SURVIVAL AND SPREADING ABILITY OF ENDEMIC AND EXOTIC GRASSES ON A DESERT GRASSLAND SITE

by

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STATEMENT BY AUTHOR

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SIGNED: Ramón Claverán

APPROVAL BY THESIS DIRECTOR

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John H. Ehrenreich — Oct. 6, 1964

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Date

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ABSTRACT

A vegetative analysis was made in a desert grassland site near Sonoita, Arizona seeded in 1939 and 1940 to the following native species *Bouteloua curtipendula*, *Bouteloua filiformis*, *Bouteloua gracilis*, *Bouteloua hirsuta*, and *Hilaria belangeri*, and to the exotic species *Andropogon ischaemum*, *Astrebla elymoides*, *Astrebla lappacea*, *Chloris berroi*, *Eragrostis curvula*, *Eragrostis lehmanniana*, and *Panicum antidotale*.

The results showed that all the native grasses seeded are present except slender grama (*Bouteloua filiformis*). The success of the native grass reseeding was difficult to evaluate because it could not be determined whether the plants on the plots resulted from the reseeding or from native plants on the adjacent area. However, curly mesquite (*Hilaria belangeri*) ranked second in importance (1.8 percent basal density).

The only exotic grasses found were Turkestan bluestem (*Andropogon ischaemum*) and Lehmann lovegrass (*Eragrostis lehmanniana*). Turkestan bluestem ranked third in basal density (1.0 percent) in the plots, and was not able to move outside the reseeded area. Lehmann lovegrass ranked first in basal density (2.0 percent) of all species and

it increased its original reseeded area about 20 times. Outside the reseeded area it had not spread significantly. Under the present environmental conditions, Lehmann lovegrass became dominant only when the native sod was disturbed by mechanical means. The seed transporting agents and grazing effects were of secondary importance in its spread.

INTRODUCTION

Desert grassland and the associated subtypes of oak and mesquite savannahs are perhaps the most arid of all the North American grasslands (Humphrey, 1958a) and present many difficult problems to successful reseeding. Yet reseeding may be necessary on many depleted desert grassland ranges, where they cannot be returned to good condition through grazing management, shrub control and other treatments. Thus it is essential to know what success can be expected in the long run from reseeding various species. This study was run to evaluate reseeding success 23 years after seeding.

The desert grassland and associated oak and mesquite savannahs extend from southeastern Arizona, through southern New Mexico, southwestern Texas and south to as far as the vicinity of Mexico City. However, the main body of the desert grassland type lies in the North and Central Plateaus in the states of Chihuahua, Coahuila, Durango and Zacatecas (Shreve, 1942).

Desert grassland has been used essentially as a source of forage for domestic livestock since the early expeditions of the Spanish conquerors. European livestock were introduced to Mexico in the early fourteenth century by Cortez. Coronado in 1540 began a long journey across the Southwest from Compostela on the Pacific coast to as far as present-day Kansas. He brought about 1500 animals of all kinds. Almost 60 years later Juan de Onate organized an expedition for the conquest and colonization of New Mexico and introduced 6, 000 head of different kinds of livestock. Francisco Eusebio Kino, a Jesuit missionary, in 1651 established the first ranches in Arizona, and livestock reproduced almost without any control until about the second half of the last century when big ranches were organized. Therefore the desert grassland has been grazed to a significant extent by domestic animals for about 150 years in Southwestern United States and about 300 years or more in Mexico (Dusenberry, 1963; Humphrey, 1958a).

The disturbance by grazing along with fire control (Glendening and Paulsen, 1955; Humphrey, 1958a; Mehrhoff, 1955) have been the principal causes of range depletion. These deteriorated ranges can be improved by good management or in some cases by vegetation control and reseeding when advanced stages of depletion are present.

The importance of range reseeding and results of the early trials have been described since the beginning of the present century (Griffiths, 1901; Cotton, 1908; Sampson, 1913). However, no reseeding of great importance was made in the Southwest until the 1930's when the Soil Conservation Service started testing several grasses. The principal objectives of this artificial revegetation were to protect the soil from erosion and to increase the forage yield of the degraded ranges (Stewart, 1949).

