Cultural, Seasonal, and Site Effects on Pinyon-Juniper Rangeland Plantings

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Highlight: *Planting season and cultural treatment effects on emergence and survival of three range species were determined for two cold, dry pinyon-juniper sites in north central Arizona. Plowing was the most effective seedbed preparation for controlling plant competition. Furrow drilling also eliminated a large amount of competition. Emergence and survival (E & S) of Luna pubescent and Nordan crested wheatgrass averaged highest with fall planting, but summer planting was best for E & S of fourwing saltbush. E & S averaged highest on plowed seedbeds and decreased progressively on undercut, undercut-strip, presprayed, sprayed, and control seedbeds. Surface drilling on tilled seedbeds increased E & S over furrow drilling for fourwing saltbush and usually for Nordan crested wheatgrass. Drilling in wide, shallow furrows increased Luna pubescent wheatgrass E & S. Furrow drilling increased E & S for all species on nontilled seedbeds. There were some significant interactions among treatment combinations. Practical application of results is discussed.*

Seeding is often required on pinyon-juniper rangeland to reclaim depleted areas and to balance or increase forage. However, cold, dry sites with spring and fall drought, such as those in central Arizona, are difficult to seed successfully (Gomm and Lavin, 1968).

Under arid rangeland conditions germination, emergence, and establishment are the most critical phases in the growth cycle of seeded plants. Adapted species once established are able to survive conditions that would kill the seedlings. Improving the microenvironment offers a promising potentiality for increasing establishment. Some of the more practical means for bringing about this improvement are planting when growing conditions are most favorable and using seedbed preparation and planting methods that ameliorate soil moisture and temperatures to better suit plant needs (Lavin and Springfield, 1955).

Species requirements and moisture and temperature pattern dictate the best planting time. The larger a seedling becomes before it is subjected to drought, frost, and other adversities, the better chance it has to survive (Plummer et al., 1955). Reynolds et al. (1949) recommended early summer and fall as best time for planting cool season species at the higher elevations in Arizona and New Mexico. Springfield (1956) working in northwestern New Mexico concluded that dependable winter snowfall is needed for fall plantings of pubescent and crested wheatgrass to be consistently successful. Results reported from season of planting trials for fourwing saltbush have been variable, so that all seasons have received favorable recommendation for time to plant (Wilson, 1928; Bridges, 1942; Hervey, 1955; Plummer, Monsen and Christensen, 1966; Springfield, 1970).

Seedbed preparation is usually essential for range seeding success (Pearse, 1952; Plummer et al., 1955; Gomm and Lavin, 1968). The seedbed may vary with the needs of the different species (Waisel, 1962; Pendleton, 1966; Cohen and Tadmor, 1969) but must include control of competing vegetation (Ellern and Tadmor, 1966; Gomm and Lavin, 1968). Seedbeds may be prepared by mechanical or chemical methods (Plummer et al., 1955; Hull et al., 1958). Numerous adaptations have been used, each with its advantages and limitations (Pearse, 1952).

Plowing reduces initial competition to a minimum and is one of the oldest and most widely used of the mechanical methods (Currier, 1971). Undercutting leaves a mulch of vegetative litter on the soil surface, which often improves the microclimate for germination and emergence (Gomm and Lavin, 1968; Tadmor et al., 1968).

Chemical methods involve applying herbicides to unwanted vegetation. These methods create a minimum of soil disturbance and leave a mulch of dead plants on the soil surface (Gomm and Lavin, 1968). They can also be used on areas difficult to prepare by mechanical means. Problems are the planting difficulties engendered by the dead vegetation (Larson et al., 1970; Henry and Johnson, 1971); time and placement requirements of the herbicide used; adverse effects the herbicide may have on the seeded species; and possible herbicide residues.

