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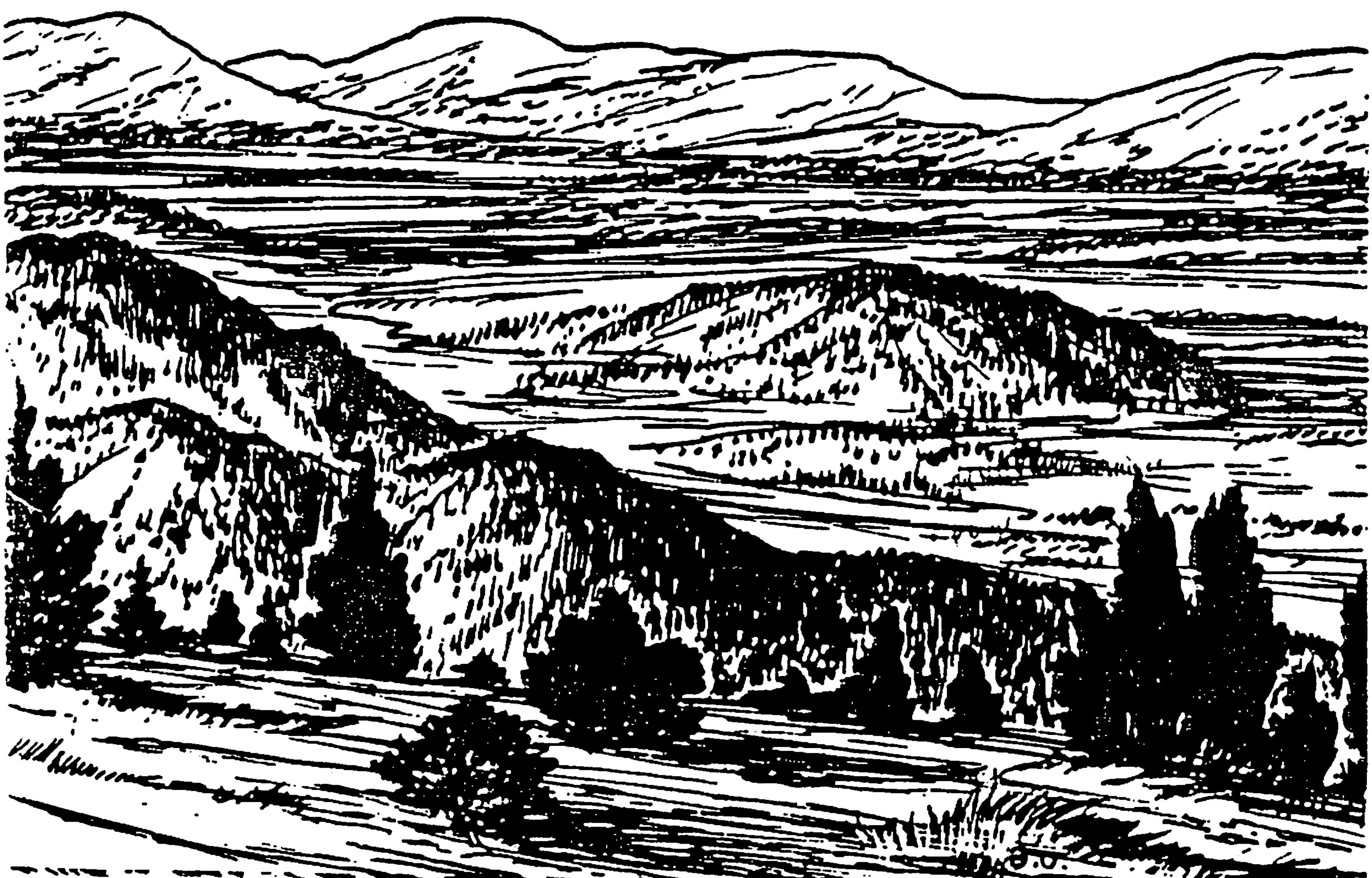

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SEEDING PINYON-JUNIPER SITES IN THE SOUTHWEST

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ABSTRACT: Past efforts to reseed southwestern pinyon-juniper sites are briefly reviewed, specific problems unique to this area are discussed, and research needs suggested. Twenty-six species adapted to one or more of nine suggested southwestern pinyon-juniper climatic subtypes are tabulated.

INTRODUCTION

Many southwestern pinyon-juniper ranges need understory vegetation restoration or improvement to increase plant cover, protect soils, increase forage, improve forage balance, or extend the green feed period. Range revegetation may be done naturally or artificially (Forsling and Dayton 1931). Natural revegetation depends on increasing plant remnants by management; however, without a seed source bare ground may remain unproductive indefinitely. Artificial revegetation, or reseeding, depends on planting adapted native or introduced plants. Reseeding southwestern pinyon-juniper rangelands is difficult, expensive, and success is unpredictable. Reseeding should be tried only if natural revegetation will not work in a reasonable time and proper reseeding procedures and follow-up management will be done.

