

Department of Animal and Range Sciences

**Post-Drought Vegetation Dynamics
on Arid Rangelands
in Southern New Mexico**

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SUMMARY

The severe drought of 1951–56 greatly changed vegetation on some arid rangeland sites of the Southwest. This study presented vegetation cover and yield for various sites for several years following the drought. Perennial grasses were the most prominent portion of the herbaceous plants. The sites dominated by tobosa¹ and burrograss did not have the drastic changes as did some of the sandy sites, but there can be a tenfold increase or decrease of the basal cover of those two species within two years. Black grama cover was substantially reduced on deep sands by severe drought and did not recover during this study. These deep sands are subject to wind erosion because they lost much of their protective cover. Drought effects on black grama were not as severe on shallow sands, and its cover increased in wetter years on these sites. Because of prolific seed production, mesa dropseed's cover increased rapidly on sands following drought; but it decreased

¹See appendix 1 for complete nomenclature of plants.

substantially during the dry years in the 1960s. Propagules of annual grasses and forbs, and short-lived perennial forbs were abundant from previous populations, allowing them to increase rapidly when environmental conditions were appropriate for certain species to establish. Results indicated that protection from rodents and rabbits increased the cover of annual grasses, whereas their presence increased the cover of annual forbs. However, protecting herbaceous plants from rodents, rabbits, or cattle did not give a major response. Broom snakeweed increased on sandy soils in wetter years. Honey mesquite's increase following drought was greater on deep sands than on shallow sands, but there also was a rapid increase on shallow sands. Apparently, the absence of cattle increased honey mesquite cover, but the presence of cattle did not prevent honey mesquite increase.

Perennial grass yields were higher on shallow sands, where there was a mixture of black grama and mesa dropseed, than on deep sands dominated by mesa dropseed. The factors affecting perennial grass yields were precipitation, soil water, soil characteristics, plant species, and plant cover. The variation in annual perennial grass production on all sites was sometimes dramatic and has management implications. This study shows that large vegetation changes occurred because of severe drought and these changes are persistent on some sites.

Post-Drought Vegetation Dynamics on Arid Rangelands of Southern New Mexico

Carlton H. Herbel and Robert P. Gibbens¹

The arid and semiarid Southwest has frequent droughty periods that have a marked effect on the vegetation. Precipitation is extremely variable, both temporally and spatially (Martin and Cable 1974, Paulsen and Ares 1962). Perennial grasses provide the most reliable forage on grass-shrub ranges (Martin 1975). Cover for most species varied greatly from year to year in southern Arizona (Martin and Cable 1974). During the 1916–18 drought, black grama's basal cover on the Jornada Experimental Range (JER) in southern New Mexico declined to 42% of predrought cover (Nelson 1934). Black grama was the major plant species on lighter-textured soils. It practically recovered its stand during two years of favorable precipitation (1919–20), then dropped very suddenly in the following two years of drought to the extremely low point of 11% of the original cover. Black grama cover remained at a low level for the remainder of the 1921–25 drought, then increased to its original size when summer rainfall was above average from 1926 to 1929. The accumulated deficits from 1915–1988

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from average rainfall for July through September at the Jornada headquarters from the 1921–25 drought were 185 mm.² From 1926 to 1929, July–September rainfall was 115 mm above average. Nelson (1934) found that black grama cover is mainly influenced by plant vigor at the start of the current growing season, as determined by rainfall from the previous summer. Changes in black grama basal area were closely correlated with precipitation during a 15-month period from July 1 of one year through September 30 of the next year.

Campbell (1936) reported that black grama basal cover declined 77% on a conservatively grazed area between 1933 and 1935, because of drought in 1934. The deficit from average rainfall for July through September 1934, at JER headquarters, was 86 mm compared to the 1915 to 1988 average of 130 mm.

Herbel et al. (1972) found a direct relationship between drought damage to vegetation and soil depth during the 1951–56 drought (see fig. 1). That drought was one of the most severe in the Southwest during the last 350 years, and, perhaps, was exceeded in severity only by the Great Drought of 1275–99 (McDonald 1956 and Schulman 1956). From 1951 to 1956, precipitation was deficient for most months in Texas, Oklahoma, Kansas, New Mexico, Colorado, Arizona, and Nevada (Nace and Pluhowski 1965). Drought affected many other states in the 1950s, but it was not as severe in most situations as in the states listed above. The accumulated deficits from average rainfall for July through September at JER headquarters from 1951 to 1956 were 352 mm; the accumulated annual deficits were 600 mm. These accumulated deficits were 45 and 41%, respectively, of the 1915 to 1988 means. In 1956, the average basal cover of black grama, dropseeds, and threeawns was 10, 25, 12, and 2% of the predrought average for the deep sandy stratum (soil “0” in this study), sandy flats (soil “S”), shallow sandy (soil “T”), and low hummocky stratum (soil “P”), respectively (Herbel et al. 1972). Perennial grass yields in 1956 were 23, 42, 35, and 11% of the predrought average for deep sandy, sandy flats, shallow sandy, and low hummocky strata, respectively. Black grama cover in 1956 was 2, 20, 14, and 2% of the predrought average in those strata. Prior to the drought, black grama cover and yield did not differ greatly among the strata. Yet, there was greater

²See appendix 2 for the conversion of metric units to English units.



Fig. 1. Severe 1951–56 drought affected plants and soils.

black grama mortality on the deep sandy and the low hummocky strata than on the shallow sandy and the sandy flats strata.

Long-term droughts, such as occurred in the 1950s, have an important role in restricting the life spans of long-lived plants, such as black grama (Wright and Van Dyne 1976). Short-term droughts influence vegetation more selectively. Droughts also can change species composition, vegetational cover, and herbage production, and can drastically reduce range condition regardless of past grazing history.

Plants in southern New Mexico can grow anytime during the year when suitable environmental conditions occur. Nearly all grasses and shrubs grow during the warm part of the year, but some forbs grow when moisture is available during the cool season, and others grow during the warm season (Pieper and Herbel 1982).

High species diversity in this habitat results partly from the different life forms and photosynthetic pathways of different plant groups, each adapting to use a particular phase of the seasonally and yearly variable precipitation. Growth separation of C₃ and C₄ species is based more on the growing seasons' temperature differences than on moisture differences (Kemp 1983).

The percentage composition of black grama increased during protracted dry periods, as other less drought-enduring species died. In subsequent moist years, the associates recovered rapidly and made up their loss of the species composition, until they were replaced by black grama. When severe drought losses occurred over extensive areas, black grama recovery was slow, even with favorable moisture. Black grama basal area was reduced during extended drought to about the same point regardless of grazing intensity or protection from grazing by livestock. The greatest increase in basal area following drought—even greater than that obtained by protection from grazing—was under conservative grazing (Nelson 1934, Paulsen and Ares 1962).

The combined basal cover of black grama, the dropseeds, and red threeawn at 1 km from watering places was equal to that found 7.2 km from water on unfenced range (Wright and Van Dyne 1976). Cattle grazing had a negative influence on plant establishment, but relatively little impact on life span of established grasses. In southern Arizona, Canfield (1957) found black grama seedling survival was 39% on ungrazed sites and 35% on grazed sites.

A grazing practice involving proper use of black grama range during years with favorable precipitation and slight overgrazing in droughty years reduces black grama cover more than on areas where proper grazing occurs. Overgrazing at any time, but particularly during drought, reduces black grama cover (Nelson 1934). Where drought reduces ground cover, there is an increase of bare soil and, consequently, wind erosion increases (Marshall 1973).

Over many years, Gibbens and Beck (1988) found that conservative cattle grazing has not had a significant impact on perennial grass basal area. Droughty years have a tremendous influence on basal cover of perennial grasses, particularly in the black grama type (fig. 2). In contrast, tobosa and burrograss types are less susceptible to drought and recover relatively rapidly (Herbel et al. 1972). The densities of annual forbs, annual grasses, and perennial forbs fluctuated widely from year to year (Gibbens and Beck 1988). Densities of annual grasses and annual forbs were higher in the 1920s and 1930s than from 1957 to 1977.

About 90% of the semidesert Southwest's native warm-season perennial grass is produced during the summer rainy season (Culley 1943). Perennial grass production fluctuated yearly due to variations in precipitation (Cable and Martin 1975, Pieper and Herbel



Fig. 2. A black grama stand during drought.

1982). Precipitation components having the greatest effects on year-to-year changes were rainfall for August of the current summer, and the interaction of the current August rainfall times June through September rainfall of the previous summer. The most influential component was the interaction, which accounted for 64 to 91% of the annual variation in perennial grass production. This was probably due to effects of rainfall during the previous summer on vigor and perennial grass cover.

Herbel and Gibbens (1987, 1989) presented soil water regimes from 1957 to 1976 for most soils discussed in this paper. The warm-season perennial grasses do about 90% of their growing during summer when soil water is available to plants. However, Herbel and Gibbens (1987, 1989) reported that there was more soil water available in winter than summer. They found that the factors affecting soil water regimes are precipitation amount and time, position on the landscape, soil and vegetation type, and microrelief. The purpose of this bulletin is to present vegetation information for various sites following the severe 1951–56 drought.

MATERIALS AND METHODS

These studies were conducted on the Jornada Experimental Range (JER) in southern New Mexico (fig. 3) from 1957 to 1988, with emphasis on soil water, plant cover, and yield.

Description of the Study Area

The JER is included in the area described by Merriam (1898) as the Lower Sonoran Life Zone; by Shreve (1917), Shantz and Zon (1924), and Dick-Peddie (1993) as desert grassland; by Clements (1920) as desert plains; by Kuchler (1964) as the grama-tobosa shrubsteppe; and by Buffington and Herbel (1965) as semidesert

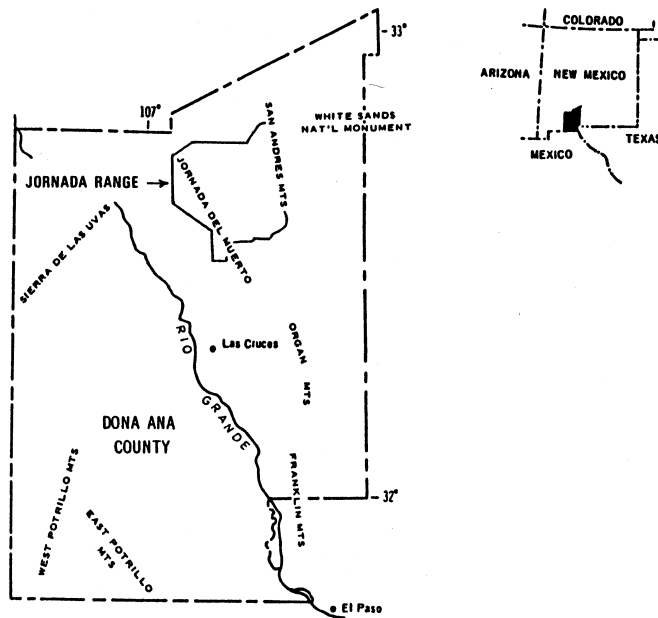


Fig. 3. Location of the Jornada Experimental Range (JER) in Doña Ana County, New Mexico.

grassland. Recently, the area included in the JER has been considered the northern extension of the Chihuahuan Desert (Humphrey 1987, Van Devender 1990). The abiotia and biota are typical of occurrences in southeastern Arizona, southern New Mexico, western Texas, and northern Mexico. Sites that once supported grassland now mainly support desert shrubs, such as honey mesquite, creosotebush, and tarbush (Canfield 1948, Branscomb 1958, Buffington and Herbel 1965, and York and Dick-Peddie 1969). After establishment, the shrubs maintain their dominance unless humans take action (fig. 4) (Archer 1989, Herbel et al. 1970, Herbel 1985, and Herbel and Gould 1995).

Precipitation

At JER headquarters, precipitation from 1915 to 1989 averaged 241 mm annually and 131 mm from July 1 to September 30. Rainfall from July 1 to September 30, most of the growing season for C_4 plants, averaged 54% of the annual precipitation and represents a distinct peak in the yearly precipitation pattern.



Fig. 4. Mesquite sand dunes on JER.

Most winter precipitation occurs as low-intensity rains or occasionally as snow, while most summer rainfall comes as high-intensity, localized, convectional thunderstorms. Rainfall during the summer is highly variable spatially and temporally. Groundwater occurs at a depth of 90 to 140 m in basin-filled deposits (King et al. 1971), and there is a permanent dry zone between the surface layers and groundwater.

Temperature

JER averages about 200 frost-free days. Temperatures are generally moderate with an annual mean of 15°C. The diurnal variation is often 20°C. Maximum temperatures are highest in June, averaging 36°C; in January, the coldest month, the average maximum temperature is 13°C (Paulsen and Ares 1962).

Wind and Evaporation

JER's average annual wind movement is 17,346 km. Wind velocities average 2.4 to 3.2 km/hr for March through June, but velocities up to 64.4 km/hr occur. High velocities in the spring under droughty conditions result in sandstorms. For the remainder of the year, average wind velocities range from 1.0 to 1.6 km/hr (Paulsen and Ares 1962).

High temperature, low humidity, and high winds cause large water losses by evaporation, especially during late spring and early summer. Evaporation from a free water surface at JER headquarters averaged 2352 mm a year or about 10 times the average precipitation. The evaporation for June averaged 343 mm (Dittberner 1971).

Climate components become collectively favorable for plant growth when moisture is available from July through September. In occasional years, the growing season may begin in June or even May and extend into October.

Soil and Topography

JER is located on the southern portion of the Jornada de Muerte Plain. The plain is a bolson or desert basin, consisting of unconsolidated Pleistocene detritus with no permanent streams or surface drainage outlets. Soil parent materials in the basin floor are sandy sediments of the Camp Rice Formation (El Paso Geological Society 1970, Strain 1966). Generally, the fluvial sediments have been

moved by wind or local water erosion. Alluvial piedmont sediments adjacent to the basin floor were derived from sedimentary rocks in the San Andres Mountains to the east, and igneous rocks in the Doña Ana Mountains to the southwest (Kottlowski 1960, Kottlowski et al. 1956). Calcium carbonate and clay from the atmosphere are also important parent materials (Gile et al. 1970). Soils with gypsum crystals, such as soil B, were formed in alluvium from sedimentary and igneous rocks resting on gypsum of lacustrine origin. The alluvial fill is 92 m thick in places, and the aggradation process is still active. Coarser materials are found in the mountains, foothills, and uplands with a grading of finer materials toward the old lake beds and swales in the plain. The topography is gently undulating to nearly level uplands, interspersed with swales and lake beds formed during Pleistocene. The elevation at JER headquarters is 1317 m (Paulsen and Ares 1962, Dittberner 1971). The sites in this study vary only slightly from this elevation.

The soils have almost no humus and have little change in texture between surface soil and subsoil. All soil types have some calcium carbonates that may solidify in the substratum, particularly in coarser soils. The pH of the surface soils is from 7.8 to 8.2. None or only small amounts of sodium or soluble potassium salts are present. The surface is Pleistocene Age (Gile and Hawley 1968, Hawley and Gile 1966). Plant cover on the range differs primarily due to soil types. The soils listed in table 1 are generally arranged in order of soil texture with the A soil being the heaviest. Detailed profile descriptions are found in Herbel and Gile (1973), USDA (1980), and Herbel et al. (1994). Fig. 5 shows soil locations on JER. Most of the names and classification were suggested after a review in the field (L.H. Gile, personal communication, 1993).

Soil Water

Gypsum electrical resistance blocks were placed at several locations depending on soil depth. The soil water stations were located within a livestock enclosure. An ohmmeter was used to record resistance measurements one to three times per week, when the matric potential was ≥ -1.5 MPa during the summer. Measurements were recorded monthly during the remainder of the year when there were fewer changes in soil water. The blocks were calibrated in light- and medium-textured soils by determining their

Table 1. Soils in this study.

Soil	Classification	Series	Texture	Depth
A	Typic Torriorthent	Engholm	Clay	Deep to moderately deep
B	Typic Calciorthid	Batross	Loam	Moderately deep to deep
D	Ustollic Calciorthid	Reagan	Silt loam	Moderately deep to deep
E	Ustollic Haplargid, Typic Haplargid, Ustollic Calciorthid	Headquarters-Doña Ana-Chispa	Sandy loams and clay loams	Deep
F	Typic Calciorthid, Ustollic Calciorthid	Algerita-Chispa	Loam	Deep to moderately deep
G	Ustollic Haplargid	Stellar	Clay loam	Deep
M	Typic Calciorthid	Tumey, et al.	Sandy loam	Deep to moderately deep
O	Typic Haplargid	Berino, Yucca, Onite	Sand	Deep
P	Typic Torripsamment	Bluepoint	Loamy sand	Moderately deep to shallow
R	Typic Haplargid	Palma, et al.	Loamy sand	Deep
S	Petrocalcic Paleargid, Typic Paleorthid, Typic Haplargid	Hueco, Cacique, et al.	Sand	Moderately deep
T	Petrocalcic Paleargid, Typic Paleorthid	Hueco, Simona, et al.	Sand	Shallow

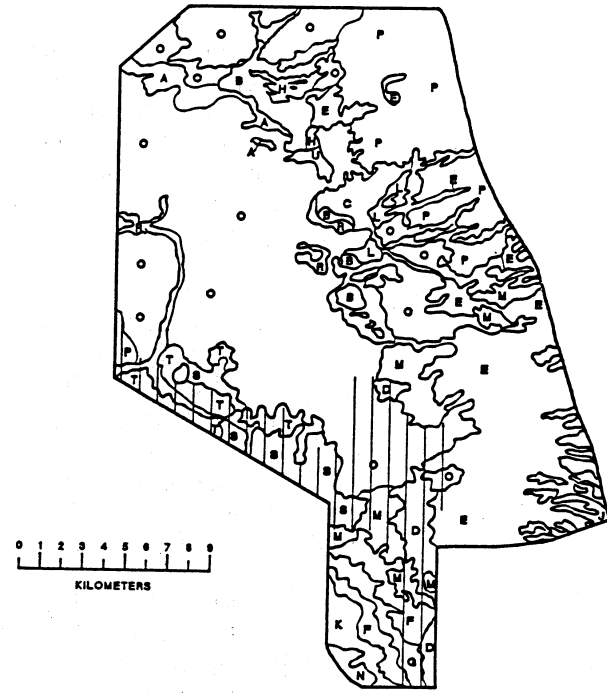


Fig. 5. The location of the soils (letters) and transect series (straight lines) on JER.

resistance at different pressures in a pressure plate extractor (Taylor et al. 1961).

The gypsum medium didn't deteriorate in these aridisols. No change in calibration of the blocks was observed. At the same time as soil matric potentials, soil temperatures also were recorded with thermistors placed at six depths at four locations. All resistance observations were corrected to 15.6°C.

The principal forces that contribute to soil water potential are matric potential and osmotic potential of the soil solution (Kramer 1983). The soils in this study were nonsaline as determined by a U.S. Salinity Laboratory method (1954). Therefore, soil water measurement was assumed to be a measure of matric potential. Each resistance reading was translated to megapascals (MPa). For days when the resistance was not measured, matric potential was

determined by previous matric potential determinations at that depth, matric potential at other depths at that location, current precipitation, and previous precipitation events at that location. All the daily determinations were grouped into matric potentials of 0 to -0.1 MPa (readily available to plants), -0.1 to -1.5 MPa, and < -1.5 MPa (dry). Detailed soil descriptions and soil water information are given in Herbel et al. (1994).

Stocking Rates

Stocking rate is the number of animals grazing on rangeland per unit area. A heavy stocking rate may lead to a change in plant species and increased soil erosion that eventually could cause permanent deterioration to the system (Herbel and Pieper 1990). Stocking records are available for all JER units. The practice has been to use the amount of available forage in the fall to establish the stocking rates until the next summer (Herbel and Nelson 1969, Herbel 1973, Herbel and Gibbens 1981, Holechek and Herbel 1982). Because of a history of light stocking, Gibbens (1978) found a minimal association between stocking and forage produced. Table 2 shows the hectares per animal unit month (AUM) for typical JER units. From 1956 to 1975, the average stocking rate was 7 ha/AUM on units 9, 10, 11, and 13, whereas it was 11 ha/AUM on units 4, 8, and 12. The former units (9, 10, 11, and 13) have less honey mesquite than units 4, 8, and 12. The average stocking rate was 9 ha/AUM for these seven units for this 20-year period. Fig. 6 shows stocking on JER from 1945 to 1990. Note the precipitous decrease in 1954 because of drought.

Procedures

Precipitation

At JER headquarters, precipitation was recorded daily in a standard U.S. Weather Bureau rain gauge. Precipitation was recorded after each storm in a standard rain gauge, modified with a funnel and stoppered plastic bottle to reduce evaporation loss (Gomm 1961) at the following locations: Ber, Co-op Well, Doña Ana, Exclosure A, Exclosure B, Northeast Exclosure, Pasture 2, Rabbit, South Boundary, South Well, Stuart, West Well, and Yucca (fig. 7).

Table 2. Stocking rate (ha/animal unit month [AUM]) during the crop year (1 Oct.–30 Sept.) for seven units on the Jornada Experimental Range (Gibbens 1978).

Crop year	Unit						
	4	8	9	10	11	12	13
	ha/AUM						
1956	34	16	38	31	7	101	13
1957	17	0	21	12	8	24	0
1958	14	12	8	3	8	12	6
1959	8	16	8	7	4	8	6
1960	9	4	4	2	3	6	3
1961	10	16	8	11	6	7	2
1962	8	8	2	4	4	5	4
1963	4	20	5	3	4	6	3
1964	9	16	2	5	6	7	4
1965	5	5	2	5	9	5	2
1966	12	5	5	10	15	4	2
1967	11	5	4	5	12	5	3
1968	6	8	4	7	8	8	1
1969	6	9	5	3	5	8	5
1970	8	10	6	7	9	4	3
1971	9	6	5	6	5	6	0
1972	17	13	11	4	8	13	32
1973	8	5	4	2	5	6	32
1974	14	7	7	2	4	6	0
1975	5	7	6	1	5	3	16

Plant Cover

Plant cover was measured on JER's southern portion each year from 1957 to 1977. The basal cover of all plants and honey mesquite's canopy cover were measured on all areas not dominated by shrubs from June through August. The line-intercept method described by Canfield (1941) was used. In measuring vegetation intercepted by a wire line 30.48 m long, a rod graduated in 3.048 mm units was used to measure the basal diameter at the intercept. If only a single forb stem, or a culm or live grass stolon was intercepted, it was counted as 3.048 mm (fig. 8). When honey mesquite was encountered, the canopy (drip line) intercepted by the line was measured. Each measurement of 3.048 mm was then directly converted to 0.01%.

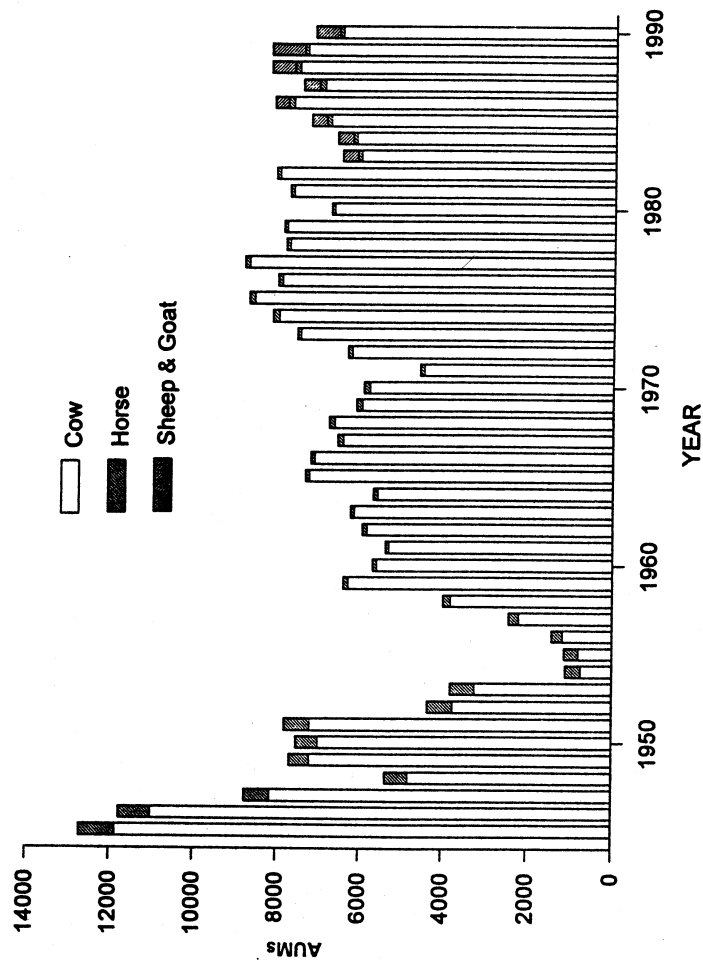


Fig. 6. Total stocking (AUM = animal unit month) by cattle, horses, sheep, and goats on JER from 1945 to 1990.

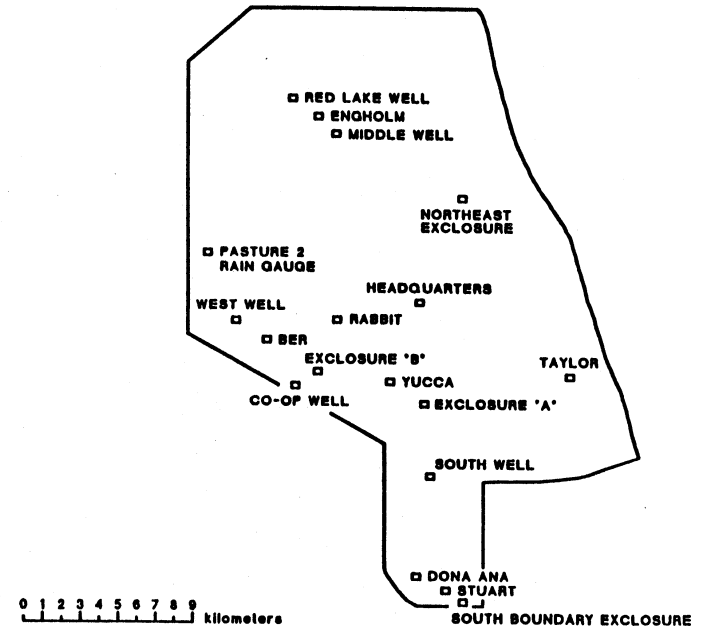


Fig. 7. The location of sites within JER.