Two planting methods used in range seeding are surface and furrow drilling. Surface drilling is a preferred method that

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Fig. 1. *Study areas: (*left*) Red Mountain pinyon-juniper savannah showing the dense, even understory of blue grama sod; (*right*) cleared pinyon-juniper woodland at Hart Ranch showing irregular sod cover and shallow, rocky soil.*

provides good control of seed distribution, planting depth, seed coverage and seed-soil contact, allowing a full stand to be obtained with a minimum amount of seed (Lavin and Springfield, 1955; Plummer et al., 1955; Bates and Cox, 1969; Currier, 1971). Furrow drilling increases soil moisture by concentrating precipitation, decreasing runoff, increasing infiltration, and decreasing evaporation (Bertrand, 1965). Furrow drilling alone may eliminate sufficient competition where only remnant cover exists for successful establishment of seeded species (Currier, 1971). Hull et al., (1958) cautions that furrow drilling should be used only in stable soil, so seed will not be buried too deeply by soil sloughing.

Site Description

The study was conducted at two sites: Red Mountain, which is 35 miles northwest, and Hart Ranch, 33 miles southeast of Flagstaff, Ariz. (Fig. 1). Climatic conditions are similar for both sites. Annual precipitation averages between 12 and 14 inches with extremes ranging from less than 6 to over 18 inches. Precipitation is highest during July and August and peaks again in January and February. The driest weather usually occurs from May through June, followed by a less severe dry period from October through November.

Summers are mild with maximum ambient temperatures rarely exceeding 100°F. Winters are cool to cold with temperatures occasionally falling below 0°F. Winter precipitation usually falls as snow that melts quickly and seldom covers the ground for more than a few days at a time.

The elevation above sea level is 6,400 ft at Red Mountain and 6,500 ft at Hart Ranch. The topography at both sites is flat to gently rolling with slopes up to 2%. The Red Mountain site is located on a moderately deep clay loam soil of the Thunderbird Series derived from basaltic material. The Hart Ranch soil is a shallow gravelly loam of the Laporte Series derived from Kaibab limestone. Both are major soil series in the pinyon-juniper woodland of Arizona and New Mexico.

The native vegetation at Red Mountain was pinyon-juniper savannah with a thin stand of medium to small oneseed juniper (*Juniperus monosperma* (Engelm.) Sarg.) and pinyon pine (*Pinus edulis* Engelm.) as the main tree species. The trees were cleared and removed from the experimental area as needed during the progress of the study. The understory consisted predominantly of a dense, uniform blue grama (*Bouteloua gracilis* (H.B.K.) Lag.) sod. At Hart Ranch the original tree stand was denser and larger than at Red Mountain and consisted of a oneseed juniper, Utah juniper (*Juniperus osteosperma* (Torr.) Little) and pinyon pine mixture. This stand had been cabled in 1961. The dead trees on the experimental area were piled with a bulldozer in fall, 1964, and burned in early spring, 1965. Blue grama and broom snake weed (*Gutierrezia sarothrae* (Pursh) Britt. & Rusby) were the main understory species. The blue grama sod was sparser and more broken than at Red Mountain. It also contained fairly large openings where the trees had been piled and burned.

Procedures

Plantings were made at Red Mountain from 1964 through 1966 and at Hart Ranch in 1965 and 1966. A combination split plot-split block design with four replications was used. Split sequence in order of decreasing size was two planting seasons, six seedbed preparations, three species, and two planting methods. Size of the smallest plot was 10 by 18 ft. Data were analyzed by analysis of variance and the Duncan Range Test (Duncan, 1955).

The two planting seasons were summer and fall. Summer plantings were made in late June or early July, with the exception of 1964 at Red Mountain, which was made in early August. Fall plantings were made in early October.

The six seedbed preparations tested were control, prespray, spray, undercut, undercut-strip, and plow. The control received no treatment except for clearing of trees and brush. Prespraying was done one month before seeding with the sodium salt of dalapon[1] in a water carrier. Application was at a rate equivalent to 2 lb active ingredient and at a volume of 20 gal solution/acre. The herbicide solution was applied by boom from a pressure-regulated compressed air sprayer. For the spray method, herbicide was applied immediately before seeding. In all other respects application was the same as for prespraying. Undercutting was done with knife weeder blades attached to an A-frame tool bar. This treatment undercut the native vegetation, mainly blue grama sod, and left it on the soil surface as litter. The undercut-strip method left 8-inch wide strips of live vegetation between 16-inch undercut swaths. Otherwise, procedure was the same as for the undercut method. For summer and fall, 1966, both the undercut and undercut-strip treatments were undercut twice. Plowing was done with a two-bottom moldboard plow to a depth of 4 to 6 inches. After plowing the ground was

[1] Mention of a trademark name or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable.

