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Mulching, Furrowing, and Fallowing of Forage Plantings on Arizona Pinyon-Juniper Ranges

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Abstract

Mulching with plastic film, cinders, or juniper slash; deep furrowing; and fallowing increased penetration and retention of soil moisture, delayed soil surface crusting, and lowered seeding-zone temperatures in tests at five different pinyon-juniper range locations. Responses of seven forage species to these practices varied. The combination of plastic film mulching, deep furrowing, cinder mulching, and fallowing uniformly had resulted in greater soil moisture, more seedlings, and better early growth than other combinations. Plants under juniper slash had a longer growing season and were protected from excessive grazing by rabbits, with no evidence of toxic effects from the juniper. Cinder mulch increased seedling emergence and establishement, but in one year appeared to be toxic to the planted species. Deep furrowing generally had no advantage over surface drilling. Fallowing benefited pubescent wheatgrass and fourwing saltbush at a cold-moist pinyon-juniper site. The number of seedlings emerging gave little indication of the plant stand several years later.

Attempts to revegetate depleted southwestern pinyon-juniper ranges often fail because the normally dry springs and falls make plant establishment difficult (Gomm and Lavin 1968). Widely used cultural practices such as mulching, furrowing, and fallowing affect plant establishment, growth, and survival by modifying soil properties such as moisture content and temperature (Geiger 1959; Jacks et al. 1955; Mathews and Cole 1938). However, little is known about the effectiveness of these practices in establishing and maintaining forage plantings on semiarid pinyon-juniper rangelands. Although these practices are expensive, the increasing cost of range rehabilitation has renewed interest in attempting to increase the changes of adequate establishment at first planting rather than relying upon repeated plantings. This paper reports the results of a long-term study of the effectiveness of mulching, furrowing, and fallowing on forage plantings in Arizona pinyon-juniper.

Limited work done on juniper ranges in the 1940's and 1950's indicated that natural mulches seemed to improve establishment and maintenance of grass stands (Judd 1948; Judd 1966; Lavin unpublished data). However, the practice of range mulching was considered too expensive, and no followup studies were done at that time.

Mulches modified soil temperature and conserved soil moisture in the seeding zone on New Mexico pinyon-juniper sites (Springfield 1972). Straw mulching also protected the soil surface from puddling and erosion, reduced runoff, and increased infiltration. Mulching onto moist soils consistently improved seedling emergence, but adequate plant establishment depended on additional rainfall. Hot, dry, windy weather reduced mulching effectiveness.

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Polyethylene mulches modify soil temperatures (Andrews et al. 1976; Hopen 1965) and moisture levels (Knavel and Mohr 1967). Generally, when air temperature is high, soil temperatures and evaporation losses are lower with black plastic than with clear plastic (Knavel and Mohr 1967), so black plastic might be more beneficial for establishment of range plantings.

Gravel mulch conserved soil moisture and protected the soil surface from crusting (Corey and Kemper 1968). It was suggested that narrow bands of gravel might be effective on seeded areas. Readily available local materials might be suitable for this application.

Furrows increase soil moisture content and decrease evaporation (Bertrand 1965). Seeding zone moisture was higher with furrowing than with surface drilling throughout the growing season in Arizona pinyon-juniper, but excessive sloughing of soil in deep, narrow furrows was detrimental to seedling emergence (Lavin et al. 1973). Furrow shape, size, and spacing; soil type, and precipitation intensity are all related to seeding success with furrowing (Wein and West 1971). Establishment of crested wheatgrass [*Agropyron desertorum* (Fish. ex Link) Schult.] was improved with deep furrowing (McGinnies 1959; Young et al. 1969) but this species is reported to establish equally well with surface drilling (Hull 1970). Fourwing saltbush [*Atriplex canescens* (Pursh) Nutt.] became established in deep furrows at one New Mexico site but failed due to soil sloughing at another (Springfield 1970).

The degree to which fallowing increases soil moisture in subsequent years varies with the pattern and amount of precipitation (Mathews and Cole 1938). Precipitation is stored in the soil more effectively in cool, moist weather than in warm, dry weather. The prolonged spring and fall dry periods and limited rainfall in Arizona pinyon-juniper ranges do not seem conducive to increasing soil moisture by fallowing, but it might be useful on wetter sites and during wetter years.