Reseeding has been used on southwestern pinyon-juniper rangelands to increase plant cover in openings within juniper stands and to establish forage plants following juniper control. Responses have been variable. A review of 370 reseeding projects on Arizona and New Mexico pinyon-juniper ranges showed at least two-thirds failed within two years (Johnsen unpublished data). Most of these failures seem to be due to improper planting times, methods, species, and competition. These failures indicate a need for more reliable information and an exchange of this information between researchers and land managers.

Past research and reseeding efforts in the pinyon-juniper of the southwest have been summarized by Fosling and Dayton (1931), Parker and McGinnies (1940), Gomm and Lavin (1968), and Springfield (1976). This paper briefly reviews past works, elaborates on specific problems of reseeding southwestern pinyon-juniper ranges, and suggests research needs. Such information is useful in Arizona, New Mexico, and parts of Colorado, Utah, and Nevada.

BACKGROUND

Efforts to reseed southwestern ranges began just before the turn of the century. Although little of this early work was done on pinyon-juniper ranges, much of what was learned had general application, such as the need for site preparation, use of adapted species, proper planting methods, and season of planting. Forsling and Dayton (1931), summarizing the results of reseeding ranges on western National Forests, conclude that reseeding should be limited to the moister sites. Wilson (1931), in New Mexico, stressed the need for seedbed preparation, weed control, rabbit control, and planting shrubs in the fall or winter to avoid the spring and summer dry periods. Parker and McGinnies (1940) summarized the results of Forest Service reseeding in the southwest, recognizing the different growth requirements of individual species. Bridges (1942) emphasized the need to remove junipers for successful seeding or to plant only natural clearings larger than one acre, cover broadcast seeds, and plant in July or August. Lavin (1948) suggested species for reseeding of Arizona pinyon-juniper, stressed early summer planting, seedbed preparation, proper planting depth, and protection from grazing. Gomm and Lavin (1968) summarized reseeding efforts in the southwestern pinyon-juniper, emphasizing a need for interseeding into blue grama sod for a better forage balance. Springfield (1976) listed species adapted to climatic and soil subtypes of the Arizona-New Mexico pinyon-juniper. Jordan (1981) summarized Arizona reseeding problems, species to use and how to manage them. Work on reseeding pinyon-juniper in other areas has been reported for Colorado by Hull and others (1958) and McGinnies and others (1963), and for Utah by Plummer and others (1968).

CLIMATIC CONSIDERATIONS

One unique feature of the southwest is the seasonal distribution of rainfall (Sellers and Hill 1974; Tuan and Everard 1965). Briefly, Arizona has a rainfall pattern with wet summers and winters and dry springs and falls. This bimodal pattern extends northward into southern Utah and Nevada where winter precipitation

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becomes more dominant. The summer rainfall peak disappears and winter rain dominates just west of Arizona in southern California. Winter rainfall loses its importance and summer rains predominate eastward from eastern Arizona into New Mexico. Short dry spells occur every year, but there can be occasional extended dry periods of a year or more.

Summer rains fall in July to mid-September, often as high-intensity, local thunderstorms with limited moisture penetration into the soil. Summer storms vary widely in spatial distribution. Winter storms occur in November through March, usually as low-intensity, generalized storms, often wetting the entire soil profile. Snow may fall but melts quickly at the lower elevations. Winter storms, although widespread, are more erratic than summer storms, occurring unevenly throughout the winter.

Higher elevations generally are cooler and wetter than lower elevations. New Mexico's rough terrain causes rapid mixing of cold and warm air which results in New Mexico sites being warmer than similar sites at the same elevation in Arizona.

PINYON-JUNIPER CLIMATIC SUBTYPES

Using a combination of temperature, rainfall, and elevation, Lavin (1954) classified Arizona pinyon-juniper study sites to facilitate application of study results. This system has been modified to include more sites and parameters (Springfield 1976; Lavin and Johnsen 1977a, 1977b) and has been useful for identifying potential planting sites. These classifications are based on comparing short-term weather observations at study sites with nearby weather stations to estimate climatic conditions on the site. The temperature classifications for the southwestern pinyon-juniper are as follows:

	Mean Temperatures - °F	
Subtype	Annual	January
Cold	49 or less	31 or less
Cool	50 - 53	32 - 35
Warm	54 - 58	36 - 39
Hot	59 or more	40 or more

Sites with an average of 15 inches or less rainfall annually are classed as dry; 16 inches or more as moist. A site with a dry winter or summer receives less than half of the annual rainfall and averages less than 6 inches for that season. Winter is defined as November through April, and summer as May through October.