Native and exotic grasses have been used widely to reseed desert grassland; however, only few evaluations of those trials have been made after a long period of time to determine the effect of grazing by domestic animals.

The economic importance of the desert grassland in the livestock industry makes it necessary to obtain more knowledge about the relationship between site characteristics, grasses seeded, methods of seeding, and grazing management in order to prevent expensive failures.

The objective of the present study was to evaluate the success of native and introduced grasses seeded in 1939 and 1940 on a typical desert grassland site under continuous grazing. Vegetative composition and basal area density of the reseeded species were investigated to determine their survival capacity. In addition, their ability to spread beyond the seeded area into two neighboring pastures with similar ecological characteristics but under different management was determined.

LITERATURE REVIEW

Necessity of Range Reseeding

Since the turn of the century there has been a great deal of interest in the deterioration of the vast western rangelands. Griffiths, in 1901, interviewed some of the old-time ranchers of the Arizona Territory and concluded that the rangelands have deteriorated because of overstocking and that forage production had decreased greatly over the years. This deterioration is exemplified by a decrease in the desirable grasses and invasion of less desirable grasses, forbs and shrubs.

Several years later Sampson (1913) and Jardine (1915), two famous early range conservationists, analyzed the range depletion problem and concluded that the principal causes were trampling and overgrazing by domestic livestock.

More recently, however, Humphrey (1958a) summarized the causes of depletion of the desert grasslands as: (a) change of climate, (b) grazing by domestic livestock, (c) plant competition, (d) effect of rodents, and (e) fire prevention. He assumed change of climate is the least important, and prevention of range fires the most important factor. Humphrey assumed that fire prevention favored the invasion of undesirable woody plants.

In the early development of the science of range management, it was believed that complete resting for one or more growing seasons was the only way to improve range conditions. Sampson (1908) recommended deferred grazing during the early part of the growing season to give the grass plants an opportunity to produce abundant seed. He pointed out that later introduction of animals would help in seed distribution and seeding. About the same time Cotton (1908) suggested resting meadow vegetation to improve range conditions.

These authors and other contemporary investigators mentioned the idea of providing seed to the range from outside sources in order to accelerate the natural process of range improvement. Griffiths (1901), in his work on the Arizona desert grassland, described the possibility of reseeding deteriorated areas with seed collected from native perennial plants. He designed a 52-acre enclosure where about 40 different native and introduced species were seeded in 60 plots. A few years later Griffiths (1904) made a large enclosure of about 31,488 acres in the Santa Rita (Arizona) area.

A little later Cotton (1908) reseeded several plots in the northwest, but the seeding was not successful. He assumed the failure was caused by the unfavorable condition of the soil. Although the majority of these early reseeding trials were failures, some helpful information was obtained.

There were some investigators at this time, however, who questioned the practicability of range reseeding. Thornber (1910) observed the Griffiths' small enclosure and wrote " . . . The small range enclosure which is typical of this class of ranges has not shown any marked improvement as concerns forage production . . . The most economical plan for handling such ranges appears to be to graze them moderately." Several years later Wooton (1916) pointed out that all the reseeding trials made in Arizona had negative results. This plus the low value of the desert grasslands led him to conclude that improvement of the range rests only on proper management.

In spite of the aforementioned efforts and the early reseeding works of the U. S. Forest Service on large acreages of public lands (Sampson, 1913), it was not until the early 1930's that a great deal of interest was developed in finding ways to restore range productivity and rebuild the soil cover through range reseeding. Since this time a large number of species has been introduced into the Southwest and several reseeding trials were started. Unfortunately, most of these studies were interrupted by World War II (Stewart, 1951; McGinnies _et al._, 1963).

