biomass was added as a measured parameter in the 1980 field season. Biomass data were collected on a species basis. Soil moisture data were collected on a monthly basis throughout 1980 and in 1979 only during the growing season. Monthly precipitation was also measured from 1978 to 1980.

Percent pure live seed for each of the five shrub and one forb species was determined in the laboratory at Montana State University during 1979-1980. This was based on percent pure seed and percent viable seed. The latter was obtained through the use of tetrazolium testing (Weber and Wiesner 1980). Actual number of seeds per pound for each species was also extrapolated from the samples used during percent pure seed determination.

RESULTS AND DISCUSSION

Laboratory Seed Analyses

Table 2 presents post-seeding seed analysis results for shrub species

Table 1. Shrub and perennial grass species evaluated and associated direct seeding rates, Shrub Establishment Study, Colstrip, Montana.

	Seeding Rate (lb/A) Bulk	PLS[1]	Estimated[3] No. Seeds/ft^2
A. Individually Seeded Shrubs			
1. Big sagebrush (*Artemisia tridentata*)	4.0	nd[2]	21.5
2. Cudweed sagewort (*Artemisia ludoviciana*)	4.0	nd	21.5
3. Skunkbush sumac (*Rhus trilobata*)	46.0	nd	21.4
4. Rubber rabbitbrush (*Chrysothamnus nauseosus*)	11.0	nd	21.9
5. Winterfat (2 ecotypes) (*Ceratoides lanata*)	12.0	nd	20.7
6. Nuttall's saltbush (2 ecotypes) (*Atriplex nuttallii*)	20.0	nd	22.0
B. Perennial Grass Mixture			
1. Western wheatgrass (Rosana) (*Agropyron smithii*)	13.1	10.3	25.8 (PLS)
2. Streambank wheatgrass (Sodar) (*A. riparium*)	7.1	6.6	25.6 (PLS)
3. Canada bluegrass (Reubens) (*Poa compressa*)	1.6	1.4	nd
4. Prairie sandreed (Goshen) (*Calamovilfa longifolia*)	5.3	4.1	26.3 (PLS)
5. Indian ricegrass (Paloma) (*Oryzopsis hymenoides*)	7.0	4.6	25.1 (PLS)
6. Switchgrass (Blackwell) (*Panicum virgatum*)	6.6	3.3	21.1 (PLS)
TOTAL - Perennial Grasses	40.7	30.3	150 (minimum)

[1]PLS = pure live seed

[2]nd = not determined @ time of seeding

[3]Estimations based upon literature-derived seed number/weight relationships; shrub seeds/ft2 highly tentative @ time of seeding due to lack of prior PLS analysis (for later determined actual shrub PLS/ft^2, see Table 2).

utilized in this study. Skunkbush sumac exhibited the highest overall percent pure live seed (95.6) with rubber rabbitbrush the lowest (0.7). It should be noted that locally collected winterfat and Nuttall's saltbush seed demonstrated higher percent pure live seed than commercially purchased seed.

Plummer et al (1968) stated what they felt were acceptable percent purities for all shrub species of the present study except cudweed sagewort. These were 10 percent for big sagebrush and rubber rabbitbrush, 30 percent for skunkbush sumac and Nuttall's saltbush, and 50 percent for winterfat. Seed lots for all shrub species of this study except Nuttall's saltbush had higher percent purities, with the latter species approximately 5 to 10 percent lower.

No information was available in the literature on either acceptable percent viability or percent pure live seed for the shrubs seeded. It would appear, however, that percent viabilities were low for all species except skunkbush sumac, with rubber rabbitbrush and commercially purchased (i.e., exogenous ecotype) winterfat seed viability especially poor. These low percent viabilities resulted in low percent pure live seed, especially with respect to commercially purchased winterfat, big sagebrush, rubber rabbitbush, and cudweed sagewort.

Table 2 also exhibits actual seeds per pound and pure live seeding rate data derived from laboratory seed analysis as opposed to initially estimated seeding rates based upon literature information. Numbers of seeds per pound for seedlots used derived from laboratory analysis were higher for all species than values obtained from researched literature sources, especially for big sagebrush, cudweed sagewort and rubber rabbitbrush.

Percent pure live seed (PLS) results substantially lowered pound per acre PLS seeding rates from levels originally desired for all shrub species except skunkbush sumac.

Although laboratory derived number of seeds per pound were higher than literature based numbers, these differences were for certain species not sufficient to offset the low percent pure live seed factor, which resulted in low numbers of pure live seeds per square foot for winterfat (local and commercially purchased seed) and rubber rabbitbrush. All other species, except cudweed sagewort, had numbers of pure live seeds per square foot similar to those initially desired. Cudweed sagewort was inadvertently seeded at rates to yield a much higher number of pure live seeds per square foot due to extremely high numbers of seeds per pound.

These results confirm the necessity of having accurate analyses for seedlots of direct-seeded shrubs prior to definition of bulk seeding rates. In this study, lack of seed analysis data at seeding resulted in widely variable (and often low) actual numbers of pure live seeds per unit area among shrubs seeded, due both to deviations in numbers of seeds per pound from literature values and wide variations among species in percent purity and viability. These results also confirm the low percent seed purity and/or viability inherent to many native shrub species, which may often necessitate increased bulk seeding rates.

Table 2. Laboratory seed analysis results, and associated effects on actual field seeding rates vs. rates estimated at time of seeding, Shrub Direct Seeding Study, Colstrip, Montana.

Species/Ecotype	Seed Analysis Results				Seeding Rate		PLS Number/ft²	
	% Purity	% Viability	% PLS	Seeds /lb	Bulk lb/A[1]	PLS lb/A[2]	Estimated @ Time of Seeding[1]	Actual[2]
Big sagebrush	20.1	42.4	8.5	2,343,017	4.0	0.3	21.5	18.3
Cudweed sagewort	34.3	34.6	11.9	18,259,767	4.0	0.5	21.5	199.5
Skunkbush sumac	99.6	96.0	95.6	27,127	46.0	44.0	21.4	27.3
Rubber rabbitbrush	14.8	4.5	0.7	1,189,053	11.0	0.1	21.9	2.1
Winterfat (exogenous ecotype)	45.5	19.9	9.1	127,806	12.0	1.1	20.7	3.2
Winterfat (local ecotype)	61.2	44.6	27.3	105,269	12.0	3.3	20.7	7.9
Nuttall's saltbush (exogenous ecotype)	84.0	40.8	34.3	176,838	20.0	6.9	22.0	27.9
Nuttall's saltbush (local ecotype)	80.7	45.4	36.6	167,167	20.0	7.3	22.0	28.1

[1]From Table 1

[2]Based upon results of post-seeding seed analysis

Soil and Precipitation Data

The cover (top- + sub-) soil of the study site was approximately 60 cm thick, and had a sandy loam texture (59% sand, 24% silt and 18% clay). It exhibited no apparent deleterious chemical properities when analyzed.

In terms of precipitation patterns, September, 1978 (the month of seeding) exhibited substantial, well above average precipitation. Since little or no shrub germination was observed in fall, 1978, much of this increased soil moisture may have been stored over winter and hence may have been available for seed germination and subsequent growth in the spring (Redmann 1975).

In 1979 and 1980, precipitation during the April through July period, the season of characteristically highest precipitation and plant production (Sindelar et al., 1973) was abnormally low -- roughly 50 and 30 percent of average, respectively. Compounding this low spring precipitation was the fact that sandy soils, such as those at the study site, have relatively high infiltration and percolation rates, and low water holding capacities (Redmann 1975). In times of limited precipitation, as in 1979 and 1980, such soils are especially droughty.

Field Plant Density of Seeded Shrubs

Table 3 presents comparisons of seeded shrub/forb species mean density by treatment and by species for two sampling dates in each of 1979 and 1980. Data for local winterfat and Nuttall's saltbush ecotypes were not included in this analysis due to the fact that the perennial grass mixture treatment was not applied to these species ecotypes.

Data for June 11, 1979 reflect initial shrub species establishment in terms of density. Three species, Nuttall's saltbush, skunkbush sumac and cudweed sagewort, exhibited significant differences between with/without perennial grass mixture treatments and highest overall mean densities among shrubs seeded (in that order). Nuttall's saltbush and skunkbush sumac established in significantly higher densities when seeded alone than when concurrently seeded with the perennial grass mixture. Cudweed sagewort, somewhat surprisingly, demonstrated opposite results. The other three species exhibited no significant differences between treatments and very low overall mean densities.

The lack of significant differences between treatments for winterfat and rubber rabbitbrush and their low overall mean densities were felt to be related to extremely low number of pure live seeds per square foot actually seeded (see Table 2).

Nuttall's saltbush and skunkbush sumac, conversely, had higher numbers of pure live seeds per square foot, which were similar to concentrations initially desired. For these two species, sufficient numbers of pure live seeds were apparently applied to the soil to allow germination and establishment of a sufficient number of seedlings to initially colonize the site and compete with other concurrently establishing vegetation. In this situation, the initial

Table 3. Comparison of seeded shrub/forb species mean seedling density (plants/m^2) by treatment (with and without concurrently seeded perennial grass mixture) and by species at four sampling dates, Shrub Direct Seeding Study, Colstrip, Montana, 1979 and 1980.[1]

Species	June 11, 1979		Aug. 19, 1979		May 19, 1980		July 30, 1980	
	w/PG Mixture	w/o PG Mixture	w/PG Mixture	w/o PG Mixture	w/PG Mixture	w/o PG Mixture	w/PG Mixture	w/o PG Mixture
Big sagebrush	0.37e	0.30e	0.37c	0.22c	0.30c	0.30c	0.30c	0.22c
Rubber rabbitbrush	0.44e	0.37e	0.30c	0.37c	0.07c	0.00	0.00	0.00
Winterfat	0.00	0.07e	0.00	0.00	0.00	0.00	0.00	0.00
Cudweed sagewort	2.00d	0.22e	1.11c	0.44c	0.00	0.15c	0.00	0.07c
Nuttall's saltbush	5.63b	7.33a	5.26b	6.89a	3.56b	6.81a	2.96b	4.89a
Skunkbush sumac	2.52d	3.85c	0.59c	0.15c	0.00	0.00	0.00	0.00

[1]Values within each sampling date block followed by different letters significantly different @ 5% level (Duncan's Multiple Range Test).

benefit of seeding these species alone as compared to seeding them with perennial grass mixtures was significant.

Big sagebrush, although seeded at a rate to yield comparable numbers of pure live seeds per square foot as with Nuttall's saltbush and skunkbush sumac, showed no significant differences between treatments and exhibited low overall mean seedling densities. This species was also found to be uniformly distributed in terms of density throughout the study site in sagebrush seeded plots as well as those not seeded with this species. Big sagebrush seedlings were also present outside the study site (61 plants were observed at distances up to 100 meters and farther from the site in 1980, and frequency data collected resulted in a value of 1.25 percent). Based on this information, it is believed that residual seed of this species was present in the cover soil (topsoil) prior to seeding. The apparent low success of inital germination of applied sagebrush seed is rather perplexing. One possibility may have involved a lack of overcoming seed dormancy by spring, 1979 which would account for the lack of any appreciable seedling density in seeded plots (Sindelar et al., 1974).

Cudweed sagewort was seeded at a rate that applied far greater numbers of pure live seeds per square foot than all other seeded shrubs (see Table 2). It also showed significantly higher density values when seeded with the perennial grass mixture than when seeded alone. This was not expected. This species' unexpected initial treatment response was believed to have been affected by unusual difficulties in direct seeding. The bulk seed contained a great amount of fibrous material which clung to the seeds to such an extent that uniform seed distribution throughout seeded plots was impossible. The seed could not be separated from this material in the field, and clumps of the seed-fiber mass tended to be distributed instead of single seeds. This seed distribution pattern was more pronounced in plots seeded to cudweed sagewort alone, since agitation with concurrently seeded perennial grass seeds in seeding of plots with cudweed sagewort plus perennial grasses tended to improve breakup of shrub seed-fiber masses. Since seed-fiber masses contained many seeds and the seed-fiber mass problem was greater in plots seeded to cudweed sagewort alone, it is highly probable that many seeds never made sufficient contact with the soil for proper germination. It is believed that especially uneven stands of this species in plots where seeded along was the result, thus accounting for reduced overall seedling densities.

Initial establishment densities of all shrub species were probably adversely affected by below average precipitation in the early growing season (April-June) during 1979. This limited precipitation may have had an inhibitory effect on initial establishment through reduced germination and increased subsequent seedling mortality. Although there was above average precipitation in September, 1978, it is difficult to say how much of this moisture was stored near the soil surface over winter due to the sandy nature of the soil (Redmann 1975).

Density data of August 19, 1979, May 27, 1980 and July 30, 1980 (Table 3) illustrate the deleterious effects of two successive growing seasons with very low precipitation on shrub species growth following initial establishment.

Nuttall's saltbush suffered a gradual reduction in density over the two growing seasons, and by the end of the second season its density was approximately half that of initial establishment for both treatments. However, it still maintained a signficantly higher density when seeded alone than that which occured when it was concurrently seeded with a perennial grass mixture. This demonstrates benefits of seeding this species alone rather than with perennial grass mixtures not only in terms of initial establishment, but also in terms of subsequent survival.

