Forage Plantings on Six Arizona Pinyon-Juniper Subtypes

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Abstract

Forty-four species and varieties of forage plants, including 3 shrubs, 6 forbs, and 35 grasses, were planted at each of six sites in four Arizona pinyon-juniper climatic subtypes. Represented were cold-moist and cold-dry climatic subtypes each on medium and fine-textured soils; a warm-moist climatic subtype on fine-textured soil; and a warm-dry climatic subtype on medium-textured soil. Sites are described and classified to help identify planting potential and facilitate wider application of results. Data are given on plant emergence, establishment, survival during 12 growing seasons, and forage production. *Agropyron smithii* Rydb., *A. intermedium* var. *trichophorum* (Link) Halac., and *Sitanion hystrix* (Nutt.) J.G. Sm. successfully revegetated swelling clay soils. These three species, *Atriplex canescens* (Pursh) Nutt., and *Bouteloua gracilis* (H.B.K.) Lag. ex Steud. were the most widely adapted species tested.

Successfully revegetating pinyon-juniper rangeland depends on using species adapted to specific sites. Information is needed to help determine why planted species succeed or fail on a given area and how to correlate species and sites (Gomm and Lavin 1968).

Species adaption on pinyon-juniper rangelands has been reported by Judd (1966), Renney (1972), Judd and Judd (1976), and Lavin and Johnsen (1977a, 1977b) for Arizona; Springfield (1965) and Merkel and Herbel (1973) for New Mexico; McGinnies et al. (1963) for Colorado; and Plummer et al. (1968) for Utah.

This study reports the results of forage-species plantings made in relation to pinyon-juniper climatic subtypes (Lavin and Johnsen 1977a, 1977b) paired with soil types.

The accompanying site descriptions and classifications help identify potential planting sites and facilitate wider application of the results onto similar sites within 20.7 million ha of pinyon-juniper rangeland in Arizona, New Mexico, Colorado, and Utah. This includes many areas invaded by junipers since the turn of the century (Johnsen 1962; Johnsen and Elson 1979), on which forage production could be restored. Site conditions not previously reported are included. Data are presented to help determine why various species failed or are not desirable at specific sites.

Materials and Methods

Site Descriptions and Classifications

Six study sites in four pinyon-juniper climatic subtypes were used (Table 1). Cold-moist sites were represented by Cosnino, 14 km east of Flagstaff, in the SE. ¼ sec. 24, T. 21 N., R. 8 E., and Indian Flat, 27 km north of Flagstaff, in the NW. ¼ sec. 21, T. 24 N., R. 7 E. Cold-dry sites were represented by Hart Ranch, 37 km southeast of Flagstaff, in the SW. ½ sec. 20, T. 19 N., R. 11 E., and Red Mountain, 43 km northwest of Flagstaff, in the NE. ¼ sec. 1, T. 25 N., R. 4 E. Warm-moist sites were represented by Bluegrade, 59 km southwest of Flagstaff, in the NE. ¼ sec. 25, T. 16 N., R. 6 E. Warm-dry sites were represented by Drake, 90 km southwest of Flagstaff, mainly in the SE. ¼ sec. 28, T. 19 N., R. 1 W.

The pinyon-juniper climatic subtypes are based on precipitation and temperature (Lavin and Johnsen 1977a). Data from nearby weather stations and more distant stations with similar elevation, physiography, and vegetation (Sellers and Hill 1974) were combined with limited on-site measurements to make the classifications.

Arizona has distinct periods of summer and winter rainfall, with dry springs and falls. Indian Flat and Red Mountain receive more than half of their annual rainfall from May through October; Bluegrade and Drake, more than half from November through April; and Cosnino and Hart Ranch, about equal amounts during each rainfall period. All sites receive some snow during the winter.

Soils were described from on-site examination by soil scientists experienced with Arizona pinyon-juniper range soils. Four soil series are represented (Table 1). Cosnino and Hart Ranch have similar Wiona loams classified as loamy, carbonatic, mesic, Lithic Torriorthents. Indian Flat and Red Mountain have similar Thunderbird clay loams classified as fine, montmorillonitic, mesic, Aridic Arguistolls. Bluegrade has a Springerville clay loam classified as fine, montmorillonitic, mesic, Typic Chromusterts. Drake has a Tajo gravelly loam classified as fine-loamy, mixed, mesic Petrocalcic Paleustolls. All the soils have moderate infiltration rates (1.5 to 5.1 cm per hour) except that at Bluegrade which has a slow infiltration rate (0.15 to 1.5 cm per hour) (Miller and James 1972; Wheeler and Williams 1974; Wendt et al. 1976). Soil depths range from 15 to 50 cm, with an estimated water-storage capacity of 7.6 to 12.7 cm, at Cosnino, Hart Ranch, and Drake. Soil depths at Indian Flat and Red Mountain range from 56 to 102 cm, with estimated water-storage capacities of 20 to 25 cm. The Springerville soil at Bluegrade ranges from 91 to more than 152 cm deep, with an estimated water-storage capacity of 46 to 56 cm. During late spring, soils at the study sites are usually dry throughout. Moisture from high-intensity, brief summer thunderstorms seldom penetrates deeply into the soil; deep-soil moisture is usually replenished by low-intensity, long-lasting winter storms.