At the present time many aspects of range reseeding have been partially explored and some basic principles and recommendations have been derived from these explorations. These recommendations do not eliminate all the hazards involved in reseeding but they could be a helpful aid. For instance, Hull et al. (1950) recommended reseeding only where cover of perennial forage plants is less than 15 percent. Otherwise they contend that good management will be sufficient to obtain range establishment.

Particularly in the Southwest, precipitation is the most important factor in determining where some success from artificial reseeding can be expected. Anderson et al. (1957), Hamilton (1959), and Reynolds (1959) determined that a mean-annual precipitation of 11 inches is the lower limit for reseeding in the Arizona desert grassland. The low precipitation rates of that area are the principal cause of the very slow response of the vegetation compared with more mesic ranges. For example, a desert grassland site of southern New Mexico required eight years to double its forage production with total protection from rodents, rabbits and cattle (Norris, 1950).

It is recognized that there are several other site characteristics influencing moisture effectiveness and forage production in general. The complex relationships between climate, topography, and edaphic characteristics were grouped and classified by Humphrey

(1960) in relation to the maximum forage production potential that each range is able to produce under good management. This classification system of range condition can be used as a guide to determine proper sites to be revegetated.

Hamilton (1959) concluded that since range reseeding is an expensive operation and many hazards are involved, its use should be restricted to locations where the natural recovery of vegetation is not possible by reducing grazing pressure or removal of brush competition.

Seedbed Preparation and Reseeding Methods

Proper seedbed preparation has been found to be helpful if not essential in obtaining good reseeded stands in the Southwest. In 1931 Wilson suggested that plowing or similar soil preparation is necessary for reseeding in New Mexico desert grassland. More than a decade later Bridges (1942) reported that drilling was more effective and also more economical in the use of seed on New Mexico ranges and that broadcasting should be restricted to areas not accessible to drills. Other investigations such as Anderson et al. (1957), Barnes and Anderson (1944) and Hamilton (1959) have recommended careful seedbed preparation to increase the moisture available for the seedlings and also to reduce competition with native plants. More recently Douglas et al. (1960) compared the effect of five land preparation methods. They concluded: "Planting directly into unprepared land gives the poorest stands and slowest development." Wheeler (1964) has reported that in all cases stands of Lehmann lovegrass (Eragrostis lehmanniana Nees)[1] and Boer lovegrass (Eragrostis chloromelas Swartz) obtained from drilling were better than those obtained by broadcasting on a depleted desert grassland of southern Arizona.

Several methods and seeding techniques have been devised to increase the efficiency of the practice. Pelleted grass seed was developed by L. S. Adams (Adams, no date) and many beneficial assumptions were theorized. However, the practical results of the method are far from the theoretical concepts. Wagner (1949) described the unsuccessful results of a reseeding operation made on 90,000 acres (some of them in desert grassland vegetation type) in four southwestern Indian Reservations by using pelleted seed of Lehmann and weeping lovegrass, sand dropseed [Sporobolus cryptandrus (Torr.) Gray] and western wheatgrass (Agropyron smithii Rydb.). Later Wagner and Kinkor (1950) evaluated these same seedlings and concluded that non-pelleted seed gave similar results as seeding with pelleted seed. Bleak and Hull (1958) found that pelleted seed had no advantage over non-pelleted seed in four southwestern range types. However,

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[1] Scientific names unless otherwise indicated correspond with those in Kearney and Peebles (1960) and Hitchcock (1950).

Wheeler (1964) concluded that grass stands of Lehmann and Boer lovegrass from non-pelleted seed were better than those obtained from pelleted seed under identical conditions of drilling and broadcasting.

Range reseeding from airplanes has some advantages by time saving and economy of operation (Killough, 1950). On the Santa Rita Experimental Range in Arizona, Cable and Tschirley (1961) obtained a good stand of Lehmann lovegrass, by aerial seeding before spraying 2, 4, 5-T (2, 4, 5-trichlorophenoxy-acetic acid) to control velvet mesquite [*Prosopis juliflora* var. *velutina* (Woot.) Sarg.]. They did not use any previous seedbed preparation. Generally, however, results have been better from ground methods with proper seedbed preparation. Stewart (1949) compared air-dry forage yields following airplane and ground seeding methods in sagebrush ranges and found that the airplane-seeded areas produced five to 50 times less forage than drill-seeded areas.