Nuttall's saltbush exhibited the best performance of all species in terms of initial establishment and sustained survival under conditions of drought. All other species, except skunkbush sumac, exhibited various problems in initial establishment and were not present in seedling densities sufficiently adequate to allow meaningful initial or ultimate comparisons between the seeded alone/seeded with perennial grass treatments. It is interesting to note, however, that of these other species, big sagebrush appeared to have the best performance and was able to best maintain its initial densities under both treatment effects throughout the drought period of this study.

Skunkbush sumac appeared to be most severely affected by drought conditions. After its initial establishment, it suffered a severe reduction in density in both treatments, and by the beginning of the 1980 growing season had suffered complete mortality.

Although final analysis and interpretation are presently incomplete, preliminary data indicate, as expected, substantially higher perennial grass initial density and ultimate productivity in plots seeded with shrubs plus perennial grasses than in plots seeded with shrubs alone. This increased competitive stress in plots concurrently seeded with both shrubs and grasses no doubt induced the superiority of skunkbush sumac and Nuttall's saltbush initial establishment in plots where seeded alone, as well as the ultimate superiority of Nuttall's saltbush in plots where seeded alone. Lack of such initial and/or ultimate differences in shrub density between seeding method treatments for other species may have been related to certain or a combination of the following factors: initially poor germination and/or establishment of sufficient shrub densities (discussed previously), excessive shrub mortality due to protracted drought (discussed previously), and/or effects of competition from non-seeded, volunteer plant species. The last possible factor may in final analysis prove significant, since substantial growth of volunteer "weedy" species (most notably Russian thistle) occured both in plots seeded to shrubs alone and in plots seeded to shrubs and perennial grasses concurrently.

The preceding results and discussion represent only an initial, preliminary analysis of data of this study. A study final report is forthcoming which will synthesize shrub density data presented here with results of measurements of cover, productivity, vigor and a number of other parameters for both seeded shrubs and other classes/species of vegetation. A truly comprehensive evaluation of study results will then be possible.

Field Comparison of Local vs. Exogenous Shrub Ecotype Density

Table 4 presents mean plant densities of commercially purchased (exogenous) ecotype versus locally collected ecotype winterfat and Nuttall's saltbush for 1979 and 1980.

Table 4. Mean plant density (plants/m^2) of commercially purchased (exogenous) ecotype versus locally collected ecotype seed of winterfat and Nuttall's saltbush in 1979 and 1980, Shrub Direct Seeding Study, Colstrip, Montana.[1]

Species	1979 Date 1 (June 11)	1979 Date 2 (August 19)	1980 Date 1 (May 27)	1980 Date 2 (July 30)
Winterfat (exogenous ecotype)[2]	0.07c	0.00	0.00	0.00
Winterfat (local ecotype)	0.44c	0.44c	0.30c	0.30b
Nuttall's saltbush (exogenous ecotype)[2]	7.33b	6.89b	6.81b	4.89a
Nuttall's saltbush (local ecotype)	17.04a	16.96a	8.96a	4.74a

[1]Values within hatured blocks followed by different letters significantly different at 5% level (Duncan's Multiple Range Test).

[2]For these species, exogenous ecotype comparisons made using without perennial grass mixture treatment only.

In 1979 date 1, the locally collected Nuttall's saltbush ecotype showed significantly higher initial density than the exogenous ecotype. This was due in part to the locally collected ecotype's somewhat higher number of pure live seeds per square foot when compared to that of the exogenous ecotype (see Table 2). However, the local ecotype apparently also possessed much higher germinative characteristics, in order to show a mean density approximately two times greater than that of the exogenous ecotype. Densities for both local versus exogenous ecotypes were maintained at the second sampling date in 1979.

In 1980, effects of the protracted drought became apparent for Nuttall's saltbush, particularly at the second sampling date. Although the locally collected ecotype still showed significantly higher densities over the exogenous ecotype in May, it had suffered a much greater loss in density. The exogenous ecotype better maintained its density from 1979 to 1980. This trend continued at the second (July) sampling date in 1980, by which time there was no significant difference in density between the two ecotypes.

These data patterns suggest a strong beneficiality of use of locally collected ecotype seed of Nuttall's saltbush in terms of initial establishment. However, for this particular study, it was found that the commercially obtained (exogenous) ecotype exhibited higher survival under protracted drought than the local ecotype. From this, it would appear that the exogenous ecotype (which was collected in a more arid region) was somewhat more adapted to drought conditions than the local ecotype collected in semi-arid southeastern Montana -- at least in the seedling stage.

There were no significant differences between locally collected versus commercially purchased (exogenous) ecotypes of winterfat in 1979 and 1980. This was a considered result of low numbers of pure live seeds per square foot in both cases (see Table 2). However, although there were no significant differences between the two, the locally collected winterfat ecotype did perform better than the exogenous ecotype. This was partially, but not completely, due to the fact that locally collected ecotype seed was inadvertently applied at two times as many pure live seeds per square foot as commercially purchased (exogenous ecotype) seed (see Table 2). The local winterfat ecotype also largely maintained its initial seedling density throughout the drought conditions of 1979 and 1980, whereas the exogenous ecotype exhibited ultimate complete mortality. Thus, although differences were not statistically significant, the pattern of data tends to support the premise of beneficiality of use of local shrub ecotypes for direct seeding of winterfat, both in terms of initial establishment and ultimate survival.

CONCLUSIONS AND RECOMMENDATIONS

The data analysis and results presented in this paper are preliminary in nature. Final analyses and interpretations will be presented in the forthcoming M.S. thesis of Clarke (in prep.) at Montana State University and subsequent derived professional papers. Based upon results presented in this paper, the following inital recommendations can be made relative to shrub direct seeding:

1) For meaningful derivation of shrub direct seeding rates, it is essential to conduct accurate analyses of seedlots for numbers of seeds per pound, seed purity and seed viability, since much variability in the in the above parameters can be expected not only among species but also within a given species. Relatively low purity and/or viability may often be expected with many native shrubs, as was the case with big sagebrush, rubber rabbitbrush, winterfat and cudweed sagewort in the present study.

2) For Nuttall's saltbush and, probably, winterfat, use of seed of local ecotypes may be recommended in terms of improved initial seedling establishment.

3) For Nuttall's saltbush and skunkbush sumac, seeding alone (without concurrently seeded perennial grasses) may be recommended to improve initial seedling establishment; for Nuttall's saltbush, ultimate survival was also enhanced by seeding alone.

4) For big sagebrush, results of this study indicated that volunteer seedling establishment from seed stored in salvaged-reapplied topsoil was similar to seedling establishment from directly applied seed (under seeding methods/rates employed), although absolute densities in either case were low. If improved seedling densities are to be

achieved for big sagebrush via direct seeding, additional research is warranted.

5) In terms of initial establishment, among shrub species direct seeded in the fall Nuttall's saltbush exhibited greatest success, followed by skunkbush sumac and cudweed sagewort. Marginal initial establishment was achieved with big sagebrush, winterfat and rubber rabbitbrush.

6) In terms of seedling survival during two years of drought following direct seeding, Nuttall's saltbush exhibited highest numbers of surviving seedlings followed by big sagebrush. Skunkbush sumac, rubber rabbitbrush and cudweed sagewort seedlings exhibited relatively high and/or complete drought-induced mortality.

Serious shortcomings of this study included lack of a "low" shrub seeding rate control against which to evaluate effects of the elevated seeding rates employed, and the unavailability of detailed pure live seed analysis prior to derivation and field implementation of bulk seeding rates. Although it is felt by the authors that "heavier" seeding rates may indeed be desirable to promote adequate establishment of certain shrub species on mined lands, more research is obviously needed to substantiate or disprove this. Also, in light of the overriding adverse impacts of drought on results of this study, it is strongly urged that accelerated research evaluations on feasibility and effects of temporary, initial irrigation on success of shrub direct seeding be conducted.

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SHRUB ESTABLISHMENT ON COAL AND BENTONITE CLAY MINE SPOILS[1]

by

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ABSTRACT

Shrubs and some trees are an important component of the premining landscape in Wyoming. From this perspective, they should be returned to the postmining landscape, and reclamation practices should be designed for their establishment. Research results indicate shrubs and trees can be established on coal and bentonite spoils providing managers properly select planting stock and ameliorating cultural practices. Some species responded well to certain cultural practices, others showed no response, and still others showed a deleterious response. Therefore, managers need to decide carefully on the species and establishment operations to insure the return of the shrub and tree element in the postmining landscape.

[1]Research reported here was conducted in cooperation with AMAX, ARCO, Surface Environment and Mining Program, Medicine Bow National Forest, Soil Conservation Service, South Dakota School of Mines and Technology, and the University of Wyoming.

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THE STUDY PERSPECTIVE ON SHRUBS AND TREES

Introduction

Shrubs and trees are components of the natural vegetation mosaic in nearly all of the Great Plains, but vary widely in abundance and dispersion. In the more arid portions of the region, trees and taller shrubs are found almost exclusively along drainageways and around impoundments. These areas of the landscape are zones of maximum biological activity and production. Water is a key factor because of the prevailing arid to subhumid climate.

One of the key surface mine reclamation requirements is restoration of terrain to a form similar to that before mining. Considering the characteristic undulating to rolling terrain of the surface coal mining areas of northeast Wyoming, this means the formation of drainage ways and/or water impoundments where careful treatment and management can achieve maximum enrichment of the biological potential in any planned postmining land use. Trees and shrubs are an important component of the premining landscape. For this reason they should also be returned to the postmining landscape, and reclamation practices should be designed to form topographic sites favorable for their establishment. It appears it may even be possible to establish and manage such areas in a way that they can play an even greater role in the total bio-activity than in the premining state.

Reports dealing with reclamation problems and potentials of the northern Great Plains emphasize moisture supply as the greatest limiting factor in most places (Packer, 1974; USDA, SCS 1971). A report, entitled "Rehabilitation Potential of Western Coal Lands" (Study Committee, 1973), states that in areas receiving annual precipitation of less than 10 inches per year the probability of successful reclamation is very low. The report further states that revegetation can be accomplished under such conditions only with major effort and then not with any assurance of enduring success. The report concludes that where there is more than 10 inches of precipitation per year reclamation is more feasible; however, the site-specific information needed to insure success of specific management goals is lacking.

Annual precipitation in the central Wyoming area averages about 14 inches. In 40% of years, the amount of precipitation is less than 10 inches, making the successful establishment of vegetation a high risk. The high cost of revegetation efforts and the regulatory requirements of prompt reclamation are compelling incentives for application of cultural treatments that can help insure success of initial revegetation attempts.

The purpose of this paper is to discuss the restablishment of shrubs and trees on spoils resulting from open pit mining for coal and bentonite clay. The first part will discuss research on the survival and growth of shrubs and trees on coal spoils when planted as container or bare root planting stock, irrigated or not irrigated and fertilized or not fertilized. The second part discusses the survival and growth of shrubs and two forbs planted on bentonite spoils in the greenhouse and in the field with spoil amendments of sawdust, perlite, gypsum, straw vermiculite and no amendment.

REESTABLISHMENT OF TREES AND SHRUBS ON COAL SPOIL

Introduction

The first research on coal spoil involved tests of reestablishment of tree and shrub species on a site which would be similar to those associated with waterways. This involved the use of tests of dryland reestablishment with bare root planting stock. Later phases involved tests with the use of trickle irrigation and container-grown woody plant stock.

The Belle Ayr South Mine of AMAX Coal Company, the site of the research described here, is about 18 miles SSE of Gillette in Campbell County, Wyoming. It is one of a number of coal mines along the eastern boundary of the Powder River Basin along the Wyodak outcrop (Smith et al. 1972).

Plan of Study

A study plot of two acres was laid out and fenced in the spring of 1973 on replaced overburden removed from the initial cut of the Belle Ayr Mine along Caballo Creek. The finished lift consisted of a 4- to 5-foot depth composed of the surface 10 feet of overburden previously removed in that initial cut. In this operation the overburden was deposited by end dump trucks backing up and dumping against the fill on the travel level. Thus the trucks did not travel on and compact the final lift. A blade equipped crawler tractor was then used to level and finish the surface. The resulting spoil was of a loamy texture, slightly more saline than surrounding natural soils. Nutrient levels were low for ideal plant growth (Yamamoto 1975). SCS and AMAX, prior to the start of the first (1973) growing season, seeded the area. A mixture of wester wheatgrass and green needlegrass in which a small amount of 4-wing saltbush (about ½ pound per acre) was drilled. A dryland planting of shrubs and trees was superimposed on this planting, and survival was moderately successful (over 50% survival) after two growing seasons (Orr 1977). A similar procedure was conducted on a bentonite clay mining spoil and survival was also moderately successful (Bjugstad 1979).

A second phase of study involved trickle irrigation and nonirrigation on bare root stock. The trickle irrigation system was designed to apply one gallon of water in one hour each four days to individual plants, starting as early as possible in May and continuing through September for two growing seasons. Water, obtained from a deep well, was of the following quality: Ca-8.1, Na-44.9, K-5.6, Mg-1.6, SO_4-<2 in mg/l.