Site Descriptions

The study was done at five locations near Flagstaff, Arizona (Table 1). Cosnino, 16 km east, and Indian Flats, 40 km north, are classed as cold-moist pinyon-juniper subtypes (Lavin and Johnsen, 1977); Hart Ranch, 53 km southeast, and Red Mountain, 58 km northwest, as cold-dry; and Drake, 96 km southwest, as warm-dry. Drake has relatively mild winters with hot summers. The other locations have cold winters with mild summers; Indian Flats is the coldest. Although the total annual precipitation differs, the locations all average 20 to 25 cm of rainfall between May 1 and October 31, with dry springs and falls.

The topography at each location is fairly level. Indian Flats and Red Mountain have similar clay-loam soils classed as Aridic Argiustolls derived from volcanic materials. Cosnino and Hart Ranch have similar gravelly loam soils classed as Lithic Haplustolls derived from sedimentary rock. Drake has a gravelly loam soil classed as a Petrocalcic Paleustoll derived from volcanic material. Soils on the plots are all moderately deep to deep.

Junipers (*Juniperus* spp.) with some pinyon (*Pinus edulis* Engelm.) form the overstory. Blue grama [*Bouteloua gracilis* (Willd. ex H.B.K.) Lag. ex Griffiths] is the dominant grass species except at Drake, where it is part of a mixture of several grasses.

The study areas were all fenced to exclude livestock. The Hart Ranch location was opened to yearlong grazing by cattle and horses in 1970. All but Hart Ranch are in national forests.

Procedure

Studies were made in both 1967 and 1968 at Indian Flats, Red Mountain, and Drake, but only in 1967 at Cosnino and Hart Ranch.

Luna pubescent wheatgrass [*Agropyron intermedium* var. *trichophorum* (Link) Halac. cv. Luna], sideoats grama [*Bouteloua curtipendula* (Michx.) Torr. A 3603], spike muhly (*Muhlenbergia wrightii* Vasey A 8604), and fourwing saltbush (Winslow) were planted each year at each location. Crested wheatgrass (Nordan) was planted only in 1967. Weeping lovegrass [*Eragrostis curvula* (Schrad.) Nees commercial] and western wheatgrass (*Agropyron smithii* Rydb. Chino A 16634) were planted only in 1968, and western wheatgrass was planted only on nonfallowed plots.

Seedbeds were prepared in late April and early May each year. Half of each seedbed was planted between mid-June and mid-July; the other half was fallowed for planting the following year. Seeds were planted 1.25 to 2.5 cm deep, the grasses at eight pure live seeds and the shrub at three live seeds per linear 10 cm of row. Weeds were controlled as needed on the fallowed halves of seedbeds by light disking. All plots were disked, harrowed, and cultipacked before being planted.

The species were planted in random order. Plots consisted of 10 adjoining rows, 10.8 m long, and spaced 60 cm apart, for each species in each of three replicate blocks at each location. Each species plot was divided into two subplots of five adjoining rows each; one subplot was planted with the standard practice of surface drilling and the other was planted by drilling in the bottoms of deep furrows. The deep furrows were 5 cm deep and 45 cm wide, with relatively broad bottoms and gently sloping sides firmed after planting to reduce excessive sloughing of soil.

Three mulching treatments were used on all species: cinders, juniper slash, and no mulch. These were applied in random order across all of the planted rows within each of the three replicate blocks (Fig. 1A). Each mulching treatment covered one-third of each species plot.

Red volcanic cinders, up to 2.5 cm in diameter, were spread over the drilled rows in bands 15 cm wide and averaging 1.25 cm deep. The cinders were obtained from the same source each year.

Juniper slash was placed over the plantings no more than 45 cm deep and covering 75% of the ground. The slash was obtained by cutting 2.5- to 7.5-cm diameter branches from nearby juniper trees at each location.

A fourth mulching treatment, 6-mil black plastic film, was used only on cindered, deep-furrowed plantings of pubescent wheatgrass (Fig. 1B). The plastic film was slit over the planted rows and fastened down by wooden blocks held in place by large spikes. In 1968 at Indian Flats and Red Mountain, the plastic was placed only on fallowed plots.

Plant responses measured were number of seedlings, number of plants established at the end of the first growing season by 10 random 30-cm sections in the center rows of each plot, plant height growth, and relative stands of plants in subsequent years. Relative stand ratings incorporated the number of plants and their distribution, vigor, average height, and development (Hull 1954). The last ratings were done in August 1975. Supplementary observations of weed competition, native plant invasion, animal damage, and relative plant vigor were also made from 1967 through 1977. Numerical data for seedling establishment were converted to letter ratings (Gomm 1974) for ease of presentation.