Reliable data are needed to help identify planting sites and to determine site potentials. Researchers should describe the vegetation and soils of study locations, and make daily records of rainfall, temperatures, humidity, and wind. Also, some measure of plant production should be made, even in the earliest trials. Such records will help characterize the site and aid in comparisons between sites and years of planting.

JUNIPER EFFECTS ON RESEEDING

Junipers affect reseeding by: 1) competing for soil moisture, 2) providing barriers to planting, 3) reducing soil wetting, 4) forming water-repellent soils under burned juniper slash, and 5) providing mulch which might aid some species and inhibit others.

Junipers are evergreen, using water throughout the year. Plantings in juniper stands often fail because of the seedlings' inability to compete for moisture with the widespread root system of junipers (Hull and others 1958). Johnsen (1962) reported one-seed juniper lateral root lengths were more than twice the height of the tree. Thus, a 10-foot-tall tree would affect plants growing within 20 feet; 34 such trees could affect all plants on an acre of land. Juniper removal is generally recommended before reseeding. Furthermore, standing trees, stumps, or slash are barriers to equipment movement through the stands. Removal of such barriers may be necessary before an area can be reseeded with ground equipment.

Juniper litter reduces the surface soil wettability under the tree, markedly retarding infiltration (Scholl 1971). Skau (1964) showed Utah junipers intercepted from 3 to 34 percent of the rainfall. Johnsen (1962) showed soils under one-seed junipers did not wet as deeply as soils between trees or under the tree base. This reduced wetting could delay or prevent the establishment of some plants under the tree crown. However, weeds and perennial grasses grow under herbicide-killed trees within a year of treatment, indicating detrimental effects do not last very long after rainfall interception and fresh litterfall are reduced. However, some species, such as muttongrass, do grow under junipers (Clary and Morrison 1973).

In Arizona, burning juniper slash sometimes leaves the soil under the burned slash bare for several years. Increased runoff from the bare spot causes an increase in grass growth on the edges of the bare spot (Arnold and others 1964). These fire-related bare spots seem more pronounced on sandy soils and may be the result of the movement into soils of organic materials vaporized by the fire (Savage 1974), especially when the burn is on dry, coarse-textured soils (DeBano and others 1976). The effects of litter or fire-induced water repellency appear to be localized and may not affect overall planting success except for small-scale experimental plots. Plowing or disking should do away with the detrimental effects by destroying the layer resistant to wetting.

Laboratory studies have shown extracts from juniper foliage and litter are phytotoxic to the seedlings of several grasses (Jameson 1970). Utah juniper foliage extracts repressed some grasses, such as blue grama, side oats grama, and crested wheatgrass, had little effect on pubescent wheatgrass and weeping lovegrass and increased fourwing saltbush growth (Lavin and others 1968). This indicates that juniper foliage and litter used as a mulch might harm some plants but help others. This, combined with the water repellency of soils under juniper litter, might explain the difficulty of establishing some plants by reseeding. However, juniper slash mulch has been successfully used in reseeding (Judd 1948; Judd 1966; Lavin and others 1981). In Arizona, juniper slash mulch increased survival, extended the green growth period, and protected the plantings from rabbits but did attract rodents (Lavin and others 1981). Excessive shading from fresh branches was initially detrimental to pubescent wheatgrass and fourwing saltbush, but this effect disappeared when the foliage fell from the branches (Lavin and others 1981). Weeds invaded under the juniper slash when established forage plants were absent. Scattering juniper branches as a mulch following juniper fuelwood harvesting is recommended to improve desirable plant remnants and aid broadcast seeds in the southwest (Lavin and others 1981). Dead, standing trees killed by herbicides aided understory recovery (Clary and others 1974) and water yield (Baker 1984).

ADAPTED SPECIES

Successful reseeding depends on establishing and properly managing species adapted to the area planted. During the past 50 years several hundred species have been planted to determine survival and growth at one or more locations in the southwestern pinyon-juniper. The 26 species listed in table 1 have established fair or better stands of vigorous plants in multiple-year plantings at one or more of 20 locations listed in table 2: 16 in Arizona and four in New Mexico (Springfield 1965; Lavin and Johnsen 1975, 1977a, 1977b; Johnsen and Gomm 1981). The plantings used were all seeded and evaluated in the same way. The results of other species adaptation trials in the southwestern pinyon-juniper have been reported by Judd (1966), and Judd and Judd (1976) for Arizona; and Merkel and Herbel (1973) and Springfield (1976) for New Mexico.