Two individuals, trained in identifying plants and the method, began sampling near JER's southwest corner. A point was randomly selected near the south boundary in the western half of the section (259 ha). They took an observation (30.48 m line-transect) there and then at each 160.9 m heading north until land dominated by brush was reached. Each group of observations between the south and north boundaries was called a "series." As a series was completed on a tier of sections, sampling was initiated on the next tier to the east (on the western half of that tier of sections) until the eastern boundary (White Sands Missile Range western boundary) was encountered. Following that, a series of observations were taken on the eastern half of each tier of sections, starting again in the southwestern part of JER. Thus, 10 observations per section were taken in June or early July, and 10 observations per section were taken in July or August. The unit number, soil type, vegetation



Fig. 8. Measuring vegetation basal cover along a line-transect.

type, topography, series number, transect number, observation date, and examiners, as well as the intercept data were recorded for each observation. After all series were completed, a minimum of 10 observations for each soil type in a unit was obtained by randomly locating observations in each unit. The observations were combined by soil type. Fig. 5 shows the location of the soils and the transect series. Generally, plant species are mentioned only if their cover exceeded 0.01%.

Yields

Above-ground perennial grass herbage yields were obtained at a number of locations during October and November. All perennial grasses within the plots were clipped at ground level. Old growth from previous years was separated from the clipped sample and discarded so that observations were of perennial grass biomass that grew during the current year. Care was taken to avoid areas that had been clipped in previous years. All samples were air-dried from 1957 to 1974 and oven-dried (60°C) from 1975 to 1988 before weighing.

Perennial grass yields were estimated at a site dominated by black grama in units 2 and 9, and on a site dominated by mesa dropseed in unit 11. Perennial grass yields were obtained annually from 1958 to 1988 on about 17 transects in unit 2. Yields were estimated by clipping a 5.08 cm x 30.48 m belt at intervals of 0.16 km. The same technique was used to sample an area south of a ridge in unit 9, annually from 1958 to 1988 (15–20 observations); and an area north of the ridge from 1960 to 1988 (15–20 observations). The same technique also was used to sample two areas in unit 11. The number of 5.08 cm x 30.48 m transects sampled west of the main Jornada road annually from 1958 to 1988 varied from 14 to 20, and east of the road from 15 to 20. The usual number was 18 and 17, respectively.

Twenty-five, 0.305 x 1.463 m plots were clipped annually from 1957 to 1988 on a site dominated by tobosa and a site dominated by burrograss in the vicinity of a livestock enclosure at the South Boundary in unit 6. Yields also were obtained on 25, 0.305 x 1.463 m plots from 1957 to 1988 on a site dominated by a mixture of burrograss and tobosa in the vicinity of a livestock enclosure about 5 km north of headquarters in unit 12. A site dominated by alkali sacaton was clipped annually from 1978 to 1988 in unit 3. Gibbens (1978) provided additional details on perennial grass yields.

Protection Plots

A set of four plots was constructed or marked at two locations in 1957. Each location had four, 38.1 x 45.7 m plots as follows: 1. a plot surrounded by 21 ga., 9.5 mm mesh hardware cloth, 121.9 cm wide, buried 15 cm in the soil, and flared at the top to exclude rodents, lagomorphs, and livestock (Ro); 2. a plot surrounded by 2.5 cm mesh poultry netting, 91.4 cm wide, buried 10 cm in the soil, to exclude lagomorphs and livestock (Ra); 3. a plot surrounded by four strands of 12 1/2 ga. barbed wire to exclude livestock (Li); and 4. a marked plot open to all influences (Op, fig. 9).

Both studies A and B had a relatively high black grama cover prior to the 1951–56 drought. There is only a light scattering of honey mesquite plants at A, but B is located on a transition between honey mesquite and grassland. Each plot was divided into 15 subplots 2.5 m wide x 30.48 m long. All vegetation basal cover and



Fig. 9. The plot that excluded rodents, lagomorphs, and livestock at study A in 1957.

honey mesquite canopy cover were measured annually each August from 1957 to 1977. Four, 30.48 m line-intercept transects per subplot were recorded in 1957 and 1958, using the method described in the cover section, whereas two transects per subplot were recorded from 1959 to 1977. Perennial grass yields were estimated by clipping three, 5.08 cm x 30.48 m belt-transects on every third subplot each October from 1959 to 1977. This system was rotated so that each subplot was clipped only every three years and even then the transects were located to avoid areas that had been previously harvested. The method has been described in the yield section.

RESULTS AND DISCUSSION

Plant Cover

Ustollic Calciorthid Reagan (soil D)

A description of this soil is provided by Gile and Grossman (1979, p. 830-831) and the soil water data from 1957 to 1976 were given by Herbel et al. (1994, p. 370-415). Fig. 5 shows the location of this soil (D) and the location of the transect series. It occurs in the lower parts of the basin and receives some flood water during heavy thunderstorms. From 1958 to 1977, precipitation for the transect-year of July 1 to June 30 averaged 262 mm, and 107 mm for October 1 to June 30 (table 3). The number of transects taken annually ranged from 56 to 96. Herbaceous plants' basal cover averaged 1.692% and perennial grass basal cover averaged 98% of that. Burrograss averaged 78% of the herbaceous plants' basal cover, from 1957 to 1977 on the Reagan soils (fig. 10). Other perennial grasses of importance were tobosa (table 3), ear and sand muhlys, black grama, alkali sacaton, mesa dropseed, fluffgrass, and red and poverty threeawns. Annual grasses were not abundant ($> 0.01\%$ basal cover) in any year from 1957 to 1977.

Perennial forbs' basal cover averaged 0.027% from 1957 to 1977 (table 3). The major perennial forbs were leatherweed, desert holly, rattlesnakeweed, Fendler's bladderpod, and paperflower. Leatherweed was abundant (basal cover $> 0.01\%$) in 1959, 1961, 1972, 1973, 1975, and 1976. In those six years, leatherweed occurred on 26% of the transects. Desert holly was plentiful ($> 0.01\%$) in 1961, 1962, and 1968. Soil water > -0.1 MPa was observed during the winter in those three years. The basal cover of rattlesnakeweed was abundant in 1957, at the end of the severe 1951–56 drought, but it occurred on only 4% of the transects. Fendler's bladderpod was plentiful in 1958, when soil water > -1.5 MPa was observed during the previous fall, winter, and early spring. Paperflower basal cover was abundant ($> 0.01\%$) in 1975, when there was soil water > -0.1 MPa during the previous fall and winter. Paperflower occurred on 22% of the transects in 1975.

The major annual forbs encountered from 1957 to 1977 were Russian thistle and annual broomweed. Russian thistle basal cover was abundant ($> 0.01\%$) in 1962, 1968, and 1973—all years which had soil water > -0.1 MPa during the previous winter. Annual

Table 3. Precipitation (mm) and cover (10^{-2}) of vegetation on Ustollic Calciorthid Reagan (soil D).

Year	Precipitation (mm) ¹		Basal cover (0.01%) ²							Canopy cover (0.01%)	
	Annual ²	FWS ³	Himu	Sebr	TPG	TAG	TPF	TAF	Gusa	Prgl	
1957	88	51	104.9	228.8	352.9	0	3.3	0	0.5	16.1	
1958	385	209	43.3	204.2	248.8	0	3.2	1.9	0.3	0	
1959	243	79	11.8	214.2	233.5	0	2.7	0.2	2.4	1.5	
1960	296	61	9.0	82.9	98.2	0	0.6	0.1	0.8	5.1	
1961	194	104	28.9	206.2	240.3	0	3.3	0.1	1.0	0.4	
1962	315	122	10.2	77.6	93.1	0.2	3.4	3.0	0.4	0.4	
1963	307	76	8.3	67.3	84.1	0	0.9	0	0.1	15.2	
1964	251	70	3.5	74.8	84.0	0	0.4	0.1	0.4	0.8	
1965	185	58	3.3	51.2	60.4	0	0.5	0.1	0.3	6.9	
1966	207	123	6.0	80.4	87.8	0	1.0	0	0.2	2.2	
1967	140	61	4.0	38.5	45.8	0	0.9	0.4	0.6	22.9	
1968	310	105	4.9	91.7	101.3	0.9	2.7	5.3	0.4	0.9	
1969	304	100	4.9	56.3	63.2	0.1	1.2	1.0	0.3	6.2	
1970	211	90	4.3	46.9	54.2	0	0.7	0.5	0.2	15.0	
1971	116	34	3.5	44.9	49.4	0	0.4	0	0.6	15.9	
1972	322	175	12.5	71.4	88.6	0	2.7	0.9	0	4.2	
1973	417	249	8.8	83.2	99.3	0	4.6	5.4	1.4	0	
1974	183	39	10.4	52.9	72.6	0	0.4	0.8	1.0	14.8	
1975	449	194	13.5	196.8	232.7	0	9.6	2.6	2.6	62.1	
1976	353	158	48.0	336.6	429.2	0.6	10.9	1.6	6.8	24.7	
1977	235	97	46.0	466.1	648.0	0	3.0	3.4	23.0	84.0	
Average	262	107	18.6	132.0	165.1	0.1	2.7	1.3	2.1	14.3	

¹Precipitation = Stuart Rain Gauge, July 1, 1956–June 30, 1977 (fig. 7). / ²Annual = July 1 of the previous year through June 30 of the indicated year. / ³FWS = Oct. 1 of the previous year through June 30 of the indicated year. / ⁴Cover: Himu = tobosa; Sebr = burrograss; TPG = total perennial grasses; TAG = total annual grasses; TPF = total perennial forbs; TAF = total annual forbs; Gusa = broom snakeweed; Prgl = honey mesquite.



Fig. 10. Burrograss and tobosa on JER.

broomweed was plentiful in 1962, when it occurred on 30% of the transects.

Broom snakeweed was only a small component of the plant cover, but it increased in basal cover in 1976 and 1977 (table 3). Honey mesquite was a minor component of the vegetation on Reagan soil, but it increased somewhat in the latter part of the study period. The other major shrubs encountered were Torrey's and longleaf ephedra, tarbush, crucifixion thorn, and creosotebush.

Haplargids-Calciorthid Headquarters-Doña Ana-Chispa Complex (soil E)

This site is characterized by natural terraces and low, relatively flat areas between the terraces. The erosional scarps are formed by sheet erosion of coarser soils from deteriorated sites higher on the landscape and wind erosion on the mostly bare areas between scarples. The soils on the terraces are sandy loams, while the soils between the terraces are clay loams. The terrace vegetation is dominated by tarbush, alkali sacaton, mesa dropseed, and tobosa. There are areas with no vegetation between the terraces and other

areas with dead or dying tarbushes and vegetation dominated by tarbush and burrograss.

The number of transects taken annually ranged from 14 to 118. Fig. 5 shows the location of the soil E and the transect series. Precipitation from 1957 to 1977 for the transect-year averaged 218 mm and for October 1 to June 30 averaged 95 mm (table 4). Herbaceous plants' basal cover averaged 1.3%. Burrograss cover averaged 59% of the herbaceous cover on this soil. Burrograss cover was above average from 1957 to 1959, 1961, 1968, from 1972 to 1973, and from 1976 to 1977 (table 4). Precipitation measured from July 1 to September 30, from October 1 to June 30, or annually (July 1 to June 30) was above average only about half the years when burrograss cover was above average. This indicates burrograss cover on this soil was minimally affected by precipitation. Other important perennial grasses on this site were tobosa (table 4); bush, ear, and sand muhlys; black grama; alkali sacaton; mesa dropseed; poverty, red, and Wootton threeawns; vine mesquite; fluffgrass; and Hall's panicum. Sixweeks grama, an annual grass, was abundant (basal cover > 0.01%) in 1960 and 1962.

The major perennial forbs encountered were leatherweed, desert holly, wooly sumpweed, Fendler's bladderpod, trailing windmills, and scarlet globemallow. Leatherweed basal cover was abundant (> 0.01%) in 1958, 1959, 1961, 1965, and each year from 1973 to 1977. It occurred on 38% of the transects during those 9 years. Desert holly was plentiful (basal cover > 0.01%) in 1961, 1967, 1969, and 1973. Wooly sumpweed was abundant in 1958 and 1961. It occurred on 18% of the transects. Fendler's bladderpod basal cover was > 0.01% in 1959. Trailing windmills was abundant in 1967, and scarlet globemallow was plentiful in 1975.

The major annual forbs were Russian thistle, annual broomweed, saucerleaf buckwheat, spectaclepod, and gray goosefoot. Russian thistle basal cover was > 0.01% in 1958, 1962, 1968, and 1973. It occurred on 55% of the transects. Fig. 11 shows a Russian thistle stand. Annual broomweed was plentiful in 1962 and 1973. Saucerleaf buckwheat was abundant in 1957 at the end of the 1951–56 drought, but it occurred on only 2% of the transects. Spectaclepod was plentiful in 1973 and gray goosefoot was abundant in 1977.

Broom snakeweed was only a small component of the vegetation, but its basal cover averaged more than twice as much on Haplargids-Calciorthid Headquarters-Doña Ana-Chispa complex

Table 4. Precipitation (mm) and cover (10^{-2}) of vegetation on Haplargids-Calciorthid Headquarters-Doña Ana-Chispa complex (soil E).

Year	Precipitation (mm) ¹		Basal cover (0.01%) ²						Canopy cover (0.01%)	
	Annual ²	FWS ³	Himu	Sebr	TPG	TAG	TPF	TAF	Gusa	Prgl
1957	111	39	128.3	141.1	315.1	0.1	4.5	2.8	3.2	4.5
1958	306	176	61.7	113.5	202.8	0	5.6	2.5	0.9	9.5
1959	197	40	3.6	112.4	171.8	0	10.7	0	2.4	47.2
1960	134	32	8.1	71.9	83.7	2.6	1.9	0	1.3	67.1
1961	167	85	24.9	120.0	190.7	0.2	6.0	0	0.8	0
1962	201	82	1.8	44.8	57.5	1.5	4.5	6.0	1.1	26.7
1963	266	69	5.7	58.5	76.3	0	0.6	0	0.2	7.9
1964	184	64	3.1	41.4	53.8	0	0.5	0	0.4	23.3
1965	238	76	1.0	38.2	50.2	0	1.5	0	0.3	11.6
1966	203	119	11.3	63.3	76.6	0	0.8	0	0.1	5.0
1967	193	115	11.3	26.2	54.3	0.6	5.0	0.9	2.7	56.8
1968	156	92	3.0	104.0	117.5	0.3	2.0	2.7	0.3	6.0
1969	302	103	1.0	59.8	62.6	0	2.1	0.6	0	2.6
1970	220	85	28.7	65.5	99.0	0	1.4	0	0.4	14.4
1971	151	54	8.5	35.4	44.9	0	0.3	0	0.9	15.4
1972	245	137	10.9	90.4	104.8	0	2.6	1.0	0	0
1973	430	224	1.0	89.4	101.4	0	9.4	9.5	5.7	0
1974	104	27	0	48.3	55.1	0	2.3	1.0	6.7	13.5
1975	323	151	4.5	41.6	93.5	0	39.5	2.4	7.9	53.8
1976	314	129	0	169.8	332.9	0	10.7	1.4	23.0	34.3
1977	141	97	49.2	106.7	292.8	0	4.8	4.4	52.9	58.0
Average	218	95	17.5	78.2	125.6	0.3	5.6	1.7	5.3	21.8

¹Precipitation = Taylor Well Rain Gauge, July 1, 1956–June 30, 1977 (fig. 7). / ²Annual = July 1 of the previous year through June 30 of the indicated year. / ³FWS = Oct. 1 of the previous year through June 30 of the indicated year. / ⁴Cover: Himu = tobosa; Sebr = burrograss; TPG = total perennial grasses; TAG = total annual grasses; TPF = total perennial forbs; TAF = total annual forbs; Gusa = broom snakeweed; Prgl = honey mesquite.



Fig. 11. A Russian thistle stand in unit 7.

as on Ustollic Calciorthid Reagan (tables 3 and 4). Other major shrubs on the transects were honey mesquite, tarbush, whitethorn, longleaf ephedra, creosotebush, soaptree yucca, and datil.

Calciorthids Algerita-Chispa Complex (soil F)

This site is adjacent to the Ustollic Haplargid Stellar (see fig. 5 for location of soil F and the transect series). It occurs below the alluvial fans of the Doña Ana Mountains and is associated with the Jornada basin's lower-lying soils. It may occasionally be flooded by runoff water from higher areas. It is dominated by tarbush with an understory dominated by burrograss. From 1957 to 1977, between 12 and 44 transects were taken each summer on the grassier portions. The precipitation for the transect-year averaged 263 mm (table 5). It averaged 110 mm for October 1 to June 30 during those years. Burrograss basal cover averaged 66% of the herbaceous cover on the transects taken on this soil. Burrograss cover was particularly high in 1976 and 1977. Other important perennial grasses were tobosa (table 5), ear muhly, alkali sacaton, fluffgrass, poverty and red threeawns, black grama, and mesa dropseed. Annual grasses were not observed on this site.

Table 5. Precipitation (mm) and cover (10^{-2}) of vegetation on Calciorthids Algerita-Chispa complex (soil F).

Year	Precipitation (mm) ¹		Basal cover (0.01%) ⁴							
	Annual ²	FWS ³	Himu	Scbr	TPG	TAG	TPF	TAF	Gusa	Fice
1957	116	41	155.0	123.6	283.3	0	2.8	0	0	55.5
1958	379	230	25.0	82.4	107.4	0	3.9	3.6	0.1	0.5
1959	307	84	9.2	76.5	86.3	0	2.0	0.9	0.3	0
1960	314	53	25.6	72.2	98.7	0	2.5	0	0.2	1.6
1961	216	104	79.6	132.2	215.4	0	4.6	0.5	3.3	2.1
1962	319	103	8.9	52.6	68.3	0	1.8	2.5	0.2	0.9
1963	266	68	9.8	62.5	82.0	0	1.2	0.2	0.2	0
1964	180	60	9.6	57.0	75.1	0	1.2	0	0.2	0
1965	163	67	4.0	34.8	40.2	0	0.6	0.1	0.5	2.6
1966	174	112	4.1	43.4	50.1	0	1.9	0.6	1.0	2.6
1967	195	84	23.0	39.9	66.2	0	1.3	0.3	0.5	9.2
1968	275	93	9.0	59.5	74.2	0	1.5	4.3	0.2	1.6
1969	315	104	6.8	32.8	42.5	0	0.5	0.6	0.1	2.6
1970	229	109	6.4	51.5	61.6	0	0.9	0.6	0.4	0.8
1971	222	88	8.4	47.7	57.8	0	0.3	0	0.7	0
1972	285	190	18.4	47.2	67.0	0	2.2	1.1	0	0.2
1973	452	241	12.2	76.6	90.6	0	4.8	8.4	2.3	0
1974	163	40	11.0	53.4	67.4	0	0.2	2.2	6.8	0
1975	389	192	28.1	87.8	137.6	0	8.5	2.2	2.6	0.7
1976	358	164	63.2	283.9	438.8	0	1.9	0.8	7.1	1.2
1977	196	81	79.7	282.2	436.0	0	2.9	2.1	30.3	113.0
Average	263	110	28.4	85.7	126.0	0	2.3	1.5	2.7	9.3

¹Precipitation = South Well Rain Gauge, July 1, 1956–June 30, 1977 (fig. 7). / ²Annual = July 1 of the previous year through June 30 of the indicated year. / ³FWS = Oct. 1 of the previous year through June 30 of the indicated year. / ⁴Cover: Himu = tobosa; Scbr = burrograss; TPG = total perennial grasses; TAG = total annual grasses; TPF = total perennial forbs; TAF = total annual forbs; Gusa = broom snakeweed; Fice = tarbush.

Perennial forbs' basal cover averaged 0.023%. The major ones were desert holly, leatherweed, rattlesnakeweed, and paperflower. Desert holly basal cover was > 0.01% in 1958, 1961, 1972, and 1973. It occurred on an average of 58% of the transects. Leatherweed was abundant (basal cover > 0.01%) in 1961, 1975, and 1976. Rattlesnakeweed and paperflower were plentiful (> 0.01%) in 1975.

Major annual forbs were Russian thistle, annual broomweed, desert marigold, Dakota vervain, purple scorpionhead, deerstongue, and gray goosefoot. Russian thistle basal cover was > 0.01% in 1962, 1968, and 1969. It occurred on 41% of the transects. Annual broomweed was prevalent (0.01%) in 1958 and 1973. Desert marigold, Dakota vervain, and purple scorpionhead were abundant in 1973, a transect-year with very high precipitation. Deerstongue basal cover was > 0.01% in 1975 and gray goosefoot was plentiful in 1977.

Broom snakeweed increased from 1976 to 1977 (table 5). The major shrub was tarbush. Other important shrubs were whitethorn, longleaf ephedra, creosotebush, honey mesquite, Engelmann's pricklypear, and soaptree yucca.

Ustollic Haplargid Stellar (soil G)

For a detailed description of the Stellar soil and soil water data from 1957 to 1976 see Herbel et al. (1994, p. 323-370; 413-533). See fig. 5 for location of soil G and the transect series. It is in the basin and receives runoff water. From 1957 to 1977, precipitation for the transect-year (July 1 to June 30) averaged 262 mm, while precipitation for October 1 to June 30 averaged 107 mm (table 6). The number of transects taken annually ranged from 11 to 33. Tobosa and burrograss averaged 73 and 26%, respectively, of the herbaceous plants' basal cover from 1957 to 1977. Some of the other perennial grasses encountered were sand muhly, vine mesquite, bush muhly, black grama, poverty threeawn, and fluffgrass. The only year with any annual grass was 1968.

Perennial forbs' basal cover averaged 0.015% from 1957 to 1977 (table 6). The major perennial forbs were dingy falsenightshade (1957), wrinkled globemallow (1961 and 1968), and desert holly (1973). Abundant annual forbs (> 0.01% basal cover) were tansy mustard (1958), bitterweed (1958), and western fleabane (1973). Soil water > -0.1 MPa was plentiful during the previous fall,

Table 6. Precipitation (mm) and cover (10^{-2}) of vegetation on Ustollic Haplargid Stellar (soil G).

Year	Precipitation (mm) ¹		Basal cover (0.01%) ⁴								
	Annual ²	FWS ³	Himu	Schr	TPG	TAG	TPF	TAF	Gusa	Flee	
1957	88	51	1243.0	49.2	1295.8	0	6.3	0	0	0	25.5
1958	385	209	1984.9	2.5	1987.7	0	2.8	2.8	0	0	0
1959	243	79	162.2	30.2	192.5	0	1.1	0.4	0.7	0	0
1960	296	61	137.8	8.4	146.2	0	1.3	0.7	1.9	0	0
1961	194	104	401.8	120.3	523.2	0	1.5	0	25.2	0	0
1962	315	122	183.4	28.5	212.9	0	1.5	0.1	0.1	0.1	0.1
1963	307	76	124.0	6.8	132.2	0	0.1	0	0.6	0	0
1964	251	70	49.4	19.2	74.6	0	0.8	0	0	0	0
1965	185	58	66.0	6.8	72.9	0	0.8	0	0.8	0	0
1966	207	123	56.5	29.4	85.9	0	1.2	0	0.2	0	0
1967	140	61	21.2	66.8	88.1	0	0	0	0	0	17.3
1968	310	105	49.2	41.3	91.1	1.7	3.7	8.3	0.5	1.9	0
1969	304	100	35.9	13.5	49.5	0	0.4	0	0.3	0.4	0
1970	211	90	35.7	11.5	47.9	0	0.1	0	0.5	0.5	0
1971	116	34	44.9	11.7	56.6	0	0	0	1.2	0.4	0
1972	322	175	0.8	34.6	35.4	0	1.3	0.3	0	6.3	0
1973	417	249	2.3	153.4	155.6	0	3.3	3.8	0.1	1.5	0
1974	183	39	44.1	29.2	73.3	0	0.1	0	0.1	0	0
1975	449	194	69.9	221.4	292.2	0	1.3	0.1	0	9.8	0
1976	353	158	411.2	427.4	841.2	0	0.4	0	7.2	14.6	0
1977	235	97	203.0	550.0	772.6	0	1.8	1.0	2.1	22.6	0
Average	262	107	253.7	88.7	344.2	0.1	1.5	0.8	2.0	4.8	0

¹Precipitation = Stuart Rain Gauge, July 1, 1956–June 30, 1977 (fig. 7). / ²Annual = July 1 of the previous year through June 30 of the indicated year. / ³FWS = Oct. 1 of the previous year through June 30 of the indicated year. / ⁴Cover: Himu = tobosa; Schr = burrograss; TPG = total perennial grasses; TAG = total annual grasses; TPF = total perennial forbs; TAF = total annual forbs; Gusa = broom snakeweed; Flee = tarbush.

winter, and spring of 1958, 1968, and 1973, but in 1961 it was limited to 10 and 25 cm during winter and early spring.

The major shrub and shrub-like plants were tarbush and broom snakeweed (table 6). Fig. 12 shows a Stellar soil with tobosa being invaded by tarbush. Some of the other shrubs were lotebush, soap tree yucca, honey mesquite, longleaf ephedra, and littleleaf sumac.