Soil moisture and temperature were measured on each replicate of each mulching-furrowing treatment combination at each location. Soil moisture was measured with gypsum blocks (Taylor et al. 1961) placed 1.25 and 5 cm deep near subplot centers. Additional blocks were placed 15, 30, 45, and 60 cm deep in one replicate only. Readings were taken weekly during the growing season and twice a month otherwise. Soil temperature was measured with copper-constantan thermocouples placed 1.25 cm deep within a drill row of each mulching-furrowing combination. Spot readings with a

Fig. 1. *Mulching treatments at Drake, early in second growing season. (A) Juniper slash, bare soil, and cinder mulching on standard drilled plots, large cans cover soil moisture monitoring lead terminals; and (B) Plastic film combined with deep furrows and cinder mulching on Luna pubescent wheatgrass, one-half of the plastic film has been removed to determine the effects of rabbit grazing.*

Table 1. Classification and description of Arizona pinyon-juniper forage study sites.

Subtype and name of study site	Elevation (M)	Mean annual temp. (°C)[1]	May 1-Oct 31 Rainfall (cm) 1967	1968	1969	Soils series and surface texture[2]	Natural vegetation[3] Overstory	Understory
Cold-moist								
Cosnino	2,010	8.9	28.0	21.3	19.2	Laporte, G	Juos, Pied	Bogr
Indian Flats	2,220	7.8	28.2	17.6	30.1	Thunderbird, C	Jumo, Pied	Bogr, Chna, Teca
Cold-dry								
Hart Ranch	1,980	9.4	21.6	14.8	16.3	Laporte, G	Juos, Jumo, Pied	Bogr, Gusa
Red Mountain	1,950	9.4	17.0	18.1	22.2	Thunderbird, C	Juos, Pied	Bogr, Chna
Warm-dry								
Drake	1,400	12.2	30.1	26.1	24.9	Tajo, G	Juos	Hija, Bogr, Bocu

[1]Adapted from records of the nearest U.S. Weather Service Station
[2]G = gravelly loam, C = clay loam
[3]Key to names: Bocu = *Bouteloua curtipendula* (Michx.) Torr.; Bogr = *Bouteloua gracilis* Willd. ex H.B.K.) Lag. ex. Griffiths; Chna = *Chrysothamnus nauseosus* (Pall.) Britt.; Gusa = *Gutierrezia sarothrae* (Pursh) Britt & Rusby; Hija = *Hilaria jamesii* (Torr.) Benth.; Jumo = *Juniperus monosperma* (Engelm.) Sarg.; Juos = *Juniperus osteosperma* (Torr.) Little; Pied = *Pinus edulis* Engelm.; Teca = Tetradymia canescens D.

portable potentiometer were made at irregular intervals; only data obtained on clear days were used for comparisons. Additional soil temperature data were obtained at Red Mountain, Hart Ranch, and Drake with recording thermographs whose sensing elements were buried under 1.25 cm of soil.

Precipitation was recorded with 1966 through 1970 with standard rain gauges modified to reduce evaporation losses (Gomm 1961). Air temperature and relative humidity were recorded with hygrothermographs. Observations were made at each location, weekly during the growing season and monthly at other times.

Results and Discussion

Variables Influencing Treatment Effectiveness

The 1967 plantings had good distribution of rainfall throughout the growing season, with little evidence of plant moisture stress until the fall. These plantings generally had fair to good emergence and establishment (Table 2). Plant survival was good through the winter of 1967-68 except for losses due to rodent damage at Cosnino, losses on bare soil and cindered plots at Drake, and high mortality of all species except the wheatgrasses at Indian Flats.

The 1968 plantings had adequate soil moisture early in the growing season from heavy winter snowfalls, and seedling emergence was good. However, an extended dry period occurred late in the growing season, killing many seedlings and resulting in generally poor establishment and survival, especially at Drake (Table 3).

Cosnino, Drake, and Indian Flats received the most growing-season rainfall in 1967, and Red Mountain and Hart Ranch received the least (Table 1). Drake received the most growing-season rainfall in 1968. Only growing-season rainfall is reported because of difficulties in measuring moisture from snowfall, especially that of mid-December 1967.

Soil temperatures were highest with bare soil and surface drilling treatments and coolest with slash and deep furrows (Table 4). Maximum soil temperature with deep furrows averaged 21.3°C, 2°C lower than the average with surface drilling (23.3.°C). The temperature difference between deep furrows and surface drilling (23.3°C). The temperature difference between deep furrows and surface drilling was greatest with bare soil. Temperature differences would have the greatest effect during drier years with the higher temperature causing a faster rate of drying near the soil surface and possibly reducing seedling establishment.