In elevation, precipitation, temperature, soil, and vegetation (Table 1), the sites represent a wide range of conditions common in Arizona pinyon-juniper rangelands. The study sites are all relatively level, so differences due to slope and aspect are minimal. Study sites were fenced against livestock, but Hart Ranch was opened to livestock grazing in late 1970. All sites are on national forests except Hart Ranch, which is on privately owned land. Drake and Red Mountain are located near species-adaptation test sites reported earlier; Red Mountain is adjacent to the earlier Dog Knobs site (Lavin and Johnsen 1977a, 1977b).

Procedure

Seed plantings of 44 promising species and recognized varieties were made June 8 to July 1, 1966. Seedbed preparations began with removal of live trees at Red Mountain, Indian Flat, and Drake, and of slash left from chaining and burning at Hart Ranch, Cosnino, and Bluegrade. Seedbeds were plowed during May; rocks and other debris were removed, and the seedbeds were smoothed and lightly packed with a cultipacker.

Seeds were planted 0.6 to 2.5 cm deep at the rate of 25 to 30 pure

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Hart Ranch permitted use of land; U.S. Forest Service, Southwestern Region, provided land and much of the fencing; U.S. Soil Conversation Service provided technical assistance on soils; and Plant Materials center at Tucson, Arizona, furnished much of the seed.

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live seeds per 0.3 m in shallow furrows. Planting dates were: Hart Ranch, June 8; Cosnino, June 9; Bluegrade, June 14; Drake, June 17; and Red Mountain, July 1. Indian Flat plantings were delayed by rainstorms; partial plantings were made on June 29, June 30, and July 1. Weeds were not controlled. Similar plantings had been made at Hart Ranch and Red Mountain in 1965.

Individual plots were 1.5 by 6.1 m, with four rows spaced 30 cm apart and 60 cm between rows of adjacent plots. A randomized-block experimental design with four replicates was used at each site.

A standard rain gauge modified to reduce evaporative losses (Gomm 1961) collected rainfall at each site. Recording rain gauges were also used at Red Mountain, Hart Ranch, Indian Flat, and Drake. Totalizing anemometers recorded wind movement. Duplicate sets of gypsum electrical-resistance blocks (Taylor et al. 1961) buried 1.3, 5, 15, 30, 46, and 61 cm deep in the soil measured soil moisture-depletion trends at each site. Thermographs in furrow bottoms at Hart Ranch, Red Mountain, Bluegrade, and Drake recorded soil temperature and relative humidity 7.6 cm above the soil at Red Mountain, Hart Ranch, and Drake.

Plant numbers were determined by sampling 12 random 0.3 m row segments per plot at the time of apparent maximum emergence, at the end of the first growing season, and at the beginning and end of the second growing season. Seed were recovered from plots with little or no emergence to determine the condition of the seeds. Estimates of percent stand (Gomm 1974) were made in the fall of 1968, 1969, and 1970. Forage production was determined by double sampling and weight estimates in the fall of 1969 and 1970 for selected grass species. Long-term relative stand ratings (Hull 1954) were made during the spring and fall of 1977 to obtain representative ratings of both cool- and warm-season plants. Stands were rated on a scale of 0 to 10, representing the actual stand in relation to the best possible stand, considering plant numbers, distribution, vigor, and height. Seed dormancy, stand increase, weed invasion, native plant establishment, plant damage, and growth stages were also observed.

Since planting in succeeding years could not be done, results were compared to those of prior plantings at the same or similar sites with the same climatic and soil subtypes. Because the results of the older plantings had been reported as adjective ratings, numerical data were converted to adjective ratings; thus, 0 = failure, 1 to 2 = very poor, 3 to 4 = poor, 5 to 6 = fair, 7 to 8 = good, and 9 to 10 = excellent. Only stand ratings differing by two or more adjective rating classes were considered to be different.

Results and Discussion

Climate

Precipitation was generally below the average in most of the Arizona pinyon-juniper sites in 1966. Bluegrade had the most total rainfall, 40.1 cm, and Hart Ranch the least 19.9 cm (Table 2). However, most of the warm-season rain came as thunderstorms from July 11 to August 1. These intense rains usually did not increase deeper soil-moisture content. During the summer, soils at the 1.3 cm depth remained dry (15 bars or more) after as much as 0.25 cm of rain had fallen; usually at least 0.6 cm of rainfall was needed to moisten the surface 1.3 cm of soil. At Indian Flat 6.1 cm of rainfall from a thunderstorm increased soil moisture content to a depth of only 30.5 cm; much of the water ran off the site.