Table 1. Live plant cover (%) remaining after seedbed preparation and planting method treatments at Red Mountain.

Seedbed preparation	Planting method		
	Surface drill	Furrow drill	Mean
Control	22	14	18
Prespray	15	9	12
Spray	19	12	16
Undercut	6	4	5
Undercut-strip	16	9	13
Plow	Trace	0	Trace
Mean	13	8	11

disked, harrowed, and cultipacked producing a fine, firm, smooth seedbed free of plant litter.

Species studied were Luna pubescent wheatgrass (*Agropyron trichophorum* (Link) Rict.), fourwing saltbush (*Atriple canescens* (Pursh) Nutt.) and Nordan crested wheatgrass (*Agropyron desertorum* (Fisch.) Schult.). Seeding rate was 25 viable seed per linear foot of drill row.

Planting methods were surface and furrow drilling. With surface drilling seed was planted ½ to 1 inch deep in rows made with double disk furrow openers. Seeding depth was controlled with depth bands. For furrow drilling, furrows were first formed with hiller disks mounted on a tool-bar assembly. Seed was then drilled into the furrow bottoms in the same manner as for surface drilling. Individual plots had five drill rows starting 1 ft in from the corner on the short axis and spaced on 2-ft centers.

Furrows used in 1964 and in summer of 1965 were 4 inches deep, measured from the original soil surface, and approximately 1 ft wide. A modified furrow was substituted from fall, 1965, through fall, 1966. This furrow was formed with two overlapping hiller disks. It was 2 inches deep from the initial soil surface and approximately 18 inches wide with a broader bottom and more gently sloping sides than the original furrow.

Climatic measurements were made of precipitation by standard rain gauge, air temperature and humidity by hygrothermograph, soil temperature by thermocouple, and soil moisture by gypsum resistance block.[2]

Treatment effects on the existing plant cover were evaluated by ocular estimate and expressed as percentage of total area covered by live vegetation (Brown, 1954). The mean of 12 individual plots was used for each treatment combination. Estimates are for Red Mountain only because the vegetative cover at Hart Ranch was too irregular for meaningful evaluation of treatment effects.

Number of seeded plants per 1000 ft of row length was used to compare treatment effects on seedling emergence and plant establishment. All plants in each plot were counted. Emergence counts were made when seedlings were most numerous and survival counts at the beginning of the second growing season. Since maximum emergence for fall plantings did not occur until the following spring, counts were made during the first and second spring after planting.

Results and Discussion

Elimination of Original Cover

Plowing was the most effective and dependable seedbed treatment tested for eliminating plant competition (Table 1). Undercutting ranked second. Some of the blue grama sod, especially in the undercut-strip seedbeds, died back so slowly after a single undercutting that final plant kill could not be accurately determined in the initial observation. Undercutting the same area twice reduced competing vegetation from 8 to 2% for the undercut treatment and from 19 to 10% for the undercut-strip treatment.

Initial response of blue grama to dalapon prespray and spray treatments was highly variable. Most rapid control was obtained by treatment of actively growing plants. Application often was not made at this time because of our planting schedule. Response of slow-growing and dormant plants to dalapon was delayed. Within a year after treatment, however, control improved and differences among planting seasons and years decreased. Remnant live cover, however, still varied from 1 to 14%.

Bioassays with pubescent wheatgrass and oats were made on soil samples taken from the treated areas 3 to 5 months after spraying. All tests were negative for toxic quantities of dalapon. Thiegs (1955) found that dalapon is broken down in warm moist soil by microbial action in 2 to 4 weeks. Brown and Carvell (1961), however, obtained good control of grasses for 3 years with dalapon.

Surface drilling with double disk openers eliminated very little existing vegetation. Furrow drilling, however, eliminated about one-third of this cover. The deep, narrow furrows appeared to be slightly more effective for vegetation control than the wide, shallow ones.

Emergence and Survival

Planting season and site

Both emergence and survival of Luna pubescent and Nordan crested wheatgrass

Table 2. Plant emergence and survival per 1000 linear ft of row with summer and fall plantings.