The various mulches and furrowing increased penetration and retention of soil moisture (Fig. 2), reduced soil temperatures near the surface (Table 4), and reduced soil surface crusting, all effects that favor seedling emergence and establishment. However, much of the effectiveness of the treatments was lost during the first growing season after planting: cinders washed away, plastic ripped and blew away, slash lost foliage and broke apart, and deep furrows filled in.

Another factor reducing treatment effectiveness over time was that moisture penetrated to greater depths in freshly plowed seedbeds than in older ones. Moisture from summer storms at Red Mountain penetrated 30 to 40 cm into soil plowed in the preceding spring, 15 to 30 cm into soil plowed the previous year, and only 5 to 20 cm into soil plowed 2 years previously. Findings were similar at the other locations. Weeds invaded fallowed plots, especially at Red Mountain. Weed growth can reduce soil moisture content markedly, thereby reducing the effectiveness of fallowing.

There was little relationship between low numbers of seedlings emerging and stand development of some species. Emergence of fourwing saltbush was variable at each location each year, often having poor first-year establishment but usually developing fair or better stands (Tables 2 and 3). Even with poor initial establishment due to delayed germination, western wheatgrass still developed fair or better stands at Indian Flats and Red Mountain (Table 3).

Generally, plant establishment and stands were better on the cold-moist sites at Cosnino with its medium-textured soil than elsewhere (Table 2). Plant stands on cold-dry sites were better on the fine-textured soils at Red Mountain than on the medium-textured soils at Hart Ranch (Table 2). At Drake, the only warm-dry site, seedling emergence was fair or better each year of planting, but only fourwing saltbush, spike muhly, and sideoats grama developed some fair or better stands each year (Tables 2 and 3).

Weeping lovegrass established fair to good stands at Indian Flats and Red Mountain (Table 3) but did not survive because of frost heaving the winter after planting. Western and pubescent wheatgrasses and spike muhly grew best on the colder sites; sideoats grama grew well on the warmer site only, and crested wheatgrass grew well only at Indian Flats, the cold-moist site with fine-textured soil (Tables 2 and 3). Fourwing saltbush grew best on

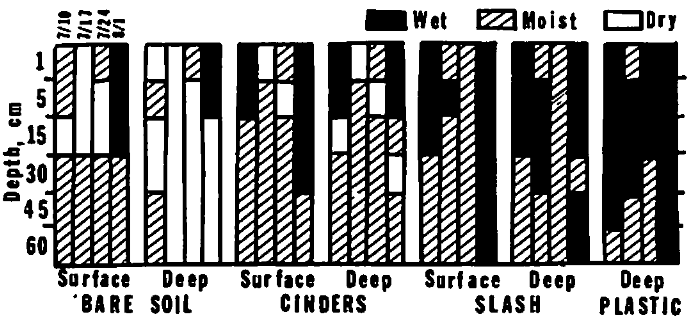

Fig. 2. *Soil moisture at weekly intervals during a drying cycle in 1968 showing effects of mulches and furrows at Red Mountain. "Wet" soils are at or below 0.1 bar; "dry" soils are at or above 15 bars and "moist" soils are between these values.*

Table 2. Average seedling establishment and stand ratings as affected by mulcing and furrowing in different pinyon-juniper subtypes and locations planted in 1967.