As expected, the moisture content of the surface 15 cm of soil varied greatly at all sites. However, the 5-cm depth was dry for only about 1 week in late September at Cosnino, for about 2 weeks in late August through early September at Indian Flat, and from early September to early November at Red Mountain. This layer of soil was dry from mid-August to mid-September and then from late September to early November at Bluegrade and Drake, and from early August to early November at Hart Ranch.

Although the surface 15 cm of soil varied widely in moisture content, deeper soils were moist throughout the growing season at all sites. Soils deeper than 15 cm were dry in early July at only Indian Flat and Drake, and in October at only Drake.

Precipitation totals the year after planting ranged from 19.7 cm at Red Mountain to 41.0 cm at Bluegrade (Table 2). Infrequent light showers occurred until June, but storms were relatively frequent from June 15 to September 25. This frequent precipitation should have favored seedling emergence, establishment, and survival. Precipitation from October 1 to December 13 was infrequent and light. Widespread heavy snowstorms occurred from December 13 to 17, with 1.2 to 2.1 m of snowfall, containing an estimated 10 to 18 cm of moisture. The soils were not frozen, so much of the snowmelt went into the ground, wetting the entire soil profile and favoring survival of young established plants through the following spring drought.

After planting at Drake, soil at the 1.3-cm soil depth in planted

Table 1. Classification and description of study sites.

Subtype and name of study site[1]	Elevation, (m)	Mean annual precipitation, (cm)	Soils		Main plant species[2]	Distance (km) and direction from Flagstaff, Arizona
			Series	Texture		
Cold-moist						
Cosnino	2024	46	Winona	Gravelly loam	Juos, Pied, Jumo, Pipo, Bogr, Gusa	16 east
Indian Flat	2219	43	Thunderbird	Clay loam	Jumo, Pied, Pipo, Bogr, Chna, Teca, Gusa	40 north
Cold-dry						
Hart Ranch	1966	33	Winona	Gravelly loam	Juos, Pied, Bogr, Gusa	53 southeast
Red Mountain	1951	31	Thunderbird	Clay loam	Jumo, Pied, Bogr, Gusa, Chna	56 northwest
Warm-moist						
Bluegrade	1649	41	Springerville	Clay loam	Juos, Pied, Qutu, Bogr, Bocu, Gusa	56 south
Warm-dry						
Drake	1402	33	Tajo	Gravelly loam	Juos, Pied, Bogr, Boer, Bocu, Gusa	97 southwest

[1]Cold = annual mean temperature of 9.4C or less, January mean of -0.6C or less; Warm = annual mean temperature of 12.2-14.4° C; January mean of 2.3-3.9° C. Moist = 40 cm or more annual precipitation; Dry = 39 cm or less.

[2]Bocu = *Boutelous curtipendula;* Boer = *B. eriopoda;* Bogr = *B. gracilis;* Chna = *Chrysothamnus nauseosus;* Gusa = *Gutierrezia sarothrae;* Jumo = *Juniperus monosperma;* Juos = *J. osteosperma;* Pied = *Pinus edulis;* Pipo = *P. ponderosa;* Qutu = *Quercus tubinella;* Teca = *Tetradymia canescens.*

Table 2. Annual and warm-season (May 1–October 31) precipitation in 1966 and 1967 at six Arizona pinyon-juniper sites.

Climatic subtype and site	Precipitation, cm			
	1966		1967[1]	
	Annual	Warm-season	Annual	Warm-season
Cold-moist				
Cosnino	30.3	14.8[2]	35.8	27.9[5]
Indian Flat	32.1	19.0[3]	29.9	27.8[3]
Cold-dry				
Hart Ranch	19.9	9.7	25.7	21.6[3,4]
Red Mountain	23.5	14.8[2]	19.7	17.6[2]
Warm-moist				
Bluegrade	40.1	20.6[3,4]	41.0	23.1[3,4]
Warm-dry				
Drake	25.8	10.2[2]	35.8	29.9[5,6]

[1]Does not include December 13–17 storms.
[2]Includes one storm with more than 2.5 but less than 5.1 cm of rain.
[3]Includes one storm with more than 5.1 cm of rain.
[4]Includes two storms with more than 2.5 but less than 5.1 cm of rain.
[5]Includes four storms with more than 2.5 but less than 5.1 cm of rain.
[6]Includes two storms with more than 5.1 cm of rain.

rows reached 66.7° C in July, 61.1° C in August, and 60.0° C in September. Drake and Bluegrade were the warmest sites. Soil temperatures at the 1.3-cm soil depth exceeded 50° C on 30 days in August and 22 in September at Drake; 7 days in June, 5 days in July and 2 days in August at Red Mountain; 1 day in June and 6 days in July at Hart Ranch; and 27 days in August and 9 days in September at Bluegrade. Soil temperatures were not recorded until mid-July at Drake and Bluegrade and were not recorded at all at Cosnino and Indian Flat.