Species, site and planting year	Emergence		Survival	
	Summer	Fall	Summer	Fall
Luna pubescent wheatgrass				
Red Mountain				
1964	20	233*[1]	3	47[2]
1965	2	512*	6	146[2]
1966	1927	888*	213	189
Hart Ranch				
1965	1238	3648**[1]	285	700**
1966	5	282*	2	170**
Mean	638	1113	102	250
Fourwing saltbush				
Red Mountain				
1964	59	1[2]	6	T[3]
1965	30	T*	7	7
1966	930	0	195	27*
Hart Ranch				
1965	552	0[2]	122	0[2]
1966	0	0	0	2
Mean	314	T	66	7
Nordan crested wheatgrass				
Red Mountain				
1965	T	262*	3	32*
1966	477	185	16	40**
Hart Ranch				
1965	191	940*	52	133
1966	0	13**	0	13**
Mean	167	350	18	55

[1] Significant differences between planting seasons are indicated by * at the 5% level and ** at the 1% level.
[2] Analysis of variance not appropriate because plant numbers did not have normal distribution, but differences are obvious.
[3] T = less than one plant per 1000 linear ft of row length.

[2] Lavin, Fred, F. B. Gomm, and T. N. Johnsen, Jr. Some cultural, seasonal, and site effects on soil temperature and moisture for pinyon-juniper rangelands. Unpublished manuscript.

averaged highest from fall plantings (Table 2). Planting year 1966 at Red Mountain was an exception, with summer plantings best. Seedlings from fall plantings did not emerge until the following spring. Springfield (1956) obtained similar results with the same species in northern New Mexico. Frischknecht (1951) reported that fall planting appeared to stimulate growth and development of some cool season grasses and suggested this stimulation might be a contributing factor for increased survival.

Only summer plantings of fourwing saltbush produced adequate emergence and survival. Fall plantings mainly failed, but a few fall-planted seed sometimes emerged during the following summer. At Hart Ranch in 1966, summer as well as fall plantings failed because of the prolonged summer drought. Springfield (1970) found that fourwing saltbush germinated best between 55° and 75°F. Plummer et al., (1966) reported that fourwing saltbush seedlings are highly sensitive to freezing temperatures. Damping off also causes major losses when seedlings emerge during cold wet weather.

Plantings with the best emergence usually had the highest survival. At Red Mountain in 1966, however, summer-planted Nordan crested wheatgrass had the best emergence but the poorest survival because of droughty post-emergence conditions. Survival counts sometimes exceeded those for emergence because of unusually small or grazed seedlings missed in the initial count or because of delayed germination. Cook et al. (1967) found no appreciable number of viable seed remaining after the first growing season for crested and pubescent wheatgrass.

A review of precipitation pattern-planting date relationships indicate their importance to both emergence and survival. In 1964 at Red Mountain the bulk of the rains occurred before and within a week after summer planting and the fall was dry. As a result, stands were poor because the soil was too dry for plant establishment much of the time. In 1965, Red Mountain summer plantings were poor because light showers germinated the seed but did not provide sufficient soil moisture for good establishment during the 15-day dry period that followed. At Hart Ranch the soil remained dry for 2 weeks after summer planting. Then a 1.06-inch rain germinated the seed and five additional well-distributed storms maintained soil moisture above permanent wilting point for a month. This timely moisture resulted in excellent

Table 3. Seedling emergence per 1000 linear ft of row with six seedbed preparation methods.

Species, location and planting year	Control	Prespray	Spray	Undercut	Undercut-strip	Plow	Sig.[1]
Luna pubescent wheatgrass							
Red Mountain							
1964	18b[2]	29b	28b	83b	64b	537a	**
1965	119	284	89	493	306	254	
1966	673d	956cd	1064cd	2305a	1484bc	1962ab	**
Hart Ranch							
1965	1703b	1990b	1940b	2346b	2339b	4340a	**
1966	183	47	70	182	209	167	
Mean	539	661	638	1082	880	1452	
Fourwing saltbush							
Red Mountain							
1964	16	2	32	24	48	57	
1965	1b	0b	2b	6b	0b	82a	**
1966	144c	157c	160c	722b	359bc	1249a	**
Hart Ranch							
1965	98b	47b	338b	266b	65b	842a	*
1966	0	0	0	0	0	0	
Mean	52	41	106	204	94	446	
Nordan crested wheatgrass							
Red Mountain							
1965	106	254	67	146	124	90	
1966	113c	243bc	170c	445ab	357bc	660a	**
Hart Ranch							
1965	312c	663b	414bc	473bc	487bc	1044a	**
1966	9	1	1	4	12	12	
Mean	135	290	163	267	245	452	