A third phase of study involved the use of both container grown woody plant stock and bare root stock, ½ trickle irrigated and ½ left unirrigated for two growing seasons. These refinements, trickle irrigation and use of container grown stock, were tested on the theory that both should result in higher survival, quicker establishment, and more rapid growth of woody plants. Supplemental water should provide relief against climatic stress and the use of container grown stock should reduce transplant shock.

All plantings were weeded each spring in a 1-foot wide strip along each side of each row. A fence was constructed to exclude rabbits, deer, and antelope in order to obtain results unconfounded by animal browsing.

Species selected for trial were:

- Green ash - Fraxinus pennsylvanica lanceolata
- Russianolive - Elaeagnus angustifolia
- Silver buffaloberry - Shepherdia argentea
- Caragana - Caragana arborescens
- American plum - Prunus americana
- Ponderosa pine - Pinus ponderosa
- Rocky Mountain juniper - Juniperus scopulorum

These species were listed by the USDA, SCS (1971) as suitable for planting in the general area.

Results and Discussion

Survival four years after planting varied by species, whether planted as container stock or irrigated for two years after planting (Table 1). Therefore, a general statement cannot be made stating supplemental irrigation water increased the survival of trees and shrubs. Container stock significantly increased the survival percentage of only unirrigated Rocky Mountain juniper. Each species must be considered individually as to whether supplemental water will increase survival and if benefits are great enough to offset the additional cost of this treatment. For example the container stock costs 5 to 10 times more than bare root stock and irrigation systems are expensive.

The data indicate caragana had the highest survival with nonirrigated container stock (Table 1), but annual growth was highly variable with little, if any, benefit from irrigation (Table 2). Growth appeared to be little affected by cultural treatment for most species. However, this characteristic was difficult to measure because of the relatively slow growth of some species, for example green ash. Survival of buffaloberry, ponderosa pine, American plum and Rocky Mountain juniper was significantly higher when irrigated, but the use of container stock was of no benefit. The use of container stock significantly increased the survival rate of Rocky Mountain juniper when not irrigated, but not any other species. Consequently, careful evaluation of cultural practices must be utilized to decide on whether to use container stock or irrigate to have the highest survival of these species at the lowest cost.

Table 1.--Percentage survival of irrigated container and bare root nursery stock at the Amax Belle Ayr Coal Mine planting site, Gillette, Wyoming, four years after planting[1/]

Species	Container		Bare root	
	Irrigated	Not Irrigated	Irrigated	Not Irrigated
Green ash	55	40	80	67
Russianolive	47	40	53	60
Buffaloberry	60	47	73**	27
Caragana	93	100	87	93
Ponderosa pine	53**	0	40*	7
American plum	60	27	87**	40
Rocky Mountain juniper	93	[2/]67	93**	27

1/Percent based on 15 plants per treatment

2/Significantly different from the bare root nonirrigated at the 0.10 probability level.

*, **Significantly different from the nonirrigated at the 0.10 and 0.05 probability levels, respectively.

Table 2.--Mean current annual growth (CM)for irrigated container vs bare root nursery stock at the Amax Belle Ayr Coal Mine planting site, Gillette, Wyoming, four years after planting

Species	Container		Bare root	
	Irrigated	Not Irrigated	Irrigated	Not Irrigated
Green ash	2.1 ± 0.5**	6.7 ±[1] 2.3	5.2 ± 0.9	6.4 ± 2.3
Russianolive	10.5 ± 1.8	12.2 ± 3.4	15.4 ± 2.8	13.8 ± 3.8
Buffaloberry	6.6 ± 1.0	9.4 ± 2.0	5.0 ± 0.6*	9.6 ± 1.8
Caragana	10.6 ± 1.8	7.3 ± 0.8	11.1 ± 1.0	10.9 ± 1.0
Ponderosa pine	7.3 ± 1.0	0 ± 0.0	5.1 ± 1.2	4.5 ± 0.0
American plum	8.6 ± 2.2	5.7 ± 2.5	6.2 ± 1.1	3.3 ± 0.7
Rocky Mountain juniper	8.6 ± 0.5**	4.2 ± 0.5	4.2 ± 0.6	2.5 ± 0.6

1/ ±Standard error

*, **Significantly different from the nonirrigated respectively at the 0.10 and 0.05 probability level, respectively.

REESTABLISHMENT OF UPLAND SHRUBS ON COAL SPOILS

Introduction

In 1975, research was planned to study ways to enhance establishment and growth of woody plant species on an upland shrub site within the area of the Black Thunder Coal Mine in Campbell County, Wyoming.

No mining had yet been done; hence there were no spoils upon which to establish a study area. Therefore, ARCO contracted for removal and replacement of overburden to prepare a suitable plot area that would be essentially identical to a finished spoil area of an active mining. Approximate dimensions of the plot prepared were 200 feet wide and 400 feet long.

Plan of Study

In September 1975, plot areas were laid out and prepared for experimental planting the following spring. The area was ripped and harrowed, grass seeded, straw mulch applied (1 ton per acre) and crimped in to help stabilize the surface over winter. A wheatgrass-barley mix was planted to provide ground cover. The mix (pounds per acre) was as follows:

Barley (*Hordeum vulgare*)	30
Green needlegrass (*Stipa viridula*)	5
Slender wheatgrass (*Agropyron trachycaulum*)	5
Western wheatgrass (*Agropyron smithii*)	5
Total	45

Barley was included in hopes it would germinate during the fall of 1975 and help hold the plot surface stable through the winter months. It did not germinate until the following spring, providing cover and a companion crop the following growing season. The five woody species, all commercially grown container stock, selected for the study were:

- Fourwing saltbush - (*Atriplex canescens*)
- Big sagebrush - (*Artemisia tridentata*)
- Winterfat - (*Eurotia lanata*)
- Rubber rabbitbrush - (*Chrysothamnus nauseosus*)
- Rocky Mountain juniper - (*Juniperus scopulorum*)

Operations during the spring planting included rototilling the planting spots, placing plants at four-foot spacing, fertilizing (40-80-0 lbs./A), applying princeps[3] (for pre-emergent weed control), placing wood chip mulch, and laying out and operating the trickle

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[3] The use of trade and company names is for the benefit of the reader; such use does not constitute an official endorsement or approval of any service or product by the U.S. Department of Agriculture to the exclusion of others that may be suitable.

irrigation system. Water for the irrigation was pumped from a stockdam to a 4,000 gallon tank and subsequently to the plots with a centrifugal pump driven by a 36 volt DC motor operated from 3 12-volt batteries connected in series. The quality of the water was, Ca-43.3, Na-118.0, K-14.5, Mg-28.1, So_4-787.0 mg/l.

Regular water application[3] was started June 22, 1976. The first emitters used were "Mini-Flo"[3] with arrowgrip and adjustable orifice. Experience the first season proved that the adjustment for 1 gallon per hour delivery rate was very sensitive and time consuming. Moreover, the orifices plugged very easily. Another type of emitter was installed in 1977. This was a "Vortex"[3] emitter, the name designating a design that involves flow of a very high velocity vortex action which dissipates energy and at the same time allows use of a considerably larger orifice for a given delivery rate. There was less tendency for these emitters to plug, and they had a removable friction tight head for cleaning the orifice when they became plugged.

In 1976 and 1977, it was necessary to change and recharge batteries about every two weeks for uninterrupted operation of the pumping system. In spring 1978, a solar panel system was installed to charge the batteries. The system worked without any problems through the 1980 season (Anderson and Denison, in press).

There was considerable trouble with plugging of emitters soon after startup of the pumping system in the spring of 1978 because of dried algae in the system from the previous season. An algacide, Kararide,[3] which will not adversely effect plants, was introduced into the system periodically to prevent algal growth.

The entire study area was fenced to prevent browsing by rabbits. Deer and antelope were never in the plot exclosure.

Results and Discussion

Survival rates of the upland shrubs species in this study were similar to survival rates of the trees and shrubs at the Belle Ayr site, i.e., they showed considerable difference between species (Table 3) and were lower than expected. However, Van Epps and McKell (1980) reported similar survival rates for nine shrubs at certain sites in Utah. The survival rate of Rocky Mountain juniper in our study was excellent in most treatments, including the control. Juniper survival was moderate when the plants were fertilized and mulched-fertilized. The treatments had no effect on growth of juniper (Table 4). It appeared that the application or rate of application of fertilizer with and without surface mulching with pine wood chips had a detrimental effect on survival and growth.

Table 3.--Percentage survival of upland shrubs on coal mine spoil after three growing seasons[1]

Treatments	Fourwing Saltbush	Big Sagebrush	Rubber Rabbitbrush	Common Winterfat	Rocky Mountain Juniper
Mulched	33	22	19	11	85
Fertilized	37*	30	15	7	48**
Irrigated	[2]4	30	26	[2]4	70
Mulched Fertilized	22	30	30	[2]4	48**
Mulched Irrigated	22	59**	41	0	85
Fertilized Irrigated	26	48**	30	0	85
Mulched,Fertilized,Irrigated	37*	41	15	0	85
Control	11	19	26	0	74

[1] Percent based on 27 plants per treatment
[2] One plant remaining
*, **Significantly different from the control at the 0.10 or 0.05 probability level, respectively.

Table 4.--Mean volume[1] of foliage of upland shrubs on coal mine spoil after three growing seasons[2]

Treatments	Fourwing Saltbush	Big Sagebrush	Rubber Rabbitbrush	Common Winterfat	Rocky Mountain Juniper
Mulched	19.0 ±[3] 10.5**	23.0 ± 12.4	171.1 ± 70.6*	0.5 ± 0.2	18.0 ± 3.3
Fertilized	89.5 ± 33.6	33.0 ± 11.1	25.0 ± 13.7	5.9 ± 5.0	9.1 ± 2.5
Irrigated	39.0 ±[4] 0.0	35.3 ± 10.9	148.0 ± 18.7**	[4] 67.1	13.0 ± 1.9
Mulched Fertilized	122.5 ± 41.8	34.0 ± 12.2	46.0 ± 13.9	[4] 47.6	8.0 ± 1.3
Mulched Irrigated	44.7 ± 21.5*	30.3 ± 6.8	153.0 ± 49.1	0	10.9 ± 2.1
Fertilized Irrigated	55.0 ± 34.9	14.4 ± 4.7	24.4 ± 8.6	0	14.0 ± 2.0
Mulched, Fertilized, Irrigated	68.0 ± 32.5	31.0 ± 6.1	168.0 ± 26.5**	0	18.0 ± 4.8
Control	126.0 ± 32.1	21.0 ± 7.7	44.0 ± 11.8	0	17.5 ± 4.3

[1] Length x width x height, cubic centimeters x 1000
[2] Mean based on 27 plants per treatment
[3] ±Standard error
[4] One plant survival
*, **Significantly different from control at the 0.10 and 0.05 probability level, respectively.

Winterfat responded poorly to all treatments mainly because of difficulty of establishment. The other three upland shrubs, fourwing saltbush, big sagebrush, and rubber rabbitbrush, responded to certain cultural treatments (Table 3). Survival of fourwing saltbush was significantly higher when fertilized and mulched or fertilized and irrigated; but no treatment increased growth (Table 4). Big sagebrush has a significantly higher survival when mulched and irrigated or fertilized and irrigated. However, growth was the same irrespectice of treatment.

The survival of rubber rabbitbrush ranged from 15 to 40 percent with control survival rate at 26 percent. Aldon and Pase (1981) reported a survival rate of 88 percent for this species irrespective of treatment when dry-land planted in New Mexico. Growth in our study was substantially higher when the plants were mulched, irrigated, or mulched and fertilized and irrigated. This species also responded to the mulch and irrigate treatment, but the volume of foliage varied greatly between plants within a treatment (Table 4). Some plants were as much as 50 time larger than others. This can be expected because of the use of wild plant material containing a highly varied genetic gene pool and, by varietal selectivity of grazing by small mammals and arthropods. More research is needed to reduce variability within species to provide valid statistical analyses.

Conclusion

These data indicate the selection of cultural practices to promote survival and growth of trees and shrubs on mine spoils depends on the species. Practices should be selected with care, because some may be detrimental. For example fertilizer applied on Rocky Mountain juniper as it was in this study would be counter productive.

REVEGETATION OF RAW BENTONITE SPOILS

Introduction

Bentonite spoils from the Belle Fourche and Mowry shale formations are very difficult to revegetate because they are known to contain (1) clay of expanding lattice type (USGS 1975) and (2) high concentrations of salts including exchangeable sodium. These characteristics are inherited from cretaceous marine sedimentary deposits (USGS 1975). Salt efflorescence is exhibited at the surface of these shales resulting from high rates of evaporation and low rates of leaching.

When wet, the sodic montmorillonitic type clay swells, so that infiltration, permeability, and aeration of the spoils approach zero. When dry, the clay shrinks, cracks, and forms extremely hard crusts. Thus, plant roots suffer from lack of aeration and are injured by the cracking and crusting of the spoil. Furthermore, soluble salt concentrations at extremely high levels are known (USSLS, 1954) to have a specific ion effect on plant physiology; and also, subject the plants to damaging stress by increasing the osmotic potential of the spoil solution.