Emergence and Persistence

Seedlings began emerging in early August at all sites. Drouthy conditions caused by poor rainfall distribution and high soil temperatures reduced later emergence and seedling establishment, especially at Hart Ranch, Drake, and Bluegrade. Many of the seeds recovered at these three sites in late August had germinated but had died before emerging from the soil. The extended period of dry soil in the seeding zone was especially detrimental at Hart Ranch, which had the poorest seedling stands.

All 44 species and varieties emerged at Cosnino, Indian Flat, and Red Mountain, all cold sites (Table 3). Forty (91%) of the species and varieties emerged at Drake, 37 (84%) at Bluegrade, and only 15 (34%) at Hart Ranch. The best seedling stands were at Cosnino, where 25 (57%) of the species and varieties averaged two (8%) or more seedlings per 30 cm of row (Table 3). Neither Hart Ranch nor Drake had any species averaging two (8%) or more seedlings per 30 cm of row (Table 3).

Thirty-six (82%) of the 44 species and varieties planted were present on at least one site in 1977 (Table 3). Only 3 (7%) were found at all six sites, while 8 (18%) were not found on any site. Twenty-four species and varieties (55%) had stands rated 5 (fair) or better at one or more site (Table 3).

Seventeen species and varieties failed, having stands rated no better than poor and vigor no better than fair on any of the sites in 1977. Nine of these 17 had stands rated poor or very poor, six of the

Table 3. Relative stand, relative vigor, and seedling emergence of 1966 forage planting at six Arizona pinyon-juniper sites.

Species[1]	Performance[2] in indicated subtype and site.						
	Cold-moist		Cold-dry		Warm-moist	Warm-dry	
	Cosnino	Indian Flat	Hart Ranch	Red Mountain	Blue grade	Drake	Species average stand
Grasses							
Agropyron cristatum (FC 38315)	6/9/6	5/7/3	-/-/0	6/8/2	5/10/0	-/-/T	3.7
A. dasystachyum	9/10/25	5/7/4	-/-/T	-/-/22	5/7/0	-/-/1	3.2
A. desertorum (Nordan)	6/6/6	4/6/6	-/-/0	3/6/2	3/6/T	-/-/T	2.7
A. intermedium var *intermedium* (Greenar)	7/7/33	5/7/8	-/-/0	3/4/13	6/9/T	-/-/T	3.5
A. intermedium var *trichophorum* (Luna)	9/10/24	7/8/6	-/-/0	7/8/13	10/10/2	-/-/0	5.5
A. intermudium var *trichophorum* (Topar)	8/7/30	7/6/10	-/-/T	4/7/23	9/10/T	3/6/0	5.2
A. sibiricum (P-27)	4/6/8	5/8/4	-/-/0	7/9/4	7/6/0	4/7/T	4.5
A. smithii (A 4514)	10/10/28	10/10/47	-/-/T	10/10/41	10/10/1	-/-/T	6.7
Bothriochloa caucasica (Caucasian)	4/9/1	2/3/T	-/-/0	-/-/1	-/-/T	-/-/T	1.0
B. ischaemum var. *ischaemum* (El Kan)	-/-/6	3/7/2	-/-/0	7/8/1	2/7/T	4/8/T	2.7
Bouteloua curtipendula	6/8/28	-/-/19	3/5/T	-/-/1	8/9/2	8/10/1	4.2
B. eripoda (Flagstaff)	4/6/6	-/-/3	-/-/T	3/7/2	-/-/T	5/9/1	2.0
B. gracilis (Capitan)	9/10/18	5/7/8	4/9/0	5/8/2	5/10/T	6/9/T	5.7
Bromus inermis (Lincoln)	4/5/14	6/7/8	-/-/0	3/6/3	9/10/1	-/-/T	3.7
Elymus junceus (FC 36549)	4/8/6	5/8/3	-/-/0	5/10/3	4/10/T	2/4/T	3.3
Muhlenbergia wrightii (A 8604)	9/10/12	7/8/6	-/-/T	7/7/2	-/-/T	-/-/T	3.8
P. obtusum (A 11711)	3/7/20	-/-/10	3/5/T	4/6/37	9/10/4	4/5/T	3.8
Sitanion hystrix	7/10/6	4/8/6	7/5/0	8/10/15	10/10/T	5/8/1	6.8
Sporobolus airoides	4/8/7	2/5/8/	2/2/0	7/9/5	-/-/T	6/10/T	3.5
S. contractus (A 14544)	-/-/6	-/-/4	-/-/0	3/7/2	-/-/T	6/10/T	1.5
S. cryptandrus (A 16352)	3/7/12	3/7/5	-/-/0	3/5/1	4/8/T	5/8/1	3.0
Stipa comata (A Miller)	3/6/4	-/-/3	-/-/T	-/-/5	3/6/0	4/8/T	1.7
Forbs							
Medicago sativa (Normad)	/-/24	-/-/14	-/-/0	2/5/8	5/8/2	-/-/T	1.2
M. sativa subsp. *varia* (A 12357)	4/9/26	-/-/12	-/-/0	-/-/14	-/-/2	-/-/T	0.7
Menodora scabra (A 16807)	8/9/4	4/7/4	-/-/T	4/7/1	7/10/0	-/-/T	3.8
Shrubs							
Atriplex canescens	10/10/37	7/9/10	8/10/0	9/10/13	6/8/1	9/10/1	8.2
Ceratoides lanata	5/8/1	4/10/T	3/7/0	4/9/T	-/-/T	5/7/T	3.5