[1] Significant differences are indicated by * at the 5% level and ** at the 1% level.
[2] Numbers in each line followed by the same letter are not significantly different.

Table 4. Plant survival per 1000 linear feet of row with six seedbed preparation methods.

Species, location, and planting year	Control	Prespray	Spray	Undercut	Undercut-strip	Plow	Sig.[1]
Luna pubescnet wheatgrass							
Red Mountain							
1964	0[2]	18	5	10	46	72	
1965	5b	88b	6b	178a	65b	116b	*
1966	9b	62b	50b	452a	271a	363a	**
Hart Ranch							
1965	252b	352b	300b	571b	408b	1070a	**
1966	92	52	47	104	133	86	
Mean	72	114	82	263	185	341	
Fourwing saltbush							
Red Mountain							
1964	0b	0b	0b	0b	0b	20a	*
1965	0b	0b	0b	2b	1b	41a	**
1966	1b	19b	20b	142b	46b	440a	**
Hart Ranch							
1965	26b	2b	43b	47b	0b	248a	**
1966	0	2	0	2	0	2	
Mean	5	5	13	39	9	150	
Nordan crested wheatgrass							
Red Mountain							
1965	2b	17ab	9ab	34a	9ab	34a	*
1966	2b	2b	3b	29b	12b	120a	**
Hart Ranch							
1965	6c	113b	47bc	86bc	75bc	226a	**
1966	3	4	4	11	11	7	
Mean	3	34	16	40	27	97	

[1] Significant differences are indicated by * at the 5% level and ** at the 1% level.
[2] Numbers in each line followed by the same letter are not significantly different.

emergence. Many seedlings, however, died during the dry fall. Emergence of 1966 summer plantings at Red Mountain was excellent because of a favorable precipitation pattern and good soil moisture for approximately 4 weeks after seeding. However, a large number of seedlings died during late summer, fall, and spring because of several protracted dry periods. Plantings at Hart Ranch failed because a few light showers germinated the seed but did not provide enough soil moisture for emergence.

Fall planted pubescent and crested wheatgrass appeared to be able to emerge and establish with less moisture than summer plantings. This advantage was probably related to the lower temperatures associated with these plantings.

Overall, precipitation varied between sites and among months and years. Annual precipitation for completely measured years ranged from a high of 15.94 to a low of 7.75 inches with a mean of 10.85 inches. Precipitation averaged higher for Hart Ranch than for Red Mountain. Monthly precipitation ranged from a high of 3.42 to a low of 0.00 inches and over the total measurement period averaged highest for August.

Soil moisture to the 2-inch depth averaged higher for summer than for fall plantings. It also averaged slightly higher for Red Mountain than for Hart Ranch. Soil moisture in relation to treatments applied was somewhat more variable for Hart Ranch than Red Mountain.

Table 5. Plant emergence and survival per 1000 linear feet of row when seeded by surface and furrow drilling.

Species, location, and planting year	Emergence		Survival	
	Surface drill	Furrow drill	Surface drill	Furrow drill
Luna pubescent wheatgrass				
Red Mountain				
1964	187	66	45	5*[1]
1965	157	358	61	92
1966	839	1976**	150	253
Hart Ranch				
1965	2210	2677	373	611
1966	150	137	75	96
Species mean	709	1043	141	211
Fourwing saltbush				
Red Mountain				
1964	53	6*	7	0
1965	29	1*	11	3
1966	491	439	153	69**
Hart Ranch				
1965	424	128	93	29
1966	0	0	1	1
Species mean	199	115	53	20
Nordan crested wheatgrass				
Red Mountain				
1965	129	133	24	11*
1966	345	318	27	29
Hart Ranch				
1965	658	473*	108	77
1966	10	4**	6	7
Species mean	286	232	41	31
Mean	406	480	81	92

[1] Significant differences between planting methods are indicated by * at the 5% level and ** at the 1% level.