The 20 locations were divided into the climatic subtypes described earlier to help identify potential planting sites and to facilitate wider application of the results (table 2). In multiple-site subtype plantings adapted species established stands at each location planted. Subtypes represented by single

Table 1.--Reseeded forage species adapted to Arizona-New Mexico pinyon-juniper range subtypes described in text. (X = adapted, 0 = not adapted, - = not adequately tested)

	Cold			Cool		Warm		Hot	
Species	Moist	Dry Winter	Dry Summer	Moist	Dry Winter	Moist	Dry Winter	Dry	Moist
Grasses, C-3:									
Brome, Smooth	X	0	-	0	0	0	0	-	0
Fescue, Hard	0	-	-	X	0	-	0	-	-
Squirreltail, Bottlebrush	X	X	-	-	-	0	-	X	-
Wheatgrass									
Crested	0	0	X	0	0	0	0	0	0
Intermediate	0	0	X	X	0	X	0	0	0
Pubescent	X	X	-	X	0	X	0	0	0
Siberian	0	0	-	X	0	0	0	0	0
Tall	0	0	-	X	0	0	0	0	-
Western	X	X	-	X	X	X	X	X	0
Wildrye, Russian	X	X	X	X	0	0	0	0	0
Grasses, C-4:									
Bluestem, Yellow	0	X	-	X	0	0	0	0	X
Dropseed, Sand	0	0	-	0	0	0	X	0	0
Grama									
Blue	0	0	-	0	X	X	X	X	0
Sideoats	0	0	-	0	0	X	0	X	0
Lovegrass									
Boer	0	0	0	-	0	0	0	0	X
Wilman	0	0	-	-	-	0	-	0	X
Muhly, Spike	X	X	-	X	X	0	X	0	0
Sacaton									
Big	0	0	-	0	0	0	X	0	-
Alkali	0	0	-	0	0	0	X	X	0
Tridens, Rough	0	0	-	X	0	0	0	0	0
Forbs:									
Alfalfa, Yellow	0	0	-	X	0	0	0	-	-
Sweetclover, Yellow	0	0	X	0	0	X	0	0	-
Shrubs:									
Kochia, Forage	X	X	-	-	-	0	-	X	-
Saltbush, Fourwing	X	X	-	X	X	X	X	X	-
Twinberry, Rough	0	0	-	0	-	X	0	0	0
Winterfat	0	X	-	0	-	0	-	X	0

Table 2.--Subtypes, locations, rainfall, soils, and dominant woody plants on Arizona-New Mexico pinyon-juniper range reseeding sites. See text for details of subtype characteristics

Subtype	Location	Rainfall Annual	Rainfall Summer	Rainfall Winter	Soil Texture	Dominant Species[1]	Source[2]
Cold:							
Moist	Cosnino	18	9	9	loam	Juos, Pied, Jumo, Pipo	5
	Indian Flat	17	9	8	clay	Jumo, Pied, Pipo	3, 5
	Mortiz Lake	16	9	7	silt loam	Jumo, Juos, Pied	4, 5
	Peterson Flat	17	10	7	loam	Jude, Jumo, Pied	4, 5
Winter Dry	Dog Knobs	12	8	4	clay loam	Jumo, Pied	4, 5
	Red Mountain	12	8	4	clay	Jumo, Pied	3, 5
	Hart Ranch	13	8	4	loam	Juos, Pied	5
Summer Dry	Hualapai	14	6	8	loam	Juos, Pied, Artr	1
Cool:							
Moist	Mud Tank	18	9	9	clay	Jude	4
Winter Dry	Glorieta Mesa	15	10	5	sandy loam	Jumo, Pied	2
Warm:							
Moist	Blue Grade	16	8	8	clay	Juos, Pied, Qutu	3, 5
	Buckhead Mesa	20	10	10	clay	Jude, Jumo	4, 5
	Pine Creek	20	10	10	loam	Jude, Jumo	4, 5
	Pleasant Valley	19	10	9	loam	Jude, Jumo	4, 5
Winter Dry	Corona	15	10	5	clay loam	Jumo, Pied	2
	Ft. Bayard	14	9	5	clay loam	Jumo, Pied	2
	Monica	14	9	4	loam	Jumo, Pied	2
Dry	Drake	13	7	6	loam	Juos	4, 5
	Perkinsville	13	7	6	loam	Juos	4
Hot:							
Moist	Sierra Ancha	17	8	9	loam	Jude, Jumo, Qutu	4

[1]Jude = alligator juniper; Jumo = one-seed juniper; Juos = Utah juniper; Pied = pinyon; Pipo = ponderosa pine; Artr = big sagebush; Qutu = shrub live oak.
[2]1 = Schaus 1964 and field notes; 2 = Springfield 1965; 3 = Lavin and Johnsen 1975; 4 = Lavin and Johnsen 1977b; 5 = Johnsen and Gomm 1981.

locations may produce different results with more locations.

Of the 26 species (table 1), 13 are native and 13 are introduced. The three most widely adapted species, western wheatgrass, spike muhly, and fourwing saltbush, are native species. Twelve species are adapted to only one subtype, four to two subtypes, four to three subtypes, three to four subtypes, one to five subtypes, and two to seven subtypes. All species were not planted at all locations or subtypes, only three species, crested wheatgrass, intermediate wheatgrass, and Russian wildrye were planted in all nine subtypes, and 12 species were planted in eight of nine subtypes.