Typic Calciorthids (soil M)

Herbel et al. (1994, p. 267-295) present a detailed description of a Turney soil and soil water data from 1957 to 1976. Between 101 and 159 transects were taken annually from 1957 to 1977. These soils have a great variety of vegetation. Fig. 5 shows the location of M soils and the transect series. The precipitation for the transect-year (July 1 to June 30) at South Well Rain Gauge averaged 263 mm, while the precipitation for October 1 to June 30 averaged 110 mm (table 7). Herbaceous plants' basal cover averaged 0.92%. Perennial grasses averaged 88% of that. Burrograss and threeawns



Fig. 12. Tarbush invading tobosa on the Stellar soil.

averaged 32 and 14%, respectively, of herbaceous plants' basal cover from 1957 to 1977. Other important perennial grasses were fluffgrass, mesa dropseed, tobosa, black grama, spike dropseed, sand muhly, and alkali sacaton. Perennial grass basal cover was above average in 1957, 1961, and from 1975 to 1977. There was soil water > -0.1 MPa during winter and spring of 1961 and 1975, but transect-year 1976 was droughty even though total precipitation was considerably above average at 358 mm. Precipitation was widely scattered so that 1976 was a droughty year.

Annual grasses' basal cover was particularly high in 1968 and 1969. The major annual grasses were sixweeks grama in 1968 and sixweeks threeawn in 1969. Both years had winter and spring soil water > -0.1 MPa. The summer rainfall was above average in 1968, resulting in considerable sixweeks grama and enough sixweeks threeawn to furnish adequate seed for 1969. Sixweeks grama basal cover was also $> 0.01\%$ in 1960 and 1962. Soil water > -0.1 MPa at 10 cm was observed during the fall and winter in 1959 and 1960, and at 10, 25, 40, and 60 cm during the winter and early spring of 1961 and 1962.

The major perennial forbs were leatherweed, Fendler's bladderpod, paperflower, rattlesnakeweed, wrinkled globemallow, trailing windmills, western sensitivebriar, twinleaf senna, scarlet globemallow, and plains zinnia. The leatherweed population was high in all the transect-years except 1977. The Fendler's bladderpod population was particularly prevalent in 1959, when soil water was < -1.5 MPa from December to June at the 10-, 25-, and 40-cm depths, but the soil water at those depths was > -0.1 MPa in the late summer and early fall 1958. There was considerable paperflower in both 1959 and 1975. The winter and spring in 1974 to 1975 had soil water > -0.1 MPa at the 10-, 25-, 40-, 60-, and 90-cm depths, but soil water > -0.1 MPa was limited in summer 1974. The rattlesnakeweed population was high in 1960, when most of the rainfall occurred in July and August 1959, but there was some soil water > -0.1 MPa at the 10-cm depth in the winter. The highest wrinkled globemallow populations were encountered in 1961 and 1962, when soil water during winter and early spring was > -0.1 MPa at depths of 10, 25, 40, and 60 cm. Trailing windmills' population was relatively high in 1967, when precipitation for the transect-year was below average, but soil water was > -0.1 MPa at 10 cm in June. Western sensitivebriar basal cover was abundant ($> 0.01\%$)

Table 7. Precipitation (mm) and cover (10^{-2}) of vegetation on Typic Calciorthids (soil M).

Year	Precipitation (mm) ¹		Basal cover (0.01%) ²						Canopy cover (0.01%)	
	Annual ²	FWS ³	ARI	Sebr	TPG	TAG	TPF	TAF	Gusa	Prgl
1957	116	41	0	77.5	107.4	0	12.1	0.6	1.9	16.1
1958	379	230	4.6	22.5	55.7	0	5.5	6.6	1.1	19.2
1959	307	84	3.0	27.1	50.2	0	9.5	0.6	7.4	16.0
1960	314	53	0.7	22.7	34.7	2.4	3.7	0.4	1.9	28.9
1961	216	104	3.3	53.6	92.5	0.4	7.5	1.8	7.2	30.5
1962	319	103	0.7	16.7	33.7	1.8	7.2	10.5	4.8	14.7
1963	266	68	1.3	12.2	27.6	0	2.1	0.2	0.7	13.5
1964	180	60	1.6	14.2	24.6	0	1.9	0.2	1.3	3.4
1965	163	67	1.7	6.4	18.2	0	4.5	1.0	1.8	12.0
1966	174	112	1.2	14.2	25.8	0.2	5.4	1.6	1.5	17.8
1967	195	84	1.4	12.3	23.4	0.8	4.0	3.2	3.2	47.4
1968	275	93	2.3	6.7	20.7	4.9	5.2	16.6	1.3	15.6
1969	315	104	3.5	10.5	27.8	4.1	3.5	4.3	1.5	50.5
1970	229	109	3.0	7.0	20.2	0.2	3.2	7.5	1.3	47.6
1971	222	88	0.9	9.0	18.0	0	1.0	0	1.9	40.5
1972	285	190	5.2	24.6	43.1	0	5.8	2.0	2.4	18.3
1973	452	241	8.3	27.7	47.1	0	11.9	10.4	5.5	17.4
1974	163	40	13.1	17.7	54.2	0	3.6	0	3.1	24.3
1975	389	192	16.9	39.1	100.5	0	18.5	4.4	4.4	71.5
1976	358	164	66.2	101.8	323.2	1.3	15.4	1.2	17.9	41.0
1977	196	81	125.7	103.9	547.9	0.1	7.2	6.5	46.7	57.7
Average	263	110	12.6	29.9	80.8	0.8	6.6	3.8	5.7	28.8

¹Precipitation = South Well Rain Gauge, July 1, 1956–June 30, 1977 (fig. 7). / ²Annual = July 1 of the previous year through June 30 of the indicated year. / ³FWS = Oct. 1 of the previous year through June 30 of the indicated year. / ⁴Cover: ARI = poverty, purple, red, and Wootton threearn; Sebr = burrograss; TPG = total perennial grasses; TAG = total annual grasses; TAF = total perennial forbs; TPF = total annual forbs; Gusa = broom snakeweed; Prgl = honey mesquite.

in 1973, when soil water > -0.1 MPa was abundant during the winter and spring. Twinleaf senna population was high in 1976, when soil water > -0.1 MPa was encountered at 10 cm in February, June, and the previous November. Scarlet globemallow and plains zinnia populations were relatively high in 1977, when precipitation was below average.

The major annual forbs on these soils were desert marigold, Russian thistle, Texas selenia, spike spiderling, woolly indianwheat, saucerleaf buckwheat, deerstongue, and gray goosefoot. Desert marigold population was highest in 1962, 1973, and 1977. The first two years had above-average precipitation and soil water > -0.1 MPa, while precipitation was below average in 1977. The highest populations of Russian thistle were encountered in 1958, 1962, from 1967 to 1970, and in 1973. Five of those seven years had above-average precipitation. One of the years that had below-average precipitation, 1970, had above-average soil water > -0.1 MPa in the fall and winter; the other year, 1967, had soil water > -0.1 MPa at the 10-cm depth in June. A high Texas selenia population was encountered in 1962, when there was considerable soil water > -0.1 MPa during the transect-year at depths of 10, 25, and 40 cm. The spike spiderling population was plentiful (> 0.01% basal cover) in 1969, when there was soil water > -0.1 MPa during the winter. Woolly indianwheat was particularly abundant in 1970, when precipitation was below average, but soil water > -0.1 MPa was observed at depths of 10, 25, 40, and 60 cm during fall and winter in 1969 and 1970. A high saucerleaf buckwheat population was encountered in 1973, when precipitation and days with soil water > -0.1 MPa were above average. Deerstongue was particularly abundant in 1975, when precipitation was high and soil water was > -0.1 MPa at depths of 10, 25, 40, 60, and 90 cm during fall, winter, and early spring in 1974 and 1975. Gray goosefoot population was high in 1977, when precipitation was low.

With respect to all forbs, both annual and perennial, 86% of the years prior to the year of abundance had a presence of that species. Even in those years not having a forb presence in the year prior to the year of abundance, the majority of the plants was encountered two to five years before the year of abundance. This would indicate an abundance of propagules when environmental conditions were appropriate for that particular species. With the exception of leatherweed, 72% of the years with an abundance of forbs had

above-average precipitation for the transect-year. Leatherweed is a strong perennial plant that is abundant in both wet and dry years.

The major shrubs on Typic Calciorthids were honey mesquite, soap tree yucca, longleaf ephedra, creosote bush, three fans, and tarbush. Broom snakeweed basal cover averaged 0.057%, but it had a substantial increase in both 1976 and 1977 (table 7).

Typic Haplargids Berino and Yucca (soil O)

This soil has a great variety of vegetation and had considerable changes in vegetation during the 1951–56 drought (Herbel et al. 1972). A detailed description of this soil and the soil water data from 1957 to 1976 were given by Herbel et al. (1994, p. 26, 51-81). The number of transects taken annually from 1957 to 1977 ranged from 113 to 171. Fig. 5 shows the location of soil O and the transect series. See fig. 13 for a typical scene on this site. The precipitation for the transect-year at Yucca Rain Gauge averaged 236 mm for July 1, 1956 to June 30, 1977, and the precipitation for October 1 to June 30 averaged 93 mm (table 8). Herbaceous plants' basal



Fig. 13. A typical scene on loamy sands on Typic Haplargids Berino and Yucca.

cover from 1957 to 1977 averaged 0.67%. Dropseeds and black grama averaged 43 and 9%, respectively, of the herbaceous plants' basal cover from 1957 to 1977. Other perennial grasses of note were fluffgrass, burrograss, red and poverty threeawns, tobosa, sand muhly, alkali sacaton, vine mesquite, Hall's panicum, and plains bristlegrass. It is interesting that fluffgrass basal cover averaged 0.001% from 1957 to 1958, 0.003% from 1959 to 1961, 0.010% from 1962 to 1965, 0.020% from 1966 to 1969, 0.009% from 1970 to 1971, 0.037% from 1972 to 1973, 0.074% from 1974 to 1975, and 0.40% from 1976 to 1977. In 1976 and 1977, fluffgrass basal cover was 14% of the perennial grasses' cover. Dropseeds' basal cover, the major perennial grass, was quite low from 1962 to 1972, but increased dramatically in 1976 and 1977 (table 8). Only a small amount of poverty threeawn was detected on the transects in 1975, but the basal cover was abundant ($> 0.01\%$) in 1976 and 1977. Hall's panicum and plains bristlegrass were plentiful ($> 0.01\%$ basal cover) only in 1976, when soil water > -1.5 MPa was observed at 10 and 25 cm during the previous late fall and winter.

Annual grasses' basal cover was highest in 1960, 1962, 1968, 1969, and 1977. Sixweeks grama was abundant in the first four years but sixweeks threeawn was the major annual grass in 1969. Mexican witchgrass was the only annual grass observed in 1977. All five years had winter soil water > -0.1 MPa.

Major perennial forbs were leatherweed, Fendler's bladderpod, paperflower, rattlesnakeweed, trailing windmills, crowfoot falsenightshade, scarlet globemallow, plains zinnia, and hairy evolvulus. Leatherweed was relatively abundant ($> 0.01\%$) on the transects on the Berino and Yucca soils every year except 1971 and 1977. The Fendler's bladderpod population was high in 1959, when the soil water was > -0.1 MPa during the previous fall and winter. Paperflower was particularly prevalent in 1959, 1973, 1975, and 1976, when the soil water was > -0.1 MPa during the fall and winter of 1958 and 1959, 1972 and 1973, and 1974 and 1975, and > -1.5 MPa during fall and winter of 1975 and 1976. Rattlesnakeweed populations were particularly prevalent in 1960 and 1962. Summer precipitation was above average in both 1959 and 1961 (table 8), which probably affected rattlesnakeweed populations the next summer. There were considerable trailing windmills in 1967. The precipitation for the 1967 transect-year was below average, but about 40 mm occurred in one day in early July

Table 8. Precipitation (mm) and cover (10^{-2}) of vegetation on Typic Haplargids Berino and Yucca (soil O).

Year	Precipitation (mm) ¹		Basal cover (0.01%) ²							Canopy cover (0.01%)	
	Annual ²	FWS ³	Boer	SPO	TPG	TAG	TPF	TAF	Gusa	Prgl	
1957	100	31	8.9	50.2	73.3	0	4.3	0.1	1.4	53.7	
1958	360	228	4.8	45.9	65.4	0	4.8	13.2	0.9	56.0	
1959	234	52	5.0	26.0	40.0	0	9.8	1.4	7.1	114.1	
1960	229	43	2.9	8.4	15.0	5.5	3.5	0.1	2.5	101.3	
1961	180	91	6.1	27.2	40.0	0.2	6.0	2.2	9.2	83.6	
1962	293	78	3.9	12.1	21.6	5.6	8.5	15.2	6.6	51.0	
1963	321	70	3.9	9.5	15.6	0.1	2.4	2.4	0.6	62.0	
1964	151	52	5.4	6.3	14.8	0	2.3	0.3	0.8	68.5	
1965	168	65	3.7	6.6	11.7	0	3.7	2.2	0.6	49.4	
1966	173	98	3.9	6.5	14.1	0	5.5	4.3	0.6	48.8	
1967	177	80	2.3	8.1	15.1	1.4	4.5	5.9	1.6	165.0	
1968	248	105	2.0	5.6	12.1	4.2	5.9	18.9	0.8	68.8	
1969	254	73	2.6	3.5	10.4	4.8	3.7	6.6	0.4	101.5	
1970	240	104	1.9	3.9	8.3	0	3.6	7.2	0.4	113.5	
1971	190	55	0.3	2.6	5.2	0	0.7	0	0.6	93.4	
1972	250	131	1.2	8.5	16.7	0	7.9	5.3	2.0	71.0	
1973	394	235	1.5	10.5	27.3	0	13.3	12.7	4.9	62.4	
1974	134	28	3.9	22.5	40.7	0	3.9	0	4.1	84.3	
1975	388	148	5.4	23.9	50.5	0	15.8	12.8	4.6	164.7	
1976	273	108	18.1	92.4	186.5	0	23.7	0.8	37.3	132.3	
1977	200	79	34.5	226.8	431.0	2.4	7.9	10.7	46.1	201.4	
Average	236	93	5.8	28.9	53.1	1.2	6.7	5.8	6.3	92.7	

¹Precipitation = Yucca Rain Gauge, July 1, 1956–June 30, 1977 (fig. 7). / ²Annual = July 1 of the previous year through June 30 of the indicated year. / ³FWS = Oct. 1 of the previous year through June 30 of the indicated year. / ⁴Cover: Boer = black grama; SPO = mesa, sand, and spike dropseed; TPG = total perennial grasses; TAG = total annual grasses; TPF = total perennial forbs; TAF = total annual forbs; Gusa = broom snakeweed; Prgl = honey mesquite.

1967. The crowfoot falsenightshade population was abundant in 1972 and 1973, when soil water > -0.1 MPa was prevalent during the previous fall, winter, and spring. The basal cover of scarlet globemallow, plains zinnia, and hairy evolvulus was relatively abundant (> 0.01%) in 1977. The precipitation for transect-year 1977 was below average, but there was soil water > 0.1 MPa during the fall and winter of 1976 and 1977.

The major annual forbs during various years on Berino and Yucca soils were faintcrown, purple curleaf, tickseed, desert marigold, Russian thistle, spectaclepod, deerstongue, and gray goosefoot. The total annual forbs' basal cover from 1957 to 1977 averaged 0.058% (table 8). Faintcrown was particularly abundant (> 0.01% basal cover) in 1958, when soil water was > -0.1 MPa at depths of 10, 25, and 40 cm for the fall, winter, and early spring of 1957 and 1958. Purple curleaf was plentiful (> 0.01%) in 1958, 1963, 1973, and 1975, when precipitation for the transect-year was above average. Tickseed was most abundant in 1961, 1962, 1965, and 1968, when soil water was > -0.1 MPa during the previous winter of all four years. High populations of desert marigold were encountered in 1975 and 1977, when precipitation for the transect-year was above average in 1975 and below average in 1977, but 1977 had soil water > -0.1 MPa at 10 cm during the previous winter. Russian thistle was most abundant in 1958, 1962, from 1965 to 1970, 1972, and in 1973. Seven of those 10 years had above-average precipitation. The transect-years of 1965 to 1967 had precipitation that was below average, but two of those years had soil water > -0.1 MPa at 10 cm during the winter. Eight years prior to the year of abundance had Russian thistle present, indicating the prevalence of propagules for the high population year. The highest spectaclepod populations (> 0.01% basal cover) were encountered in 1966, 1972, 1973, 1975, and 1977. Three of those five years had above-average precipitation during the transect-year, but all of those years had some soil water > -0.1 MPa during winter. Deerstongue was relatively abundant in 1972, 1973, and 1975, when the precipitation for the transect-year was above average. The gray goosefoot population was high in 1977, when the precipitation was below average.

With the exception of leatherweed, 72% of the years with an abundance of forbs had precipitation that was above average for the transect-year. With respect to all forbs, 73% of the years prior to the

year of abundance had some of the same species, indicating some propagules were present.

Major shrubs and shrub-like plants were honey mesquite, broom snakeweed, longleaf ephedra, tarbush, creosotebush, datil, and soaptree yucca. The broom snakeweed basal cover averaged 0.063%, and it was above average in 1959, 1961, 1962, 1976, and 1977, following the droughty years from 1951 to 1957, 1960, and 1974 (table 8). The honey mesquite canopy cover was > 1.0% for eight years.

Torrripsammet Bluepoint (soil P)

This soil has some low hummocks dominated by honey mesquite, but most of the transects were in areas dominated by herbaceous vegetation. A detailed description of a Petrocalcic Paleargid Cruces and the soil water data at the Pasture 2 Rain Gauge from 1964 to 1976 were given by Herbel et al. (1994, p. 82, 194-209). The number of transects taken annually from 1957 to 1977 ranged from 15 to 53, with all but three years having 32 or more. The location of soil P and the transect series are shown in fig. 5. Precipitation at West Well Rain Gauge averaged 232 mm for the transect-year and 91 mm for October 1 to June 30 (table 9). Herbaceous plants' basal cover from 1957 to 1977 averaged 0.62%. Dropseeds and black grama averaged 46 and 35%, respectively, of the herbaceous plants' basal cover. Dropseeds basal cover increased dramatically from 1973 to 1977—a response to the above-average precipitation received from 1972 to 1976 (except for the 1974 transect-year). Black grama basal cover was above average in 1957, 1958, 1976, and 1977, but the increased values in the 1970s were not as dramatic as for the dropseeds. Other minor perennial grasses were red and poverty threeawns, fluffgrass, and plains bristlegrass.

Annual grasses' basal cover was highest in 1969 (table 9), when sixweeks grama was the major species. Soil water > -0.1 MPa occurred at depths of 10 and 25 cm during the winter and early spring of that transect-year.

Perennial forbs' basal cover averaged 0.031% (table 9). The major perennial forbs were twinleaf senna, Fendler's bladderpod, leatherweed, and rattlesnakeweed. Twinleaf senna was abundant (> 0.01%) in 1957, 1966, and from 1975 to 1977. Soil water was > -0.01 MPa at 10 cm during the winters of 1965 and 1966, 1974

Table 9. Precipitation (mm) and cover (10^{-2}) of vegetation on Torrripsammet Bluepoint (soil P).

Year	Precipitation (mm) ¹		Basal cover (0.01%) ²							Canopy cover (0.01%)	
	Annual ²	FWS ³	Boer	SPO	TPG	TAG	TPF	TAF	Gusa	Prgl	
1957	118	57	50.1	6.6	62.1	0	3.9	2.5	2.6	237.1	
1958	367	185	84.2	12.8	97.0	0	2.4	33.1	2.2	380.1	
1959	242	55	29.3	12.8	43.4	0	5.1	7.2	6.1	475.8	
1960	269	53	14.9	5.8	21.3	0	1.2	0	3.0	359.3	
1961	133	81	17.8	7.3	25.9	0	1.3	4.1	1.4	474.0	
1962	346	90	15.1	9.6	24.7	0.1	2.5	10.9	5.5	312.6	
1963	316	85	18.4	10.8	30.1	0	2.6	11.2	0.9	176.8	
1964	218	54	13.4	3.8	20.4	0	1.8	0.5	2.5	212.5	
1965	149	47	9.8	9.5	20.6	0	1.4	0.4	0.8	146.1	
1966	167	77	3.0	6.6	10.5	0	2.9	3.5	0.4	287.3	
1967	243	93	22.1	10.7	34.4	0.1	2.1	1.3	1.5	183.0	
1968	240	95	12.1	12.4	25.3	0.7	2.4	6.7	1.0	517.9	
1969	187	61	11.5	13.2	26.2	3.7	2.2	11.1	1.2	364.1	
1970	222	85	15.4	4.0	20.0	0	1.5	3.4	2.6	338.3	
1971	150	50	3.9	2.9	6.9	0	0.2	0	0.8	638.7	
1972	253	152	3.5	7.0	10.9	0	2.8	6.5	0.4	244.0	
1973	349	217	5.2	18.4	24.3	0	3.9	10.5	7.6	231.5	
1974	104	27	4.7	42.6	48.1	0	1.8	0.8	23.4	177.5	
1975	334	157	7.1	35.2	43.6	0	7.2	8.9	10.7	442.0	
1976	243	102	44.8	113.8	160.6	0	9.4	3.9	45.3	424.0	
1977	229	87	72.9	251.3	342.3	0	6.2	0.6	42.2	417.0	
Average	232	91	21.9	28.4	52.3	0.2	3.1	6.1	7.7	335.2	

¹Precipitation = West Well Rain Gauge, July 1, 1956–June 30, 1977 (fig. 7). / ²Annual = July 1 of the previous year through June 30 of the indicated year. / ³FWS = Oct. 1 of the previous year through June 30 of the indicated year. / ⁴Cover: Boer = black grama; SPO = mesa, sand, and spike dropseed; TPG = total perennial grasses; TAG = total annual grasses; TPF = total perennial forbs; TAF = total annual forbs; Gusa = broom snakeweed; Prgl = honey mesquite.

and 1975, 1975 and 1976, and 1976 and 1977. Fendler's bladderpod basal cover was plentiful ($> 0.01\%$) in 1959 and 1977, when precipitation for the transect-year was about average. The rattlesnakeweed population was highest in 1976, when the soil water was > -0.1 MPa at 10 cm during fall and early winter. Leatherweed was abundant ($> 0.01\%$ basal cover) in 1972 and 1973, when there was soil water > -0.1 MPa during the winter and early spring.

Annual forbs' average basal cover was nearly twice that of perennial forbs (table 9). During various years, the major annual forbs on Bluepoint soils were faintcrown, deerstongue, annual broomweed, purple curleaf, Russian thistle, spectaclepod, gray goosefoot, and desert marigold. Faintcrown was particularly abundant ($> 0.01\%$) in 1958, 1959, 1962, 1963, 1973, 1975, and 1976, when precipitation for the transect-year was above average. Deerstongue populations were highest in 1958, 1963, 1973, and 1975, and annual broomweed was most abundant in 1958. High purple curleaf populations were encountered in 1958, 1959, 1962, 1963, and 1973. Russian thistle basal cover was highest in 1957, 1958, 1962, 1968, and 1969. Soil water was > -0.1 MPa at 10 and 25 cm during winter and early spring in 1968 and 1969. Spectaclepod was most abundant ($> 0.01\%$ basal cover) in 1959, 1962, 1972, 1973, and 1976. Gray goosefoot was relatively abundant in 1961 and 1966, when precipitation for the transect-year was below average. The highest desert marigold populations were observed in 1963 and 1975, when precipitation was above average for transect-years 1963 and 1975.

The major shrubs and shrub-like plants were honey mesquite, broom snakeweed, longleaf ephedra, and soaptree yucca. Honey mesquite canopy cover was more than 3.5 times greater on Bluepoint soils than on Berino and Yucca soils. Broom snakeweed basal cover averaged 0.077% , but it increased from 1973 to 1977 (table 9).

Typic Haplargids (soil R)

These are coarse-textured soils with a slope $> 1\%$. These soils occupy long, narrow, sloping ridges that border the O, S, and T soils. They are subject to wind erosion, but sand accumulations are generally less than 45 cm over the underlying soil. The number of transects taken annually from 1957 to 1977 ranged from 14 to 39, but after 1962 it was > 23 . Fig. 5 shows the location of soil R and

the transect series. The precipitation averaged 225 mm for the transect-year and 87 mm for October 1 to June 30 (table 10). Herbaceous plants' basal cover from 1957 to 1977 averaged 0.69% . Black grama and dropseeds averaged 35 and 34% of the herbaceous plants' basal cover, respectively. Black grama basal cover was above average from 1957 to 1959, 1961, 1976, and 1977, with a rapid increase the latter two years. Dropseeds basal cover was above average in 1961 and each year from 1975 to 1977, with a great increase in 1976 and 1977. Other perennial grasses abundant in some years were red and poverty threeawns, fluffgrass, bush muhly, and plains bristlegrass.

Annual grasses' basal cover was highest in 1962 and 1969 (table 10). Sixweeks grama was the major annual grass, but sixweeks threeawn was also present in 1969.

Perennial forbs' basal cover averaged 0.039% (table 10). The major perennial forbs were twinleaf senna, leatherweed, trailing windmills, paperflower, hog potato, desert holly, rattlesnakeweed, and plains zinnia. Twinleaf senna was the most prevalent perennial forb, being abundant ($> 0.01\%$ basal cover) 10 of the 21 years. The next most prevalent perennial forb was leatherweed, which was abundant in only three of the 21 years.