			Establishment/stand ratings at indicated location[1]					
			Cold-moist		Cold-dry		Warm-dry	
Mulch	Furrow	Species[2]	Cosnino	Indian Flats	Hart Ranch	Red Mountain	Drake	Species average
None	Surface	Agde	E/V	E/E	V/V	F/V	P/V	F/P
		Agtr	E/G	E/G	F/V	E/G	E/O	E/F
		Atca	G/E	P/V	F/G	F/F	P/G	F/F
		Bocu	F/V	E/O	G/V	E/O	G/G	G/V
		Muwr	E/E	G/G	V/O	F/F	P/F	F/F
		Average	G/F	G/F	P/V	G/P	F/P	G/P
	Deep	Agde	E/V	G/E	O/O	G/V	G/V	F/P
		Agtr	E/F	E/G	F/V	E/G	E/V	E/F
		Atca	F/E	P/V	P/G	G/G	P/F	F/F
		Bocu	P/V	G/V	F/O	F/V	G/E	F/P
		Muwr	F/G	F/G	O/O	P/G	P/V	P/F
		Average	G/F	G/F	P/V	G/F	F/P	F/F
Cinders	Surface	Agde	E/V	E/G	P/V	G/V	P/O	G/V
		Agtr	E/E	E/G	G/V	E/G	E/V	E/F
		Atca	G/G	P/O	F/G	F/F	P/G	F/F
		Bocu	G/F	G/O	E/V	G/V	G/G	G/P
		Muwr	F/F	F/F	P/O	G/F	P/V	F/F
		Average	G/F	G/P	F/V	G/P	F/P	G/P
	Deep	Agde	E/V	F/G	O/O	G/V	P/O	F/V
		Agtr	E/G	E/G	G/V	E/G	E/O	E/F
		Atca	F/G	P/V	P/E	G/F	P/F	F/F
		Bocu	F/V	F/O	G/V	F/V	P/G	F/V
		Muwr	P/F	P/F	P/O	P/V	P/V	P/P
		Average	G/F	F/P	P/V	G/P	F/P	F/P
Slash	Surface	Agde	E/V	G/F	F/O	E/V	P/O	G/V
		Agtr	E/G	E/G	G/V	E/F	E/F	E/F
		Atca	P/G	P/V	P/G	F/F	P/G	P/F
		Bocu	P/V	P/O	F/V	G/V	G/E	F/P
		Muwr	G/F	P/G	P/O	P/F	P/F	P/F
		Average	G/F	F/P	F/V	G/P	F/F	F/P
	Deep	Agde	E/O	F/F	G/O	E/P	F/O	G/V
		Agtr	E/G	E/F	E/V	E/F	E/F	E/F
		Atca	P/F	P/V	P/G	P/F	P/F	P/F
		Bocu	P/O	P/O	F/O	G/O	G/G	F/V
		Muwr	V/F	P/P	P/V	P/V	P/G	P/P
		Average	F/P	F/P	F/V	G/P	F/F	F/P
Plastic	Deep	Agtr	E/G	E/G	E/V	E/F	E/F	E/F

[1] Average seedling establishment at end of first growing season (O = 0 seedlings per foot (0.3 m) of row, V = less than 0.5, P = 0.5 to 1.0, F = 1.1 to 2.0, G = 2.1 to 4.0, and E = more than 4.0)/average stand rating in fall of 1975 (O=failure, V=very poor, P=poor, F=fair, G=good, E=excellent. Refer to text for details of bases of stand ratings.
[2] Agde=*Agropyron desertorum* (crested wheatgrass); Agtr=A. intermedium var. *trichophorum* cv. Luna (luna pubescent wheatgrass); Atca=*Atriplex canescens* (fourwing saltbush); Bocu=*Bouteloua curtipendula* (sideoats grama); *Muwr=Muhlenbergia wrightii* (spike muhly).

the limy, medium-textured soils of Cosnino and Hart Ranch (Table 2); western and pubescent wheatgrasses grew best on the fine-textured soils of Indians Flats and Red Mountain, pubescent also grew well on medium-textured soils at Cosnino (Tables 2 and 3).

Mulching

Cinder mulching seemed to help crested wheatgrass seedling emergence and establishment on surface-drilled plots in the 1967 planting year (Table 2). Generally, emergence and seedling growth was slightly better with cinder mulching than on bare soil. Emergence was slightly better on cinder mulched surface-drilled plots than on cinder-mulched deep-furrowed plots, probably because some seeds were buried too deeply by sediment from erosion of deep furrow sides. Cinder-mulched soils retained moisture longer than bare soils, but not as long as soils mulched by slash or plastic (Fig. 2). Cinders lost their effectiveness when scattered and washed away by thundershowers, and the soil surface then becoming crusted. Cindered plots often became dominated by a cover of robust weeds.

Markedly variable seedling emergence between replications on cinder-mulched plots in 1968 suggested that the cinders might have toxic effects of an undetermined nature. These toxic effects would prevent using cinders as mulch; locally available gravel or sand might be substituted to avoid such affects.

Juniper slash mulching usually did not markedly improve seedling emergence (Tables 2 and 3). The best stands of sideoats grama were on slash-mulched plots at Drake. We noted no toxic effects of the juniper foliage on plant growth such as those reported from laboratory studies of juniper foliage extracts (Jameson 1961; Lavin et al. 1968). Early in the 1967 growing season, pubescent wheatgrass seedlings under slash mulch were spindly and weak but they were almost as tall as those mulched with plastic. These seedlings developed into vigorous plants after the foliage dropped from the slash, which indicates that shading might have caused the initial weak growth. Grasses remained green and grew several weeks longer with slash than with the other mulches, especially at Red Mountain, Hart Ranch, Drake, and Indian Flats (Fig. 3). However, long-term survival of planted species and stand development was similar to those with the other mulching treatments in 1967 and slightly better in 1968 plantings.