Seedbed preparation

Both emergence and survival averaged highest on the plowed seedbed and decreased progressively on the other five seedbeds as follows: undercut > undercut-strip > prespray > spray > control (Tables 3 and 4). For all species, locations, and planting years, considering significant differences only, seedling emergence ranked highest on the plowed or undercut seedbeds and lowest on the control or prespray. Plant survival ranked highest on the plowed or undercut seedbeds and lowest on the control. Species' sensitivity to seedbed preparation appeared to rank as follows: fourwing saltbush > Nordan crested wheatgrass > Luna pubescent wheatgrass. Other research (Lavin and Springfield, 1955; Springfield, 1970) also has shown that seedbed preparation is required for successful range seeding and that seedling establishment usually increases in proportion to the amount of competing vegetation removed.

Variability in emergence and survival on the prespray and spray seedbeds resulted in part from the corresponding variability in initial control of the competing vegetation. Dalapon, even when applied under optimum conditions, usually controlled the blue grama sod too slowly for satisfactory establishment of the seeded species during the same year.

The plowed and undercut seedbeds were the most effective for retaining soil moisture. Inconsistencies obtained, however, suggest that type of seedbed best suited for moisture conservation could differ with precipitation and site characteristics.

Planting methods

Emergence and survival of Luna pubescent wheatgrass averaged highest with surface drilling for 1964 plantings when deep, narrow furrows were used in the alternate treatment. For 1966, however, when wide shallow furrows were used, furrow drilling averaged highest (Table 5). For 1965, emergence and survival averaged highest with surface drilling for summer plantings when deep, narrow furrows were used but was highest for furrow drilling in fall plantings with wide, shallow furrows. In California the best establishment of pubescent wheatgrass was obtained from furrow drilling (Cornelius and Burma, 1970).

Fourwing saltbush emergence and survival averaged best with surface drilling. However, more plants became established in wide, shallow furrows than in deep, narrow ones. Springfield (1970) found that fourwing saltbush emerged best with shallow planting. He was able to establish this species in furrows at one site in New Mexico; but at another, sloughing from the furrow sides caused complete failure.

Nordan crested wheatgrass emergence and survival averaged highest with surface drilling, but results were variable among planting years. Number of emerging and surviving plants were higher with wide, shallow furrows than with deep, narrow furrows. McGinnies (1959) obtained improved establishment of crested wheatgrass in furrows, but Hull (1970) reported equally good establishment of the same species from both surface and furrow drilling.

Soil moisture was consistently higher for furrow than for surface drilling with differences most pronounced where competing vegetation had not been adequately controlled by seedbed preparation. The deep, narrow furrows first used, however, were detrimental to the species planted, because soil sloughing covered the seed too deeply for satisfactory emergence. The wide, shallow furrows were always best for Luna pubescent wheatgrass. Surface drilling was usually best for Nordan crested wheatgrass and always best for fourwing saltbush. Wein and West (1971) concluded that successful seeding in furrows is related to furrow shape, size and spacing, to soil type, and to intensity of precipitation.

Species' response to the planting methods tested are assumed to be related to inherent germination and seedling growth characteristics. Luna pubescent wheatgrass germinates vigorously, and the young seedlings grow rapidly. Thus it could be expected to overcome any adverse effects of moderate silting in wide shallow furrows. Nordan crested wheatgrass germinates well, but initial seedling growth is relatively slow so that both seed and seedlings could be buried too deeply for emergence even in wide, shallow furrows. Fourwing saltbush is sensitive to planting depth and emerges best from shallow plantings. This species, therefore, could be expected to do best with surface drilling.

Interactions

Interaction effects on seedling emergence and plant survival were analyzed between (1) planting season and seedbed preparation, (2) planting season and planting method, (3) seedbed preparation and planting method, and among (4) planting season, seedbed preparation, and planting method. Only significant interactions are discussed unless otherwise designated.