Annual forbs' average basal cover was more than twice that of perennial forbs (table 10). During various years, the major annual forbs on these Typic Haplargids were Russian thistle, faintcrown, deerstongue, purple curleaf, spectaclepod, desert marigold, tickseed, gray goosefoot, annual broomweed, purslane, and woolly indianwheat. Russian thistle was abundant in eight of the 21 years, deerstongue and purple curleaf in seven years, faintcrown in six years, and spectaclepod in five of the 21 years.

The major shrubs and shrub-like plants were honey mesquite, broom snakeweed, longleaf ephedra, and soaptree yucca. The honey mesquite canopy cover on these Typic Haplargids was greater than on the Berino and Yucca soils (tables 8, 10). However, honey mesquite on these Typic Haplargids averaged only 36% of the cover on the Torripsamments (tables 9, 10). Broom snakeweed basal cover averaged 0.092% from 1957 to 1977, but it increased dramatically in 1976 and 1977 (table 10).

Table 10. Precipitation (mm) and cover (10⁻²) of vegetation on Typic Haplargids (soil R).

Year	Precipitation (mm) ¹		Basal cover (0.01%) [†]							Canopy cover (0.01%)	
	Annual ²	FWS ³	Boer	SPO	TPG	TAG	TPF	TAF	Gusa	Prgl	
1957	118	57	44.9	10.6	55.5	0	1.4	5.7	5.5	90.7	
1958	367	185	70.3	20.1	91.0	0	1.6	31.4	1.0	220.4	
1959	242	55	26.0	21.1	47.7	0	3.0	16.6	4.3	38.8	
1960	269	53	14.4	10.6	26.1	0	0.5	0	3.1	210.8	
1961	130	78	51.2	27.9	79.1	0	1.9	3.4	1.1	291.1	
1962	350	87	17.6	13.8	31.7	7.0	2.6	13.4	2.8	132.2	
1963	287	75	11.6	12.8	24.4	0	1.2	8.0	0.8	89.3	
1964	162	38	22.0	3.6	28.2	0	1.2	0.7	1.2	34.5	
1965	171	53	8.7	5.1	14.6	0	2.9	0.6	0.9	28.5	
1966	149	64	13.0	7.7	21.2	0	1.6	5.1	0.2	87.0	
1967	184	49	22.7	17.3	45.1	2.6	7.3	2.1	1.9	77.7	
1968	257	103	9.5	8.9	24.2	3.3	3.2	19.4	1.0	100.8	
1969	176	54	7.6	6.1	15.1	11.8	2.8	14.7	1.4	222.3	
1970	181	71	3.5	4.2	8.4	0	1.4	7.1	1.2	115.7	
1971	151	54	4.9	2.7	9.0	0	0.4	0	0.8	128.1	
1972	249	148	2.5	4.0	10.5	0	4.9	8.6	0.9	58.4	
1973	345	209	4.0	7.6	18.1	0	4.2	14.7	8.5	202.9	
1974	106	25	9.9	20.9	35.4	0	3.6	0	10.5	72.5	
1975	337	150	11.8	26.7	41.3	0	6.9	12.1	9.3	162.9	
1976	259	112	58.7	80.5	150.5	0	12.3	3.5	59.1	54.8	
1977	228	101	96.6	188.4	403.0	0	16.2	4.0	76.9	110.8	
Average	225	87	24.4	23.8	56.2	1.2	3.9	8.1	9.2	120.5	

¹Precipitation = West Well Rain Gauge, July 1, 1956–Sept. 30, 1960; Ber Rain Gauge, Oct. 1, 1960–June 30, 1977 (fig. 7). / ²Annual = July 1 of the previous year through June 30 of the indicated year. / ³FWS = Oct. 1 of the previous year through June 30 of the indicated year. / ⁴Cover: Boer = black grama; SPO = mesa, sand, and spike dropseed; TPG = total perennial grasses; TAG = total annual grasses; TAF = total perennial forbs; TAF = total annual forbs; Gusa = broom snakeweed; Prgl = honey mesquite.

Paleargids-Paleorthids-Haplargids (soil S)

This soil had moderate vegetation changes during the 1951–56 drought (Herbel et al. 1972). A detailed description of this soil and the soil water data from 1957 to 1976 were given by Herbel et al. (1994, p. 82 and 114–141). The number of transects taken annually from 1957 to 1977 ranged from 75 to 107. The location of soil S and transect series are shown in fig. 5. Precipitation for the transect-year averaged 217 mm for July 1, 1956 to June 30, 1977, and the precipitation for October 1 to June 30 averaged 86 mm (table 11). Herbaceous plants' basal cover from 1957 to 1977 averaged 0.7%. Black grama and dropseeds averaged 40 and 30% of herbaceous plants' basal cover, respectively, from 1957 to 1977. The basal cover of both black grama and the dropseeds increased dramatically in 1976 and in 1977, responding to the above-average precipitation patterns of 1975 and 1976 (table 11). Other significant perennial grasses were poverty and red threeawns, tobosa, Hall's panicum, fluffgrass, and plains bristlegrass.

Annual grasses' basal cover was above average in 1962, 1968, and 1969. Sixweeks grama was the dominant annual grass in all three years, but sixweeks threeawn was also present in 1969. Soil water > -0.1 MPa occurred during the previous winter and early spring of all three years.

Perennial forbs' basal cover from 1957 to 1977 averaged 0.048% (table 11). The major perennial forbs were leatherweed, twinleaf senna, paperflower, Fendler's bladderpod, trailing windmills, wooly-white, silverleaf nightshade, strapleaf spineaster, and hog potato. Leatherweed was abundant (> 0.01%) in 12 of the 21 years. Twinleaf senna was abundant in 1965, 1972, and from 1975 to 1977; soil water > -1.5 MPa was observed during the winter or early spring at 10 cm all five years. Paperflower was particularly prevalent (> 0.01%) in 1959 and 1975, when soil water > -0.1 MPa was observed in late summer of the previous year until early spring of the transect-year. The Fendler's bladderpod population also was high in 1959. Trailing windmills were abundant in 1967, when soil water > -0.1 MPa was observed at 10 and 25 cm from June 21 to July 15. Wooly-white and silverleaf nightshade were relatively abundant in 1976, when late fall and early winter were dry, but late winter and early spring had soil water > -1.5 MPa at 10, 25, 40, 60, and 90 cm. Strapleaf spineaster and hog potato were abundant in 1977, when precipitation was average for the transect-year, and

Table 11. Precipitation (mm) and cover (10⁻²) of vegetation on Paleargids-Paleorthids-Haplargids (soil S).

Year	Precipitation (mm) ¹		Basal cover (0.01%) ²						Canopy cover (0.01%)	
	Annual ²	FWS ³	Boer	SPO	TPG	TAG	TPF	TAF	Gusa	Prgl
1957	78	35	40.2	9.8	52.8	0	3.9	1.3	2.3	65.9
1958	331	212	62.5	13.5	83.0	0	2.4	14.1	1.3	43.7
1959	247	53	22.0	19.0	41.4	0	5.5	7.3	10.5	73.4
1960	227	47	12.0	10.8	23.3	0.2	1.8	0.2	2.9	119.9
1961	143	85	46.8	31.5	81.3	0	3.4	3.5	6.8	72.0
1962	314	91	34.8	19.5	57.0	8.9	4.7	14.6	6.9	36.7
1963	313	58	22.5	19.8	44.4	0	1.3	3.3	0.7	41.9
1964	115	50	23.5	8.5	35.9	0	0.6	0.1	0.8	91.7
1965	167	51	18.0	7.7	27.0	0	5.0	1.5	0.5	17.8
1966	172	83	17.0	6.8	25.6	0	3.3	5.1	0.5	38.4
1967	151	9	13.1	6.5	23.4	0.9	3.6	5.2	3.1	73.1
1968	202	88	9.5	5.7	19.3	7.1	3.4	19.0	1.7	77.0
1969	229	78	9.6	4.8	19.0	9.2	2.8	8.9	0.9	64.7
1970	161	78	3.6	2.5	6.6	0	1.7	9.3	0.7	92.4
1971	163	53	2.5	1.7	5.9	0	0.2	0	1.0	104.4
1972	265	149	4.8	3.1	9.9	0	4.8	10.7	2.7	64.1
1973	313	205	6.9	9.5	20.4	0	8.2	17.3	5.7	33.8
1974	108	21	17.1	17.7	40.7	0	1.4	0	5.9	63.8
1975	398	166	18.7	13.6	41.7	0	10.1	16.1	11.3	150.0
1976	245	94	98.0	69.3	207.0	0.1	20.7	1.3	39.8	104.1
1977	217	93	101.5	150.7	327.0	0	11.4	7.0	74.7	225.4
Average	217	86	27.8	20.6	56.8	1.3	4.8	6.9	8.6	78.8

¹Precipitation = Co-op Well Rain Gauge, July 1, 1956–June 30, 1958; Exlosure B Rain Gauge, July 1, 1958–June 30, 1977 (fig. 7). ²Annual = July 1 of the previous year through June 30 of the indicated year. / ³FWS = Oct. 1 of the previous year through June 30 of the indicated year. / ⁴Cover: Boer = black gram; SPO = mesa, sand, and spike dropseed; TPG = total perennial grasses; TAG = total annual grasses; TAF = total perennial forbs; TAF = total annual forbs; Gusa = broom snakeweed; Prgl = honey mesquite.

there was soil water > -0.1 MPa at 10 and 25 cm during winter 1976 and 1977.

Annual forbs' basal cover on these soils averaged 0.069% from 1957 to 1977 (table 11). The major annual forbs were Russian thistle, purple curlleaf, faintcrown, deerstongue, spectaclepod, gray goosefoot, tickseed, and woolly indianwheat. Russian thistle was abundant (> 0.01% basal cover) in 1958, 1962, and from 1966 to 1970; the first two years had high amounts of precipitation, but the last five years had less precipitation. Faintcrown and purple curlleaf were abundant in 1958, 1959, 1962, 1963, 1973, and 1975. All six years had soil water > -0.1 MPa during the previous winter. Purple curlleaf was also abundant in 1970, when soil water also was > -0.1 MPa during the previous winter. Deerstongue and spectaclepod were abundant in 1972, 1973, and 1975, when soil water > -0.1 MPa was observed in the winter and early spring at 10, 25, 40, 60, and 90 cm. Deerstongue also was abundant in 1970, when soil water > -0.1 MPa also was prevalent in winter and early spring. Spectaclepod also was plentiful (basal cover of > 0.01%) in 1977, when precipitation was average (table 11). Gray goosefoot was abundant in 1961, 1968, and 1977, when soil water > -0.1 MPa during the previous winter was observed, but precipitation for the transect-year was average or lower than average. Tickseed basal cover was plentiful in 1968 and 1969, when soil water > -0.1 MPa in the winter and early spring was observed at depths of 10, 25, 40, and 60 cm. Woolly indianwheat was abundant in 1970, when there was considerable soil water > -0.1 MPa during winter and early spring, but precipitation for the transect-year was below average.

The major shrubs and shrub-like plants were honey mesquite, broom snakeweed, and soaptree yucca. Honey mesquite's average canopy cover was lower than that measured for the three previous soils. Broom snakeweed basal cover was above the 21-year average in 1959 and from 1975 to 1977 (table 11).

Paleargids-Paleorthids (soil T)

These soils had minor changes to the perennial grasses' basal cover during the 1951–56 drought (Herbel et al. 1972). A detailed description of a similar soil and the soil water data from 1960 to 1976 were given by Herbel et al. (1994, p. 82 and 141-163). The number of transects taken annually ranged from 65 to 92. Fig. 5 shows the location of soil T and the transect series. The precipita-

tion for the transect-year averaged 225 mm for July 1, 1956 to June 30, 1977, and the precipitation for October 1 to June 30 averaged 87 mm (table 12). The herbaceous plants' basal cover from 1957 to 1977 averaged 0.67% and the broom snakeweed basal cover averaged 0.088%.

From 1957 to 1977, black grama and dropseeds averaged 47 and 26% of the herbaceous plants' basal cover, respectively. Fig. 14 shows black grama on this site. Black grama had a large increase in basal cover in 1976, and dropseeds increased in both 1976 and 1977, responding to above-average precipitation during transect-years 1975 and 1976 (table 12). Other perennial grasses of significance were fluffgrass, and red and poverty threeawns.

The annual grasses' basal cover was above average in 1962, 1968, and 1969. Sixweeks grama was the dominant annual grass in all three years, but there also was considerable sixweeks threeawn in 1969. Soil water > -0.1 MPa was abundant during the winter and early spring of all three years.

From 1957 to 1977, perennial forbs' basal cover averaged 0.032% (table 12). Major perennial forbs were twinleaf senna, leatherweed, trailing windmills, and Fendler's bladderpod. Twinleaf senna was abundant (> 0.01% basal cover) 10 of the 21 years. There was some soil water > -0.1 MPa during the previous winter in all 10 years, although briefly in one of those years. The leatherweed population was plentiful (> 0.01%) in 1973, 1975, and 1976. The precipitation for the transect-year was above average in all three years, and there was considerable soil water > -0.1 MPa in fall, winter, and early spring in transect-years 1973 and 1975 and some soil water > -1.5 MPa during fall, winter, and early spring of transect-year 1976. Trailing windmills were abundant in 1962 and 1967; there was ample soil water > -0.1 MPa in 1962, but in transect-year 1967 it was limited to the summer and a few days in late winter. Fendler's bladderpod was plentiful (> 0.01%) in 1959, when precipitation for the transect-year was above average.

Annual forbs' basal cover on these soils averaged 0.072% from 1957 to 1977 (table 12). Major annual forbs were faintcrown, purple curleaf, Russian thistle, spectaclepod, deerstongue, warty carpetweed, and wooly indianwheat. Faintcrown and purple curleaf were abundant (basal cover > 0.01%) in 1958, 1959, 1962, 1963, 1973, and 1976. Precipitation for the transect-year was above average in all six years. In addition, faintcrown was plentiful in

Table 12. Precipitation (mm) and cover (10⁻²) of vegetation on Paleargids-Paleorthids (soil T).

Year	Precipitation (mm) ¹		Basal cover (0.01%) ²							Canopy cover (0.01%)	
	Annual ²	FWS ³	Boer	SPO	TPG	TAG	TPF	TAF	Gusa	Prgl	
1957	118	57	55.4	8.6	64.9	0	2.4	1.6	2.2	107.8	
1958	367	185	58.3	7.6	67.2	0	2.7	24.6	1.7	145.8	
1959	242	55	33.0	10.4	44.3	0	3.3	10.2	6.3	192.6	
1960	269	53	16.6	5.5	22.6	0	0.7	0	4.7	192.5	
1961	130	78	44.0	16.4	61.2	0	1.0	2.1	3.9	124.0	
1962	350	87	28.1	7.7	37.8	9.2	6.1	16.8	3.5	70.4	
1963	287	75	28.9	10.3	41.0	0	0.6	5.2	0.8	144.8	
1964	162	38	23.5	6.7	31.4	0	0.6	0	1.2	204.1	
1965	171	53	19.2	7.4	27.0	0	4.2	0.5	0.6	45.5	
1966	149	64	19.6	7.0	28.4	0	2.4	1.3	0.5	46.6	
1967	184	49	17.6	13.5	35.3	0	4.6	4.2	2.0	175.5	
1968	257	103	19.4	8.8	31.8	9.0	3.3	16.2	1.0	129.8	
1969	176	54	19.3	8.7	30.7	10.6	2.8	10.6	1.1	83.3	
1970	181	71	10.4	3.4	14.6	0	1.2	8.5	0.6	131.2	
1971	151	54	4.9	2.0	8.7	0	0.2	0	1.2	185.1	
1972	249	148	6.2	4.0	11.8	0.1	2.8	11.5	1.7	122.2	
1973	345	209	5.5	9.6	17.6	0	4.2	19.3	5.5	99.9	
1974	106	25	14.1	21.1	43.5	0	0.6	0	12.1	105.0	
1975	337	150	26.0	20.0	53.5	0.2	7.6	11.5	10.9	108.3	
1976	259	112	101.1	51.9	164.9	0	9.1	5.8	47.0	77.4	
1977	228	101	115.7	139.5	321.1	0	5.6	2.1	75.7	289.0	
Average	225	87	31.8	17.6	55.2	1.4	3.2	7.2	8.8	132.4	

¹Precipitation = West Well Rain Gauge, July 1, 1956–Sept. 30, 1960; Ber Rain Gauge, Oct. 1, 1960–June 30, 1977 (fig. 7). / ²Annual = July 1 of the previous year through June 30 of the indicated year. / ³FWS = Oct. 1 of the previous year through June 30 of the indicated year. / ⁴Cover: Boer = black grama; SPO = mesa, sand, and spike dropseed; TPG = total perennial grasses; TAG = total annual grasses; TAF = total perennial forbs; TAF = total annual forbs; Gusa = broom snakeweed; Prgl = honey mesquite.



Fig. 14. Black grama on the Paleargids-Paleorthids (soil T) during a droughty year.

1975, and purple curleaf was abundant in 1970, when there was considerable soil water > -0.1 MPa during the previous fall, winter, and early spring of both years. Russian thistle was prevalent in 1957, 1958, 1962, and from 1967 to 1969. Half of those years had below-average precipitation during the transect-year (table 12). Spectaclepod was abundant in 1959, 1972, 1973, and 1976, when precipitation was above average for the transect-year. Deerstongue was plentiful in 1970, 1972, 1973, and 1975, when all four years had considerable soil water > -0.1 MPa during fall, winter, and early spring. Warty carpetweed was abundant in 1967, when precipitation was below average. Precipitation was also below average in 1970, when woolly indianwheat was plentiful but soil water > -0.1 MPa was ample during the fall, winter, and early spring of 1969 and 1970.

The major shrubs and shrub-like plants were honey mesquite, soap tree yucca, and broom snakeweed. The average honey mesquite canopy cover was greater on this site than the previous site (tables 11 and 12). Broom snakeweed basal cover was above

average from 1974 to 1977, and it increased substantially in 1976 and again in 1977 (table 12).

Production of Perennial Grasses

Perennial grass production was determined annually by harvesting at the end of the growing season in the fall.

Typic Torriorthent Engholm (soil A)

This site is in a playa about 1.6 km northwest of Middle Well on JER. Fig. 5 shows the location of soil A, and fig. 7 locates the site. The playa receives run-in water from adjacent soils and from a long drainage leading to the adjacent San Andres Mountains. The vegetation on this playa was dominated by alkali sacaton.

Yields were determined annually from 1978 to 1988. The average perennial grass production during this period was 648 kg/ha (table 13). Yields in 1988 were more than twice as great as those obtained in 1986. Highest precipitation, 393 mm, at Middle Well was measured from October 1, 1987 to September 30, 1988. Of this, 313 mm occurred between July 1 and September 30, 1988. Perennial grass production was above average in 1979, 1984, 1986, and 1988. The crop-year precipitation for those four years averaged 351 mm, while the seasonal precipitation averaged 182 mm. With the exception of 1988, seasonal precipitation for the other three years averaged 139 mm, only slightly above the mean. This indicates that in some years some perennial grass growth occurred during spring. Perennial grass production was low in 1982 and 1983, when precipitation during the crop-year averaged 160 mm and during the growing season averaged 60 mm (table 13). Production decreased from 641 kg/ha in 1981 to 181 kg/ha in 1982, whereas it increased from 493 kg/ha in 1987 to 1805 kg/ha in 1988.

Ustollic Calciorthid Barcross (soil B)

This site is located in the vicinity of Northeast Enclosure (fig. 7), approximately 4.8 km north of JER headquarters. The site is level and in a small playa at the end of a drainage that begins on the slopes of the San Andres Mountains. This playa is flooded about twice every three years. The description of the soil and the soil water from 1957 to 1976 were given in Herbel et al. (1994, p. 533-580). The vegetation consisted of burrograss interspersed with tobosa stands

Table 13. Precipitation and yields of perennial grasses on Typic Torriorthent Engholm (soil A).

Year	Precipitation ¹		Yield ± s.e. ⁴
	Crop-year ²	Seasonal ³	
	mm		kg/ha
1978	258	143	446 ± 74
1979	368	136	850 ± 97
1980	168	63	340 ± 65
1981	224	143	641 ± 157
1982	114	64	181 ± 29
1983	205	56	133 ± 19
1984	275	123	755 ± 152
1985	327	107	592 ± 77
1986	367	158	900 ± 127
1987	236	71	493 ± 64
1988	393	313	1805 ± 246
Average	267	125	648

¹Precipitation = Middle Well Rain Gauge, Oct. 1, 1977–Sept. 30, 1988 (fig. 7). / ²Crop-year = Oct. 1 of the previous year through Sept. 30 of the indicated year. / ³Seasonal = July 1–Sept. 30 of the indicated year. / ⁴Yield and standard error of the mean (s.e.) = end-of-growing-season harvest of perennial grasses on Typic Torriorthent Engholm (soil A).

(fig. 15). The two species were sampled separately. Yields were determined annually from 1957 to 1988. Average burrograss production during this period was 778 kg/ha, and tobosa production averaged 1348 kg/ha (table 14). The average production from 1978 to 1988 was 516 and 735 kg/ha for burrograss and tobosa, respectively, as compared to 648 kg/ha of alkali sacaton on the Engholm site for the same years (tables 13, 14).

Burrograss yields at Barcross were considerably above average (> 878 kg/ha) in 10 years from 1957 to 1977 (table 14). During those 10 years, seasonal precipitation averaged 170 mm. The only year with low seasonal precipitation was 1977, when some soil water > -1.5 MPa was observed during the winter of 1976–77. Soil water > -1.5 MPa was observed during fall and winter of 1957–58, 1958–59, 1960–61, 1961–62, 1968–69, 1971–72, and 1974–75. From 1957 to 1977, tobosa production was considerably above average (> 1498 kg/ha) in 11 years (table 14). Seasonal precipita-



Fig. 15. Burrograss with patches of tobosa at the Northeast Enclosure.

tion during these 11 years averaged 175 mm. Seasonal precipitation was low in 1966 and 1973. There was some soil water > -1.5 MPa, during the winter of 1965–66, and considerable soil water > -1.5 MPa during the winters of 1972–73 and 1973–74.

From 1966 to 1984, burrograss yields were about average (678 to 878 kg/ha) six years. Seasonal precipitation for those years averaged 115 mm, and precipitation for the crop-year averaged 262 mm. Tobosa yields were about average (1198 to 1498 kg/ha) during 1977 and 1979. Both the seasonal and crop-year precipitation were below the 32-year average in 1977 and above average in 1979.

Half the time, burrograss production was < 678 kg/ha. The seasonal precipitation for those 16 years averaged 117 mm. Three of those 16 years with burrograss production < 678 kg/ha—1967, 1974, and 1988—had seasonal precipitation > 133 mm, the 32-year average. The seasonal precipitation for 1974 was 316 mm, but burrograss production averaged only 410 kg/ha. The precipitation for the crop-year for those 16 years averaged 217 mm. Six of those

Table 14. Precipitation and yields of burrograss (B) and tobosa (T) on *Ustollic Calciorthid* Barcross (soil B).

Year	Precipitation ¹		Yield \pm s.e. ⁴	
	Crop-year ²	Seasonal ³	B ⁵	T ⁶
	mm		kg/ha	
1957	200	157	1263 \pm 109	3274 \pm 215
1958	274	188	1960 \pm 124	2501 \pm 273
1959	221	177	2582 \pm 340	3965 \pm 433
1960	79	36	9(e) ⁷	11(e)
1961	295	185	1944 \pm 111	2803 \pm 208
1962	305	217	1527 \pm 96	1970 \pm 127
1963	150	83	150 \pm 10	251 \pm 31
1964	183	117	326 \pm 72	783 \pm 120
1965	145	101	41 \pm 10	530 \pm 85
1966	155	78	724 \pm 48	3013 \pm 268
1967	214	142	289 \pm 26	549 \pm 81
1968	231	128	374 \pm 37	709 \pm 94
1969	310	204	1252 \pm 99	2950 \pm 141
1970	202	112	369 \pm 34	637 \pm 56
1971	138	99	118 \pm 19	151 \pm 16
1972	296	129	1710 \pm 119	2359 \pm 155
1973	297	85	728 \pm 57	1732 \pm 125
1974	352	316	410 \pm 24	1645 \pm 128
1975	293	185	1045 \pm 65	2920 \pm 206
1976	271	163	942 \pm 130	1006 \pm 79
1977	188	92	1471 \pm 127	1280 \pm 98
1978	262	141	722 \pm 67	1075 \pm 96
1979	362	159	824 \pm 43	1428 \pm 116
1980	228	113	420 \pm 40	458 \pm 41
1981	205	120	729 \pm 60	903 \pm 70
1982	164	102	178 \pm 14	380 \pm 48
1983	245	66	223 \pm 23	348 \pm 36
1984	291	108	771 \pm 89	783 \pm 59
1985	326	112	433 \pm 38	615 \pm 43
1986	295	98	586 \pm 27	1021 \pm 62
1987	246	80	568 \pm 29	458 \pm 31
1988	276	161	223 \pm 13	613 \pm 31
Average	241	133	778	1348

¹Precipitation = Headquarters Rain Gauge, Oct. 1, 1956–Aug. 17, 1957; Northeast Exclosure Rain Gauge, Aug. 18, 1957–Sept. 30, 1988 (fig. 7). / ²Crop-year = Oct. 1 of the previous year through Sept. 30 of the indicated year. / ³Seasonal = July 1–Sept. 30 of the indicated year. / ⁴Yield and standard error of the mean (s.e.) = end-of-growing-season harvest of perennial grasses at the exclosure north of Headquarters. / ⁵B = burrograss on Barcross soil. / ⁶T = tobosa on Barcross soil. / ⁷e = visual estimate.

16 years had crop-year precipitation above the 32-year average, but only 1974 and 1985 had > 300 mm.