With the addition of original topsoil on bentonite spoils, some success in plant survival has been achieved by planting bare root shrub stock (Bjugstad 1979) and by seeding grass, forbs, and shrubs (Hemmer et al. 1977). In reality, much of the bentonite lands from Upton, Wyo., northwestward to Alzada, Mont., appear to have no surface soil or perhaps less than 6 inches. So the requirement of restoring the original soil to bentonite-mined lands, as meritorious as it may be, is not practical in many instances. Thus, our revegetation effort at Upton, Wyo., on the property of American Colloid Company is an experiment in establishing forbs, shrubs, and trees on raw bentonite spoils. This study was initiated to determine from both field and greenhouse trials (1) plant species most adaptive to saline and alkaline conditions, and (2) promising spoil amendments conducive to plant growth and establishment without topsoiling.

Plan of Study

Bentonite spoils were first collected and analyzed by standard agricultural soil analysis procedures (Table 5) for pilot studies in determining the rate of physical and chemical amendment applications.

The spoils were treated similarly for the greenhouse and field experiment as follows: except for the controls, all spoils were covered with woodchips, treated with gypsum, fertilized (NPK), and physically amended with organic or inorganic materials. The six spoil amendments were named and described in the following way:

(1) Control, i.e., no treatment.
(2) Gypsum: woodchip, gypsum, and NPK fertilization.
(3) Sawdust: woodchip, gypsum, NPK, and sawdust mixed into spoil at 50:50 volume ratio.
(4) Straw: woodchip, gypsum, NPK, and wheat straw mixed into spoil at 50:50 volume ratio.
(5) Perlite: woodchip, gypsum, NPK, and perlite mixed into spoil at 50:50 volume ratio.
(6) Vermiculite: woodchip, gypsum, NPK, and vermiculite mixed into spoil at 50:50 volume ratio.

The nine plant species selected for field and greenhouse pot planting trials on the basis of potential drought and alkaline soil tolerance (Wright and Bretz 1949; Gill 1949; McKell 1978) are as follows:

1. Fourwing saltbush (*Atriplex canescens*)
2. Rubber rabbitbrush (*Chrysothamnus nauseousus*)
3. Big sagebrush (*Artemisia tridentata*)
4. Common winterfat (*Eurotia lanata*)
5. Rocky Mountain juniper (*Juniperus scopulorum*)
6. Russianolive (*Elaeagnus angustifolia*)
7. Common yarrow (*Achillea millifolium*)
8. Desert globemallow (*Sphaeralcea ambigua*)
9. Scarlet globemallow (*Sphaeralcea coccinea*)

Table 5.--Chemical properties of Belle Fourche and Mowry shale spoil (samples from six randomly selected points; 0-8 inch depth)[1]

Properties	Values
Macronutrients	
NO_3 - N, lbs/ac ft.	17
NH_4 - N, lbs/ac ft.	49
P, ppm	39
K, ppm	170
Ca, meq/100 g	17.4
Mg, meq/100 g	3.7
Micronutrients	
S, ppm	326
B, ppm	2
Zn, ppm	3.2
Mn, ppm	31
Cu, ppm	4.2
Fe, ppm	102
EC, electrical conductivity, mmhos/cm	9.2
SAR, sodium absorption ratio, range	20-56
ESP, exchangeable sodium percentage, %, range	22-46
pH	
OM, organic matter, %	1.1
CEC, cation exchange capacity, mez/100 g	30

[1]Soil chemical analysis was done by the Agricultural Service Dept., United States Testing Co., Inc., Richland Laboratories (Richland, Washington 99352)

These species except for Russianolive (bare root) were obtained as a container-grown stock.

Survival counts and morphological measurements were taken to relate plant growth responses to spoil treatments. These measurements were:

1. height
2. length and width (length of widest section of plant and width measured at right angle to length)
3. leaf length
4. leaf width
5. twig length (including terminal twig)
6. number of branches
7. number of flowers
8. length of petiole
9. diameter-inch-high (woody species)

Results and Discussion

The spoil chemical analysis showed as expected, that the spoil problems were principally associated with the high salt and alkali (sodium) concentrations shown by EC, SAR, and ESP values (Table 5). Total salt concentration indicated by EC of 9.2 was far above the threshold value of 4, indicating that plant growth was restricted to highly salt tolerant species only. The ranges of SAR and ESP values indicate that the spoil is saline-alkali (USSLS 1954) and problems associated with salt toxicity, osmotic potential, and exchangeable sodium must be expected.

Exchangeable sodium appeared to be related more with properties of swelling and to a lesser degree to structural dispersion and slaking as reported for alkali soils. Although pH of about 8.5 was expected because of high SAR values (USSLS 1954), the lower pH value of 6.8 may have been due to the formation of sulfuric acid from inherent sulfate ions (USSLS 1954, Allen 1977) which neutralizes the alkaline effects of the spoil. A high level of sulfur seems to support this supposition.

Although few statistically significant differences between treatment and control effects on plant growth were detected in the greenhouse, treatments in general appeared to enhance plant growth in both the greenhouse (Table 6) and field trial plants. Spoil treatment effects varied with plant species and no single morphological measurement was best to assess plant responses. However, without discussing the treatment effects on plant morphology species by species, the general conclusion after nine months of growth in the greenhouse was that common yarrow on the average responded best to all treatments in comparison to control treatment. Sawdust, perlite, and vermiculite were in general the best treatments in promoting growth and survival in the greenhouse.

Table 6.--Average morphological measurements of eight plant species as related to six treatments on bentonite spoils grown in a greenhouse.

	PLANT SPECIES							
Treatment	Fourwing Saltbush	Rubber Rabbitbrush	Big Sagebrush	Common Winterfat	Rocky Mtn. Juniper	Russian-olive	Common Yarrow	Desert Globemallow
Height								
Sawdust	32.2[1] ± 3.6	25.0 ± 1.6	8.5 ± 0.5	25.1 ± 3.0	31.1 ± 1.4	55.5 ± 0.0	15.4 ± 0.9***	34.9 ± 5.0*
Perlite	31.4 ± 2.8	27.7 ± 2.0	9.4 ± 1.1	27.5 ± 8.6	30.5 ± 1.3	28.5 ± 0.0	13.6 ± 1.6*	35.6 ± 3.6**
Gypsum	40.4 ± 9.7	28.1 ± 2.9	5.8 ± 1.2	21.9 ± 6.0	30.3 ± 2.9	12.0 ± 0.0	16.6 ± 2.7**	29.8 ± 4.8
Straw	28.8 ± 3.0	21.2 ± 3.2	5.7 ± 0.6	22.0 ± 7.0	31.0 ± 2.0	15.5 ± 0.0	10.0 ± 0.0	25.8 ± 4.4
Vermiculite	35.9 ± 5.2	34.5 ± 4.1	7.3 ± 1.0	32.7 ± 5.4	32.1 ± 1.2	43.2 ± 2.4	12.8 ± 3.8	32.8 ± 5.2
Control	28.1 ± 3.8	26.9 ± 2.8	6.0 ± 2.0	22.7 ± 3.2	32.1 ± 1.4	- -	8.6 ± 1.8	19.8 ± 5.2
Length								
Sawdust	28.9 ± 3.6	19.5 ± 1.1	5.1 ± 1.0	18.0 ± 3.3	18.0 ± 2.3	27.5 ± 0.0	21.9 ± 1.4**	37.1 ± 4.3***
Perlite	26.8 ± 5.0	20.7 ± 2.5	4.7 ± 0.6	18.3 ± 6.3	17.5 ± 1.0	23.5 ± 0.0	20.7 ± 2.9*	31.1 ± 2.4**
Gypsum	33.9 ± 8.4	21.4 ± 2.8	4.0 ± 0.4	15.0 ± 5.0	16.9 ± 2.2	5.2 ± 0.8	19.1 ± 2.6	32.0 ± 2.6***
Straw	29.0 ± 4.8	12.1 ± 1.6	3.8 ± 0.3	18.9 ± 5.1	19.7 ± 2.0	17.5 ± 0.0	15.5 ± 0.5	27.7 ± 4.1
Vermiculite	34.5 ± 7.0	25.7 ± 3.9*	5.0 ± 0.7	25.4 ± 4.5	16.6 ± 1.0	29.0 ± 2.6	14.1 ± 4.1	33.3 ± 4.3**
Control	21.8 ± 4.3	16.8 ± 1.8	4.5 ± 0.5	14.2 ± 2.3	20.5 ± 1.8	- -	13.1 ± 2.7	21.8 ± 1.8
Width								
Sawdust	19.4 ± 3.3	9.5 ± 1.1	3.5 ± 0.7	13.2 ± 2.4	11.5 ± 1.6	19.0 ± 0.0	17.4 ± 1.7**	23.8 ± 1.4**
Perlite	19.1 ± 4.8	12.2 ± 1.2	3.2 ± 0.1	11.5 ± 3.5	10.7 ± 0.7	18.0 ± 0.0	15.8 ± 2.4*	16.2 ± 2.6
Gypsum	13.5 ± 2.8	12.4 ± 2.2	3.0 ± 0.2	6.4 ± 2.5	10.2 ± 1.1	4.2 ± 0.2	14.4 ± 2.4	15.3 ± 1.8
Straw	17.8 ± 1.5	8.6 ± 1.8	3.0 ± 0.2	10.2 ± 2.8	12.8 ± 1.0	12.0 ± 0.0	12.8 ± 0.2	15.1 ± 1.5
Vermiculite	24.4 ± 2.3	13.7 ± 1.2**	3.8 ± 0.6	16.9 ± 2.5	11.1 ± 1.1	22.7 ± 2.5	9.2 ± 2.6	19.6 ± 2.5
Control	17.5 ± 3.1	9.7 ± 1.0	3.8 ± 0.2	10.8 ± 2.7	12.6 ± 1.3	- -	9.1 ± 2.2	17.3 ± 1.5
Number of Branches								
Sawdust	23.0 ± 4.6	4.7 ± 1.2	1.5 + 0.5	9.5 ± 2.4	25.5 ± 1.4	13.0 ± 0.0		
Perlite	17.3 ± 3.2	4.0 ± 0.7	1.6 ± 0.6	6.0 ± 1.7	23.3 ± 0.9***	5.0 ± 0.0		
Gypsum	11.7 ± 2.0	4.4 ± 1.4	1.0 ± 0.0	8.0 ± 5.1	25.5 ± 2.0	2.0 ± 0.0		
Straw	15.2 ± 3.6	3.0 ± 1.3	1.0 ± 0.0	4.0 ± 1.7	32.7 ± 3.6	7.0 ± 0.0		
Vermiculite	18.0 ± 2.9	3.8 ± 0.4	2.0 ± 0.8	12.0 ± 6.8	34.2 ± 4.7	7.0 ± 0.0		
Control	14.8 ± 3.1	2.6 ± 0.8	1.5 ± 0.5	5.0 ± 1.5	28.1 ± 0.9	- -		
Twig Length								
Sawdust	7.8 ± 0.6	14.0 ± 0.9	5.8 ± 1.4	9.3 ± 1.0	6.3 ± 0.2	8.6 ± 1.7		
Perlite	11.3 ± 3.2	14.2 ± 1.2	6.4 ± 1.4	10.1 ± 2.7	6.1 ± 0.2	13.7 ± 2.8		
Gypsum	11.0 ± 1.7**	12.4 ± 1.5	4.4 ± 1.3	6.7 ± 1.4	6.1 ± 0.2	2.6 ± 0.3		
Straw	9.0 ± 0.9	10.2 ± 1.8	5.7 ± 0.6*	9.6 ± 2.5	6.9 ± 0.3	5.6 ± 0.8		
Vermiculite	9.2 ± 1.0	18.6 ± 2.1	3.8 ± 0.8	9.8 ± 1.6	5.9 ± 0.2	18.3 ± 2.0		
Control	6.7 ± 0.8	13.8 ± 2.5	3.2 ± 1.4	8.7 ± 1.8	6.6 ± 0.2	- -		
Number of Leaves								
Sawdust	655 ± 148	99 ± 23	119 ± 3***	416 ± 66		105 ± 0	41 ± 5	44 ± 6
Perlite	532 ± 148	81 ± 16	132 ± 26***	408 ± 132		37 ± 0	38 ± 6	64 ± 10
Gypsum	450 ± 145	82 ± 15	59 ± 10*	306 ± 71		12 ± 1	40 ± 5	47 ± 11
Straw	510 ± 119	55 ± 22	68 ± 1	211 ± 51		51 ± 0	32 ± 12	34 ± 6
Vermiculite	576 ± 94*	106 ± 14*	70 ± 6	490 ± 92		86 ± 6	26 ± 8	53 ± 14
Control	311 ± 93	64 ± 15	66 ± 1	304 ± 74		- -	22 ± 10	49 ± 7
Leaf Length								
Sawdust	1.6 ± 0.09	3.1 ± 0.11	1.1 ± 0.04	0.9 ± 0.04		3.9 ± 0.18	3.7 ± 0.34***	1.7 ± 0.06
Perlite	1.7 ± 0.10	3.2 ± 0.10	1.0 ± 0.03	0.9 ± 0.06		3.7 ± 0.26	6.4 ± 0.37**	2.1 ± 0.07
Gypsum	1.6 ± 0.09	3.2 ± 0.11	1.0 ± 0.04	0.9 ± 0.05		2.4 ± 0.10	5.5 ± 0.29	1.8 ± 0.06
Straw	1.5 ± 0.09	2.7 ± 0.10	1.2 ± 0.04	0.9 ± 0.04		2.9 ± 0.08	4.8 ± 0.34	1.8 ± 0.05
Vermiculite	1.6 ± 0.10	3.4 ± 0.11	1.3 ± 0.05	1.0 ± 0.04		3.6 ± 0.13	5.7 ± 0.37	1.6 ± 0.07
Control	1.5 ± 0.13	3.1 ± 0.10	1.1 ± 0.07	0.9 ± 0.05		- -	5.1 ± 0.35	2.1 ± 0.06

[1]Treatment averages are expressed in centimeters except for number of branches and number of leaves (mean ± standard error).