[1]Refer to text for species rated 4 or less for stand and 6 or less for vigor on all sites. Name or numbers following species name is cultivar identity.
[2]Relative stand/relative plant vigor/seedling emergence. Relative stand and relative vigor; = failure, 1 to 2 = very poor, 3 to 4 = poor, 5 to 6 = fair, 7 to 8 = good, 9 to 10 = excellent. Seedling emergence; percent based on 25 seeds per 0.3 m of row. T = less than 1%, 1% to 4% = poor, 4% to 8% = fair, 8% to 16% = good; 17% up = excellent (Gomm, 1974). Stand and vigor rated in 1977, emergence in 1966.

nine having had seedling emergence rated good or better: 'Mission' veltgrass (*Ehraharta calycina* Sm.), 'A-84' boer lovegrass (*Eragrostis chloromelas* Steud.), 'A-67' weeping lovegrass [*E. curvula* (Schrad.) Nees], 'A 11965' wilman lovegrass (*E. superba* Peyr.), 'A 14254' green sprangletop [*Leptochloa dubia* (H.B.K.) Nees], and 'A-130' blue panicgrass (*Panicum antidotale* Retz.). 'A-68' Lehmann lovegrass (*Eragrostis lehmanniana* Nees) had fair seedling emergence, while 'A 11527' sand lovegrass [E. *trichodes (Nutt.)* Wood] and 'A 13273' bush muhly (*Muhlenbergia porteri* Schribn.) had seedling emergence rating no better than very poor.

Eight of the 17 cultivars which failed had no stands at any site in 1977. Five of these 8 had good to excellent seedling emergence: 'Kangaroo Valley' ryegrass (*Lolium multiflorum* Lam.), 'Madrid' and 'PI 187985' yellow sweetclover [*Melilotus officinalis* (L.) Lam.], 'A 9971' plains bristlegrass (*Setaria macrostachya* H.B.K.), and 'A 8084' Arizona cottontop [*Trichachne californica* (Benth.) Chase]. Three species with no stands also had very poor or no seedling emergence: 'A 11904' Australian saltbush (*Atriplex semibaccata* R. Br.), 'A 14152' bicolor lovegrass (*Eragrostis bicolor* Nees), and 'A 14173' small burnet (*Sanguisorba minor* Scop.). Planting rates were based on current germination tests so emergence failure was not due to poor seeds. Either site conditions were unfavorable for emergence or the planting methods used were not suitable for these species.

Responses on Individual Sites

Cosnino, a cold-moist site with medium-textured soils, had 26 species (59%) present in 1977, 14 (32%) having stand ratings of 5 (fair) or better, and six others having vigor ratings of 7 (good) or better (Table 3). The best species were fourwing saltbush [*Atriplex canescens* (Pursh) Nutt.], thickspike wheatgrass [*Agropyron dasystachyum* (Hook.) Scribn.), 'Luna' pubescent wheatgrass [*A. intermedium* var *trichophorum* (Link) Halac.], western wheatgrass (*A. smithii* Rydb.), blue grama [*Bouteloua gracilis* (H.B.K.) Lag. ex Steud.], and spike muhly (*Muhlenbergia wrightii* Vasey), all rated 9 or 10 (excellent) for stand and vigor. Intermediate wheatgrass [*Agropyron intermedium* (Host) Beauv. var. intermedium], 'Topar' pubescent wheatgrass, squirreltail [*Sitanion hystrix* (Nutt.) J.G. Sm.], and twinberry (*Menodora scabra* Gray) had stands rated 7 or 8 (good). There were no earlier plantings at Cosnino for comparison.