Some species, such as fourwing saltbush, are adapted to several subtypes but a single seed source may grow better in some subtypes than others. Other species, such as luna pubescent wheatgrass, may grow equally well in several subtypes (Johnsen and Gomm 1981). This indicates that seed source or cultivars are important for some species but not others. Some species adapted to a subtype may do better on one soil than another, which should be considered when planting specific sites. Immigrant forage kochia, a new species for the southwestern pinyon-juniper, is spreading rapidly on some sites and deserves further investigation.

Generally, C-3 grasses seem better suited to the cooler, moister locations and subtypes, while C-4 grasses seem better suited to the warmer, drier subtypes (table 1). This agrees with the reported distributions of species with these carbon pathways (Hattersely 1983). Descriptions of the characteristics of most of the species listed may be found elsewhere and will not be dealt with here (Merkel and Herbel 1973; Jordan 1981). However, little is known about the successional patterns of most planted species, especially the introduced ones.

Species failure is not, by itself, proof that a plant is not adapted. Some species may require special seed treatment or planting methods; others might survive in larger plantings with less severe animal depredations. Species needs for establishment, survival, and reproduction and how to meet those needs should be determined. Species adaptation is dependent first on seedling emergence and then its growth and survival. Transplanting has been used in limited studies to bypass emergence problems (Springfield 1970; Lavin and Johnsen 1975). The results of these limited tests indicate transplanting can be a useful tool in species adaptation trials which should be used more often.

SEEDBED PREPARATION

Seedbed preparation is usually considered essential for successful range seeding (Gomm and Lavin 1968; Jordan 1981). Numerous adaptations of mechanical and chemical seedbed preparation methods have been used for seeding southwestern pinyon-juniper; each has its advantages and limitations. Generally, plowing is the best method for preparing seedbeds. Moldboard plows are best for deep bottomland soils, but disk plows are preferred for rough, rocky sites. Plowing combined with disking, harrowing, and cultipacking produces a fine, firm, smooth, friable seedbed free of competition and effective for retaining soil moisture (Lavin and others 1973). However, plowed seedbeds are often invaded by weeds during the growing season after preparation. More gophers and mice may be found on plowed seedbeds, perhaps attracted by the weeds. Some plowed soils form a vesicular crust after the initial rains, making broadcast seeding and seedling emergence difficult. In Arizona, seedling emergence and survival were highest on plowed seedbeds, decreasing progressively on undercut sod, strip-undercut sod, herbicide-sprayed before planting, herbicide-sprayed at planting, and unplowed seedbeds (Lavin and others 1973).

On untilled seedbeds practices such as pitting, furrowing, interrupted furrows, and ripping have been tried with inconsistent results and, except for furrowing, are seldom used. Deep, wide furrows, which remove much of the competing vegetation, and concentrate rainwater, have been the best of the non-tilled seedbed preparation methods (Lavin and others 1981). In furrows, seed zone moisture was high throughout the growing season in Arizona but excessive soil sloughing was detrimental to seedling emergence (Lavin and others 1973, 1981). Species such as the wheatgrasses do well with deep furrowing (Lavin and others 1973, 1981), but species such as fourwing saltbush do best without furrows (Springfield 1970; Lavin and others 1981). Mulching increases furrowing effectiveness by reducing soil sloughing (Lavin and others 1981). Furrows and pits help seedling establishment in the southwestern pinyon-juniper during dry years but not in wet years or periods of extended drought. Plowing and furrowing are difficult to do on juniper control areas without first removing the debris.

Generally, prolonged spring and fall dry periods and the limited rainfall of the southwestern pinyon-juniper do not favor fallowing plowed seedbeds. However, fallowing has resulted in improved establishment and survival in Arizona (Lavin and others 1981). Pubescent wheatgrass and fourwing saltbush had better stands with fallowing than with nonfallowing on a cold, moist site, but not on dry sites. Fourwing saltbush was also helped by fallowing combined with juniper mulching on both cold and warm dry sites. Side oats grama and spike muhly had improved stands when fallowing was combined with juniper mulching of deep furrows on a warm, dry site. Weeds invade fallowed areas and may reduce the amount of stored soil water.

In Arizona, soils at or deeper than 12 inches did not become dry for at least 7 years after the junipers were killed by herbicides and left standing, while soils in adjacent areas with live trees dried to bedrock each spring (Johnsen 1980). Leaving the dead standing trees in place increased water yields (Baker 1984) and may help forage plant establishment. Removal of trees after the seeded plants are established would reduce the visual impact of a stand of dead trees but result in a drier site (Baker 1984). However, dead-tree removal should not affect the survival of established adapted species.