*, **, *** Significantly different from control respectively at the 0.10, 0.05, and 0.01 probability level.

Survival percentages of greenhouse plants, based on six plants/species/treatment, in raw bentonite spoils after 17 months were as follows: desert globemallow (94), fourwing saltbush (92), rubber rabbitbrush (89), winterfat (64), big sagebrush (64), common yarrow (53), Rocky Mountain juniper (39), and Russianolive (17).

At the Upton field trials (20 plants/species/treatment) there was no consistent response of the morphological measurements to treatment, and the data confounded also from inconsistent survival. There is evidence that the controls produced poorer survival since no control species except fourwing saltbush survived. Plantings of Russianolive died after less than two weeks, and further documentation of this species was discontinued. Survival in the field after two growing seasons was totally different than that recorded in the greenhouse. Fourwing saltbush, which performed very well in the greenhouse, had the highest average survival of 52% and survived under all field treatments. Survival was higher with perlite, vermiculite, and gypsum treatments for this species.

Common yarrow did not survive with control treatment, but its average survival of 20% with treatments is noteworthy. Sawdust, straw and vermiculite treatments produced higher survival rates for common yarrow. The survivals (% of 20 plants/species/treatment) of other plants were: big sagebrush (4), scarlet globemallow (2), Rocky Mountain juniper (0), and rubber rabbitbrush (0).

Superior halophytic capabilities exhibited by fourwing saltbush may be due to osmotic adjustment by solute accumulation (Waisel 1972). It may also be due to the plant's ability to preferentially absorb certain ions and exclude others. According to the data of Wallace and Romney (1972) and Wallace et al. (1973), several Atriplex species absorb large amounts of sodium but only minute quantities of magnesium. Thus, according to Richardson and McKell (1980) different effects of specific ions in the soil solution on plant growth may not be due only to the degree of ion toxicity but also to differences in osmotic adjustment caused by different rates of ion absorption. The need for sodium by many species of Atriplex was also established by the report of Brownell (1979).

In contrast to fourwing saltbush, common yarrow did not survive in a control medium. Field observations of surviving common yarrow indicate that this species seems to adapt well with treatment. Similarly, the few remaining scarlet globemallow and big sagebrush are showing surprisingly good vigor. A species such as common yarrow, exhibiting poor natural adaptability, may successfully establish itself with suitable treatment of raw bentonite spoils.

Conclusion

Results of this study suggest that growth and survival of salt tolerant plants in bentonite spoils were benefited by treatment. Mulching, fertilizing (NPK), chemical binder (gypsum), and physical amendments (sawdust, straw, perlite, vermiculite) have all contributed to some degree in promoting establishment of plants in a saline-alkali spoil which becomes essentially impermeable with swelling. The physical amendments provide rapid improvements in physical conditions that are often unattainable with chemical binder only.

Spoil treatment effects varied with plant species and no morphological measurement was best to assess plant growth responses in the greenhouse. Sawdust, perlite, and vermiculite were the best treatments in promoting growth and survival in the greenhouse.

Fourwing saltbush naturally adapts to bentonite spoils. Greenhouse and field trials confirmed that this species also responds to spoil amendments. Common yarrow did not survive in the untreated plots but appears adaptable to treated spoils. The field experiment has not persisted long enough to justify long range performance predictions for these two plant species. However, this study demonstrated that it may be possible to successfully revegetate bentonite spoils with desirable plant species and encourages further screening of other plant species with new spoil amendments.

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THE EFFECTS OF MULCHES AND FERTILIZER ON VEGETATION ESTABLISHMENT IN SOUTHWESTERN WYOMING

by

Ronald K. Smith[1]

ABSTRACT

The use of mulches and fertilizers have generally been recognized as beneficial to the establishment and production of vegetation in the arid west. Seven combinations of mulch and fertilizer treatments were evaluated for their effectiveness in aiding seedling establishment and biomass production. Wild (grass) hay mulch applied at two tons per acre proved far superior to fabric mulch and non-mulched treatments for seedling establishment of grasses and various species of *Atriplex* but proved to be detrimental for shrub biomass production. Fertilization benefited the establishment of grass and weedy species but had little or no effect on establishment of seeded shrubs. Fertilizers did however have a positive effect on the individual weights of all species planted. Fabric mulch was a detriment to the establishment of winterfat, had little or no effect on the establishment of grasses and the three *Atriplex* spp. planted, and benefited the establishment of weedy species.

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INTRODUCTION

A notable amount of information has been written on the pros and cons of mulching disturbed areas in order to increase the porbability of vegetation establishment. It has generally been agreed upon that mulching benefits revegetation efforts by temporarily providing protection for the soil surface against erosion, retarding evaporation, increasing infiltration of rainwater, protecting the soil and seed against the impact of raindrops, intercepting surface runoff, reducing soil temperature ranges and generally increasing seedling establishment (Bond and Willis, 1969, Meyer et al., 1970; May et al., 1971; Meyer et al., 1971: Springfield, 1971; Kay, 1978). Conversely (Hopkins, 1954) found that mulch can retard the initiation of growth because the soils warmed more slowly than normal. Weaver and Rowen (1952) concluded that too much mulch caused excessive water stress by intercepting precipitation followed by evaporation. Gould et al. (1975) felt that hay and straw mulching may be detrimental to the establishment of native range plants due to the competition from seeds contained within the mulch.

Researchers also differ as to recommended types of effective mulch. Packer et al. (1976) indicated that straw was the most effective and widely used of the common mulches. Dudeck et al. (1970) found excelsior mat or jute to yield the best seedling grass plots of eleven mulch treatments tested. Mason et al. (1980) found that standing stubble resulted in greater water infiltration, trapped more snow, and gave longer lasting protection than crimped straw.

The use of fertilizers is also a controversial subject in the arid west. Dwyer (1970) found that fertilizers are not effective in areas receiving less than 14 inches of annual precipitation in New Mexico and Cook (1965) has stated that at least 11 inches of precipitation is needed for efficient use of fertilizers on Utah rangelands.

On the other hand, DePuit and Coenenberg (1979), Cook and Redente (1980), and others have found that visual as well as measurable plant growth response will result from the fertilization of arid areas. Berg (1980) suggested that fertilization of revegetated areas benefited annual weedy species and perennial grass which resulted in moisture competition to woody species that do not respond to fertilization.

The research reported here includes the first-year results of a study to determine the effects of seven combinations of mulching treatments and fertilization on grass and shrub establishment on a disturbed site at the Stauffer Chemical Company of Wyoming Big Island Mine and Refinery.

DESCRIPTION OF THE STUDY AREA

An examination of reclamation research of disturbed lands that has been conducted over the past decade reveals a great amount of seemingly conflicting data. I believe the reason for this phenomenon to be that reclamation in the arid west is critically site specific. I therefore feel it is important to include in each report a description of the important physical factors that may affect the research results.

Location

The Stauffer Chemical Company of Wyoming Big Island Mine and Refinery is located in west-central Sweetwater County, Wyoming; approximately 15 air miles northwest of the City of Green River, Wyoming.

The specific study site is located approximately 1 mile north of the Stauffer Plant site at a closed sanitary landfill.

Geology

The Stauffer Mine Permit Area is located within a large synclinal basin known as the Green River Basin. The area is made up of the Wilkens Peak, member of the Green River Formation. The extensive trona beds which underlie the area were formed as Lake Gosuite shrank in size (Bradly, 1964).

Climate

General Description of Climate

McKell (1978) stated that "efforts to revegetate disturbed areas...in arid regions have generally met with failure because of the harsh environmental conditions and lack of suitable technology." Moisture has generally proven to be the most critical environmental condition effecting reclamation in the arid west. Therefore a description and analysis of climatic conditions, particularly precipitation, may be necessary in order to properly evaluate results obtained from research.

According to Koppen's classification of climates (Trewartha, 1954) this region would be considered a "BSK" climate or a climatic type where the potential evapo-transpiration rate exceeds the average annual precipitation (B), semi-arid or steppe (S) and the average temperature of the coldest month of the year is less than 32°F (K).

Temperature

The area's annual range in temperature is very great and may vary as much as 144°F. Daily fluctuations in temperature can also be very great. It is usually these extremes rather than the means which effect the abundance and distribution of plants and animals. July, on the average, is the hottest month of the year with a mean temperature of 69.0°F and January is the coldest month with a mean temperature of 18.7°F.

The long term average frost free period for the area is 103 days, although freezing temperatures have occurred during every month of the year. The last day of frost in the spring, on the average, occurs on May 31, and the first day of frost in the fall typically occurs on September 12.

Precipitation

The average annual precipitation for the area is less than 8 inches. The annual precipitation is also quite unpredictable, with periodic drought the rule rather than the exception. Highest amounts of precipitation, however, typically occur in the spring and again in the fall. Approximately 40% of the annual precipitation occurs as snow with an average annual fall of 30.4 inches. Precipitation occurring as snow has several peculiarities. It usually occurs after the ground is frozen so any snow which melts is subject to runoff rather than percolation into the soil. Snow is also blown about and distributed in uneven patterns. Areas, such as hill tops, windward sides of hills, and vegetation accumulate little or no snow. Conversely, areas such as gullies, leeward sides of hills, and shrubs may receive relatively large amounts of snowfall. Snow is also vulnerable to sublimation. Sixty to eighty percent of an annual snowfall may be sublimated (May et al, 1971). It would not be unreasonable to assume that only 60 percent or less of the annual precipitation in any given year is available for vegetation use. A moisture deficit exists during most of the growing season in this area. This is due to the low amount of summer precipitation coupled with a high evapo-transpiration rate. The annual potential evapo-transpiration rate at the U.S. Weather Bureau's Green River Station averaged 49.7 inches over a twelve year period. Figure 1 shows precipitation patterns during the last four years.

Soils

The majority of soils in this area belong to the order known as Aridisols and to the sub-order argids. These soils are defined as mineral soils, found mostly in dry climates. All horizons are dry more than 6 months of the year. The soils have pedogenic horizons and are low in organic matter. The soils have an ochric epipedon, generally light in color. They may have a horizon of calcium carbonate, gypsum, or other more soluble salt accumulation. The soils usually also have a horizon of clay accumulation (Bradley, 1964).

Particle size analysis of soils at the project site showed the soils to have a silty clay texture. Average pH and electrical conductivity of the soil saturation paste were 8.1 and 6.2 mmhos/cm respectively. The average SAR was 13. The soils consisted of an unconsolidated mixture of native topsoil and subsoil.

MATERIALS AND METHODS

An area formerly used as a sanitary landfill was selected as the experiment site. This site was prepared for seeding during the second week of March, 1980, by first chiseling, followed by harrowing of the site. Sixteen 1/100 acre (20.87' x 20.87') quadrats were then permanently staked at the site. It was decided that seven different treatments would be tested at the site. The treatments included: (1) Barley Stubble, (2) Barley Stubble-Fertilized, (3) Fabric Mulched-Fertilized-Seeded, (4) Hay Mulched-Seeded, (5) Hay Mulched-Fertilized-Seeded, (6) Seeded, (7) Fertilized-Seeded. Each treatment was