At Indian Flat, a cold-moist site with fine-textured soils, 22 species (50%) were present in 1977, 12 (27%) having stands rated 5 (fair) or better and five others having vigor ratings of 7 (good) or better (Table 3). Western wheatgrass had excellent stands. Luna and Topar pubescent wheatgrass, spikey muhly, and fourwing saltbush were rated good. Winterfat [*Ceratoides lanata* (Pursh) J.T. Howell] had a stand rating of 4 (poor) but a vigor rating of 10 (excellent). Only two (9%) of the 22 species and varieties compared at Indian Flat had fair or better stands rated two or more classes better in the earlier planting than in the 1966 plantings: crested wheatgrass [*Agropyron desertorum* (Fisch. ex Link) Schult.] and sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.] (Table 4).

Table 4. Stands of forage species rated fair or better in 1966 plantings on six locations and in previous plantings in the same or similar climate subtypes of Arizona pinyon-juniper.

	Stand rating[1] in indicated subtype, site, and planting					
	Cold-moist		Cold-dry		Warm-moist	Warm-dry
	Cosnino	Indian Flat	Hart Ranch	Red Mountain	Bluegrade	Drake
	1966/old[2]	1966/old[3]	1966[4]/old[5]	1966/old[6]	1966/old[7]	1966/old[8]
Grasses						
Agropyron cristatum	F/-	F/0	0/0	F/0	F/0	0/0
A. dasystachyum	E/-	F/0	0/-	0/-	F/0	0/-
A. desertorum	F/-	P/F	(F)/(F)	P/F	P/P	0/V
A. intermedium var *intermedium*	G/-	F/0	(G)/(F)	P/F	F/F	0/0
A. intermedium var. *trichophorum* cv. Luna	E/-	G/F	(F)/(F)	G/G	E/F	0/F
A. intermedium var. *trichophorum* cv. Topar	G/-	G/-	(F)/(F)	P/-	E/-	P/-
A. sibiricum	P/-	F/0	(P)/(F)	G/V	G/0	P/0
A. smithii	E/-	E/G	(G)/(G)	E/E	E/E	0/E
Bothriochloa ischaemum var. *ischaemum*	0/-	P/F	0/0	G/F	V/E	P/G
Bouteloua curtipendula	F/-	0/F	P/P	0/0	G/F	G/G
B. eriopoda	P/-	0/P	0/0	P/0	0/0	F/P
B. gracilis	E/-	F/0	P/G	F/0	F/F	F/G
Bromus inermis	P/-	F/F	(F)/(F)	P/0	E/0	0/-
Elymus junceus	P/-	F/F	(G)/E	F/P	P/0	V/F
Muhlenbergia wrightii	E/-	G/G	(P)/(P)	G/E	0/G	0/P
Panicum obtusum	P/-	0/0	P/0	P/0	E/0	P/0
Sitanion hystrix	G/-	P/F	G/G	G/0	E/0	F/F
Sporobolus airoides	P/-	V/0	V/0	G/0	0/0	F/F
S. contractus	0/-	0/0	0/0	P/0	0/V	F/0
S. cryptandrus	P/-	P/0	(F)/G	P/0	P/0	F/V
Forbs						
Medicago sativa	0/-	0/0	0/0	V/-	F/0	0/-
Menodora scabra	G/-	P/-	(G)/-	P/0	G/E	0/0
Shrubs						
Atriplex canescens	E/-	G/F	G/E	E/G	F/G	E/E
Ceratoides lanata	F/-	P/0	P/F	P/E	0/0	F/F

[1]Rating: - = not planted, 0 = failure, V = very poor, P = poor, F = fair, G = good, and E = excellent.
[2]No other planting on similar subtype in Arizona.
[3]Mortiz Lake and Paterson Flat (Lavin & Johnsen, 1977a, 1977b).
[4]Rating in bracket is 1970 observation (before livestock grazing) if different from rating in 1977.
[5]1965 planting in same area, heavily grazed after 1970 (unpublished data, Johnsen).
[6]1965 planting in same area and older Dog Knobs plantings (Lavin and Johnsen, 1977a, 1977b).
[7]Pleasant Valley, Pine Creek, and Buckhead Mesa (Lavin & Johnsen, 1977a, 1977b).
[8]Drake (Lavin & Johnsen, 1977a, 1977b).

Five species (23%) having stand ratings of 5 or better had better stands in the 1966 plantings. Generally the results of the 1966 plantings were as good or better than might have been expected from the earlier planting results.

At Hart Ranch, a cold-dry site with medium-textured soils, seven species (16%) were present in 1977, two (5%) having stand ratings of 7 (good), squirreltail and fourwing saltbush, and two others, blue grama and winterfat, having vigor ratings of 7 (good) or better (Table 3). In the fall of 1970, before heavy livestock use began, 11 species (25%) had 5 (fair) or better stand ratings (Table 4). One (5%) of the 22 species compared had stand rated two or more ranking classes better in the earlier planting than in the 1966 planting, (Johnsen, unpublished data): blue grama. No species did better in the 1966 plantings than in the earlier plantings (Table 4). Combining the 1970 evaluation results of the 1965 and 1966 plantings shows that 18 species (41%) were present, 14 (32%) with stands rated 5 (fair) or better 5 to 6 growing seasons after planting. Thus, this site may not be as harsh as was indicated by the 1977 evaluations, which were affected by livestock grazing.