PLANTING METHODS

Many planting methods have been tried on southwestern pinyon-juniper ranges but, if seeds are properly covered, planting method seems less important than seedbed preparation. Overall, drilling is the best planting method, but, except for the rangeland drill, is often limited to relatively smooth, rock-and debris-free areas. Drilling may not be successful without seedbed preparation unless there is little plant competition. Because fine seeds may be difficult to drill, rice hulls or bran are sometimes used as a filler to make seeding small seeds easier (Lavin and Gomm 1968). Seeding depth is critical, especially with small seeds which are apt to be seeded too deeply and fail to emerge.

Seeds broadcast onto rough, rocky or debris-laden areas do best on loose soils with little plant competition. Seeds may be scattered and covered by soil disturbance during juniper clearing by bulldozing or chaining. Usually, however, the debris is burned and as soon after burning as possible, seeds are broadcast into the fresh ashes and newly disturbed soils before rain-induced crusts form. Small seeds may need no further treatment, but large seeds may need to be covered by raking, harrowing, cultipacking, or chaining. Seeds are sometimes hand-broadcast into disturbed soils and holes left by uprooting the trees without removing debris. On fuelwood harvest areas, seeds are hand-broadcast into the juniper slash and the areas under the cut trees with no other treatment. Responses to these planting methods have been variable, but the best responses are on areas with little plant competition.

Natural mulching materials improved seeding results in early southwestern pinyon-juniper seeding trials (Judd 1948, 1966) but the practice was felt to be too expensive and was not developed further. Since then, many different materials such as straw, litter, cinders, gravel, asphalt, and plastic films have been tried (Springfield 1972; Lavin and others 1981). Mulching improved seedling emergence but survival depended on additional rainfall during the growing season. Long-term survival and stand development have been similar with all mulches tried in Arizona (Lavin and others 1981). In Arizona, grasses remained green several weeks longer under juniper slash than under cinder or plastic film mulches (Lavin and others 1981). Areas mulched with juniper slash without established planted species became very weedy; native species then became established while adjacent unmulched areas remained weedy (Lavin and others 1981). Plastic film and juniper slash attracted rodents that damage plantings.

SEASON OF PLANTING

Early summer plantings are generally recommended in the southwest because this is when soil moisture and temperatures are most favorable for rapid germination and growth. However, fall plantings are considered for cool season plants such as the wheatgrasses. Seeding studies and large-scale plantings done between 1945 and 1966 in Arizona and New Mexico all indicated the best responses are from plantings which are followed closely by adequate rainfall for extended periods. Frequent rains which keep the seedling root zone moist are more important than planting into moist soil. For example, plantings made when the subsoils were wet and remained wet through the growing season failed if the surface 2 inches of soil dried between rainstorms (Lavin and others 1973; Johnsen and Gomm 1981).

Good stands have sometimes been established from plantings made at other times of the year. However, winter and spring plantings succeed only if rain is delayed until summer; otherwise the seeds germinate but seedlings die during the dry spring. Fall plantings succeed during wet, warm falls which allow the seedlings to grow rapidly and become large enough to survive the following dry spring; the seedlings may still fail if the summer is dry or the rains arrive late. Springfield (1956) concluded that fall planting success in northern New Mexico depended on snows which protect the seedlings from frost heaving and provide early spring moisture for early growth. Summer plantings fail if the rains are late or the fall dry period is early or lengthy. Late summer plantings may not survive the fall dry period. Delayed germination and emergence following planting, especially in the fall and spring, may cause failures due to a build up of a thick crust on the surface of some soils which can prevent seedling emergence. Some species, such as fourwing saltbush, have been successfully planted at a variety of times (Bridges 1942; Springfield 1970; Lavin and others 1973). This may be due as much to population variability of this species as to yearly weather variations. Some planting reports are from abnormally wet years and may be misleading for more typical years, thus planting trials should be done over a period of several years. Damping off during cold wet periods can also kill seedlings (Lavin and others 1973). Frost heaving can kill seedlings during winters with little snow. Regardless of season of planting, stand development depends on plants surviving the initial dry spring following planting. Thus, initial growing season success may not indicate successful stand establishment.

GRAZING SEEDED AREAS

Reseeding may not succeed even when planted properly under good growing conditions (Hessing and Johnson 1982). Generally, reseeded areas are protected from livestock for two or more growing seasons after planting. However, the area may receive concentrated use by wildlife and the seedlings may be lost. If the area is part of a larger pasture, it may receive concentrated, selective use by both wildlife and livestock, resulting in overuse. Reseeded areas must be protected from overuse. This has been attempted by expensive fencing which controls large animal access, and by planting large areas. Plummer and others (1968) recommend seeding pinyon-juniper areas in Utah larger than 500 acres to reduce the impact of animal concentrations. Little is known about how patterned placement of reseeded areas might avoid overuse or how reseeded areas would respond to the various grazing methods. It is not certain how long or to what degree plantings should be protected. Some species might benefit from light grazing near the end of the first growing season by reducing plant water needs and causing additional tillering or stooling. The effects of fertilizers have only been briefly examined on southwest ranges. Little is also known about how reseeded species fit into successional patterns and the longevity of planted stands under optimal management.