Tobosa production was < 1198 kg/ha 19 of 32 years (table 14). The seasonal precipitation for those 19 years averaged 110 mm. Four of those 19 years with tobosa production < 1198 kg/ha—1967, 1976, 1978, and 1988—had seasonal precipitation > 133 mm. The precipitation for the crop-year for those 19 years averaged 218 mm. Five of the eight years with crop-year precipitation > 241 mm, the 32-year average, had seasonal precipitation < 113 mm.

There was considerable variation in annual production. For example, burrograss yielded 1527 kg/ha in 1962, and 150 kg/ha in 1963. For the same years, tobosa produced 1970 and 251 kg/ha. In 1971 and 1972, burrograss yielded 118 and 1710 kg/ha, while tobosa yields were 151 and 2359 kg/ha.

Ustollic Calciorthid Reagan (soil D)

This site is located in the vicinity of JER's south boundary (fig. 7). The soil description was given in Gile and Grossman (1979, p. 830-831), Herbel and Gile (1973), and Herbel et al. (1994, p. 323, 370). The soil water description was given in Herbel et al. (1994, p. 370-415). The vegetation is primarily burrograss.

The average burrograss production from 1957 to 1988 was 785 kg/ha (table 15), while it was 778 kg/ha at the Barcross site (table 14), even though these sites are 21 km apart. From 1957 to 1986, it was considerably above average (> 878 kg/ha) at Reagan for 11 years. Seasonal precipitation during those 11 years averaged 159 mm. Of the 11 years, seasonal precipitation was below the 32-year average of 146 mm in 1958, 1969, 1973, and 1986. Crop-year precipitation for the 11 years averaged 299 mm. Of those years, three had crop-year precipitation below the 32-year average of 260 mm. Soil water was measured from August 16, 1957 to December 31, 1976, except for August 7 to December 31, 1972. There was some soil water > -0.1 MPa during the winters of 1957–58, 1961–62, 1962–63, 1968–69, 1971–72, 1972–73, and 1974–75. During the 11 years, either the crop-year or seasonal precipitation was above average, or there was soil water > -0.1 MPa during the winter.

From 1961 to 1984, burrograss yields were about average (678 to 878 kg/ha) for seven years (table 15). Seasonal precipitation

Table 15. Precipitation and yields of burrograss (B) on Ustollic Calciorthid Reagan (soil D) and tobosa (T) on Ustollic Haplargid Stellar (soil G) at the south boundary.

Year	Precipitation ¹		Yield \pm s.e. ⁴	
	Crop-year ²	Seasonal ³	B ⁵	T ⁶
	mm		kg/ha	
1957	228	177	946 \pm 94	1880 \pm 189
1958	332	119	1660 \pm 128	1523 \pm 261
1959	276	182	3017 \pm 163	1846 \pm 164
1960	134	79	89 \pm 11	390 \pm 45
1961	264	173	754 \pm 68	978 \pm 61
1962	283	180	1135 \pm 47	1285 \pm 72
1963	259	180	1745 \pm 116	1666 \pm 99
1964	158	98	142 \pm 19	165 \pm 19
1965	154	82	70 \pm 16	14 \pm 6
1966	170	79	719 \pm 56	782 \pm 162
1967	260	195	849 \pm 87	2207 \pm 122
1968	277	174	469 \pm 48	1495 \pm 186
1969	205	125	973 \pm 73	2061 \pm 158
1970	201	89	216 \pm 19	461 \pm 39
1971	211	149	810 \pm 64	2206 \pm 91
1972	356	201	1314 \pm 87	3718 \pm 207
1973	347	134	1202 \pm 120	1855 \pm 137
1974	282	242	689 \pm 57	2258 \pm 182
1975	332	203	1217 \pm 84	2291 \pm 110
1976	248	133	495 \pm 43	1030 \pm 101
1977	211	134	492 \pm 41	541 \pm 37
1978	325	197	801 \pm 46	1236 \pm 125
1979	370	159	1087 \pm 86	1355 \pm 100
1980	215	98	246 \pm 19	439 \pm 51
1981	223	133	596 \pm 46	684 \pm 62
1982	142	69	61 \pm 8	136 \pm 28
1983	243	96	195 \pm 33	206 \pm 30
1984	306	162	728 \pm 64	1319 \pm 139
1985	360	161	632 \pm 41	966 \pm 109
1986	298	87	965 \pm 70	1488 \pm 113
1987	330	173	495 \pm 46	792 \pm 74
1988	310	208	314 \pm 29	1002 \pm 74
Average	260	146	785	1259

¹Precipitation = Stuart Rain Gauge, Oct. 1, 1956–July 14, 1958; South Boundary Rain Gauge, July 15, 1958–Sept. 30, 1988 (fig. 7). / ²Crop-year = Oct. 1 of the previous year through Sept. 30 of the indicated year. / ³Seasonal = July 1–Sept. 30 of the indicated year. / ⁴Yield and standard error of the mean (s.e.) = end-of-growing-season harvest of perennial grasses at the enclosure south of Headquarters. / ⁵Reagan soil dominated by burrograss. / ⁶Stellar soil dominated by tobosa.

during those seven years averaged 171 mm, and the crop-year precipitation averaged 260 mm. Only 1966 had seasonal and crop-year precipitation below the 32-year average. Some soil water > -1.5 MPa was observed at 10 cm during the winter of 1965–66.

Burrograss production was < 678 kg/ha for 14 of the 32 years. Seasonal precipitation for those 14 years averaged 123 mm, and the crop-year precipitation averaged 229 mm. Four of those 14 years had seasonal and crop-year precipitation above the 32-year average. Soil water was measured during one of those four years, and it showed considerable soil water > -0.1 MPa at depths of 10, 25, 40, 60, 90, and 120 cm during fall, winter, and early spring, but limited soil water > -0.1 MPa during the growing season. The tobosa production at the nearby Stellar site was slightly above average that year, but it still did not reflect the considerable soil water > -0.1 MPa during the cool season. As an example of the variability, the yields were 1745 kg/ha in 1963, 142 kg/ha in 1964, 70 kg/ha in 1965, and 719 kg/ha in 1966 (table 15).

Ustollic Haplargid Stellar (S1, soil G)

This site is located in the same enclosure as the Reagan site, about 140 m apart. Both sites are nearly level, but the Stellar site has more days of soil water > -1.5 MPa than the Reagan site. The soil description was given in Gile and Grossman (1979, p. 838-839), Herbel and Gile (1973), and Herbel et al. (1994, p. 323-327). The soil water was given in Herbel et al. (1994, p. 326-370). The vegetation is dominated by tobosa. From 1957 to 1988, the average tobosa production at this site was 1259 kg/ha (table 15), while it was 1348 kg/ha at the Barcross site (table 14). From 1957 to 1986, tobosa production at Stellar was > 1409 kg/ha for 13 years (table 15). Seasonal precipitation during those 13 years averaged 167 mm, and crop-year precipitation averaged 282 mm. Of those 13 years, there was seasonal precipitation below the 32-year average of 146 mm in 1958, 1969, 1973, and 1986. Soil water was measured from August 17, 1957 to December 31, 1976, except for August 8 to December 31, 1972. There was some soil water > -0.1 MPa during the winters of 1957–58, 1968–69, and 1972–73.

Tobosa yields were about average (1109–1409 kg/ha) in 1962, 1978, 1979, and 1984 (table 15). Seasonal and crop-year precipitation during those four years averaged 174 and 321 mm, respectively. All four years had seasonal and crop-year precipitation

above the 32-year average. There was soil water > -0.1 MPa at 10 and 25 cm during the winter and early spring of 1961–62.

Tobosa production was < 1109 kg/ha for 15 years. The seasonal precipitation for those 15 years averaged 120 mm, and the crop-year precipitation averaged 224 mm. Four of those 15 years (1961, 1985, 1987, and 1988) had seasonal and crop-year precipitation above the 32-year average. Soil water was measured during one of those four years, and it showed soil water > -1.5 MPa at 10 and 25 cm during the winter, a few days during July and August of > -0.1 MPa at 10 cm, and about 30 days during September 7, of > -0.1 MPa at 10, 25, and 40 cm. Both tobosa yields at this site and burrograss yields at the nearby Reagan site were below average in 1985, 1987, and 1988, even though seasonal and crop-year precipitation were above average. As an example of the variability, tobosa production was 1666 kg/ha in 1963, 165 kg/ha in 1964, 14 kg/ha in 1965, and 782 kg/ha in 1966 (table 15).

Ustollic Haplargid Stellar (S3, soil G)

This site is located in JER's Fertilizer Exclosure. This site is situated at the edge of a playa that received more run-in water from the adjacent Doña Ana Mountains than the Stellar site discussed previously. This site is about 0.8 km from the other Stellar site (S1). The site is dominated by a dense tobosa stand, and yields were determined annually at the end of the growing season from 1957 to 1966 on the check plots of the Fertilizer Exclosure. The fertilizer study was discussed by Herbel (1963). Precipitation was recorded at Stuart Rain Gauge, about 0.3 km north of this site. The soil description and the soil water data were given in Herbel et al. (1994, p. 437-533).

Average tobosa production at this site was 2433 kg/ha (table 16), while for the same years it was 1053 kg/ha at the Stellar site discussed previously (table 15). The additional runoff water at this site dramatically increased tobosa production. Tobosa production was > 2676 kg/ha in 1959, 1961, and 1966. Seasonal and crop-year precipitation during those three years averaged 169 and 271 mm, respectively. Both seasonal and crop-year precipitation were below average in 1966, but there was considerable soil water > -1.5 MPa during fall, winter, and early spring of 1965–66.

Tobosa yields were about average (2190–2676 kg/ha) in 1957, 1958, 1962, and 1963. Seasonal and crop-year precipitation during

Table 16. Precipitation and yields of perennial grasses on Ustollic Haplargid Stellar (soil G) in the Fertilizer Exclosure.

Year	Precipitation ¹		Yield ± s.e. ⁴
	Crop-year ²	Seasonal ³	
	mm		kg/ha
1957	228	177	2472 ± 228
1958	377	164	2319 ± 87
1959	314	235	3125 ± 351
1960	151	90	1668 ± 224
1961	296	193	4907 ± 322
1962	354	232	2330 ± 109
1963	257	181	2230 ± 99
1964	198	127	646 ± 42
1965	142	84	569 ± 43
1966	202	79	4061 ± 114
Average	252	156	2433

¹Precipitation = Stuart Rain Gauge, Oct. 1, 1956–Sept. 30, 1966 (fig. 7). / ²Crop-year = Oct. 1 of the previous year through Sept. 30 of the indicated year. / ³Seasonal = July 1–Sept. 30 of the indicated year. / ⁴Yield and standard error of the mean (s.e.) = end-of-growing-season harvest of tobosa on the control plots in the Fertilizer Exclosure.

those four years averaged 188 and 304 mm, respectively. All four years had seasonal precipitation above the 10-year average.

Tobosa production was < 2190 kg/ha in 1960, 1964, and 1965. Seasonal precipitation for those three years averaged 100 mm, and the crop-year precipitation averaged 164 mm. Both seasonal and crop-year precipitation were below the 10-year mean during each of the three years. Two of those years, 1960 and 1964, had only a few days of soil water > -1.5 MPa during the cool season, whereas 1965 did not have effective seasonal precipitation until September 6.

Typic Haplargids Berino and Yucca (soil O)

There are two clipping sites on these soils, unit 11E and unit 11W. Perennial vegetation is mainly mesa dropseed, with a few plants of broom snakeweed, honey mesquite, and soaptree yucca (figs. 16, 17). A Typic Haplargid Yucca was described by Herbel et al. (1994, p. 26 and 51-58).



Fig. 16. Vegetation on the Berino-Yucca site during a droughty year.



Fig. 17. Vegetation on the Berino-Yucca site during a year with above-average precipitation.

Perennial grasses yielded an average of 198 kg/ha from 1958 to 1988, on these two sites (tables 17 and 18). Production averaged > 220 kg/ha for 37% of the 31 years. It was < 175 kg/ha for 52% of the time. Cover estimates were low most of the years when yields were low (table 8). Perennial grasses averaged 345 kg/ha in 1959 and 61 kg/ha in 1960 (table 17). In 1971, perennial grasses produced 92 kg/ha; it was 371 kg/ha in 1972 (table 18).

Unit 11E. This site is east of the main road that bisects unit 11. The precipitation was recorded at South Well Rain Gauge from October 1, 1956 to July 14, 1958, and at Exclosure A Rain Gauge from July 15, 1958 to September 30, 1988 (fig. 7). Soil water estimates at Exclosure A from 1957 to 1976 were discussed by Herbel et al. (1994, p. 29-52). Perennial grass production at the end of the growing season was determined annually from 1958 to 1988 (table 17). Average perennial grass yield at this site was 188 kg/ha. From 1958 to 1979, average production was > 220 kg/ha for nine years. Seasonal and crop-year precipitation for these nine years averaged 150 and 304 mm, respectively, well above the 32-year mean. Even though precipitation in 1977 and 1978 was below average, dropseed cover increased dramatically in 1977 (table 8).

Perennial grass yields were about average (175 to 220 kg/ha) in 1970, 1976, and 1988 (table 17). Seasonal and crop-year precipitation during those three years averaged 149 and 259 mm, respectively.

Perennial grass production was < 175 kg/ha for 19 of the 31 years (table 17). Seasonal and crop-year precipitation during those 19 years averaged 121 and 222 mm, respectively. Seasonal and crop-year precipitation were below the 32-year mean for 13 of those 19 years. Cover estimates taken annually from 1957 to 1977 showed dropseed cover was < 0.1% in 1960 and from 1963 to 1972 (table 8). Production was < 175 kg/ha in those years except in 1970 and 1972, when precipitation was above average. Precipitation was also above average in 1962 and 1968, but cover estimates were low.

Unit 11W. This site is about 0.3 km west of the main road that bisects unit 11. The precipitation was recorded at Yucca Rain Gauge (fig. 7), located 1.0 to 2.6 km from the yield estimates. Soil and soil water at Yucca Rain Gauge from 1957 to 1976 were discussed by Herbel et al. (1994, p. 51-81). The average yield at this

Table 17. Precipitation and yields of perennial grasses on Typic Haplargids Berino and Yucca (soil O).

Year	Precipitation ¹		Yield ± s.e. ⁴
	Crop-year ²	Seasonal ³	
	mm		kg/ha
1957	190	149	
1958	388	159	224 ± 25
1959	264	204	345 ± 59
1960	119	89	61 ± 7
1961	281	184	267 ± 38
1962	314	228	81 ± 18
1963	159	96	76 ± 17
1964	162	104	21 ± 6
1965	123	56	9 ± 3
1966	212	82	53 ± 23
1967	180	112	39 ± 17
1968	291	184	33 ± 13
1969	227	136	109 ± 21
1970	253	161	193 ± 47
1971	187	136	93 ± 23
1972	336	190	374 ± 53
1973	348	129	371 ± 40
1974	296	265	162 ± 26
1975	326	144	918 ± 213
1976	245	125	215 ± 22
1977	233	106	263 ± 32
1978	206	107	444 ± 38
1979	355	130	429 ± 60
1980	213	105	121 ± 21
1981	192	118	151 ± 31
1982	186	125	12 ± 6
1983	183	37	10 ± 4
1984	268	129	130 ± 33
1985	342	129	154 ± 31
1986	236	28	135 ± 30
1987	319	149	124 ± 23
1988	279	161	213 ± 43
Average	247	133	188

¹Precipitation = South Well Rain Gauge, Oct. 1, 1956–July 14, 1958; Enclosure A Rain Gauge, July 15, 1958–Sept. 30, 1988 (fig. 7). / ²Crop-year = Oct. 1 of the previous year through Sept. 30 of the indicated year. / ³Seasonal = July 1–Sept. 30 of the indicated year. / ⁴Yield and standard error of the mean (s.e.) = end-of-growing-season harvest of perennial grasses, unit 11E.

Table 18. Precipitation and yields of perennial grasses on Typic Haplargids Berino and Yucca (soil O).

Year	Precipitation ¹		Yield ± s.e. ⁴
	Crop-year ²	Seasonal ³	
	mm		kg/ha
1957	163	132	
1958	410	182	180 ± 31
1959	237	185	244 ± 38
1960	133	89	92 ± 14
1961	305	214	309 ± 60
1962	330	252	108 ± 16
1963	169	99	25 ± 7
1964	154	103	36 ± 12
1965	141	76	15 ± 4
1966	195	97	137 ± 22
1967	223	143	67 ± 12
1968	286	181	68 ± 24
1969	209	136	133 ± 29
1970	238	134	194 ± 25
1971	177	119	92 ± 24
1972	289	159	371 ± 59
1973	341	105	353 ± 31
1974	268	240	201 ± 35
1975	313	165	453 ± 91
1976	229	121	385 ± 36
1977	172	93	224 ± 32
1978	204	107	414 ± 49
1979	314	98	443 ± 65
1980	217	103	204 ± 38
1981	213	138	119 ± 26
1982	158	90	14 ± 3
1983	211	73	11 ± 3
1984	294	134	272 ± 43
1985	341	130	327 ± 60
1986	242	62	290 ± 47
1987	302	155	257 ± 49
1988	270	160	386 ± 58
Average	242	134	207

¹Precipitation = Yucca Rain Gauge, Oct. 1, 1956–Sept. 30, 1988 (fig. 7). / ²Crop-year = Oct. 1 of the previous year through Sept. 30 of the indicated year. / ³Seasonal = July 1–Sept. 30 of the indicated year. / ⁴Yield and standard error of the mean (s.e.) = end-of-growing-season harvest of perennial grasses, unit 11W.

site was 207 kg/ha from 1958 to 1988, with a range of 11 to 453 kg/ha (table 18). The average production was > 220 kg/ha for 14 of the 31 years. Seasonal and crop-year precipitation for these 14 years averaged 135 and 275 mm, respectively. Soil water was measured for six of those 14 years and without exception those six years had soil water > -1.5 MPa during the winter.

Perennial grass yields were about average (175 to 220 kg/ha) in 1958, 1970, 1974, and 1980. Seasonal and crop-year precipitation during those four years averaged 165 and 283 mm, respectively. Soil water estimates obtained at Yucca Rain Gauge for three of those years showed soil water > -0.1 MPa during the winter.

Perennial grass production was < 175 kg/ha for 13 of 31 years. Seasonal and crop-year precipitation during those 13 years averaged 123 and 200 mm, respectively. Cover estimates for dropseed were low (< 0.1%) in 1960 and from 1963 to 1972 (table 8). Except for 1970 and 1972, this coincided with production of < 175 kg/ha.

Typic Torripsamment Bluepoint (soil P)

This site is in the vicinity of the Pasture 2 Rain Gauge (fig. 7). The soil at the rain gauge has been described as Petrocalcic Paleargid Cruces (Herbel et al. 1994, p. 82, 182-194), but most of the soil at this site may be classified as Bluepoint. Soil water at Pasture 2 Rain Gauge from 1964 to 1976 was discussed by Herbel et al. (1994, p. 194-209). Perennial vegetation is primarily black grama, mesa dropseed, soap tree yucca, honey mesquite, and broom snakeweed. An average of 35% of the herbaceous cover was black grama and 46% was mesa dropseed (table 9). Black grama cover ranged from 64% of the herbaceous cover from 1957 to 1959 to 23% of the herbaceous cover in 1976 and 1977. Perennial grass production at the end of the growing season from 1958 to 1988 averaged 401 kg/ha (table 19), about double that obtained at the Berino-Yucca sites (tables 17 and 18).

From 1958 to 1988, the average perennial grass production was > 441 kg/ha for 10 years (table 19). Seasonal and crop-year precipitation for these 10 years averaged 157 and 296 mm, respectively. For those 10 years, seasonal precipitation was below the 32-year average (140 mm) in 1966, 1977, 1978, and 1987, while crop-year precipitation was < 248 mm (the average from 1957 to 1988) in 1966, 1977, and 1978. There was soil water > -1.5 MPa during

Table 19. Precipitation and yields of perennial grasses on Typic Torripsamment Bluepoint (soil P).

Year	Precipitation ¹		Yield ± s.e. ⁴
	Crop-year ²	Seasonal ³	
	mm		kg/ha
1957	241	182	—
1958	372	187	518 ± 65
1959	271	216	361 ± 28
1960	105	52	7(e) ⁵
1961	338	257	192 ± 37
1962	321	231	287 ± 46
1963	249	164	330 ± 31
1964	183	128	373 ± 28
1965	130	85	121 ± 17
1966	209	116	463 ± 62
1967	304	214	351 ± 44
1968	224	115	368 ± 40
1969	229	155	401 ± 41
1970	141	84	93 ± 9
1971	142	110	148 ± 15
1972	323	161	344 ± 27
1973	305	96	290 ± 58
1974	152	126	270 ± 25
1975	283	150	756 ± 70
1976	277	162	498 ± 44
1977	161	85	928 ± 41
1978	231	121	886 ± 60
1979	350	121	298 ± 40
1980	195	73	156 ± 19
1981	218	135	386 ± 41
1982	97	40	316 ± 40
1983	175	43	121 ± 17
1984	266	113	192 ± 31
1985	432	248	511 ± 53
1986	369	189	819 ± 74
1987	284	105	623 ± 69
1988	345	208	1031 ± 91
Average	248	140	401

¹Precipitation = West Well Rain Gauge, Oct. 1, 1956–July 10, 1964; Pasture 2 Rain Gauge, July 11, 1964–Sept. 30, 1988 (fig. 7). / ²Crop-year = Oct. 1 of the previous year through Sept. 30 of the indicated year. / ³Seasonal = July 1–Sept. 30 of the indicated year. / ⁴Yield and standard error of the mean (s.e.) = end-of-growing-season harvest of perennial grasses in unit 2. / ⁵e = visual estimate.

winter and spring of 1965–66 at the Pasture 2 Rain Gauge. Perennial grass cover increased dramatically in 1977 (table 9).

Perennial grass yields were about average (361 to 441 kg/ha) in 1959, 1964, 1968, 1969, and 1981 (table 19). Seasonal and crop-year precipitation during those five years averaged 150 and 225 mm, respectively. For those years, soil water data were available only for 1968 and 1969, and they show water > -0.1 MPa in the winter and early spring.

Perennial grass production was < 361 kg/ha for 16 of the 31 years (table 19). Seasonal and crop-year precipitation during those 16 years averaged 123 and 225 mm, respectively. Seasonal precipitation was above the 32-year average in 1961, 1962, 1963, 1967, and 1972. Crop-year precipitation was > 248 mm (the 32-year average) in 1961, 1962, 1963, 1967, 1972, 1973, 1979, and 1984. Perennial grasses produced 401 kg/ha in 1969, when the seasonal precipitation was 155 mm, and 93 kg/ha in 1970, when the seasonal precipitation was 84 mm.

Paleargids and Paleorthids (soil T)

There are two clipping sites on these soils, unit 9N and unit 9S. Ber Rain Gauge is closest to both sites (fig. 7). A description for a Petrocalcic Paleargid Hueco and soil water data (1960–76) at Ber Rain Gauge were presented by Herbel et al. (1994, p. 82, 141-163). Perennial vegetation is primarily black grama, mesa dropseed, fluffgrass, broom snakeweed, honey mesquite, and soap tree yucca (figs. 18, 19). Black grama was 67% of the herbaceous vegetation from 1957 to 1959 and 43% in 1976 and 1977 (table 12).

Unit 9N. This site is north of the slope (northwest-southeast orientation) in unit 9 and in the vicinity of Ber Rain Gauge (the yield data are “A” in table 20). Perennial grass production at the end of the growing season from 1960 to 1988 averaged 354 kg/ha.

From 1961 to 1988, perennial grasses produced > 380 kg/ha for 11 years. Seasonal and crop-year precipitation for these 11 years averaged 149 and 274 mm, respectively. For those years, seasonal precipitation was below the 32-year average (131 mm) in 1978, 1984, 1985, and 1986, while crop-year precipitation was below the 1957–88 average (233 mm) in 1966, 1978, and 1984. There was soil water > -0.1 MPa at all depths sampled in winter and early spring of 1960–61, 1961–62, and 1971–72, and at depths of 10, 25,

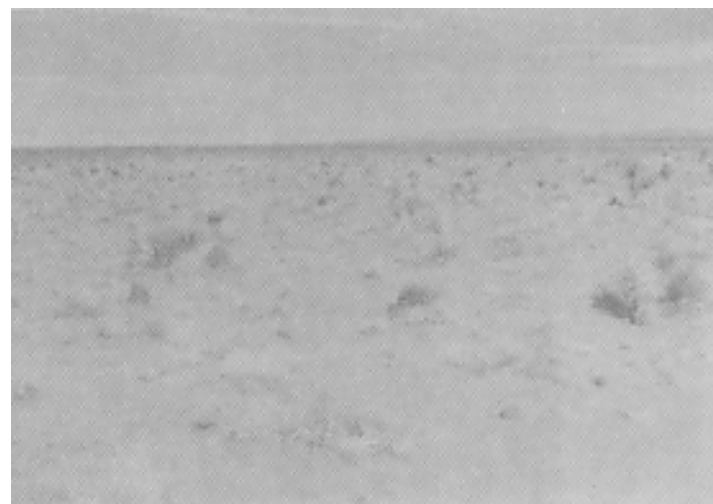


Fig. 18. Vegetation on soil T during a droughty year.



Fig. 19. Vegetation on soil T during a year with above-average precipitation.

Table 20. Precipitation and yields of perennial grasses on Paleargids and Paleorthids (soil T).