Red Mountain, a cold-dry site with fine-textured soils had 22 species (50%) present in 1977, 11 (25%) having stand ratings of 5 (fair) or better and an additional five having vigor ratings of 7 (good) or better (Table 3). Western wheatgrass and fourwing saltbush had excellent stands. Luna pubescent wheatgrass, Siberian wheatgrass [*Agropyron sibiricum* (Willd.) Beauv.], yellow bluestem [*Bothriochloa ischaemum* (L.) Keng var. *ischaemum*], spike muhly, squirreltail, and alkali sacaton [*Sporobolus airoides* (Torr.) Torr.], stands were rated good. Winterfat, with a stand rating of 4 (poor) had a vigor rating of 9 (excellent); it had a stand rating of excellent in the earlier plantings (Table 4). Only winterfat had stand rated fair or better and two or more rating classes better in the earlier planting than in the 1966 planting. Five (24%) of the 21 species and varieties compared had better stand ratings in the 1966 Red Mountain plantings than in the earlier ones.

Bluegrade, a warm-moist site with fine-textured soils, had 20 species (45%) present in 1977, 15 (34%) having stands 5 (fair) or better and three others having vigor ratings of 7 (good) or better (Table 3). Luna and Topar pubescent wheatgrass, western wheatgrass, smooth brome (*Bromus inermis* Leyss.), vine-mesquite (*Panicum obtusum* H.B.K.), and squirreltail had stands rated 9 or 10 (excellent). Russian wildrye (*Elymus junceus* Fisch.) was rated 4 (poor) for stands but 10 (excellent) for vigor. Yellow sweetclover (*Melilotus officinalis* Lam.) was not found on the plots but was common elsewhere in the area in 1977. At Bluegrade only two (9%) of 23 species and varieties compared had stands rated fair or better which were two or more rating classes better in the earlier plantings than in the 1966 plantings: yellow bluestem and spike muhly (Table 4). Eight species (35%) had better stand ratings in the 1966 plantings than in the earlier ones. Attempts to establish plants on swelling clay soils have usually failed, but the rhizomatous wheatgrasses, squirreltail, and yellow sweetclover did especially well on these soils at Bluegrade.

Drake, a warm-dry site with medium-textured soils, had 20 species (45%) present in 1977, nine (20%) having stands rated 5 (fair) or better and three others having vigor ratings of 7 (good) or better (Table 3). The best species was fourwing saltbush, with a stand rating of 9 (excellent); sideoats grama had a stand rating of 8 (good). At Drake four (20%) of the 20 species compared were two or more stand rating classes better in the earlier plantings than in the 1966 planting: Luna pubescent wheatgrass, western wheatgrass, yellow bluestem, and Russian wildrye (Table 4). Two species (10%) did better in the 1966 plantings: spike dropseed (*Sporobolus contractus* Hitchc.) and sand dropseed [*S. crytandrus* (Torr.) A. Gray].

Species Adaptation

The results of this and previous Arizona pinyon-juniper species adaptation trials on the same or similar sites show that 18 species planted in 1966 had fair or better stands on at least one site in both sets of plantings (Table 4). Fourwing saltbush, western wheatgrass, and Luna pubescent wheatgrass were the most widely adapted species. The remaining 15 species appeared to be better adapted to a given site than these results indicated. For example, gophers (*Thomomys* spp.), rabbits (*Lepus* spp. and *Sylvilagus* spp.), and insects destroyed entire plots at each planting site. Rabbits sought our pubescent wheatgrass, yellow sweetclover and alfalfa (*Medicago sativa* L.), often depleting or destroying their stands. Antelope (*Antilocapra americana* Ord) were observed grazing alfalfa at Red Mountain with indications that the plots had been sought out. Deer (*Odocoileus hemionus* Rafinesque) and elk (*Cervus canadensis* Erxleben) grazed fourwing saltbush and twinberry on the planting sites. Year-long livestock use at Hart Ranch prevented many species from developing better stands than they did, and the surviving species were closely grazed. Yellow sweetcover had good stands at Bluegrade but was not on the evaluated plots. Squirreltail was widespread throughout the plantings at Indian Flat but did poorly on the plots.