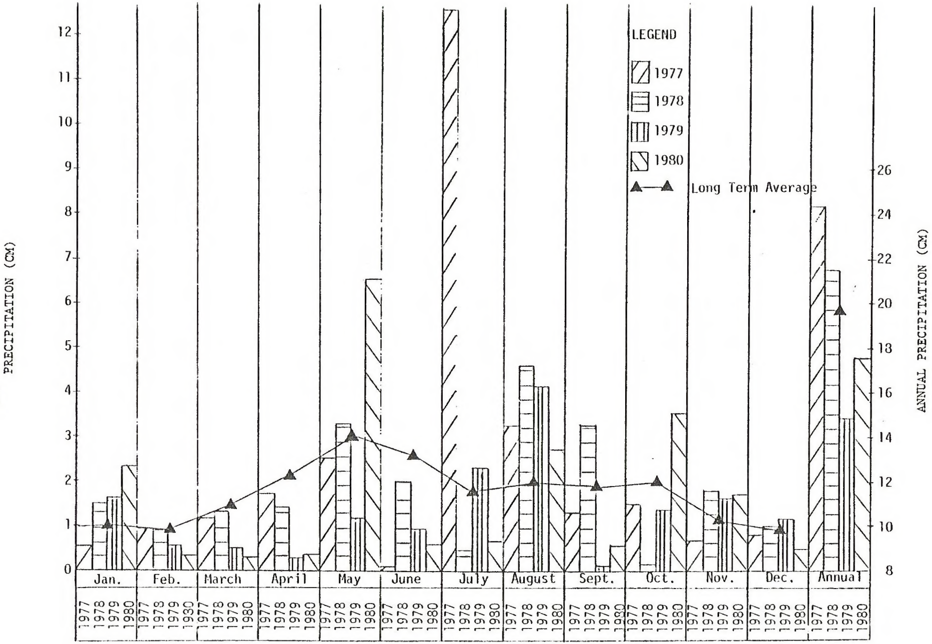

Figure 1. Precipitation Summary Green River, Wyoming, 1977-1980

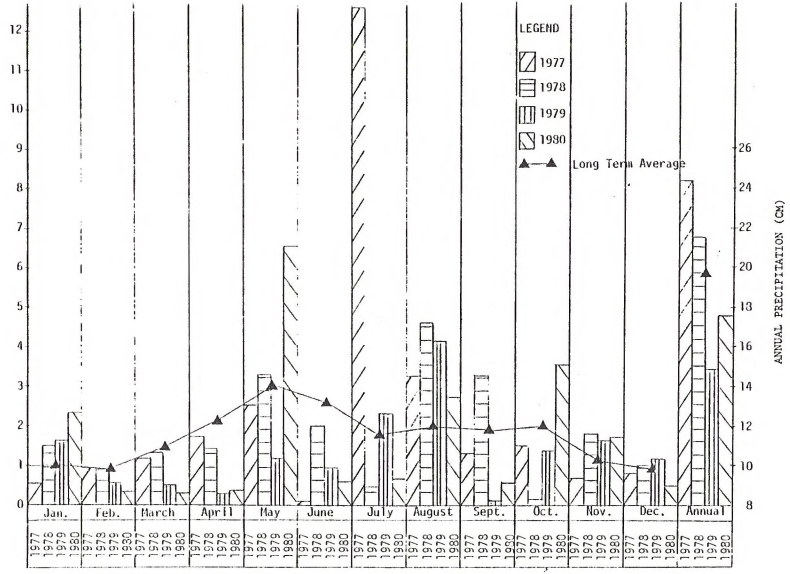

Figure 1. Precipitation Summary Green River, Wyoming, 1977-1980

replicated at least twice and up to four times. The four barley stubble plots were broadcast seeded April 3, 1980, with 91 grams PLS per 1/100 acre quadrat of annual barley (Hordeum vulgare) while the remaining twelve quadrats were broadcast seeded April 3, 1980, with 4 grams PLS of Gardners saltbush (Atriplex gardneri), 5 grams PLS of shadscale (Atriplex confertifolia), 5 grams PLS of four-wing saltbush (Atriplex canescens), 2 grams PLS of winterfat (Ceratoides lanata), 15 grams PLS of western wheatgrass (Agropyron smithii), 15 grams PLS of bluebunch wheatgrass (Agropyron spicatum), 13 grams PLS of Indian ricegrass (Oryzopsis hymenoides), 16 grams PLS of alkali sacaton (Sporobolus airoides), and 16 grams PLS of Russian wildrye (Elymus junceus) for a total of 91 grams PLS per 1/100 acre quadrat.

On April 4, 1980, 227 grams of 20-10-5 fertilizer was applied to each of the quadrats requiring fertilizer. All of the 16' quadrats were then raked to simulate drilling of the seed. Over the next three days, mulching of the plots was accomplished. Six quadrats received a wild (grass) hay mulch at the rate of two tons/acre or 40 pounds/quadrat. The hay mulch was crimped in two directions with the aid of a shovel. Two of the quadrats were mulched with an erosion control fabric which consisted of a combination of paper strips woven into a knitted mesh.

On September 29 through October 31, the quadrats were sampled for number of seedlings and also biomass production. Eight 2' x 2' plots were randomly selected in each 1/100 acre quadrat in order to obtain the sample. Individuals of all species contained within the boundaries of the eight plots were counted, however only those species that were planted were clipped for the biomass determination. The biomass determination was made by weighing the 72 hour air dried plants to the nearest .1 gram. Most of the grass seedlings had not matured enough to produce seed and therefore could not be positively identified. The seedling numbers and biomass determination for the grasses was therefore done as a composite of all the grass species. The three species of Atriplex were also lumped together for the biomass determination.

RESULTS

Probably the most important test of effectiveness for the mulch and fertilizer treatments is seedling establishment. Table 1 shows the number of seedlings/treatment sample. Note that the hay mulched-seeded treatment was replicated four times while the other treatments were replicated only twice. The figures presented in Table 1 for the hay mulched-seeded treatment have been divided by two so that an equal comparison can be made with the other treatments. As can be seen in Table 1, grass establishment varied considerably from treatment to treatment. Grass establishment in the quadrats treated with wild hay mulch and fertilizer was 1.6 times greater than in the plots mulched with wild hay but not fertilized. Grass establishment in the fabric mulched and fertilized quadrats was 3.2 times lower than the hay mulched and fertilized quadrats and 1.9 times lower than the hay mulched, non-fertilized quadrats.

Grass establishment in the fabric mulched and fertilized quadrats was nearly identical to grass establishment in the fertilized and non-mulched quadrats (Table 1). Grass establishment in the fertilized non-mulched plots was 1.6 times as great as in the non-fertilized, non-mulched quadrats (Table 1). All of the above results were statistically significant at the 10% level.

TABLE 1

TOTAL NUMBER OF INDIVIDUAL PLANTS/TREATMENT SAMPLE

	PLANTED SPECIES						INVADER SPECIES			PLANTED SPECIES
	Grasses	Atga	Atca	Atco	Cela	Hovu	Koam	Hagl	Other	% of Total
Wild Hay Mulched Fertilized, Seeded	948	11	10	2	136	0	326	3	26	76
Wild Hay Mulched Seeded	576*	8*	15*	0	73*	1*	66*	0	6*	90
Fabric Mulched Fertilized Seeded	294	2	12	0	44	2	510	4	2	41
Fertilized Seeded	288	12	0	0	72	0	114	4	1	76
Seeded	176	4	8	0	86	0	36	4	0	87
Stubble Mulched Fertilized	6	2	2	0	0	20	278	6	2	9
Stubble Mulched	1	0	0	0	0	6	168	6	4	4
TOTALS	2,289	39	47	2	411		1,498	27	41	64

* Total Sample Number Divided by 2.

As can be seen in Table 1, establishment of barley was not successful. The barley seed germinated well and appeared as if a good stand would develop. However, in late April, several large flocks of Brewers blackbirds (Euphagus cyanocephalus) were noted in the barley quadrats. Examination of the quadrats showed that the birds had pulled up the small seedlings from the soft, moist earth and had eaten the seed. Evidence was found that indicated that desert cottontail rabbits (Sylvilagus auduboni) and whitetail jackrabbits (Lepus townsendi) also ate much of the barley. No evidence was found to indicate that any of the other species planted suffered greatly from grazing.

Table 1 shows very interesting results in shrub establishment. An examination of establishment of the three species of Atriplex that were planted shows that the hay mulched and fertilized quadrats and the hay mulched and non-fertilized yielded nearly equal results. The establishment of Atriplex from these two treatments nearly doubled the Atriplex establishment of the other treatments. Apparently, fertilization had little or no effect on establishment of Atriplex. The hay mulch apparently provided a much better environment for Atriplex seedling survival than the fabric mulched quadrats and the non-mulched plots.

It was noted early in the summer that very few shadscale (Atriplex confertifolia) seedlings had emerged. According to the shipper, the germination percentage for the shadscale was rated at 63%. Subsequent laboratory experiments however showed actual germination to be 9%. This is the probable explanation for the absence of shadscale in most of the samples. The fact that this species can lay dormant for many years before germinating, probably accounts for the low seedling establishment rate.

Establishment of winterfat (Ceratoides lanata) in those quadrats that were hay mulched appeared to be affected by fertilization. Establishment of this species in the hay mulched and fertilized quadrat was nearly 1.9 times as great as in the hay mulched, non-fertilized treatment. The data indicates that the fabric mulch hindered establishment of winterfat (Table 1). The fabric mulched, fertilized treatment had the lowest rate of winterfat establishment of any of the treatments. Little difference in establishment was noted in the non-mulched fertilized treatment and the non-mulched, non-fertilized treatment. The establishment of winterfat in these two treatments was also similar to winterfat seedling establishment in the hay mulched, non-fertilized treatment (Table 1). Figure 2 graphically displays establishment of planted species.

A heavy invasion of weedy species was seen at the project site. Greenmolly summercypress (Kochia americana) was the most abundant of these invader species. Other weed species identified in the study area included common halogeton (Halogeton glomeratus), Russian thistle (Salsola kali), tansymustard (Descurania spp.), and milkvetch (Astragalus spp.). The latter two weeds were found mainly in the hay mulched quadrats and probably were carried in with the hay.

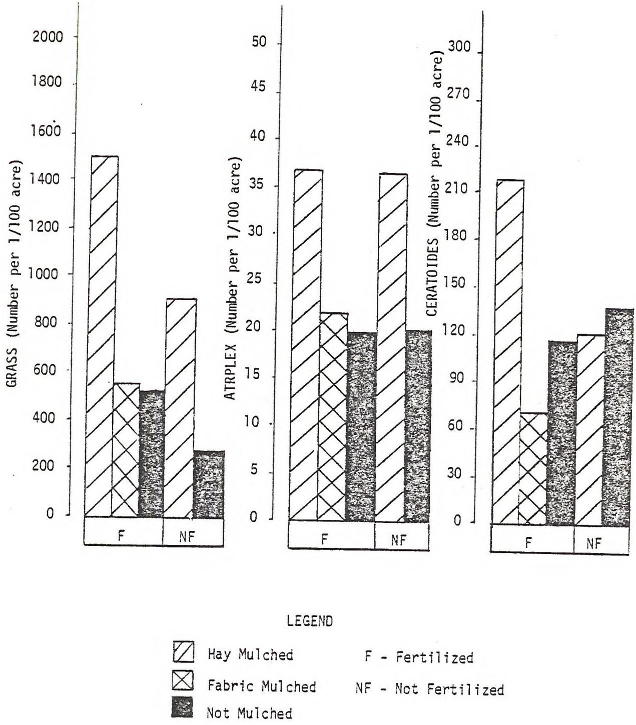

FIGURE 2. Number of plants per 1/100 acre for each treatment.

TABLE 2

TOTAL WEIGHT AND NUMBER OF GRASSES AND SHRUBS/TREATMENT SAMPLE

TREATMENT	GRASSES			ATRIPLEX			CERATOIDES			TOTALS		
	Number	Weight (grams)	Wt/Ind (grams)	Number	Weight (grams)	Wt/Ind (grams)	Number	Weight (grams)	wt/Ind (grams)	Number	Weight (grams)	Wt/Ind (grams)
Wild Hay Mulched Fertilized, Seeded	948	64.6	0.068	23	45.3	1.970	136	52.4	0.385	1.107	162.3	0.147
Wild Hay Mulched Seeded	576*	27.5*	0.048	23*	14.9*	0.648	73*	23.6*	0.323	672*	66.0*	0.098
Fabric Mulched Fertilized, Seeded	294	20.2	0.069	14	23.2	1.657	44	19.0	0.432	352	62.4	0.177
Fertilized Seeded	283	15.6	0.054	12	52.6	4.383	72	57.8	0.803	372	126.0	0.339
Seeded	176	6.6	0.038	12	44.2	3.683	86	54.5	0.634	274	105.3	0.384

* Total Sample Divided By 2.

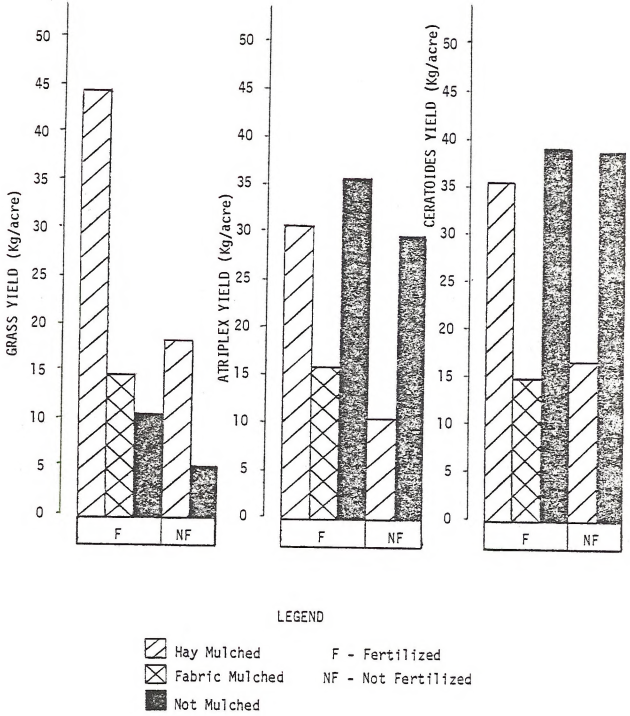

FIGURE 3. Dry-Weight biomass production for each treatment.

Table 1 shows that fertilization in all cases had a positive effect on the establishment of weedy species. The fabric mulch also appeared to aid the establishment of weeds. Weed numbers in this treatment were far in excess of weed numbers in any of the other treatments (Table 1). Percentage of planted species compared to the total of all species was also lowest in this treatment (Table 1).