SUMMARY

Many species and planting methods have been tried in attempts to seed southwestern ranges. In an attempt to facilitate the use of information from plantings and to identify potential planting sites, a system of climatic subtypes based mainly on temperature and rainfall is being developed for southwestern pinyon-juniper areas. Information is needed from more plantings to increase the usefulness of such classification systems. Junipers make seeding success difficult through competition for soil moisture, formation of water repellent soil layers, and production of materials which inhibit growth of some plants.

Southwestern pinyon-juniper forage planting success depends on: 1) planting adapted species, 2) preparing seedbeds to remove competition and enhance infiltration, 3) covering the seeds, 4) planting at the proper time, and 5) protecting plantings from overuse. Of 26 species listed as adapted to one or more of nine climatic subtypes, three species are adapted to more than half of the subtypes: western wheatgrass, spike muhly, and fourwing saltbush. Plowing is the best seedbed preparation method; whereas, low tillage methods such as ripping, pitting, furrowing, and interrupted furrows have given inconsistent results. Small seeds broadcast onto soft, loose soils may need no further treatment, but larger seeds need to be covered by drilling, harrowing, cultipacking, or chaining. The use of juniper slash as a mulch helps establish some species but not others. Fallowing has aided some species on some sites. Early summer plantings have had the most consistent success in the southwestern pinyon-juniper. Many successfully established plantings have failed because of overuse by livestock and wildlife. The plantings must be managed to prevent overuse from grazing animals concentrating on planted areas after stands are established.

REFERENCES

Arnold, J. F.; Jameson, D. A.; Reid, E.H. The pinyon-juniper type of Arizona: effects of grazing, fire, and tree control. U.S. Department of Agriculture, Production Research Report 84; 1964. 28 p.

Baker, M. B., Jr. Changes in an herbicide-treated pinyon juniper watershed in Arizona. Water Resources Research. 20:1639-1642; 1984.

Bridges, J. O. Reseeding practices for New Mexico ranges. New Mexico Agricultural Experiment Station Bulletin No. 291; 1942. 48 p.

Clary, W. P.; Baker, M. B., Jr.; O'Connel, P. F.; Johnsen, T. N., Jr.; Campbell, R. E. Effects of pinyon-juniper removal on natural resource products and uses in Arizona. Research Paper RM-128. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1974. 28 p.

Clary, W. P.; Morrison, D. C. Large alligator junipers benefit early-spring forage. Journal of Range Management. 26:70-71; 1973.

DeBano, L. F.; Savage, S. M.; Hamilton, D. A. The transfer of heat and hydrophobic substances during burning. Soil Science Society of America Proceedings. 40:779-782; 1976.

Forsling, C. L.; Dayton, W. A. Artificial reseeding on western mountain range lands. Circular No. 178; U. S. Department of Agriculture, Forest Service; 1931. 48 p.

Gomm, F. B.; Lavin, F. Range seeding problems and research in the pinyon-juniper woodland type of southwestern United States. Annals of Arid Zone. 7:209-220; 1968.

Hattersley, P. W. The distribution of 3 carbon pathway and 4 carbon pathway grasses in Australia in relation to climate. Oecologia. 57:113- 128; 1983.

Hessing, M. B.; Johnson, C. D. Early secondary succession following restoration and reseeding treatments in Northern Arizona. Journal of Range Management. 35:667-669; 1982.

Hull, A. C., Jr.; Hervey, D. F.; Doran, C. W.; McGinnies, W. J. Seeding Colorado range lands. Colorado State Experiment Station Bulletin 498-S; 1958. 46 p.

Jameson, D. A. Degradation and accumulation of inhibitory substances from Juniperus osteosperma (Torr.) Little. Plant and Soil. 33:213-224; 1970.

Johnsen, T. N., Jr. One-seed juniper invasion of Northern Arizona grasslands. Ecological Monographs. 32:187-207; 1962.

Johnsen, T. N., Jr. Picloram in water and soil from a semiarid pinyon-juniper watershed. Journal of Environmental Quality. 9:601-605; 1980.

Johnsen, T. N., Jr.; Gomm, F. B. Forage plantings on six Arizona pinyon-juniper subtypes. Journal of Range Management. 34: 131-136; 1981.

Johnsen, T. N., Jr. Unpublished data on file at: U. S. Department of Agriculture, Agricultural Research Service, 2000 East Allen Road, Tucson, AZ 85719.

Jordan, G. L. Range seeding and brush management on Arizona rangelands. Arizona Agricultural Experiment Station T81121; 1981. 88 p.