Season-seedbed interactions for emergence of Luna pubescent and Nordan crested wheatgrass were variable among planting years. Plant survival, however, was highest from fall plantings on plowed and undercut seedbeds. Elimination of blue grama competition appeared somewhat more crucial for establishment in summer than in fall plantings. This interaction probably occurred because blue grama grows most rapidly and uses the largest amounts of moisture in July and August. Fourwing saltbush emergence and survival were both highest from summer planting on the plowed seedbed. Treatment combinations which included fall planting mainly failed.

Season-planting method interaction for emergence and survival of Luna pubescent and Nordan crested wheatgrass was inconclusive because of variability among planting years. This variability resulted in part from the two types of furrows used. Fourwing saltbush emergence and survival were consistently highest from surface drilled summer plantings.

Seedbed-planting method interactions for emergence and survival of Luna pubescent wheatgrass were variable among planting seasons and years. For fourwing saltbush, however, emergence and survival were highest from surface drilling on a plowed seedbed. Nordan crested wheatgrass emergence was also highest with surface drilling on a plowed seedbed, but interactions for survival were mainly nonsignificant.

Season-seedbed-planting method interactions for Luna pubescent and Nordan crested wheatgrass were mostly nonsignificant. Overall, however, emergence and survival of Luna pubescent wheatgrass averaged best from fall planting drilled in wide, shallow furrows on a plowed seedbed. For Nordan crested wheatgrass, emergence and survival averaged best from fall planting surface drilled on a plowed seedbed. Fourwing saltbush emergence and survival were significantly best from summer planting surface drilled on a plowed seedbed.

Application

Our results suggest some practical applications for improving establishment of range plantings in the cold, dry pinyon-juniper woodland.

Fourwing saltbush and probably most warm season species need to be planted in summer. Fall is the preferred planting season for cool season species such as the wheatgrasses. They, however, have a wider temperature tolerance than warm weather species and can be planted either in summer or fall.

Plowing is currently the best seedbed preparation for eliminating competing vegetation and establishing seeded stands. Plowed seedbeds, however, were usually invaded by weedy forbs during the growing season following preparation. Gophers also were most numerous on plowed seedbeds, probably attracted by the forb growth. A vesicular crust formed on the surface of the plowed seedbeds at Red Mountain. This structure is common to many soils in arid regions (Springer, 1958).

Effectiveness of undercut seedbed preparation might be improved by using heavier equipment. This equipment should have a rigidly mounted undercutting blade and perhaps vertical fins on the upper surface of the blade to break up the sod.

Dalapon gave consistently good control of blue grama within a year after application. Effectiveness for seedbed preparation might be improved, therefore, by applying it a year ahead of planting.

We had trouble penetrating the soil and covering the seed with a double disk planter on the nontilled seedbeds. Others also have had the same difficulty (Henry and Johnson, 1971). Surface drilling on nontilled seedbeds might be improved by using single-disk openers, improved covering mechanism, and heavier equipment such as the Rangeland drill.

A light layer of native grass mulch over the seed row can improve establishment of seeded species (Springfield, 1970). We observed that the mulch provided by undercutting was pulled away from the seed row by surface drilling and completely removed by furrowing so that mulching benefits were decreased or lost. On the undercut seedbeds some attachment for pulling the mulch back over the seed row after surface drilling might be advantageous.

The advantage of furrow drilling for establishing seeded species is greatest on noncultivated seedbeds where removal of competing vegetation has been inadequate. On cultivated seedbeds, furrow drilling is recommended only for stable soils and for large-seeded species with good seedling vigor. It can be detrimental to small, slow growing seedlings even when soil sloughing from the furrow sides is minimal. Furrow shape is important. It should be wide and shallow with gently sloping sides so that young seedlings are not smothered by excessive soil sloughing.

Seedling size and vigor as well as number are increased by use of favorable seedbed preparation-planting method combinations such as plowing and surface drilling for fourwing saltbush. This increase in size and vigor helps the plants to survive many of the adverse conditions they encounter.

Planted species are damaged by insects, rodents, rabbits, and big game, particularly in the spring. The potential for damage needs to be anticipated and suitable control measures used as necessary.

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