Table 3. Average seedling establishment and stand ratings of forage species as affected by mulching, furrowing, and fallowing at different pinyon-juniper locations planted in 1968.

			Establishment/stand rating at indicated location[1]							
			Indian Flats		Red Mountain		Drake		Average	
Mulch	Furrow	Species[2]	Non-fallow	Fallow	Non-fallow	Fallow	Non-fallow	Fallow	Non-fallow	Fallow
None	Surface	Agsm	E/G	—	G/E	—	V/O	—	F/F	—
		Agtr	E/F	E/G	G/F	F/F	O/O	O/V[3]	F/P	F/F
		Atca	O/V	P/F	P/F	P/F	O/F	V/P	V/P	P/F
		Bocu	O/O	P/O	F/O	P/O	O/P	V/P	V/V	P/V
		Ercu	P/O	G/O	E/O	E/O	O/O	V/V	P/O	F/O
		Muwr	O/O	P/V	F/V	P/P	O/V	V/O	V/V	P/V
		Average[4]	V/V	F/P	F/V	F/P	O/V	V/V	P/V	P/P
	Deep	Agsm	G/G	—	F/E	—	O/O	—	P/F	—
		Agtr	E/F	E/G	F/F	F/F	O/O	O/V	F/P	F/F
		Atca	O/V	P/P	P/P	P/P	O/P	V/F	V/P	P/P
		Bocu	O/O	P/O	F/O	O/O	O/P	P/V	V/V	V/O
		Ercu	G/O	E/O	G/O	G/O	O/O	O/O	F/O	F/O
		Muwr	O/O	P/V	F/V	P/V	O/O	O/V	V/O	V/V
		Average[4]	P/V	F/V	F/V	P/V	O/V	V/V	P/V	P/V
Cinders	Surface	Agsm	P/G	—	P/G	—	O/O	—	V/F	—
		Agtr	G/F	G/F	P/F	P/P	O/O	P/V	P/P	F/P
		Atca	O/V	P/F	P/F	P/F	O/P	V/P	V/P	P/F
		Bocu	O/O	V/O	P/O	O/O	P/F	V/P	V/V	V/V
		Ercu	P/O	P/O	F/O	P/O	V/O	P/O	P/O	P/O
		Muwr	O/V	P/V	V/V	O/V	O/O	O/O	O/V	V/V
		Average[4]	V/V	P/V	P/V	V/V	V/V	V/V	V/V	P/V
	Deep	Agsm	P/F	—	P/F	—	O/O	—	V/P	—
		Agtr	F/F	F/F	P/F	P/P	V/O	V/V	P/P	P/P
		Atca	O/V	V/P	P/F	V/V	O/V	V/V	V/P	V/V
		Bocu	O/O	V/O	P/O	V/O	O/F	V/F	V/V	V/V
		Ercu	F/O	P/O	P/O	P/O	O/O	P/O	P/O	P/O
		Muwr	O/O	P/V	P/O	O/V	O/O	P/F	V/O	V/P
		Average[4]	V/V	P/V	P/V	V/V	O/V	V/P	V/V	V/V
Slash	Surface	Agsm	G/G	—	G/E	—	O/P	—	F/G	—
		Agtr	G/F	E/G	F/E	P/G	P/P	P/O	F/F	F/F
		Atca	P/F	P/E	P/P	P/G	O/P	P/E	V/P	P/E
		Bocu	O/O	P/O	P/O	V/O	F/G	P/F	P/V	P/V
		Ercu	P/O	F/O	F/O	F/O	P/V	P/O	P/O	F/O
		Muwr	O/O	F/O	P/V	O/V	P/V	P/G	V/V	P/P
		Average[4]	P/V	F/P	P/P	P/P	P/P	P/P	P/V	P/P
	Deep	Agsm	F/G	—	G/G	—	O/F	—	P/G	—
		Agtr	G/F	E/G	P/G	P/V	P/P	P/V	F/F	F/P
		Atca	V/V	V/G	V/F	P/F	O/P	P/G	V/P	P/G
		Bocu	O/O	V/O		O/O	F/G	P/G	V/V	P/V
		Ercu	P/O	G/O	F/O	P/O	F/V	P/O	F/O	F/O
		Muwr	O/O	P/O	P/V	O/V	P/V	P/F	V/V	V/V
		Average[4]	V/V	F/P	P/P	V/V	P/P	P/P	P/V	P/P
Plastic	Deep	Agtr	—	E/E	—	G/G	O/V	O/O	O/V	F/F