Year	Precipitation ¹		Yield \pm s.e. ⁴	
	Crop-year ²	Seasonal ³	A ⁵	B ⁶
	mm		kg/ha	
1957	241	182	—	—
1958	372	187	—	331 \pm 61
1959	271	216	—	516 \pm 51
1960	105	52	177 \pm 21	283 \pm 34
1961	352	263	644 \pm 44	526 \pm 57
1962	298	212	797 \pm 58	655 \pm 73
1963	199	124	336 \pm 47	132 \pm 27
1964	156	118	302 \pm 39	314 \pm 30
1965	138	85	182 \pm 20	127 \pm 15
1966	199	135	477 \pm 40	466 \pm 34
1967	203	154	145 \pm 21	215 \pm 29
1968	226	122	181 \pm 18	118 \pm 22
1969	164	110	372 \pm 29	348 \pm 28
1970	168	97	174 \pm 20	232 \pm 21
1971	148	93	249 \pm 31	225 \pm 18
1972	284	136	473 \pm 57	416 \pm 41
1973	289	81	195 \pm 25	159 \pm 21
1974	212	187	190 \pm 20	174 \pm 16
1975	297	147	344 \pm 48	395 \pm 63
1976	239	127	354 \pm 18	412 \pm 21
1977	320	219	800 \pm 91	1037 \pm 96
1978	157	75	659 \pm 72	466 \pm 55
1979	290	89	156 \pm 35	152 \pm 20
1980	189	91	179 \pm 28	92 \pm 12
1981	229	156	300 \pm 38	340 \pm 64
1982	162	99	99 \pm 19	31 \pm 8
1983	182	41	38 \pm 8	27 \pm 6
1984	194	76	480 \pm 53	372 \pm 47
1985	284	91	526 \pm 68	384 \pm 44
1986	276	122	550 \pm 59	576 \pm 60
1987	349	139	382 \pm 51	328 \pm 54
1988	305	172	500 \pm 59	539 \pm 109
Average	234	131	354	335

¹Precipitation = West Well Rain Gauge, Oct. 1, 1956–Sept. 30, 1960; Ber Rain Gauge, Oct. 1, 1960–Sept. 30, 1988 (fig. 7). / ²Crop-year = Oct. 1 of the previous year through Sept. 30 of the indicated year. / ³Seasonal = July 1–Sept. 30 of the indicated year. / ⁴Yield and standard error of the mean (s.e.) = end-of-growing-season harvest of perennial grasses. / ⁵A = unit 9N. / ⁶B = unit 9S.

and 40 cm in winter and early spring of 1965–66. Perennial grass cover increased dramatically in 1977 (table 12).

Perennial grass yields were about average (310 to 380 kg/ha) in 1963, 1969, 1975, and 1976 (table 20). Seasonal and crop-year precipitation during those four years averaged 127 and 225 mm, respectively. All four years had soil water > -1.5 MPa during the cool season prior to the growing season.

Production of perennial grasses was < 310 kg/ha for 14 of the 29 years (table 20). Seasonal and crop-year precipitation during those 14 years averaged 105 and 193 mm, respectively. Seasonal precipitation during those 14 years was above the 1957–88 average in 1967, 1974, and 1981. Crop-year precipitation was above the 32-year average (1957–88) in 1973 and 1979.

Unit 9S. This site is south of the slope in pasture 9 and in the vicinity of the IBP enclosure (yield data are “B” in table 20) about 2 km from the A site. Perennial grass production at the end of the growing season from 1958 to 1988 averaged 335 kg/ha. From 1960 to 1988, the mean for unit 9N (A) was 354 kg/ha and for unit 9S (B) was 329 kg/ha.

From 1959 to 1988, perennial grass production was > 380 kg/ha for 12 years (table 20). Seasonal and crop-year precipitation for these 12 years averaged 160 and 274 mm, respectively. During those 12 years, seasonal precipitation was below the 32-year average (131 mm) in 1976, 1978, 1985, and 1986, while the crop-year precipitation was below the 1957–88 average (233 mm) in 1966 and 1978. As mentioned previously, there was considerable soil water > -0.1 MPa during the cool season of 1965–66. Perennial grass cover increased substantially in 1976 and again in 1977 (table 12).

From 1958 to 1987, perennial grass yields were about average (310 to 380 kg/ha) for six years (table 20). Seasonal and crop-year precipitation during those six years averaged 131 mm and 244 mm, respectively.

Perennial grass production was < 310 kg/ha for 13 of the 31 years (table 20). Seasonal and crop-year precipitation during those 13 years averaged 101 and 193 mm, respectively. Seasonal precipitation during those 13 years was above the 32-year average in 1967 and 1974, while crop-year precipitation was above the 1957–88 average in 1973 and 1979.

Protection Plots

The transect-year for these studies is from August 1 to July 31 because cover estimates were determined in August, following the cover estimates discussed previously.

Study A

This site is Exclosure “A” on JER (fig. 7). It is in pasture 11, about 4 km north of South Well and about 0.3 km east of the main road (figs. 20-22). The soil is a Typic Haplargid Onite (soil O) with evidence of recent wind erosion, probably since the early 1950s drought. See Herbel et al. (1994, p. 24-52) for a detailed description of this soil and soil water from 1957 to 1976.

Cover. Cover for the surrounding area has been discussed in this report in the cover section under Typic Haplargids Berino and Yucca (table 8), but the cover observations were more concentrated in this study. From 1957 to 1977, precipitation for the transect-year (August 1-July 31) averaged 243 mm, while the



Fig. 20. Vegetation in the Ro plot at Study A in 1957.



Fig. 21. Vegetation in the Ro plot at Study A in 1970.



Fig. 22. Vegetation in the Ro plot at Study A in 1977.

precipitation for October 1 to June 30 averaged 100 mm (table 21). From 1957 to 1977, herbaceous plants' basal cover averaged 0.63%. Dropseeds cover (mesa dropseed is the dominant) averaged 43% of the herbaceous plants. There is no evidence that the degree of protection influenced perennial grass basal cover. Furthermore, black grama cover was very low or nonexistent throughout this study. Generally, dropseeds basal cover was moderate during the late 1950s and early 1960s, was low in the late 1960s and early 1970s, and then increased tremendously from 1972 to 1977. Other perennial grasses of some importance were red and poverty threeawns, fluffgrass, plains bristlegrass, and bush muhly. Red threeawn basal cover in the rodent plot (Ro) was $> 0.01\%$ from 1972 to 1976, and in the other plots only in 1976. Poverty threeawn increased in basal cover in all plots in 1976 and was $> 0.01\%$ in 1977. Fluffgrass increased in the 1970s, and the basal cover averaged 0.34% in the four plots in 1977. Plains bristlegrass basal cover was $> 0.01\%$ in all plots in 1974, and the rabbit (Ra) and livestock (Li) plots in 1976. Bush muhly's basal cover was $> 0.01\%$, only in the rabbit plot (Ra) in 1961 and 1962.

There was some evidence that protection from rodents and rabbits (Ro) and rabbits (Ra) increased annual grass basal cover (table 21). Since samples were taken later in the summer for studies A and B than the cover estimates discussed earlier, more annual grasses were observed. Sixweeks grama basal cover was $> 0.01\%$ in all plots in 1957, 1959, 1960, 1961, 1962, and 1964. In addition, it was $> 0.01\%$ in all plots except open (Op) in 1969. It was also $> 0.01\%$ in the rodent plot (Ro) in 1963 and 1968, and the rabbit plot (Ra) in 1967 and 1968. Witchgrass basal cover was $> 0.01\%$ in all plots in 1967. In 1969, sixweeks threeawn was relatively abundant ($> 0.01\%$) in all plots, except open (Op). It was abundant in Op in 1962. It was interesting that annual grass basal cover was low in the 1970s, when the dropseeds population was high.

Leatherweed basal cover in the open plot (Op) was $> 0.01\%$ for 12 of the 21 years. It was $> 0.01\%$ for five of the 21 years in the rabbit plot (Ra), four years in the livestock plot (Li), and two years in the rodent plot (Ro). Rattlesnakeweed was relatively abundant (basal cover $> 0.01\%$) in Ra for eight of the 21 years, in Li and Ro plots for two years, and in Op for one year. Paperflower was prevalent ($> 0.01\%$) in Op for four of the 21 years, in Ra and Li plots for two years, and in the rodent plot just one year. The Fendler's

bladderpod population was high in Op for three of the 21 years and in Li for two years. Other important perennial forbs for one or two years in some of the plots were: desert holly; silverleaf nightshade; blanketflower; sicklepod; western sensitivebriar; trailing windmills; and pale, scarlet, and wrinkled globemallows. There was no evidence that degree of protection affected perennial forbs population (table 21), but there was greater diversification in Op.

The major annual forb was Russian thistle. Its basal cover was $> 0.01\%$ in nine of the 21 years. Other annual forbs with basal cover $> 0.01\%$ for at least one of the 21 years were: purple curleaf, tickseed, deerstongue, spectaclepod, annual broomweed, shaggyleaf, desert marigold, warty carpetweed, faintcrown, wooly indianwheat, spike spiderling, chinchweed, wooly mouse-ear, saucerleaf buckwheat, puncturevine, whitestem stickleaf, Chihuahua flax, and gray goosefoot. Russian thistle, chinchweed, puncturevine, saucerleaf buckwheat, spike spiderling, and warty carpetweed were most populous (basal cover $> 0.01\%$) in the 1960s and early 1970s. Spectaclepod, desert marigold, deerstongue, whitestem stickleaf, shaggyleaf, Chihuahua flax, and gray goosefoot were most prevalent ($> 0.01\%$) in the mid-1970s. Protection did not effect annual forbs (table 21).

The major shrubs and shrub-like plants were honey mesquite, broom snakeweed, soap tree yucca, and longleaf ephedra. Broom snakeweed basal cover averaged 0.013%, while the honey mesquite canopy cover averaged 1.063% (table 21). Broom snakeweed basal cover increased somewhat following droughty years. There was some evidence that protection from rodents (Ro) increased the population of broom snakeweed in 1961 and 1962, and longleaf ephedra in 1976 and 1977. Honey mesquite canopy cover increased 866% between the periods of 1957 to 1961 and 1973 to 1977, when all plots were considered. The increase was only 456% on the open (Op) plot (table 21). The increase in mesquite cover was 936%, 788%, and 1282% for the rodent (Ro), rabbit (Ra), and livestock (Li) plots, respectively. More mesquite seedlings survived with some protection from cattle.

Table 21. Precipitation (mm) and cover (10⁻²%) of vegetation at Study A.

Year	Precipitation ¹ (mm)		Basal cover ⁵ (0.01%)								Canopy cover (0.01%)	
	Annual ²	FW/S ³	Plot ⁴	Boer	SPO	TPG	TAG	TPF	TAF	Gusa	Pgl	
1957	99	41	Ro	0.3	7.3	7.6	279.5	0.4	1.2	0.1	12.7	
			Ra	0.6	6.0	7.1	133.8	0.2	0.1	0.0	48.8	
			Li	0.0	8.6	9.1	68.0	0.2	0.2	0.0	23.1	
			Op	0.0	11.9	11.9	93.5	0.4	0.1	0.0	97.0	
1958	371	230	Ro	0.4	20.3	20.7	0.0	26.9	19.5	0.1	10.0	
			Ra	2.4	10.1	12.6	0.0	0.3	14.3	0.0	38.4	
			Li	0.6	24.3	24.9	0.0	2.4	14.0	0.0	33.5	
			Op	0.0	13.2	13.2	0.0	1.5	9.2	0.0	77.5	
1959	240	60	Ro	0.4	7.9	8.3	33.3	2.6	0.5	0.6	7.3	
			Ra	0.3	4.2	4.5	27.2	1.8	2.2	0.5	19.2	
			Li	0.1	8.5	8.6	18.3	2.9	1.2	0.1	23.2	
			Op	0.0	5.4	5.4	20.1	2.7	1.3	0.1	45.6	
1960	241	33	Ro	0.1	0.9	1.0	112.8	1.6	0.8	0.6	6.9	
			Ra	0.0	1.2	1.2	89.2	1.8	1.1	0.0	21.5	
			Li	0.0	2.2	2.3	67.1	2.5	1.9	0.0	5.5	
			Op	0.0	1.0	1.0	80.8	2.6	2.1	0.0	11.7	
1961	175	97	Ro	0.0	4.3	4.3	67.7	4.2	1.9	1.1	24.9	
			Ra	0.9	4.1	8.0	43.8	6.5	3.7	0.1	47.5	
			Li	0.0	3.3	3.3	18.3	6.2	2.7	0.0	34.6	
			Op	0.0	1.0	1.0	6.5	1.1	1.1	0.0	46.3	
1962	352	87	Ro	0.0	4.6	5.1	60.2	3.8	24.1	2.4	30.3	
			Ra	0.0	4.7	5.8	24.8	0.6	29.5	0.4	83.2	
1963	187	63	Li	0.0	6.5	6.5	26.2	4.3	28.5	0.7	43.8	
			Op	0.0	3.0	3.1	13.2	4.0	31.3	0.0	68.0	
			Ro	0.7	2.6	3.3	2.6	0.3	0.0	0.4	17.1	
			Ra	0.0	1.4	1.4	1.8	0.9	0.0	0.0	49.1	
1964	170	57	Li	0.2	4.7	4.9	4.9	2.6	0.0	0.0	48.6	
			Op	0.0	1.8	1.8	3.0	2.3	0.0	0.1	68.5	
			Ro	0.6	3.7	4.3	92.0	1.4	5.1	0.4	29.2	
			Ra	0.0	1.2	1.2	27.4	58.1	19.8	0.1	42.8	
1965	150	67	Li	0.0	2.5	2.5	15.9	7.0	15.1	0.0	63.7	
			Op	0.0	0.9	1.0	5.1	2.5	5.2	0.0	75.2	
			Ro	0.6	0.7	1.3	0.7	0.8	2.9	0.4	38.8	
			Ra	0.1	0.4	0.5	0.2	0.1	3.7	0.0	80.6	
1966	181	130	Li	0.0	1.0	1.0	0.0	0.4	2.2	0.0	67.3	
			Op	0.0	0.7	0.7	0.0	1.7	2.4	0.0	85.7	
			Ro	0.1	1.5	1.6	0.0	0.3	5.3	0.3	29.2	
			Ra	0.0	0.2	0.2	0.0	0.1	5.2	0.0	50.3	
1967	165	69	Li	0.0	1.6	1.6	0.0	0.3	6.2	0.0	72.7	
			Op	0.0	0.8	0.8	0.0	2.1	8.3	0.0	85.7	
			Ro	0.0	0.1	0.1	3.1	0.7	4.2	0.0	27.2	
			Ra	0.0	0.3	0.3	2.8	0.7	6.3	0.0	55.3	
1968	272	107	Li	0.0	0.3	0.3	2.1	1.3	8.8	0.0	75.7	
			Op	0.0	0.4	0.4	2.1	2.1	11.8	0.0	80.2	
			Ro	0.0	0.2	0.6	3.2	1.3	18.8	0.0	26.8	
			Ra	0.1	0.2	1.2	2.0	0.8	21.9	0.0	59.0	
			Li	0.0	0.0	0.1	0.8	0.9	21.9	0.0	68.6	
			Op	0.0	0.2	0.5	0.4	2.6	21.1	0.1	96.1	

Table 21. Precipitation (mm) and cover (10⁻²%) of vegetation at Study A, cont'd.

Year	Precipitation ¹ (mm)		Basal cover ⁵ (0.01%)							Canopy cover (0.01%)	
	Annual ²	FW/S ³	Plot ⁴	Boer	SPO	TPG	TAG	TPF	TAF	Gusa	Prgl
1969	271	93	Ro	0.2	1.8	2.6	6.4	1.2	9.2	0.0	51.8
			Ra	0.2	0.9	1.7	6.3	1.8	7.4	0.0	124.2
			Li	0.0	0.5	0.6	2.5	1.5	9.6	0.1	92.7
1970	264	92	Op	0.0	0.2	0.3	1.0	2.3	8.0	0.2	150.2
			Ro	0.0	1.6	2.2	0.1	0.4	11.5	0.0	43.4
			Ra	0.0	0.9	1.0	0.0	1.4	9.9	0.0	180.0
1971	144	51	Li	0.0	0.5	0.7	0.0	0.7	9.0	0.0	83.0
			Op	0.0	1.1	1.2	0.0	2.1	10.4	0.1	210.1
			Ro	0.0	0.9	1.0	0.0	0.2	0.0	0.0	44.0
1972	310	146	Ra	0.0	0.3	0.5	0.0	0.0	0.0	0.0	158.1
			Li	0.0	0.1	0.3	0.0	0.0	0.0	0.0	134.1
			Op	0.0	0.2	0.4	0.0	0.4	0.0	0.0	130.2
1973	432	222	Ro	0.0	10.2	13.9	0.0	1.4	6.2	0.0	54.7
			Ra	0.0	8.0	11.5	0.0	2.8	5.0	0.2	156.0
			Li	0.0	4.7	6.4	0.1	0.8	3.2	2.1	105.5
1974	187	30	Op	0.0	8.6	12.4	0.0	2.3	3.0	0.0	187.5
			Ro	0.1	23.4	27.1	0.2	11.2	39.2	2.8	29.8
			Ra	0.0	15.8	21.7	0.0	18.5	22.1	1.7	211.0
Average ⁶	243	100	Li	0.0	0.0	26.7	0.0	1.5	5.3	0.6	187.0
			Op	0.0	19.3	22.0	0.0	8.3	9.6	4.1	120.3
			Ro	0.0	40.7	45.2	0.0	10.9	24.2	1.8	206.7
Average ⁶	263	126	Ra	0.5	37.8	45.5	0.0	19.1	21.1	0.7	303.8
			Li	0.0	26.6	34.9	0.0	13.3	26.3	0.7	656.7
			Op	0.0	24.8	34.4	0.0	12.5	20.5	0.2	311.3
Average ⁶	249	120	Ro	0.0	211.2	228.5	0.0	4.1	1.4	12.2	108.0
			Ra	0.0	192.2	218.9	0.9	3.8	0.6	3.2	265.9
			Li	0.0	156.4	194.4	0.0	4.4	0.8	11.2	207.2
Average ⁶	263	126	Op	0.0	180.9	229.0	0.0	13.1	0.9	2.9	261.5
			Ro	0.0	233.6	250.2	0.0	0.6	4.2	12.4	139.2
			Ra	0.0	262.2	289.5	0.0	3.1	1.6	7.7	366.8
Average ⁶	243	100	Li	0.0	267.0	337.2	0.0	0.6	2.1	15.8	290.1
			Op	0.0	268.5	336.3	0.0	0.6	3.6	11.2	352.5
			Ro	0.2	28.5	31.2	31.5	3.5	8.9	1.8	49.2
Average ⁶	243	100	Ra	0.2	27.5	31.8	17.2	5.9	8.7	0.7	123.7
			Li	0.0	26.3	32.4	10.7	3.2	9.2	1.7	119.7
			Op	0.0	26.7	33.4	10.7	4.5	8.2	1.0	132.5
Average ⁶	243	100	Overall	0.1	27.2	32.2	17.5	4.3	8.7	1.3	106.3

¹Precipitation = South Well Rain Gauge, Aug. 1, 1956–July 14, 1958; Exclosure “A” Rain Gauge, July 15, 1958–July 31, 1977 (fig. 7). / ²Annual = Aug. 1 of the previous year through July 31 of the indicated year. / ³FWS = Oct. 1 of the previous year through June 30 of the indicated year. / ⁴Plots: Ro = rodents, rabbits, and livestock were excluded; Ra = rabbits and livestock were excluded; Li = livestock were excluded; Op = similar area open to all influences. / ⁵Cover: Boer = black grama; SPO = mesa, sand, and spike droseweed; TPG = total perennial grasses; TAG = total annual grasses; TPF = total perennial forbs; TAF = total annual forbs; Gusa = broom snakeweed; Prgl = honey mesquite. / ⁶Not additive because of rounding.

Production. Perennial grass production for the surrounding area has been discussed in this report in the production section under Typic Haplargids Berino and Yucca, unit 11E (table 17), but the production observations in this study were more concentrated. From 1959 to 1977, precipitation for the crop-year (October 1 to September 30) averaged 240 mm and the seasonal (July 1 to September 30) precipitation averaged 144 mm (table 22). The average perennial grass yields at the end of the growing season were: 214 kg/ha in the rodent plot (Ro), 175 kg/ha in the rabbit plot (Ra), 144 kg/ha in the livestock plot (Li), and 161 kg/ha in the open plot (Op) (table 22). There were few significant (probability ≤ 0.05) differences among plots within a year. Production increased several-fold in 1972 compared to 1959 to 1971. This corresponded to an increase in dropseeds cover (table 21) and an increase in precipitation.

Study B

This site is Exclosure “B” on JER (fig. 7). It is in pasture 8 about 1.6 km east of Co-op Well and about 0.1 km south of the Co-op to Headquarters Road (figs. 23-25). The soil is a Petrocalcic Paleargid Hueco. See Herbel et al. (1994, p. 76-111) for a detailed description of this soil and soil water from 1957 to 1976.

Cover. The surrounding area’s cover has been discussed in this report in the cover section under Petrocalcic Paleargids, Typic Paleorthids, and Typic Haplargids (table 11), but cover observations were more concentrated in this study. From 1957 to 1977, precipitation for the transect-year (August 1 to July 31) averaged 218 mm and precipitation for October 1 to June 30 averaged 85 mm (table 23). Herbaceous plants’ basal cover averaged 0.73%. Black grama cover averaged 52% and dropseeds 31% of the herbaceous plants. Black grama basal cover from 1957 to 1961 averaged 0.364% in the rabbit plot (Ra) and 0.372% in the open plot (Op). The 1973–77 mean for the rabbit plot was 1.365%, a 375% increase; and open plot was 0.873%, a 235% increase. Black grama basal cover in the livestock plot (Li) averaged 0.223% from 1957 to 1961 and 0.585% from 1973 to 1977, a 262% increase. In the rodent plot (Ro), the cover increased only 179% from 0.177% from 1957 to 1961 to 0.316% from 1973 to 1977. Dropseeds basal cover averaged 0.135% in the rodent plot, 0.229% in the rabbit plot,

Table 22. Precipitation (mm) and yields of perennial grasses (kg/ha) at Study A.

Year	Precipitation ¹		Plot ⁴			
	Crop-year ²	Seasonal ³	Yield \pm s.e.			
			Ro	Ra	Li	Op
			kg/ha			
1959	264	204	78 \pm 13	56 \pm 17	89 \pm 27	46 \pm 7
1960	119	89	12 \pm 3	15 \pm 7	9 \pm 3	2 \pm 1
1961	281	184	48 \pm 15	161 \pm 64	114 \pm 30	57 \pm 25
1962	314	228	31 \pm 11	50 \pm 17	75 \pm 17	35 \pm 8
1963	159	96	18 \pm 7	17 \pm 5	20 \pm 4	10 \pm 2
1964	162	104	17 \pm 7	4 \pm 1	6 \pm 2	1 \pm 1
1965	123	56	3 \pm 2	<1 \pm <1	2 \pm 1	3 \pm 2
1966	212	82	5 \pm 2	1 \pm 1	6 \pm 3	1 \pm 1
1967	180	112	12 \pm 4	5 \pm 2	3 \pm 2	3 \pm 2
1968	291	184	16 \pm 10	9 \pm 5	0 \pm 0	11 \pm 8
1969	227	136	41 \pm 17	26 \pm 12	21 \pm 11	26 \pm 7
1970	253	161	46 \pm 14	39 \pm 18	7 \pm 5	28 \pm 8
1971	187	136	31 \pm 11	32 \pm 12	19 \pm 6	34 \pm 7
1972	336	190	1509 \pm 409	1121 \pm 135	633 \pm 105	550 \pm 71
1973	348	129	369 \pm 105	496 \pm 115	348 \pm 63	476 \pm 102
1974	296	265	374 \pm 106	140 \pm 35	238 \pm 60	333 \pm 46
1975	326	144	691 \pm 75	651 \pm 91	472 \pm 76	797 \pm 120
1976	245	125	456 \pm 47	325 \pm 43	346 \pm 38	355 \pm 25
1977	233	106	313 \pm 40	184 \pm 32	332 \pm 33	293 \pm 29
Average	240	144	214	175	144	161

¹Precipitation = Exclosure “A” Rain Gauge, Oct. 1, 1958–Sept. 30, 1977 (fig. 7). / ²Crop-year = Oct. 1 of the previous year through Sept. 30 of the indicated year. / ³Seasonal = July 1–Sept. 30 of the indicated year. / ⁴Plots: Ro = rodents, rabbits, and livestock were excluded; Ra = rabbits and livestock were excluded; Li = livestock were excluded; Op = similar area open to all influences. / ⁵Yield \pm s.e. (standard error of the mean) = end-of-growing-season harvest of perennial grasses.

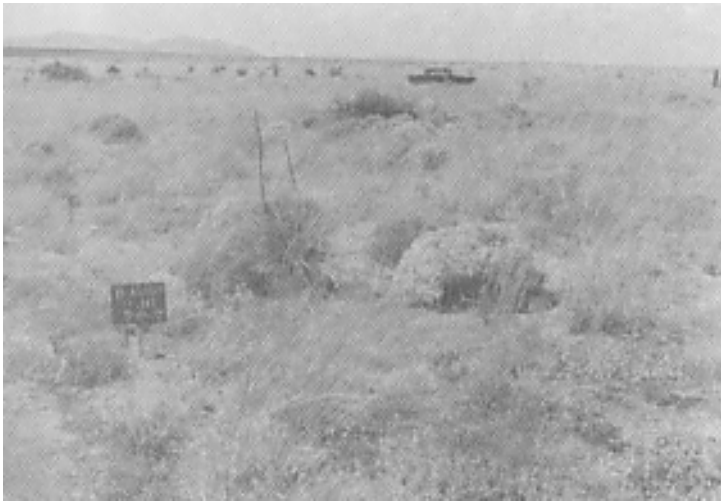


Fig. 23. Vegetation in the Ra plot at Study B in 1959.