Judd, B. I. Range seeding on the Tonto National Forest in Arizona. Journal of American Society of Agronomy. 40:567-568; 1948.

Judd, B. I. Range reseeding success on the Tonto National Forest, Arizona. Journal of Range Management. 19:296-301; 1966.

Judd, B. I.; Judd, L. W. Plant survival in the arid Southwest 30 years after seeding. Journal of Range Management. 29:248-251; 1976.

Lavin, F. Helpful hints for range reseeding in Northern Arizona. Arizona Stockman. 14(6):8, 22, 23 & 27; 1948.

Lavin, F. Promising species for artificial reseeding the woodland zone of Arizona. In: Annual Report - 1953; Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1954: 12-14.

Lavin, F.; Gomm, F. B. Stabilizing small seed dilution mixtures. Journal of Range Management. 21:328-330; 1968.

Lavin, F.; Gomm, F. B.; Johnsen, T. N., Jr. Cultural, seasonal, and site effects on pinyon-juniper rangeland plantings. Journal of Range Management. 26:279-285; 1973.

Lavin, F.; Jameson, D. A.; Gomm, F. B. Juniper extract and deficient aeration effects on germination of six range species. Journal of Range Management. 21:262-268; 1968.

Lavin, F.; Johnsen, T. N., Jr. Forage shrub adaptation trials at three pinyon-juniper sites. ARS-W-29. Tucson, AZ; U. S. Department of Agriculture, Agricultural Research Service; 1975. 5 p.

Lavin, F.; Johnsen, T. N., Jr. Planting site classification and longtime species adaptation in the pinyon-juniper woodland. ARS-W-45. Tucson, AZ: U. S. Department of Agriculture, Agricultural Research Service; 1977a. 25 p.

Lavin, F.; Johnsen, T. N., Jr. Species adapted for planting Arizona pinyon-juniper woodland. Journal of Range Management. 30:410-415; 1977b.

Lavin, F.; Johnsen, T. N., Jr.; Gomm, F. B. Mulching, furrowing, and fallowing of forage plantings on Arizona pinyon-juniper ranges. Journal of Range Management. 34:171-177; 1981.

McGinnies, W. J.; Harvey, D. F.; Downs, J. A.; Everson, A. C. A summary of range seeding trials in Colorado. Colorado Agricultural Experiment Station Technical Bulletin 73; 1963. 81 p.

Merkel, P. L.; Herbel, C. H. Seeding non-irrigated lands in New Mexico. New Mexico Interagency Range Commission Report No. 10; 1973. 95 p.

Parker, K. W.; McGinnies, W. G. Reseeding southwestern ranges. Note No. 86: U. S. Department of Agriculture, Forest Service, Southwestern Forest and Range Experiment Station; 1940. 5 p.

Plummer, A. R.; Christensen, D. R.; Monsen, S. B. Restoring big-game range in Utah. Utah Division of Fish and Game Publication No. 68-3; 1968. 183 p.

Savage, S. M. Mechanisms of fire-induced water repellency in soil. Soil Science Society of America Proceedings. 38:652-657; 1974.

Schau, D. Range Improvements on the Hualapai. Arizona Catalog. 20(10):14- 16, 18; 1964.

Scholl, D. G. Soil wettability in Utah juniper stands. Soil Science Society of America Proceedings. 35:344-345; 1971.

Sellers, W. D.; Hill, R. H. (eds.) Arizona climate 1931-1972. Tucson, AZ: University of Arizona Press; 1974. 616 p.

Skau, C. M. Interception, throughfall, and stemflow in Utah and alligator juniper cover types of Northern Arizona. Forest Science. 10:283-287; 1964.

Springfield, H. W. Relation of time of planting to establishment of wheatgrasses in Northern New Mexico. No. 24; Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1956. 9 p.

Springfield, H. W. Adaptability of forage species sites in New Mexico. Research Note RM-57. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1965. 4 p.

Springfield, H. W. Germination and establishment of fourwing saltbush in the southwest. Research Paper RM-55. Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1970. 48 p.

Springfield, H. W. Using mulches to establish woody chenopods. In: McKell, C. M.; Blaisdell, J. P.; Goodin, J. R., eds. Wildland shrubs--their biology and utilization; General Technical Report INT-1. Ogden, UT: U. S. Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station; 1972. 382-391.

Springfield, H. W. Characteristics and management of southwestern pinyon-juniper ranges: The status of our knowledge. Research Paper 160; Fort Collins, CO: U. S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station; 1976. 32 p.

Tuan, Y. F.; Everard, C. E. New Mexico's climate: the appreciation of a resource. Natural Resource Journal. 4:268-308; 1965.

Wilson, C. P. The artificial reseeding of New Mexico ranges. New Mexico Agricultural Experiment Station Bulletin No. 189; 1931. 37 p.