[1]Average seedling establishment at end of first growing season (O = 0 seedlings per foot (0.3 m) of row, V = less than 0.5, P = 0.5 to 1.0, F = 1.1 to 2.0, G = 2.1 to 4.0, and E = more than 4.0)/average stand rating in fall of 1975 (O = failure, V = very poor, P = poor, F = fair, G = good, E = excellent). Refer to text for details of bases of stand ratings.
[2]Agsm = *Agropyron smithii* (western wheatgrass); Agtr = *A. intermedium* var. *trichophorum* cv. Luna (luna pubescent wheatgrass); Atca = *Atriplex canescens* (fourwing saltbush); Bocu = *Bouteloua curtipendula* (sideoats grama); Ercu = *Eragrostis curvula* (weeping lovegrass); Muwr = *Muhlenbergia wrightii* (spike muhly).
[3]An establishment of O with stand rating of V or better indicates delayed emergence beyond the first growing season after planting.
[4]Average of treatment does not include Agsm rating.

Slash-mulched plots often became very weedy and native vegetation established under the slash on plots not dominated by planted species. Good stands of bottlebrush squirreltail [*Sitanion hystrix* (Nutt.) J.G. Smith] developed on slash-mulched plots on each location. Good mixed stands of black grama [*Bouteloua eriopoda* (Torr.) Torr.], sideoats grama, and threeawns (*Aristida* spp.) developed at Drake. Adjacent bare-soil and cinder-mulched plots often remained weedy or became covered with snakeweed [*Gutierrezia sarothrae* (Pursh.) Britt. & Rusby], rabbitbrush (*Chrysothamnus* spp.), or horsebrush (*Tetradymia canescens* D.C.). Mulching with juniper slash might be a means of improving ground cover with or without planting, if remnants of desirable species are present.

Soil moisture losses under fresh juniper slash were markedly reduced compared with those in bare soil (Fig. 2). This reduction was lessened after the foliage fell off the branches.

The smaller branches in the juniper slash broke down within 10 years of application, without disturbance by livestock. At Hart Ranch, which was heavily grazed by livestock, the juniper slash was not generally evident 3 to 5 years after grazing began. Its near disappearance indicates that small, scattered slash would not be a serious long-term aesthetic blight, mechanical barrier to livestock movement, or fire hazard.

The results with juniper slash mulching in this study generally agree with those of the limited studies done previously (Judd 1948;

Fig. 3. *Effects of juniper slash mulching at Drake 2 years after planting. Plants under slash are green and growing; those not under slash are dormant.*

Lavin unpublished data). Therefore, juniper slash mulching can probably be applied more widely than is indicated by this study.

Plastic film over cinder mulch on deep furrows had the best emergence of all of the treatment combinations used on pubescent wheatgrass, the only species so treated. Plants had good establishment and early growth. Stands in 1975 appeared slightly better with plastic than with the other mulches at Cosnino, Indian Flats, and the 1968 Red Mountain plantings (Tables 2 and 3). Plastic covered plots stayed relatively free of weeds until the plastic was removed. The plastic film tore easily and was blown loose within a year after application; remnants of it are still seen in the area 10 years later, however, so large-scale applications might result in unattractive littering of the rangeland.

Soil under plastic consistently had a higher moisture content than soil under the other mulching treatments, except immediately after soil-saturating storms (Fig. 2). Soil moisture at 1.25 cm remained high under plastic. Only at Red Mountain, Hart Ranch, and Indian Flats did the soil moisture content at 1.25 cm under plastic fall below the permanent wilting point during the dry fall of 1967; only at Red Mountain did the soil moisture content at 5 cm do so.

Furrowing

There was no general advantage of deep furrowing over surface drilling for plant establishment and survival (Tables 2 and 3). Fourwing saltbush, sideoats grama, and spike muhly emerged and survived slightly better with surface drilling than with deep furrowing. Seeds in deep furrows may have been buried by sediment during high-intensity early-summer rainstorms. This impairment of seedling emergence was especially evident with bare soil and cinder-mulched deep furrows. Mulching with slash or plastic film seemed to increase emergence in deep furrows, probably by reducing erosion and, therfore excessive seed burial, as well as by reducing soil moisture losses. The deep furrows were not evident 5 to 6 years after planting.