Fourwing saltbush was the only species tested that had fair or better stands at all six sites (Tables 3 and 4). This shrub has been reported to be widely adapted on pinyon-juniper ranges (Springfield 1976; Lavin and Johnsen, 1977a, 1977b). It did best on medium-textured soil, being taller and more robust at Cosnino and Drake than at the other sites (Table 5). Heavy livestock utilization kept it from growing taller at Hart Ranch, where newly grown branches measured 35 to 50 cm long in 1977. Elk closely grazed fourwing saltbush at Bluegrade and Indian Flat. The 1966 plantings were made with seeds collected near Winslow, Arizona. The source of seed may be important in the growth of fourwing saltbush at a given site.

Western wheatgrass had good or better stands at five sites (Tables 3 and 4). Selective grazing by rabbits may have depleted its stands at Drake and Hart Ranch. This grass developed slowly, but by 1977 its 1966 plantings had spread across adjacent plots. Western wheatgrass did best on the cold sites with fine-textured soils, being slightly taller at Red Mountain, a cold-dry site (Table 5), and producing more than twice as much forage at Indian Flat, a cold-moist site, as elsewhere (Table 6). The plants grew taller and were green longer than the native western wheatgrasses at Red Mountain, Indian Flat, and Bluegrade. The seeds used were commercially grown in Colorado.

Table 5. Average height of selected planted species with stands rated fair or better on at least three of six planting sites.

	Plant height (cm) in indicated climatic, subtype and site					
	Cold-moist		Cold-dry		Warm-moist	Warm-dry
Species	Cosnino	Indian Flat	Hart Ranch	Red Mountain	Bluegrade	Drake
Blue grama	46.5	41.4	25.4[1]	47.8	40.6	40.6
Fourwing saltbush	115.6	76.2	83.8	84.6	84.6	1443.5
Luna pubescent wheatgrass	40.6	39.4	——[2]	44.4	38.9	35.6[1]
Squirreltail	38.9	30.5[1]	16.5	38.1	22.1	14.0
Western wheatgrass	13.2	14.0	——[2]	17.0	14.0	——[2]
Winterfat	71.1	76.2[1]	31.8[1]	55.9	——[2]	25.4

[1]Plantings failed

[2]Relative stand rating of poor or very poor.

Table 6. Herbage yield of the more productive forage species planted at pinyon-juniper sites.

Species	Average yield[1] at indicated climatic subtype, and site, ka/ha.				
	Cold-moist		Cold-dry	Warm-moist	Warm-dry
	Cosnino	Indian Flat	Red Mountain	Bluegrade	Drake
Blue grama	1246	423	531	—[2]	—
Crested wheatgrass	304	936	—	—	—
Luna pubescent wheatgrass	1207	1329	620	1751	1586
Sideoats grama	1020	—	—	1423	1932
Spike muhly	4239	2505	—	—	—
Western wheatgrass	944	2285	981	1325	—

[1]Average oven-dry weights from harvests made in late August 1969 and 1970.
[2]Dash indicates lack of sufficient materials.

Luna pubescent wheatgrass had fair or better stands at five sites in 1977 (Table 4). Selective grazing by rabbits at Drake and rabbits and livestock at Hart Ranch may have depleted its stand there. Established stands are spreading. This grass was tallest at Red Mountain and shortest at Drake (Table 5), but forage production was highest at Bluegrade and lowest at Red Mountain (Table 6). There was not much difference between the Luna and Topar cultivars.

Blue grama and squirreltail were found on all six 1966 planting sites in 1977, but both species gave variable results in earlier planting trials. Blue grama planted in 1966 had stands rated fair or better at five of the six sites in 1977 (Table 3). At the sixth, Hart Ranch, where blue grama is a native, the poor stands were probably due to poor initial establishment and heavy livestock use. The Capitan cultivar planted in 1966 was green longer, had finer and longer leaves, and had taller culms than the native blue grama at all sites. The 1966 plantings of this grass did best on cold medium-textured soils. It was slightly taller at Cosnino and Red Mountain than elsewhere (Table 5), but at Cosnino it produced more than twice the forage that it did at Indian Flat and Red Mountain (Table 6). However, the combined results of the 1966 and earlier plantings indicate that blue grama may be better adapted to the warm sites. This could be due to the different cultivars used and possibly better conditions for blue grama establishment in earlier trials.

The 1966 plantings of squirreltail had fair or better stands at five of the six sites (Table 3). Poor stands at Indian Flat were due to the presence of dense stands of invading horsebrush and rabbitbrush. Squirreltail was widespread at each site but sometimes was not found on the planted plots. This distribution may also have lowered its ratings on earlier plantings. Squirreltail height growth was best on the cold-moist sites and the cold-dry site with fine-textured soils (Table 5). The plants began growth earlier and were green longer than the native squirreltail at Red Mountain, Indian Flat, and Cosnino. Planted squirreltail also often grew again in the fall, while the native squirreltail at these locations did not. The seeds used were collected from Bluegrade.

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