Fig. 25. Vegetation in the Ra plot at Study B in 1977.



Fig. 24. Vegetation in the Ra plot at Study B in 1969.

0.175% in the livestock plot, and 0.129% in the open plots from 1957 to 1961. It increased 670%, 163%, 404%, and 416%, respectively, using the 1973–77 average. Besides those shown in table 23, other perennial grasses important in some years were plains bristlegrass, red and poverty threeawns, and fluffgrass. Plains bristlegrass basal cover was $> 0.01\%$ in the rodent (Ro) and rabbit (Ra) plots in 1977, and just in the rodent plot in 1959 and 1976. Red threeawn was prevalent ($> 0.01\%$) in the rodent and livestock (Li) plots in 1967, and in the livestock plot in 1968 and 1975. Poverty threeawn basal cover was $> 0.01\%$ in the rodent and livestock plots in 1977. Fluffgrass basal cover was $> 0.01\%$ in the rodent, livestock, and open plots in 1977, and also in the livestock plot in 1976.

The major annual grass was sixweeks grama. Sixweeks grama basal cover was $> 0.01\%$ in the rodent, livestock, and open plots in 1957, 1959, 1960, 1962, 1965, 1967, 1968, and 1969. Except for 1962 and 1969, it was also $> 0.01\%$ in the rabbit plot during those same years. Sixweeks threeawn had a basal cover of $> 0.01\%$ in all plots in 1967, and in the rodent and open plots in 1968. Needle grama was prevalent ($> 0.01\%$) in 1967. Annual grasses were not detected in these plots after 1969 (table 23).

Table 23. Precipitation (mm) and cover (10⁻²%) of vegetation at Study B.

Year	Precipitation ¹ (mm)		Plot ⁴	Basal cover ⁵ (0.01%)							Canopy cover (0.01%)	
	Annual ²	FW/S ³		Boer	SPO	TPG	TAG	TPF	TAF	Gusa	Pgl	
1957	62	35	Ro	3.9	0.6	4.5	3.1	2.0	1.6	0.1	116.1	
			Ra	7.3	0.2	7.5	1.8	3.7	1.7	0.0	98.2	
			Li	6.9	4.4	11.3	3.8	2.8	3.3	0.1	131.9	
			Op	9.2	1.2	11.1	2.9	1.2	3.9	0.0	200.8	
1958	315	195	Ro	21.8	19.0	41.7	0.0	1.6	5.6	0.4	135.1	
			Ra	38.2	10.6	49.0	0.0	1.3	6.3	0.1	143.4	
			Li	31.5	12.2	43.7	0.1	0.5	8.1	0.3	173.2	
			Op	43.4	10.4	53.8	0.0	0.7	4.3	0.1	175.6	
1959	280	53	Ro	23.6	23.7	49.0	1.4	6.2	2.6	4.4	178.0	
			Ra	45.2	36.0	81.8	1.4	4.7	2.9	8.6	157.3	
			Li	26.5	26.1	52.9	3.5	3.2	5.2	11.1	236.6	
			Op	53.4	18.6	72.0	5.8	4.9	5.0	5.8	186.9	
1960	196	47	Ro	11.0	17.0	28.0	1.6	2.5	1.0	3.6	227.0	
			Ra	21.4	15.7	37.1	1.0	1.2	0.4	4.4	177.2	
			Li	12.3	8.6	21.7	6.8	0.7	0.8	4.4	186.9	
			Op	23.8	8.3	32.1	12.6	0.7	1.6	1.1	222.5	
1961	152	85	Ro	28.1	7.3	35.4	0.1	4.4	11.9	8.1	241.9	
			Ra	69.9	51.7	121.6	0.0	2.5	8.9	9.7	195.4	
			Li	34.3	36.0	70.3	0.4	1.3	8.5	3.5	270.7	
			Op	56.0	26.0	82.0	0.1	1.8	6.4	3.2	151.0	
1962	405	91	Ro	15.0	8.4	24.1	1.8	5.2	21.9	4.6	472.9	
			Ra	40.8	17.7	58.5	0.0	2.5	5.1	3.1	287.3	
			Li	23.6	16.2	39.9	3.6	1.6	9.5	2.3	299.3	
			Op	31.5	11.9	43.4	2.9	1.8	9.3	3.6	197.1	
1963	195	58	Ro	16.0	9.1	25.2	0.0	1.6	0.4	0.3	365.3	
			Ra	49.7	18.9	68.6	0.0	1.6	0.2	0.4	251.1	
			Li	21.1	16.6	38.7	0.0	0.5	0.1	0.3	331.3	
			Op	35.1	9.4	44.6	0.0	0.3	0.0	0.6	149.8	
1964	146	50	Ro	24.5	5.3	29.8	1.4	0.2	3.8	0.2	427.6	
			Ra	45.5	13.6	59.1	0.5	0.3	1.2	0.1	294.6	
			Li	20.1	10.5	30.6	3.7	1.0	5.6	0.5	347.1	
			Op	29.0	4.8	33.8	2.8	0.2	10.0	0.7	200.0	
1965	156	51	Ro	24.3	13.1	37.7	4.0	4.0	0.3	0.1	427.9	
			Ra	48.0	12.1	60.1	1.1	3.7	0.1	0.2	309.8	
			Li	22.5	10.8	33.3	5.9	4.8	0.6	6.8	371.7	
			Op	32.3	4.0	36.3	8.0	1.9	0.7	0.5	188.8	
1966	168	83	Ro	16.3	13.4	30.3	0.0	2.5	0.0	0.2	480.2	
			Ra	34.3	9.8	44.1	0.0	1.9	0.3	0.0	349.0	
			Li	14.4	7.8	22.3	0.0	2.9	0.8	0.3	414.8	
			Op	21.8	3.2	25.0	0.0	1.1	1.2	0.3	264.5	
1967	152	9	Ro	9.8	14.1	24.9	9.7	4.7	3.5	1.1	373.9	
			Ra	42.9	9.3	52.2	19.1	3.3	3.3	0.0	459.8	
			Li	13.8	8.4	24.8	12.1	8.6	3.4	4.7	468.3	
			Op	21.5	6.7	28.8	19.4	4.0	4.5	0.6	317.0	
1968	219	88	Ro	12.0	9.5	21.7	3.9	4.0	9.2	0.2	459.8	
			Ra	61.4	6.0	67.4	2.3	2.8	5.0	0.0	420.1	
			Li	27.2	7.6	35.8	1.8	2.7	9.3	0.5	468.2	
			Op	36.8	4.8	41.7	9.3	1.5	11.8	0.3	300.0	

Table 23. Precipitation (mm) and cover (10⁻²%) of vegetation at Study B, cont'd.

Year	Precipitation ¹ (mm)		Plot ⁴	Basal cover ⁵ (0.01%)							Canopy cover (0.01%)	
	Annual ²	FW ³		Boer	SPO	TPG	TAG	TPF	TAF	Gusa	Prgl	
1969	237	78	Ro	7.6	6.7	14.5	3.1	4.2	1.6			600.6
			Ra	31.3	4.3	35.6	1.2	1.8	0.4			543.6
			Li	12.6	4.1	17.0	3.3	3.0	2.2			600.7
1970	173	78	Op	16.0	2.7	18.9	6.4	2.2	3.4			317.0
			Ro	5.9	3.9	9.8	0.0	1.4	1.5			668.0
			Ra	25.3	3.2	28.6	0.0	1.4	3.2			626.4
			Li	10.9	3.2	14.6	0.0	1.1	3.9			598.0
1971	108	53	Op	16.3	1.2	17.9	0.0	1.1	3.8			333.4
			Ro	1.6	2.4	4.0	0.0	0.2	0.0			687.8
			Ra	23.1	3.2	26.3	0.0	0.5	0.0			605.9
			Li	10.8	3.4	14.8	0.0	0.1	0.0			543.3
1972	289	149	Op	15.1	0.9	16.3	0.0	0.3	0.0			366.8
			Ro	7.7	2.4	12.9	0.0	3.4	4.8			707.0
			Ra	39.2	1.7	41.6	0.0	3.1	6.8			398.6
			Li	13.8	2.4	16.4	0.0	4.6	10.3			530.2
1973	343	205	Op	12.2	0.9	13.4	0.0	4.2	8.7			195.0
			Ro	7.7	6.6	15.2	0.0	13.9	16.5			642.7
			Ra	27.4	6.3	33.7	0.0	13.4	20.8			422.5
			Li	18.9	3.6	22.9	0.0	13.9	23.5			407.3
1974	155	21	Op	19.1	6.5	25.9	0.0	9.6	23.7			403.7
			Ro	12.6	10.3	23.7	0.0	3.9	1.9			973.2
			Ra	51.7	4.3	56.4	0.0	4.4	1.2			885.0
1975	329	166	Li	12.2	8.4	21.2	0.0	5.6	4.8			782.0
			Op	21.7	5.2	27.2	0.0	6.3	4.6			440.3
			Ro	15.5	13.3	28.8	0.0	12.9	9.5			1084.5
			Ra	66.6	6.0	72.6	0.0	13.2	13.5			1035.0
			Li	25.2	7.7	34.4	0.0	21.4	22.2			1046.7
1976	245	94	Op	55.1	9.0	64.2	0.0	16.7	20.9			471.7
			Ro	60.4	136.0	203.8	0.0	12.6	0.1			1055.3
			Ra	263.2	53.8	317.3	0.0	9.6	0.1			803.1
			Li	92.0	117.8	212.3	0.0	22.0	0.0			761.4
1977	259	93	Op	170.5	57.3	229.7	0.0	12.6	0.0			376.2
			Ro	61.6	286.4	357.6	0.0	7.7	2.8			1271.7
			Ra	273.9	116.2	394.2	0.0	8.0	4.6			1018.5
			Li	144.2	216.1	370.2	0.0	14.1	5.0			937.9
Average ⁶			Op	170.3	189.9	364.2	0.0	14.4	1.6			845.9
			Ro	18.4	29.0	48.7	1.4	4.7	4.8			552.2
			Ra	62.2	19.1	81.6	1.3	3.9	4.1			451.5
			Li	28.3	25.3	53.4	2.1	5.5	6.1			471.8
			Op	42.4	18.2	61.6	3.3	4.2	6.0			300.2
Average ⁶	218	85	Overall	37.8	22.9	61.2	2.1	4.6	5.2			443.9

¹Precipitation = Co-op Rain Gauge, Aug. 1, 1956–April 14, 1958; Enclosure “B” Rain Gauge, April 15, 1958–July 31, 1977 (Fig. 7). / ²Annual = Aug. 1 of the previous year through July 31 of the indicated year. / ³FW = Oct. 1 of the previous year through June 30 of the indicated year. / ⁴Plots: Ro = rodents, rabbits, and livestock were excluded; Ra = rabbits and livestock were excluded; Li = livestock were excluded; Op = similar area open to all influences. / ⁵Cover: Boer = black grama; SPO = mesa, sand, and spike dropseed; TPG = total perennial grasses; TAG = total annual grasses; TPF = total perennial forbs; TAF = total annual forbs; Gusa = broom snakeweed; Prgl = honey mesquite. / ⁶Not additive because of rounding.

There was no evidence that degree of protection affected the perennial forbs (table 23). Leatherweed and twinleaf senna were the most common perennial forbs. Other perennial forbs plentiful ($> 0.01\%$) in more than one year were paperflower, rattlesnakeweed, dwarf dalea, sicklepod, and western sensitivebriar.

The major annual forbs were Russian thistle and faintcrown. The annual forbs had a greater basal cover in the livestock (Li) and open (Op) plots in most years after 1963 than in the rodent (Ro) and rabbit (Ra) plots (table 23). Annual forbs that were plentiful ($> 0.01\%$) more than one year at study B were Russian thistle, faintcrown, purple curleaf, gray goosefoot, tickseed, spectaclepod, and deerstongue.

The major shrubs and shrub-like plants were honey mesquite, broom snakeweed, and soaptree yucca. Broom snakeweed basal cover was $> 0.01\%$ in all plots from 1959 to 1962 and from 1972 to 1977 (table 23). Apparently, protection from rodents (Ro) decreased broom snakeweed basal cover. Honey mesquite canopy cover, which averaged 1.8% from 1957 to 1961, was the basis for selecting the various plots at Study B. Honey mesquite increased 441% between the periods from 1957 to 1961 and 1973 to 1977, when all plots were considered. The increase was only 271% in the open (Op) plot (table 23). It was 560%, 540%, and 394% for the rodent (Ro), rabbit (Ra), and livestock (Li) plots, respectively. This indicates more honey mesquite survived with protection.

These data indicate several interesting factors. Black grama cover increased substantially when the basal cover averaged $> 0.35\%$ from 1957 to 1961, and it was protected from rabbits and livestock (Ra). Black grama cover increased less dramatically in the open plot (Op), even though the two plots (Ra and Op) had about the same cover initially. Black grama cover did not increase as much in the rodent plot (Ro) as in the livestock plot (Li), even though the 1957 to 1961 average basal cover was about 0.2%. Honey mesquite canopy cover had the greatest increase in plots protected from rodents and rabbits (Ro and Ra) and the least increase in the plot open to all influences (Op). The dropseeds cover increased more in the plot with the least black grama basal cover from 1973 to 1977 and the greatest honey mesquite canopy cover (Ro).

Production. From 1959 to 1977, precipitation for the crop-year (October 1 to September 30) averaged 217 mm, and the seasonal

(July 1 to September 30) precipitation averaged 135 mm (table 24). The average perennial grass yields at the end of the growing season were 282 kg/ha in the rodent plot (Ro), 468 kg/ha in the rabbit plot (Ra), 267 kg/ha in the livestock plot (Li), and 269 kg/ha in the open plot (Op) (table 24). The rabbit plot had significantly greater (probability ≤ 0.05) perennial grass production than some of the other plots in all years except 1960, 1973, and 1974. However, there was no trend among the plots. Rather, precipitation and soil water determined yields.

Table 24. Precipitation (mm) and yields of perennial grasses (kg/ha) at Study B.

Year	Plot ⁴							
	Precipitation ¹		Ra		Li		Op	
	Crop-year ²	Seasonal ³	Yield ± s.e. ⁵	Yield ± s.e.	Yield ± s.e.	Yield ± s.e.	Yield ± s.e.	Yield ± s.e.
	mm	mm	kg/ha					
1959	233	180	471 ± 47	561 ± 66	360 ± 64	317 ± 38		
1960	104	57	76 ± 18	79 ± 12	51 ± 13	45 ± 8		
1961	308	222	277 ± 48	897 ± 82	445 ± 82	635 ± 80		
1962	346	255	356 ± 46	620 ± 40	332 ± 50	353 ± 49		
1963	122	65	82 ± 13	124 ± 12	68 ± 12	117 ± 12		
1964	167	116	207 ± 29	349 ± 25	165 ± 41	221 ± 33		
1965	140	89	163 ± 25	257 ± 32	180 ± 35	93 ± 17		
1966	224	142	401 ± 69	480 ± 107	224 ± 42	187 ± 28		
1967	123	114	231 ± 52	365 ± 38	199 ± 31	209 ± 20		
1968	240	151	342 ± 58	637 ± 51	371 ± 59	301 ± 35		
1969	162	83	190 ± 47	361 ± 28	139 ± 26	236 ± 24		
1970	188	110	208 ± 40	422 ± 49	224 ± 61	172 ± 21		
1971	169	116	209 ± 57	479 ± 86	176 ± 43	137 ± 25		
1972	257	108	329 ± 70	643 ± 76	364 ± 73	338 ± 39		
1973	292	87	457 ± 78	339 ± 58	241 ± 66	197 ± 44		
1974	252	232	239 ± 74	406 ± 88	250 ± 37	170 ± 23		
1975	317	151	268 ± 30	577 ± 63	498 ± 88	348 ± 54		
1976	217	124	471 ± 56	659 ± 53	334 ± 53	488 ± 43		
1977	262	169	372 ± 30	630 ± 28	449 ± 49	551 ± 44		
Average	217	135	282	468	267	269		

¹Precipitation = Exclosure "B" Rain Gauge, Oct. 1, 1958–Sept. 30, 1977 (fig. 7). / ²Crop-year = Oct. 1 of the previous year through Sept. 30 of the indicated year. / ³Seasonal = July 1–Sept. 30 of the indicated year. / ⁴Plots: Ro = rodents, rabbits, and livestock were excluded; Ra = rabbits and livestock were excluded; Li = livestock were excluded; Op = similar area open to all influences. / ⁵Yield ± s.e. (standard error of the mean) = end-of-growing-season harvest of perennial grasses.

CONCLUSIONS

1. There was a large variation in all plants' cover and perennial grass production due to very uneven plant distribution on the landscape within each year, uneven precipitation distribution within a year and among years, and differences among observers.
2. Perennial grasses were the most prominent portion of the herbaceous plants on the sampled sites. They made up > 94% of the herbaceous plants' basal cover for the observations taken on soils D, E, F, and G; 88% on soil M; and 79–85% on soils O, P, R, S, and T. Perennial grass basal cover averaged 3.44% on soil G, 1.65% on soil D, 1.26% on soils E and F, 0.81% on soil M, and 0.52–0.57% on soils O, P, R, S, and T. (tables 3–12). Average perennial grass basal covers on finer-textured soils (D, E, F, and G) were > 5.0% in 1957, 1958, 1976, and 1977; 2.9% in 1961; 1.9% in 1975; 1.7% in 1959; about 1.0% in 1960, 1962, 1963, 1968, and 1973. Perennial grass basal cover ranged from 0.5 to 0.7% from 1964 to 1967, from 1969 to 1972, and in 1974. There was about a tenfold increase in perennial grass basal cover in the high years compared to the low years, and this change can occur in two years. Average total perennial grass basal cover on the coarser-textured soils (O, P, R, S, and T) were > 1.5% in 1976 and 1977; 0.5–0.9% in 1957, 1958, and 1961; 0.4–0.5% in 1959, 1974, and 1975; 0.3–0.4% in 1962, 1963, and 1967; 0.2–0.3% in 1960, from 1964 to 1966, 1968, 1969, and 1973; and < 0.2% from 1970 to 1972. With a few exceptions, the years were grouped similarly for the finer- and coarser-textured soils. Perennial grass basal cover on finer-textured soils averaged 348% of perennial grass basal cover on coarser-textured soils. Generally, perennial grass basal cover was lower in the dry years of the mid-1960s and higher in the wet years of the late 1950s and the mid-1970s.
3. The perennial threeawns occurred on all soils, but they were most abundant on the M soil. Threeawns' basal cover increased from 1974 to 1977. These grasses were reduced by drought but increased during wetter years. Red threeawn was the major threeawn on the M soil from 1974 to 1976, but poverty threeawn was the dominant threeawn in 1977. Red threeawn was also

present on the D, E, and F soils in 1975 and 1976, but declined precipitously in 1977, a drier year. Perennial threeawns' basal cover exceeded 0.1% on soil D in 1977 (poverty threeawn dominated); on soil E in 1961 (red threeawn), 1975 (red), 1976 (red), and 1977 (poverty); on soil F in 1976 and 1977 (poverty threeawn); on soil G in 1977 (poverty); on soil O in 1976 (red) and 1977 (poverty); on soil R in 1977 (red); and on soil S in 1976 (red threeawn) and 1977 (poverty).

4. Black grama basal cover averaged $> 0.2\%$ on P, R, S, and T soils. It was also $> 0.2\%$ on soil M in 1976 and 1977, and on soil O in 1977. Of the herbaceous plants' basal cover, the average composition of black grama was 47% on soil T, 40% on S, 35% on P and R, and $< 10\%$ on O, M, and the finer-textured soils. Black grama basal cover in 1976 and 1977 on the S soil averaged 92% of that on the T soil. It also was 72% on R, 54% on P, 29% on M, and 24% on O soils. This indicates that 20 years after the 1951–56 drought, black grama basal cover was essentially similar on the S and T soils, still reduced on the O and M soils, while the black grama cover on R and P was somewhat intermediate to the cover on T soils. Black grama cover was substantially reduced on deeper soils (such as O) by drought and did not recover during this study. On soils S and T, drought effects were not as severe, and black grama cover increased during wetter years.
5. Fluffgrass basal cover averaged $> 0.05\%$ on soils M, R, O, and E. Generally, fluffgrass increased during the sampling period.
6. Tobosa basal cover averaged 2.54% on G, 0.28% on F, 0.19% on D, 0.17% on E, and 0.1% on M soils. It was < 0.01 on the coarser-textured soils. The severe 1951–56 drought barely affected this grass.
7. Burrograss basal cover averaged 1.32% on D, 0.89% on G, 0.86% on F, 0.78% on E, and 0.3% on M soils. The coarser-textured soils had $< 0.1\%$. Burrograss stands were minimally affected by drought.

8. Alkali sacaton basal cover averaged 0.05% on E and 0.01% on M soils. The other soils had a basal cover of $< 0.01\%$.
9. Dropseeds' basal cover (mesa dropseed was $> 90\%$ of the dropseeds) averaged 0.29% on O, 0.28% on P, 0.24% on R, 0.21% on S, 0.18% on T, and 0.11% on M and E soils. D, F, and G soils had a basal cover $< 0.1\%$. Because of their prolific seed production, the dropseeds were able to take advantage of the open plant community following drought, and they increased rapidly. Generally, the dropseeds' populations were low in 1960 and from 1962 to 1973, indicating it is dependable only in certain years and primarily on soils with a coarse texture at the surface.
10. Sixweeks threeawn basal cover was $> 0.01\%$ on M soil in 1968 and 1969, on O in 1969, on R in 1967 and 1969, on S in 1969, and T in 1969. Another annual grass, sixweeks grama, had a basal cover $> 0.01\%$ on E in 1960 and 1962; on M in 1960, 1962, and 1968; on O in 1960, 1962, 1968, and 1969; on P in 1969; and on R, S, and T in 1962, 1968, and 1969. The only other annual grass with a basal cover $> -0.01\%$ was Mexican witchgrass on O soil in 1977. There was soil water > 0.1 MPa, during the winter before those species were observed on the transects.
11. Basal cover of leatherweed, a perennial forb, was $> 0.01\%$ on D soil for six of the 21 years, on E for nine years, on F for three years, on M for 18 years, on O for 19 years, on P for two years, on R for three years, on S for 12 years, and on T soils for three years. Leatherweed is the longest-lived perennial forb in our studies. While it was ubiquitous, it was most frequently encountered on the coarse-textured O, M, and S soils. Shorter-lived perennial forbs encountered ($> 0.01\%$ basal cover) more than one year were desert holly (three years) on soil D; desert holly (four years) and woolly sumpweed (two years) on soil E; desert holly (four years) on soil F; wrinkled globemallow (two years) on soil G; paperflower (two years) and wrinkled globemallow (two years) on soil M; paperflower (four years), rattlesnakeweed (two years), and crowfoot falsenightshade (two years) on soil O; twinleaf senna (five years) and Fendler's bladderpod (two years) on soil P; twinleaf senna (10 years) and trailing wind-

mills (two years) on soil R; twinleaf senna (five years) and paperflower (two years) on soil S; and twinleaf senna (10 years) and trailing windmills (two years) on soil T. Shorter-lived perennial forbs' occurrence was more closely related to the presence of soil water > -1.5 MPa, during the winter and early spring than to leatherweed occurrence.

12. Basal cover of an annual forb, Russian thistle, was $> 0.01\%$ on soil D for three of the 21 years, on E for four years, on F for three years, on M for seven years, on O for 10 years, on P for five years, on R for eight years, on S for seven years, and on soil T for six of the 21 years. Other annual forbs encountered more than a single year with a basal cover $> 0.01\%$ were annual broomweed (two years) on E and F soils; desert marigold (three years) on M; spectaclepod (five years), purple curleaf (four years), tickseed (four years), deerstongue (three years), and desert marigold (two years) on soil O; faintcrown (seven years), purple curleaf (five years), spectaclepod (five years), deerstongue (four years), gray goosefoot (two years), and desert marigold (two years) on soil P; deerstongue (seven years), purple curleaf (seven years), faintcrown (six years), spectaclepod (five years), desert marigold (two years), and annual broomweed (two years) on R; purple curleaf (seven years), faintcrown (six years), deerstongue (four years), spectaclepod (four years), gray goosefoot (three years), and tickseed (two years) on S; and faintcrown (seven years), purple curleaf (seven years), spectaclepod (four years), and deerstongue (four years) on soil T. Generally, purple curleaf and faintcrown were plentiful in the same year. There were more annual forbs on coarse-textured soils than on fine-textured soils. As with the short-lived perennial forbs, the presence of annual forbs was often related to soil water > -1.5 MPa, during the winter and early spring of the transect-year. Propagules of the short-lived perennial forbs and the annual forbs were probably abundant from previous populations, so they could increase rapidly when environmental conditions were appropriate for establishing that particular species.
13. Average broom snakeweed basal cover from 1957 to 1977 on coarse-textured soils (O, P, R, S, and T) was 0.081% , or 270% of the average on the fine-textured soils (D, E, F, and G). There

was a rapid increase of broom snakeweed in 1976 and 1977, when the basal cover averaged 0.545% on the coarse-textured soils. With only a few exceptions, broom snakeweed basal cover was $< 0.1\%$ prior to 1976.