Table 4. Average daily maximum temperatures during the growing season 1.25 cm deep in soil of surface-drilled and deep-furrowed seedbeds with various mulching treatments, Arizona, 1967.

	Temperature (°C)	
Mulching treatment	Surface drilled	Deep furrows
Bare soil	27.5	23.8
Cinders	23.1	22.3
Slash	19.4	17.9
Plastic	—	20.8

Fallowing

Fallowing slightly improved seedling emergence and plant survival at Indian Flats, and to a lesser extent at Drake, and slightly worsened it at Red Mountain. Fallowed pubescent wheatgrass and fourwing saltbush had the best stands at Indian Flats.

Fallowed-plot plantings were all made onto moist soil because of the heavy snowfalls of the preceding winter. We suspect that Indian Flats, being at a higher elevation and nearer to the San Francisco Mountains, received much more snow the winter of 1967-68 than the other locations. It may, therefore, have had more moisture penetrating more deeply into the soil. Indian Flats, a cold-moist site, is also the most mesic of the three locations fallowed. This may be why fallowing worked best at Indian Flats. Since we measured soil moisture only to the 60-cm depth, we do not know whether there was more moisture deeper in fallowed plots than in nonfallowed ones. There is some indication that soil moisture lasts through the dry seasons in herbicide-killed juniper stands in which the dead trees are left standing (Clary et al. 1974). More research might be done on fallowing of sites protected through modification of the microenvironment by standing junipers killed by herbicides or fire.

Use By Animals

Differences in plant responses to the cultural treatments may have been increased by selective animal use. Rabbits (*Lepus* spp. and *Sylvilagus* spp.), gophers (*Thomomys* spp.), and mice (*Peromyscus* spp.) damaged plantings at all locations. Mule deer (*Odocoileus hemionus* Refinesque) used plots at each location, antelope (*Antilocapra americana* Ord) used all locations but Drake, and elk (*Cervus canadensis* Erxleben) used only Indian Flats and Hart Ranch. Livestock heavily grazed Hart Ranch yearlong since 1970 and may have caused the poor survival at that location. However, fourwing saltbush still survives at Hart Ranch in spite of heavy yearlong grazing.

Rabbits selectively grazed pubescent wheatgrass and may have eliminated it at Drake. Slash protected plants from rabbit grazing until all green vegetation had been removed from adjacent areas, and this protection was most obvious at Drake, where rabbit grazing was especially severe. This is another advantage of using juniper slash for mulching range plantings.

Removing the plastic film markedly increased the effect of rabbit grazing, perhaps because the plants did not recover as rapidly under the drier conditions without the plastic. The plastic may have repelled rabbits, but their droppings were plentiful in the planted rows of the plastic mulched plots.

The cover provided by slash and plastic film appeared to attract gophers and mice. The activities of these small mammals often destroyed a number of individual plants and may have reduced establishment under slash. Rodent activity was especially prevalent at Cosnino, Drake, and Indian Flats. Heavy losses of plants at Cosnino during the winter of 1967-68 were mainly from rodents burrowing under the plastic and slash mulches. Large-scale plantings or rodent control might alleviate the problem of small rodent damage.

Conclusions

In general, plant responses to mulching, deep furrowing, and fallowing varied because of factors such as (1) distribution of rainfall during the growing season, (2) site characteristics, (3) species planted, (4) type of mulch used, (5) weed competition, and (6) damage by small animals. These and other factors must be considered before a land manager can determine which, if any, of these practices should be used. Mulching often helped seedling emergence and initial establishment. Deep furrow planting improved seedling establishment under certain conditions but had no overall advantage over surface drilling. Fallowing resulted in slightly better establishment and survival than nonfallowing. However, survival and stand development were affected more by seasonal distribution of rainfall, location, and species than by cultural practices. If a species is not adapted to a given site, cultural practices may help it become established, but usually do not affect its growth or stand development beyond the first year or so.

The methods discussed in this paper are costly, but if they increase the chances of establishing adapted species they might be cheaper than replanting several successive years with no assurance of success. The development of equipment to apply gravel and plastic film to crop lands indicates that work should continue with these methods to see whether they might be useful in rangeland rehabilitation, roadside improvement, and critical-area planting.

At present, juniper slash mulching could be used with juniper control or firewood harvesting projects. Requiring that branches and stems be lopped and scattered as mulch could help depleted ranges invaded by pinyon-juniper to recover without reseeding if remnants of desirable plants are present. The use of dead, standing juniper as shelter for plantings should also be studied further.

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