Results show that fertilization had a positive effect on the weight/individual of the grasses and shrubs (Table 2). The mulches, both the hay and the fabric mulch had a negative effect on shrub weights, but a positive effect on grass weights when combined with fertilization. These results were statistically verified at $p = .10$. Figure 3 graphically displays biomass production in the various treatments.

CONCLUSIONS

1. Mulching with wild hay at two tons/acre had a positive effect on seedling establishment of grasses and three species of *Atriplex*. The mulch apparently had little or no effect on the establishment of winterfat.
2. Fabric mulch had little or no effect on the establishment of grass and *Atriplex* seedlings and a negative effect on the establishment of winterfat.
3. Fertilization with 50 pounds/acre 20-10-5 fertilizer positively affected seedling establishment of grasses but had no effect on *Atriplex* and winterfat establishment.
4. A combination of wild hay mulch and fertilizer treatment was superior to wild hay mulch with no fertilizer for the establishment of winterfat.
5. Fertilizer had a positive effect on the establishment of weedy species.
6. The fabric mulch benefited the establishment of weedy species.
7. Hay and fabric mulch had a detrimental effect on individual weights of *Atriplex* and winterfat.
8. Fertilizer had a positive effect on individual weights of all grasses and shrubs planted.

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COMPARATIVE RESULTS OF
SHRUB ESTABLISHMENT IN
ARID SITES

by

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and

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ABSTRACT

Shrub establishment is a key factor in the reclamation of disturbed arid lands where environmental extremes exceed the limits of conditions considered within the capability of conventional reclamation practices. With the establishment of shrubs, important ecosystem processes are initiated such as accumulation of litter and soil particles, nutrient cycling and soil stabilization. Because of the importance of shrubs to arid ecosystems the extra cost and effort involved in establishing shrubs by transplanting may well be worth the additional cost of plant materials and labor.

Establishment studies in the oil shale region of northeastern Utah where annual precipitation averages 8.5 inches (21.5 cm) have shown the value of container grown transplants over bare root transplants, spring planting over fall planting and transplanting over direct seeding. Control of weedy plant competition from Salsola Kali and Bromus tectorum for two years yielded survival of up to 88 percent. In another competition study, survival was 71 percent where weeds were controlled, as compared with 41 percent under natural conditions.

Native shrub species show various degrees of success in their establishment. Greatest success was with Atriplex canescens, Artemisia tridentata, Chrysothamnus nauseosus, Artemisia nova and Sarcobatus vermiculatus.

In very harsh habitats Atriplex corrugata, Atriplex confertifolia, and Kochia prostrata appear to be the best adapted species.

Special care must be given to handling of transplant materials and use of appropriate procedures in planting. Avoidance of planting in dry soil is essential for plant survival.

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INTRODUCTION

A multitude of various disturbances may create an imbalance in the natural vegetation of the salt desert shrub range, causing it to be absent or deficient in desirable plant types. These disturbances have generally been brought about by man through livestock grazing, construction of energy or transportation corridors, military operations, recreation, or in his development of resources to meet the technological needs of an expanding population. The potential development of oil shale motivated these particular studies.

Areas that have been disturbed or altered for one reason or another need rehabilitation in varying degrees for erosion control; watershed improvement; improved livestock grazing and wildlife habitat; increased recreational activities; or to restore aesthetic quality.

The incentive for developing effective revegetation techniques for the salt desert shrub or other vegetation types has a much broader application than dealing with the few thousand hectares that may be disturbed by oil shale or other types of energy development.

The average precipitation of the salt desert shrub vegetation type generally varies from 15 to 25 cm with the annual pattern being highly irregular and unpredictable in occurrence. The most dominant characteristic of the region is drought accompanied in many instances with saline-alkaline soil conditions. Sparse ground cover with large bare interspaces is a qualified natural characteristic but is important in balancing moisture availability. The fragility of these natural ecosystems under their harsh environment provide difficult conditions for revegetation.

Direct seeding in areas below 25 cm has generally been unsuccessful (Bleak et al. 1965, Plummer 1966, and Holmgren 1973). Natural reseeding normally accompanied by various grazing management programs has been fairly successful on some depleted ranges (Holmgren 1973). However, results from grazing management would be too slow and unpredictable for rehabilitating drastically disturbed sites. Many reasons may be attributed to rehabilitation failures from artificial direct seeding: low seed germination, nonadapted species or ecotype, frost or winter kill of emerged seedlings, planting at the wrong depth, improper time of planting, inadequate seedbed preparation, seed removal by animals, clipping or grazing of seedlings by animals, excessive plant competition, lack of soil moisture, low precipitation following emergence and seedling growth, dehydration of seedlings and surface soil by hot winds, soil compaction, disease, absence of proper mycorrhiza. Methods for establishing plants other than by artificial or slow natural seeding are essential if these vast regions are to be maintained or improved for useful productivity. Another method showing promise for establishing plants is planting bare-root and container-grown stock, although this approach has its problems.

Survival of bare-root or container-grown transplants is not assured unless proper procedures are followed to avoid poor quality plants, poor root systems, plants non-adapted to site, animal grazing, excess plant competition, lack of mycorrhiza inoculation, inappropriate size and type of container when used, moisture stress, salt problems, improper time of planting, root balling within containers, and other problems.

An excellent manual on all phases of container-grown tree seedlings, especially conifers, was prepared by Tinus and McDonald (1979). Although it does not cover container-grown shrubs for planting in arid regions, many principles are similar. Shrubs for arid regions are often specific in their growth requirements.

Results from numerous successful rehabilitation studies and commercial plantings conducted on disturbed sites in the western United States are reported by Plummer et al. (1968), Monsen and Plummer (1978), Howard et al. (1979), and DePuit and Coenenberg (1979). These studies have generally been in areas receiving 30 cm or more precipitation.

Successful results in areas receiving less than 25 cm are relatively few (Frischknecht and Ferguson 1979, Graves et al. 1978, Institute for Land Rehab. 1979, McKell 1978, Utah State Univ. 1978, Van Epps and McKell 1978, and McKell et al. 1979). Others reported success where supplemental water was applied (Aldon and Springfield 1977, Aldon 1978, and DeRemer and Bach 1977). The latter have been in Arizona and New Mexico where climatic conditions differ from most of Utah. Frischknecht and Ferguson (1979) report good plant survival from drip irrigation in their studies in Utah. Orr (1977) obtained variable results from use of supplemental water depending on plant species and comparing types of planting stock.

A common question facing a rehabilitator is whether to attempt revegetation under arid conditions by direct seeding or to rely on transplanting. Also of concern are the time and species to plant. In the fall the soil is normally dry with good chances of subsequent soil moisture improvement even though cold temperatures are imminent; in spring there is normally good soil moisture, though diminishing, but temperatures are normally favorable. Keller (1978) mentions that most investigators prefer the fall seeding of grass in the sagebrush ecosystem. Plummer et al. (1968) recommend various times according to species but concede that late fall and winter give the best stands for most species when directly seeded, while best success has been from spring planting of shrub transplants.

METHODS

Our first studies on the Utah Oil Shale Tracts consisted of the establishment of local shrub species at four harsh sites starting in 1975. Two plantings were made in early spring at each site. The major one consisted of six shrubs, planted as bare-root stock, five treatments and eight replications. The treatments were (1) a control; (2) applying 1 liter of water at time of planting; (3) water plus 9 gms of a 29-14-0 fertilizer (90 kg/ha) at time of planting; (4) same as treatment 2 plus 1 liter of water two weeks after planting; and (5) same as treatment 3 plus 1 liter of water two weeks later. The other planting at each site consisted of planting container-grown stock of fourwing saltbush. These were not planted together as a replicated experiment due to lack of container plants which must be kept in mind when comparing the two methods of planting fourwing saltbush. There were actually nine shrub species utilized but only six were planted at each location due to site differences. These were greasewood (Sarcobatus vermiculatus); fourwing saltbush (Atriplex canescens); big sagebrush (Artemisia tridentata); black sagebrush (Artemisia nova); shadscale (Atriplex confertifolia); castle valley clover (Atriplex cuneata); winterfat (Ceratoides lanata); rubber rabbitbrush (Chrysothamnus nauseosus); and spreading rabbitbrush (Chrysothamnus linifolius).

No protective measures were taken at these four sites against rodent, rabbit and domestic animal grazing or from weedy competition.

A second set of studies was initiated in 1976 at three sites and more treatment comparisons were made. Included in this study were nine shrub species comparing: (1) three methods of propagation - direct seeding, bare-root and container stock; (2) two seasons of planting - fall and spring; and (3) three post planting treatments - control - 1 liter of water - and one 12 gm fertilizer tablet consisting of a 14-4-6 ratio plus 1 liter of water. The nine species were: greasewood; fourwing saltbush; shadscale; castle valley clover of cuneate saltbush; winterfat; Greenes rabbitbrush (Chrysothamnus greenei); big sagebrush; black sagebrush; and spreading rabbitbrush.

Each site was protected with a rodent, rabbit and domestic animal proof fence, though rodents did cause extensive damage at one site due to the size and natural environment of the exclosure.

Early observations of these plantings led to a third study dealing with the effect of weedy plant competition on the survival and growth of shrubs. In this study three levels of competition (a control; one year of clean cultivation and two years of clean cultivation) were compared with two methods of planting; bare-root and container stock and four plant species, fourwing saltbush, winterfat, prostrate summer cypress (Kochia prostrata) and Russian wild ryegrass (Elymus junceus).

RESULTS AND DISCUSSION

1975 Spring Planting

Site Favorability

Site favorability is a major factor in plant survival, not only in soil and climatic variables, but also in plant competition and grazing. The trend in plant survival over the five and a half growing seasons at four sites is shown in Figure 1. Site G-5 had a uniform cover of Russian thistle each year while G-22 had a mixture of Russian thistle and halogeton. Both sites were grazed by rabbits and rodents year round and by sheep in the winter and spring. There was some cheatgrass at each location. Site G-8 varied with approximately half the plot covered with halogeton, purple mustard (Chorespora tennella), and galleta grass (Hilaria jamesii). The soil on the other half was bare of plant growth and was compacted. This site was grazed mainly by sheep. The dryness of the soil at time of planting and the period following probably reduced the possibility of good survival.

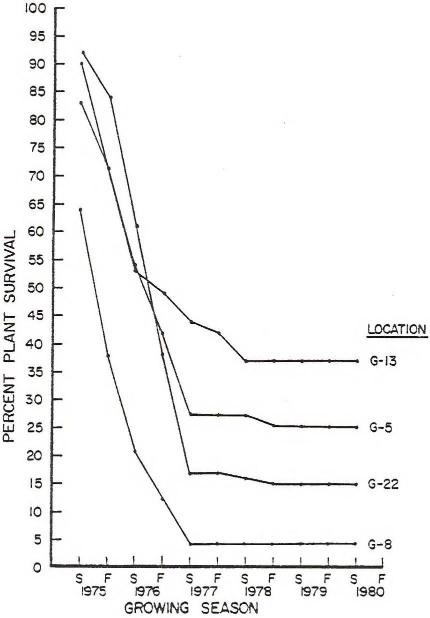

FIGURE 1.

Average survival trend of nine shrubs over four and a half growing seasons at four locations. Shrubs were planted in early spring of 1975 as bare-root transplants.

There was very little plant competition at site G-13 but it was a haven for rabbits and rodents, with minor grazing by sheep. The location was a cleared drill pad in dense underbrush along Evacuation Creek.

Rubber rabbitbrush was not adapted to the sites where it was planted. Winterfat, cuneate saltbush, and shadscale losses were due to a combination of plant competition from annual species and grazing except for site G-13 where losses of cuneate saltbush and shadscale were due entirely to rabbits.

Bare Root vs Container Grown Plants

A comparison of bare-rooted and container-grown transplants indicates a more favorable planting success with container-grown plants (Figure 2). Competition from other plants was not as critical to the survival of container-grown plants as with bare-root planting stock, due in part to less root disturbance when planting and also larger plants with an excellent root system within the planting mixture. Over half the losses of container-grown plants can be attributed to browsing by animals. No measurable differences in survival were noted in relation to the two irrigation treatments.

1975 and 1976 Spring Plantings

Direct Seeding

Shrubs

Some shrub species such as greasewood, fourwing saltbush, and the rabbitbrushes were observed to germinate in the field whether the seeds were planted in the fall or early spring. However, most seedlings survived best from the early spring planting at these sites. Others, such as the sagebrushes, germinated best from the fall plantings but few lived. Site G-17 had the poorest seedling emergence of the three locations, with only two fourwing saltbush seedlings surviving past the second growing season, even though many seedlings of greasewood, rabbitbrush, and winterfat were observed earlier.

Direct seeding of shrubs does not appear to be a dependable method for plant establishment under arid conditions, which agrees with the studies of other researchers. Even when seedlings are produced, the chances for their survival are extremely limited. However, this should not preclude direct seeding in conjunction with transplanting in soil that might be devoid of desirable species if some control of plant competition is possible.