14. Honey mesquite canopy cover was greater on the coarse-textured soils than the fine-textured soils. It was quite variable yearly because of environmental conditions and chemical control (Herbel and Gould 1995). The intensive sampling at studies A and B showed honey mesquite canopy cover increasing 860% from the period of 1957 to 1961 to the period from 1973 to 1977 at study A and 441% during the same years at study B (see tables 21 and 23). The increase of honey mesquite was greater with severe drought damage, as at study A, but there also was a dramatic increase in good grass cover, as at study B. Studies A and B did not have the control efforts on honey mesquite that occurred on the other areas discussed in this report.
15. Average production of perennial grasses at the sandy sites from 1960 to 1988 was 207 kg/ha at two sites on Typic Haplargids (table 18), 399 kg/ha on Typic Torripsamment (table 19), and 342 kg/ha at two sites on Paleargids and Paleorthids (table 20). Vegetation on the Typic Haplargids was more affected by the 1951–56 drought than the vegetation on the Typic Torripsamment and on the Paleargids and Paleorthids (Herbel et al. 1972). On sandy sites, perennial grass yields were higher on Typic Torripsamment, and Paleargids and Paleorthids, where there was a mixture of black grama and mesa dropseed, than on the Typic Haplargids, where the sites were dominated by mesa dropseed (tables 8, 9, and 12). Even in 1977 when mesa dropseed cover was peaking, the perennial grasses yielded 244 kg/ha on the Typic Haplargids, 928 kg/ha on the Typic Torripsamment, and 918 kg/ha on the Paleargids and Paleorthids (tables 17-20).
16. Factors affecting perennial grass yields were precipitation, soil water, soil characteristics, species, and plants' cover. The highest yields were obtained at the Stellar site at the check plots of the Fertilizer Exclosure, where there was considerable run-in water from the adjacent slopes. There were more years when

the yields were 10% or more below average than years when the yields were 10% or more above average. The variation in perennial grass production from year-to-year was sometimes dramatic and has definite management implications.

17. At Study A (tables 21 and 22, fig. 26), dropseeds' cover (primarily mesa dropseed) averaged 43% of the herbaceous plants. Perennial grass basal cover and yields were much higher from 1972 to 1977 than from 1959 to 1971. Annual grasses (mainly sixweeks grama) had a relatively higher basal cover during some years in the late 1950s and 1960s than during the 1970s. There was some evidence that protection from rodents and rabbits increased the annual grass basal cover. The major perennial forbs were leatherweed, rattlesnakeweed, paperflower, and Fendler's bladderpod. Sites such as the Typic Haplargid Onite can be used only in certain years, when grasses or forbs are available and when adequate cover is available to curtail soil erosion.



Fig. 26. Droughty effects on vegetation near Study A. Note the wind erosion.

18. At Study B (tables 23 and 24), black grama and the dropseeds' basal cover averaged 52% and 31%, respectively, of the herbaceous plants. Black grama cover for the period of 1973 to 1977 increased 375% from the period of 1957 to 1961, when it averaged $> 0.35\%$ in the period of 1957 to 1961, and it was protected from rabbits and cattle (plot Ra). Black grama cover increased only 235% on the Op plot, even though cover from 1957 to 1961 was similar on plots Ra and Op. Black grama basal cover was about 0.2% on the Ro and Li plots from 1957 to 1961, and it increased 179 and 262%, respectively, using the 1973 to 1977 average. Dropseeds basal cover was greatest on the plot (Ro) with the least black grama cover and the greatest honey mesquite cover from 1973 to 1977. Honey mesquite canopy cover had the greatest increase from the period of 1957 to 1961 to the period of 1973 to 1977 on plots protected from rodents and rabbits (Ro and Ra), and the least increase on the plot open (Op) to all influences. The major annual grass was sixweeks grama, but none of the annual grasses were observed from 1970 to 1977. The major perennial forbs were leatherweed and twinleaf senna, but there was no evidence that degree of protection affected the perennial forbs. The major annual forbs were Russian thistle and faintcrown, and annual forbs' basal cover was greater in most years from 1964 to 1977 on the livestock (Li) and open (Op) plots, indicating that having rodents and rabbits present sometimes increased annual forbs' cover. There was an apparent increase in broom snakeweed basal cover on the plots not protected from rodents (Ra, Li, and Op). There was no indication that protection from rodents, rabbits, or livestock affected perennial grass production.

19. Comparisons between Studies A and B (tables 21-24) indicate: a) black grama basal cover increased only at Study B, where the 1957-61 average was at least 0.18%; b) the 1957-77 basal cover of dropseeds (primarily mesa dropseed) was similar, but it increased more rapidly in 1976 and 1977 at A than at B, probably because of increased precipitation during the cool season and less competition from black grama and honey mesquite; c) there were more annual grasses and annual forbs at A than B; d) there was more broom snakeweed and honey mesquite at B than A; e) the average perennial grass production

from 1959 to 1977 was greater at B, where there was a mixture of black grama and mesa dropseed, than at A, where mesa dropseed dominated; and f) there was not a major plant response to protection from rodents, rabbits, or livestock during this 21-year study.

20. Some past studies have assumed that this system starts out relatively stable, but destabilizes from overgrazing. However, this study indicates that large vegetation changes occurred because of severe drought and these changes are persistent on some sites. Drought reduced ground cover and, on some sites, this led to increased wind erosion with reduced potential for production from the soil (UCAR 1989). Shrubs increased rapidly on some sites. If a vegetation type is in a lower successional stage, it may not respond to a change in grazing pressure (Laycock 1991, Westoby et al. 1989). Range management practices must recognize these dynamics.

LITERATURE CITED

- Allred, K. 1988. A field guide to the flora of the Jornada Plain. N. Mex. Agric. Exp. Sta. Bull. 739. 145 p.
- Archer, S. 1989. Have southern Texas savannas been converted to woodlands in recent history? *Amer. Natur.* 134:545-561.
- Branscomb, B. L. 1958. Shrub invasion of southern New Mexico desert grassland. *J. Range Manage.* 11:129-132.
- Buffington, L. C. and C. H. Herbel. 1965. Vegetational changes on a semidesert grassland range from 1858 to 1963. *Ecol. Monogr.* 35:139-164.
- Cable, D. R. and S. C. Martin. 1975. Vegetation responses to grazing, rainfall, site condition, and mesquite control on semidesert range. U. S. Dep. Agric. Res. Paper RM-149. 24 p.
- Campbell, R. S. 1936. Climatic fluctuations, p. 135-150. In: *The Western Range*. U. S. Senate Doc. 199.
- Canfield, R. H. 1941. Application of the line interception method in sampling range vegetation. *J. Forestry* 39:388-394.
- Canfield, R. H. 1948. Perennial grass composition as an indicator of condition of southwestern mixed grass ranges. *Ecol.* 29:190-204.
- Canfield, R. H. 1957. Reproduction and life span of some perennial grasses of southern Arizona. *J. Range Manage.* 10:199-203.
- Clements, F. E. 1920. *Plant Indicators*. Carnegie Inst. Wash. Publ. 290. 388 p.
- Culley, M. 1943. Grass grows in the summer or not at all. *Amer. Hereford J.* 34:9-10.
- Dick-Peddie, W. A. 1993. *New Mexico Vegetation—Past, Present, and Future*. Univ. of New Mexico Press, Albuquerque. 244 p.
- Dittberner, P. L. 1971. A demographic study of some semidesert grassland plants. MS Thesis, N. Mex. State Univ., Las Cruces. 81 p.
- El Paso Geological Society. 1970. Cenozoic stratigraphy of the Rio Grande Valley area of Doña Ana County, New Mexico. Dep. Geol., Univ. Texas, El Paso. 49 p.
- Gibbens, R. P. 1978. Precipitation and forage production relationships on the Jornada Experimental Range and the derivation of precipitation adjustment factors. A report submitted to the Bureau of Land Management. Contract NMSO-94 Bur. Land Manage., Santa Fe, N. Mex. 40 p.

- Gibbens, R. P. and R. F. Beck. 1988. Changes in grass basal area and forb densities over a 64-year period on grassland types of the Jornada Experimental Range. *J. Range Manage.* 41:186-192.
- Gile, L. H. and R. B. Grossman. 1979. The Desert Project Soil Monograph. Document number PB80-135304, the Natl. Tech. Info. Serv., Springfield, VA. 984 p.
- Gile, L. H. and J. W. Hawley. 1968. Age and comparative development of desert soils at the Gardner Spring radiocarbon site, New Mexico. *Soil Sci. Soc. Amer. Proc.* 32:709-716.
- Gile, L. H., J. W. Hawley and R. B. Grossman. 1970. Distribution and genesis of soils and geomorphic surfaces in a region of southern New Mexico. Guidebook, Soil-Geomorph. Field Conf., Soil Sci. Soc. Amer., Las Cruces, N. Mex. n.p.
- Gomm, F. B. 1961. A modification of the standard Weather Bureau rain gauge for summer and winter use. *Bull., Amer. Meteorol. Soc.* 42:311-313.
- Hawley, J. W. and L. H. Gile. 1966. Landscape evolution and soil genesis in the Rio Grande region, southern New Mexico. Guidebook, 11th Annu. Field Conf., Rocky Mt. Sect., Friends of the Pleistocene, University Park, N. Mex. n.p.
- Herbel, C. H. 1963. Fertilizing tobosa on flood plains of the semidesert grassland. *J. Range Manage.* 16:133-138.
- Herbel, C. H. 1973. Grazing systems on native range, p. K-1 to K-19. In: F. H. Baker (ed.), *Great Plains Beef Symposium*. Great Plains Agric. Coun. Publ. 63, Lincoln, Nebr.
- Herbel, C. H. 1985. Vegetation changes on arid rangelands of the Southwest. *Rangelands* 7:19-21.
- Herbel, C. H. and R. P. Gibbens. 1981. Drought and grazing management decisions, p. 187-192. In: L. D. White and A. L. Hoermann (eds.), *Proc., Int. Rancher's Roundup*. Tex. Agric. Ext. Serv., Uvalde.
- Herbel, C. H. and R. P. Gibbens. 1987. Soil water regimes of loamy sands and sandy loams on arid rangelands in southern New Mexico. *J. Soil & Water Conserv.* 42:442-447.
- Herbel, C. H. and R. P. Gibbens. 1989. Matric potential of clay loam soils on arid rangelands in southern New Mexico. *J. Range Manage.* 42:386-392.
- Herbel, C. H. and L. H. Gile. 1973. Field moisture regimes and morphology of some arid-land soils in New Mexico, p. 119-152. In: R. R. Bruce, K. W. Flach and H. M. Taylor (eds.), *Field Soil Water Regimes*. Soil Sci. Soc. Amer. Spec. Publ. 5, Madison, Wisc.
- Herbel, C. H. and W. L. Gould. 1995. Management of mesquite, creosotebush, and tarbush with herbicides in the northern Chihuahuan Desert. *N. Mex. Agric. Exp. Sta. Bull.* 775. 53 p.
- Herbel, C. H. and A. B. Nelson. 1969. Grazing management on semidesert ranges in southern New Mexico. *Jornada Exp. Range Rep. No. 1.* 13 p.
- Herbel, C. H. and R. D. Pieper. 1990. Grazing management, p. 361-385. In: J. Skujins (ed.), *Semiarid Lands and Deserts: Soil Resource and Rehabilitation*. Marcel Dekker, Inc., New York.
- Herbel, C. H., F. N. Ares and R. A. Wright. 1972. Drought effects on a semidesert grassland range. *Ecol.* 53:1084-1093.
- Herbel, C. H., P. L. Dittberner and T. S. Bickle. 1970. A quantitative ecology of the Jornada Experimental Range, p. I-133 to I-177. In: R. G. Wright and G. M. Van Dyne (eds.), *Simulation and Analysis of Dynamics of a Semidesert Grassland: An Interdisciplinary Workshop Program Toward Evaluating the Potential of Weather Modification*. Sci. Series 6, Range Sci. Dep., Colo. State Univ., Ft. Collins.
- Herbel, C. H., L. H. Gile, E. L. Fredrickson and R. P. Gibbens. 1994. Soil water and soils at soil water sites, Jornada Experimental Range, p. iii-592. In: L. H. Gile and R. J. Ahrens (eds.), *Supplement to the Desert Project, Soil Monograph, Vol. 1*, Soil Conserv. Serv., U.S. Dep. Agric. Rep. 44.
- Holechek, J. L. and C. H. Herbel. 1982. Seasonal suitability grazing in the Western United States. *Rangelands*. 4:252-255.
- Humphrey, R. R. 1987. 90 Years and 535 Miles; Vegetation Changes Along the Mexican Border. Univ. of New Mexico Press, Albuquerque. 448 p.
- Kelsey, H. P. and W. A. Dayton. 1942. *Standardized Plant Names*. J. Horace McFarland Co., Harrisburg, Penn. 675 p.
- Kemp, P. R. 1983. Phenological patterns of Chihuahuan Desert plants in relation to the timing of water availability. *J. Ecol.* 71:427-436.
- King, W. E., J. W. Hawley, A. M. Taylor and R. P. Wilson. 1971. Geology and ground water resources of central and western Doña Ana County, New Mexico. *Hydrol. Rep. 1*, N. Mex. Bur. Mines, Mineral Resources, Las Cruces. 64 p.

- Kottlowski, F. E. 1960. Reconnaissance geologic map of Las Cruces 30-minute quadrangle. Geol. Map 14, N. Mex. Bur. Mines, Mineral Resources, Las Cruces.
- Kottlowski, F. E., R. H. Flower, M. L. Thompson and R. W. Foster. 1956. Stratigraphic studies of the San Andres Mountains, New Mexico. Memoir 1, N. Mex. Bur. Mines, Mineral Resources, Las Cruces. 132 p.
- Kramer, P. J. 1983. Water Relations of Plants. Academic Press, New York, N. Y. 489 p.
- Kuchler, A. W. 1964. Potential natural vegetation of the conterminous United States. Amer. Geogr. Soc. Spec. Rep. 36. 116 p.
- Laycock, W. A. 1991. Stable states and thresholds of range condition on North American rangelands: A viewpoint. *J. Range Manage.* 44:427-433.
- Marshall, J. K. 1973. Drought, land use and soil erosion, p. 55-77. In: J. V. Lovett (ed.), *The Environmental, Economic and Social Significance of Drought*. Angus and Robertson, Sydney, Australia.
- Martin, S. C. 1975. Ecology and management of southwestern semidesert grass-shrub ranges: The status of our knowledge. U. S. Dep. Agric. Res. Paper RM-156. 39 p.
- Martin, S. C. and D. R. Cable. 1974. Managing semidesert grass-shrub ranges: Vegetation responses to precipitation, grazing, soil textures, and mesquite control. U. S. Dep. Agric. Tech. Bull. 1480. 45 p.
- McDonald, J. E. 1956. Variability of precipitation in an arid region: A survey of characteristics for Arizona. *Inst. of Atmos. Phys., Univ. of Arizona, Tucson.* 88 p.
- Merriam, C. H. 1898. Life zones and crop zones of the United States. U. S. Dep. Agric. Biol. Surv. Bull. 10. 79 p.
- Nace, R. L. and E. J. Pluhowski. 1965. Drought of the 1950s with special reference to the midcontinent. *Geol. Surv. Water-Supply Paper 1804.* 88 p. & 2 plates.
- Nelson, E. W. 1934. The influence of precipitation and grazing upon black grama grass range. U. S. Dep. Agric. Tech. Bull. 409. 32 p.
- Paulsen, H. A., Jr. and F. N. Ares. 1962. Grazing values and management of black grama and tobosa grasslands and associated shrub ranges of the Southwest. U. S. Dep. Agric. Tech. Bull. 1270. 56 p.
- Pieper, R. D. and C. H. Herbel. 1982. Herbage dynamics and primary productivity of a desert grassland ecosystem. *N. Mex. Agric. Exp. Sta. Bull.* 695. 43 p.
- Schulman, E. 1956. *Dendroclimatic Changes in Semiarid America.* Univ. Arizona Press, Tucson. 142 p.
- Shantz, H. L. and R. Zon. 1924. Natural vegetation. U. S. Dep. Agric. Atlas Amer. Agric., part 1, sect. E, 29 p.
- Shreve, F. 1917. A map of the vegetation of the United States. *Geogr. Rev.* 3:119-125.
- Strain, W. S. 1966. Blanford mammalian fauna and Pleistocene formations, Hudspeth County, Texas. *Bull. 10, Texas Memorial Museum, Austin.* 55 p.
- Taylor, S. A., D. D. Evans and W. D. Kemper. 1961. Evaluating soil water. *Utah Agric. Exp. Sta. Bull.* 426. 67 p.
- UCAR (University Corporation for Atmospheric Research). 1989. Arid ecosystems interactions, recommendations for drylands research in the global change research program. UCAR Office for Interdisciplinary Earth Studies Rep. OIES-6. 81 p.
- U.S.D.A. 1980. Soil survey of Doña Ana County, New Mexico. U. S. Dep. Agric., Soil Conserv. Serv. in cooperation with U. S. Dep. Interior and N. Mex. Agric. Exp. Sta. 177 p. & maps.
- U.S.D.A. 1982. National list of scientific plant names, vol. 1, List of plant names. U.S. Dep. Agric., Soil Conserv. Serv. SCS-TP-159. 416 p.
- U. S. Salinity Laboratory Staff. 1954. Methods for soil characterization, p. 83-126. In: L. A. Richards (ed.), *Diagnosis and Improvement of Saline and Alkali Soils.* U. S. Dep. Agric. Handb. 60.
- Van Devender, T. R. 1990. Late Quaternary vegetation and climate of the Chihuahuan Desert, United States and Mexico, p. 104-133. In: J. L. Betancourt, T. R. Van Devender, and P. S. Martin (eds.), *Packrat Middens, The Last 40,000 Years of Biotic Change.* Univ. Arizona Press, Tucson.
- Westoby, M., B. Walker and I. Noy-Meir. 1989. Opportunistic management for rangelands not at equilibrium. *J. Range Manage.* 42:266-274.
- Wright, R. G. and G. M. Van Dyne. 1976. Environmental factors influencing semidesert grassland perennial grass demography. *The Southwestern Natur.* 21:259-274.

York, J. C. and W. A. Dick-Peddie. 1969. Vegetation changes in southern New Mexico during the past hundred years, p. 157-166. In: W. G. McGinnies and B. J. Goldman (eds.), *Arid Lands in Perspective*. Univ. Arizona Press, Tucson.

Appendix 1. Nomenclature of plants in the text (Allred 1988, Kelsey and Dayton 1942, USDA 1982).

Common name	Scientific nomenclature
Perennial grasses	
alkali sacaton	<i>Sporobolus airoides</i> (Torr.) Torr.
black grama	<i>Bouteloua eriopoda</i> (Torr.) Torr.
burrograss	<i>Scleropogon brevifolius</i> Phil.
bush muhly	<i>Muhlenbergia porteri</i> Scribn.
dropseeds	<i>Sporobolus</i> spp. R. Br.
ear muhly	<i>Muhlenbergia arenacea</i> (Buckl.) A. S. Hitchc.
fluffgrass	<i>Erioneuron pulchellum</i> (H.B.K.) Tateoka
gyp dropseed	<i>Sporobolus nealleyi</i> Vasey
Hall's panicum	<i>Panicum hallii</i> Vasey
mesa dropseed	<i>Sporobolus flexuosus</i> (Thurb.) Rydb.
plains bristlegrass	<i>Setaria leucopila</i> (Scribn. & Mer.) K. Schum.
poverty threeawn	<i>Aristida divaricata</i> Humb. & Bonpl. ex Willd.
purple threeawn	<i>Aristida purpurea</i> Nutt.
red threeawn	<i>Aristida purpurea</i> Nutt. var. <i>longiseta</i> Vasey (Steud.)
sand muhly	<i>Muhlenbergia arenicola</i> Buckl.
sand dropseed	<i>Sporobolus cryptandrus</i> (Torr.) Gray
spike dropseed	<i>Sporobolus contractus</i> A.S. Hitchc.
threeawns	<i>Aristida</i> spp. L.
tobosa	<i>Hilaria mutica</i> (Buckl.) Benth.
vine mesquite	<i>Panicum obtusum</i> H.B.K.
Wooton threeawn	<i>Aristida pansa</i> Woot. & Standl.
Annual grasses	
Mexican witchgrass	<i>Panicum hirticaule</i> J. Presl.
needle grama	<i>Bouteloua aristidoides</i> (H.B.K.) Griseb.
sixweeks grama	<i>Bouteloua barbata</i> Lag.
sixweeks threeawn	<i>Aristida adscensionis</i> L.
witchgrass	<i>Panicum capillare</i> L. var. <i>brevifolium</i> Rydb.
Perennial forbs	
blanketflower	<i>Gaillardia pinnatifida</i> Torr.
crowfoot falsenightshade	<i>Chamaesaracha coronopus</i> (Dun.) Gray
desert holly	<i>Perezia nana</i> Gray
dingy falsenightshade	<i>Chamaesaracha sordida</i> (Dun.) Gray
dwarf dalea	<i>Dalea nana</i> Torr.

Appendix 1. Nomenclature of plants in the text (Allred 1988, Kelsey and Dayton 1942, USDA 1982), cont'd.

Common name	Scientific nomenclature
Perennial forbs, cont'd	
Fendler's bladderpod	<i>Lesquerella fendleri</i> (Gray) Wats.
hairy evolvulus	<i>Evolvulus nuttallianus</i> Schultes
hog potato	<i>Hoffmanseggia glauca</i> (Ort.) Eifert
leatherweed	<i>Croton pottsii</i> (Klotzsch) Muell.-Arg.
pale globemallow	<i>Sphaeralcea incana</i> Torr.
paperflower	<i>Psilostrophe tagetina</i> (Nutt.) Rydb.
plains zinnia	<i>Zinnia grandiflora</i> Nutt.
rattlesnakeweed	<i>Euphorbia albomarginata</i> Torr. & Gray
scarlet globemallow	<i>Sphaeralcea coccinea</i> (Pursh) Rydb.
sicklepod	<i>Hoffmannseggia drepanocarpa</i> Gray
silverleaf nightshade	<i>Solanum elaeagnifolium</i> Cav.
strapleaf spineaster	<i>Machaeranthera pinnatifida</i> (Hook.) Shinners
trailing windmills	<i>Allionia incarnata</i> L.
twinleaf senna	<i>Cassia bauhinoidea</i> Gray
western sensitivebriar	<i>Schrankia occidentalis</i> (Woot. & Standl.) Standl.
wooly sumpweed	<i>Iva dealbata</i> Gray
wooly-white	<i>Hymenopappus flavescens</i> Gray var. <i>canotomentosus</i> Gray
wrinkled globemallow	<i>Sphaeralcea subhastata</i> Coult.
Annual forbs	
annual broomweed	<i>Gutierrezia spaerocephala</i> Gray
bitterweed	<i>Hymenoxys odorata</i> DC.
Chihuahua flax	<i>Linum australe</i> Heller
chinchweed	<i>Pectis papposa</i> Harv. & Gray
Dakota vervain	<i>Glandularia bipinnatifida</i> (Nutt.)
deerstongue	<i>Cryptantha crassisepala</i> (Torr. & Gray) Greene
desert marigold	<i>Baileya multiradiata</i> Harv. & Gray
faintcrown	<i>Aphanostephus ramosissimus</i> DC.
gray goosefoot	<i>Chenopodium incanum</i> (Wats.) Heller
puncturevine	<i>Tribulus terrestris</i> L.
purple curleaf	<i>Nama hispidum</i> Gray
purple scorpionhead	<i>Phacelia intermedia</i> Woot.
purslane	<i>Portulaca oleracea</i> L.
Russian thistle	<i>Salsola australis</i> R. Brown
saucerleaf buckwheat	<i>Eriogonum rotundifolium</i> Benth.

Common name	Scientific nomenclature
Annual forbs, cont'd	
shaggyleaf	<i>Portulaca mundula</i> I.M. Johnst.
spectaclepod	<i>Dithyrea wislizenii</i> Engelm.
spike spiderling	<i>Boerhaavia spicata</i> Choisy
tansy mustard	<i>Descurainia pinnata</i> (Walt.) Britt.
Texas selenia	<i>Selenia dissecta</i> Torr. & Gray
tickseed	<i>Corispermum nitidum</i> Schult.
warty carpetweed	<i>Kallstroemia parviflora</i> J. B. S. Norton
western fleabane	<i>Erigeron bellidiastrum</i> Nutt.
whitestem stickleaf	<i>Mentzelia albicaulis</i> (Hook.) Torr. & Gray
wooly indianwheat	<i>Plantago patagonica</i> Jacq.
wooly mouse-ear	<i>Tidestromia lanuginosa</i> (Nutt.) Standl.
Shrubs and shrub-like plants	
broom snakeweed	<i>Gutierrezia sarothrae</i> (Pursh) Britt. & Rusby
creosotebush	<i>Larrea tridentata</i> (DC.) Cov.
crucifixion thorn	<i>Koeberlinia spinosa</i> Zucc.
datil	<i>Yucca baccata</i> (Engelm.) Trel.
Engelmann's pricklypear	<i>Opuntia phaeacantha</i> Engelm.
honey mesquite	<i>Prosopis glandulosa</i> Torr.
littleleaf sumac	<i>Rhus microphylla</i> Engelm.
longleaf ephedra	<i>Ephedra trifurca</i> Torr.
lotebush	<i>Ziziphus obtusifolia</i> (Hook. ex Torr. & Gray) Gray.
soaptree yucca	<i>Yucca elata</i> Engelm.
tarbush	<i>Flourensia cernua</i> DC.
three fans	<i>Krameria lanceolata</i> Torr.
Torrey's ephedra	<i>Ephedra torreyana</i> Wats.
whitethorn	<i>Acacia constricta</i> Gray

Appendix 2. Conversion from metric to English units.

Metric unit	English equivalent
centigrade (C)	(Fahrenheit -32) x 0.556
centimeter (cm)	0.394 x inch
hectare (ha)	2.47 x acres
kilograms per hectare (kg/ha)	1.12 x pounds per acre
kilometer (km)	0.62 x mile
megapascals (MPa)	0.1 x bar or 0.1 x atmosphere
meter (m)	1.094 x yard
millimeter (mm)	0.0394 x inch