Grass

Seedling emergence of five grasses over the four year period was very erratic. New seedlings emerged from the seeded rows as others died. The fluctuation between live seedlings varied with sites. The largest number of Indian ricegrass seedlings emerged in the spring of the third growing season and then declined during 1979 and 1980 as represented by site G-17 (Table 1). This was the only location of the three that could be adequately sampled following 1978 though the other two showed similar plant losses. Delayed germination is a

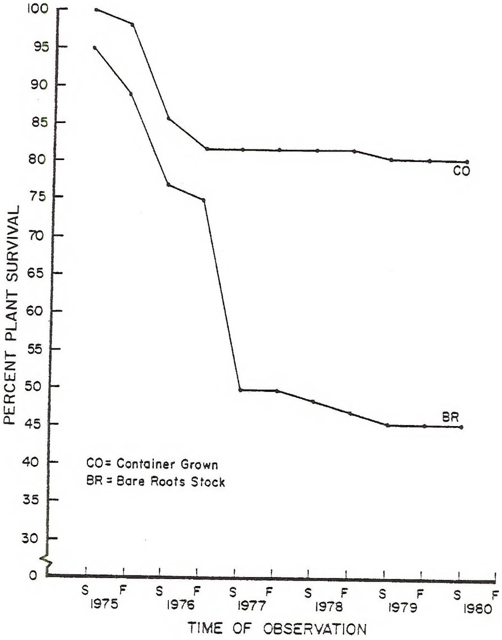

FIGURE 2.

Fourwing saltbush survival in a 1975 study comparing bare-root (BR) and container (CO) planting stock. Average of three sites (G-5; G-13; G-22).

Table 1. Grass seedlings from direct seeding in June of the second and third growing seasons for five grass species at three sites. Seedling survival is shown as the total number of seedlings from four replications comparing fall and spring planting dates.

Species	Time of Planting	Location: Site G-3 1977 No.	Site G-3 1978 No.	Site G-17 1977 No.	Site G-17 1978 No.	Site G-17 1979 No.	Site G-17 1980 No.	Section 6 1977 No.	Section 6 1978 No.
Indian ricegrass	Fall	0	30	2	167	63	10	8	50
	Spring	3	362	0	187	105	11	0	201
Needle and thread grass	Fall	7	6	11	22	3	5	6	3
	Spring	2	5	0	20	0	1	0	15
Fairway crested wheatgrass	Fall	10	4	19	11	2	5	17	18
	Spring	13	12	0	3	0	1	0	0
Russian wild ryegrass	Fall	0	0	1	4	0	0	3	2
	Spring	9	9	0	0	2	0	0	0
Bottlebrush grass	Fall	1	0	7	11	1	5	7	2
	Spring	0	2	0	2	1	4	1	0

Date of planting: Fall--November 14, 1975
Spring--March 23, 1976

natural characteristic with this species due to seed dormancy, but the reason for the high incidence of germination for the spring date of seeding at two of the sites compared to low seedling numbers from fall seeding is not known. Most seedlings of the other four species died by the third growing season.

Bare-root and Container-grown Transplants

Shrubs

The downward trend of plant survival of bare-root and container-grown stock over four and a half growing seasons is shown in Figure 3. Survival of container-grown shrubs was a significant 11.2 percent better at the end of the third growing season than bare-root transplants when averaging all three sites and 10.2 percent after four and a half seasons. Although the loss of plants at G-3 and G-17 was attributed mainly to annual plant competition and drought, plants at Section 6 were subjected to much greater stress through extreme plant competition as well as being browsed by rodents which penetrated the fence.

Spring transplanting was significantly better on the average for all treatments than fall transplanting. All three locations were similar in this respect (Figure 4).

Plant losses were still continuing during the first three years following planting. During the fourth year a general leveling off in losses occurred. Field plantings apparently need to be observed for several years before determining their permanent establishment.

In general fifty percent of the transplants survived to the end of the fourth growing season. However, the rate of survival varied considerably among species and site (Table 2). Spreading rabbitbrush was not adapted to any of these sites as it is a species which generally needs more moisture. Cuneate saltbush was not adapted to site G-3 though it did grow extremely well the first two years, including flowering, but then it died out, while at G-17 and Section 6 it was one of the better species. This same phenomenon of unadapted species growing well for two to three years then ceasing to live has been observed with ecotypes of other species at various locations.

Effects from addition of water or water plus fertilizer at planting time varied between sites. At site G-3 additional water showed better survival than the control, but the control was as good as water plus fertilizer. At site G-17 there was no survival difference due to treatments while at Section 6 there was a significant improvement in survival from the treatments over the control. Increases in survival appeared to be due to water rather than added fertilizer, though other factors may have caused these differences.

New plants from seeds of transplanted shrubs were observed at all three sites. Seedlings of big sagebrush, black sagebrush, greasewood, and winterfat were found around and under transplanted shrubs at sites G-3 and G-17 that had previously produced seed. A few of the spreading rabbitbrushes were also sprouting. Only seedlings of winterfat and big sagebrush were observed at Section 6.

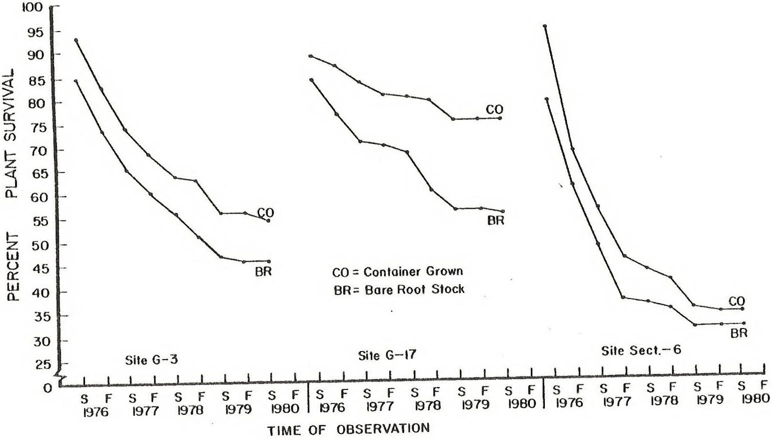

FIGURE 3.

Average survival of nine shrub species from a 1976 planting comparing two methods of propagation, bare-root (BR) and container (CO) grown stock at each of three locations over four and a half growing seasons. The two seasons of planting, spring and fall, are average within the data.

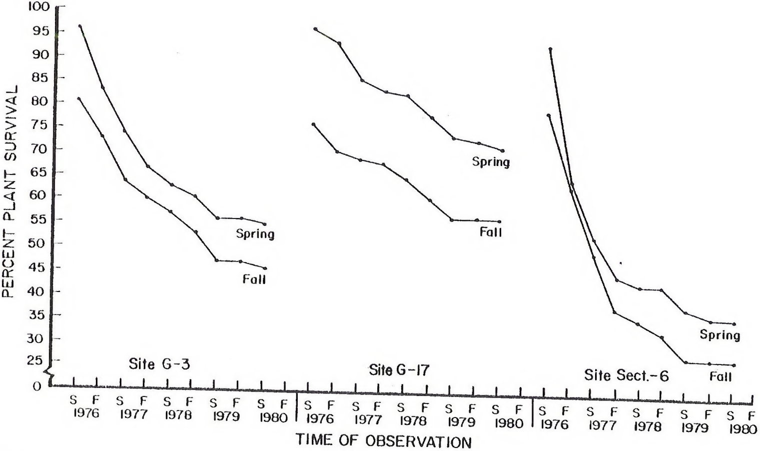

FIGURE 4.

Average survival of nine shrub species comparing seasons of planting, fall (F) and spring (S), at each of three locations. Two methods of propagation, bare-root and container, are averaged within the data.

Table 2. Field survival of nine shrub species at the end of four growing seasons at three planting sites. Plants were planted as bareroot or container-grown planting stock in the fall of 1975 or spring of 1976.

Plant Species	G-3 %	G-17 %	Section 6 %	Average Survival %
Greasewood	92	63	46	67
Fourwing saltbush	65	63	60	63
Shadscale	8	52	83	48
Cuneate saltbush	0	58	52	37
Winterfat	58	63	38	53
Greenes rabbitbrush	60	77	0	46
Black sagebrush	73	88	0	55
Big sagebrush	77	85	17	60
Spreading rabbitbrush	19	33	0	17

Grass

Container-grown grasses were 22 percent higher in survival than bare-root plantings when average over the three sites. Volunteer competition precluded obtaining measurements at site G-13. Plants at Section 6 other than western wheatgrass were too few to conclude anything meaningful. Survival data were obtained only in the spring of each year due to the grasses going dormant early under these arid conditions.

Plant survival apparently has not stabilized in harmony with the stresses of the environment because survival trends show little tendency to level off except in a couple of instances. Western wheatgrass showed the best promise of any species, possibly due to its rhizomotous sprouting habit which was noted at all locations.

Competition from annual plants greatly affected the survival of grasses at the three locations and along with the grazing of rodents was disastrous at Section 6. Planting of grasses as bare-root plugs or container-grown clones could be a highly suitable method if competition from other plants and wildlife grazing could be controlled until the shallow-rooted grasses were well established. In general, more than three growing seasons will be needed before the plants can be considered fully established.

Competition Study

During the four years duration of this study the density of *Bromus tectorum* and *Salsola kali* in the study plots was much higher than in the surrounding area as a result of disturbance to the plot area prior to planting. Hand weeding of the plots removed an average of 100-300 plants per 30 m^2.

Weedy plant competition had a direct influence on plant survival and growth of the plant species being studied (Figure 5). Average plant survival early in the fourth growing season for container-grown plants was 25, 66 and 88% under the three treatments: control, one, and two-year clean cultivation, while bare-root stock had 17, 45 and 88% survival respectively. Plant growth in terms of plant cover in the same order was 22, 27 and 28 dm^2 for container-grown and 20, 23 and 31 dm^2 for bare-root stock. Another study of competition control at the research site consisting of five shrub species showed a 41% survival rate under natural competition and 71% survival where competition was removed.

CONCLUSIONS

The data from our studies suggest that plantings need to be observed for a minimum of three to four years before concluding that plants are in a permanent survival condition. The observance of seedlings growing from seeds of transplanted shrubs presently indicates that vegetation is permanent. Assuming that plants are established when still alive at the end of the first or second growing season following field planting may be misleading. This is especially true in arid regions where plants are under a deficient moisture situation and generally subjected to other plant competition and grazing. West (1979) shows graphically that there is a fairly rapid decline even in natural seedling survival from several species during the first three growing seasons, followed by a general leveling in percent of plant survival.

Container-grown plants would normally be expected to survive better than bare-root stock. However, the survival of bare-root stock was generally high in relation to container-grown plants. In some studies the high rate of survival observed when bare-root plants of good quality stock in a dormant condition were planted in moist soil followed by clean cultivation prompted other studies. The economy of growing bare-root stock along with the ease of obtaining hardened off stock in the Intermountain area as compared with the problems associated with growing and hardening of container-grown stock for early planting is worthy of consideration. Planting of bare-root stock is also much faster, easier, and more economical than most container plantings. However, when conditions for planting are not ideal, such as inexperienced planting crews, late season planting, or when plant dormancy is broken, bare-root stock planting loses some of its advantages.

Plants with a top growth of several stems are preferred over those with a single small stem. We have found our best success with early spring planting prior to bare-root stock breaking its dormancy. Container stock for planting early must be hardened over a period of time prior to field planting.

Care must be taken in the handling of bare-root stock so that the roots are not allowed to dry. This can also happen with container stock when left in the field too long without watering. Do not dig the holes for the plants and allow them to dry out prior to planting.

Several factors need to be kept in mind when planting transplants; plant the roots down, plant at the proper depth, avoid leaving any air pockets around

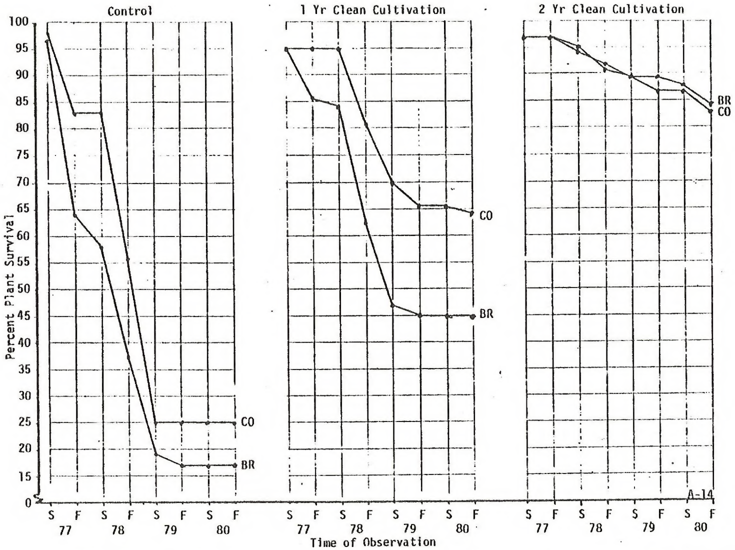

Figure 5. Influence of three levels of annual plant competition on the average survival of four plant species comparing two methods of planting - bare-root (BR) and container (CO) over four growing seasons. Date of field planting was April 5, 1977.

the roots or container medium and firm the soil, not compact, around the roots. Container plants need to be planted deep enough so as to cover the container medium with soil.

Plant establishment in arid environments by transplanting container-grown or bare-root transplants appears to be a means for initially revegetating disturbed or depleted sites. Subsequent growth and establishment of seedlings from such plants can expand the influence of the original plant to create a stable plant cover.

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