Seed Mixtures

Seeding with mixtures of several species is a common practice which apparently has some advantages over the use of a single species. Springfield and Reynolds (1951) suggested a mixture of species rather than a single species in reseeding to provide a choice of forage for cattle. However, a mixture requires both careful selection of seeding mixture and grazing management. Hull *et al.* (1950) concluded that a mixture provides more forage, better variety and longer grazing season than a single species. Based on the study of a rangeland in eastern Montana after 17 years of grazing, McWilliams and Cleave (1960) concluded that for long term production and erosion control, mixtures of native species are better for range reseeding than crested wheatgrass [Agropyron desertorum (Fisch.) Schult.] alone.

Characteristics of the Seeded Native Grasses

A knowledge of the physiological and ecological characteristics of native grasses is essential to design reseeding studies and to interpret their results. McGinnies and Arnold (1939) determined water requirements of several Arizona range plants. They found that hairy grama (Bouteloua hirsuta Lag.), Rothrock grama (Bouteloua rothrockii Vasey) and curly mesquite [Hilaria belangeri (Steud.) Nash] were better adapted than many other species to the amount and pattern of precipitation in the area. Tanglehead [Heteropogon contortus (L.) Beauv.], Arizona cottontop [Trichachne californica (Benth.) Chase], slender grama [Bouteloua filiformis (Fourn.) Griffiths] and black grama (Bouteloua eriopoda Torr.) were moderately well adapted while poverty threeawn (Aristida divaricata Humb. and Bonpl.), sideoats grama [Bouteloua curtipendula (Michx.) Torr.], threeawn (Aristida sp.) and feather grass (Chloris virgata Swartz) were the least adapted.

Canfield (1957) studied the growth characteristics of native grasses by analyzing 17 years of chartograph records in Arizona desert grassland. He grouped the plants into primary species, such as black grama, sideoats grama, hairy grama, Arizona cottontop, tanglehead, mesa threeawn (*Aristida hamulosa* Henr.) and Texas timothy (*Lycurus phleoides* H. B. K.) which are found predominantly on lands under light or no grazing, and secondary species, such as Rothrock grama, sprucetop grama [*Bouteloua chondrosioides* (H. B. K.) Benth], slender grama and curly mesquite, which are more frequent on overgrazed ranges. He found that black grama, sprucetop grama, Arizona cottontop, and mesa threeawn were the longest lived. He also reported that primary grasses tended to be longer lived where protected than where grazed, whereas the opposite was true for the secondary grasses.

Blue grama and sideoats grama were used more than the other native grasses in this reseeding study. McGinnies *et al.* (1963) reported that native blue grama has been successfully seeded in Colorado upland plains and clay upland hills where the annual precipitation varies from 11 to 19 inches. Sideoats grama has been successfully established by artificial seeding on the same sites where precipitation is greater than 15 inches.

Characteristics of the Seeded Exotic Grasses

Many grasses from other parts of the world have been introduced to this country. Sometimes it is by accident such as with Turkestan bluestem (*Andropogon ischaemum* L.) (Harlan, 1951) and sometimes it is according to a planned program such as with Lehmann lovegrass in 1934 (Boyle, 1945). Harlan (1951) discussed the problems found in the interpretation of successful revegetation with introduced grasses caused by the great number of genetic strains. Most species have a variation within different parts of their natural range and it is difficult to obtain an adequate sample of genetic material for proper evaluation. He concluded that differences in performance between strains of one species in many cases are more variable than differences between species.

Turkestan bluestem is an example of variation within a species. Some investigators have reported it to be easily established but quite unpalatable. However, other investigators have reported just the opposite.

Crested wheatgrass, another exotic grass used in this study, was introduced from Russia in 1898. Since that time it has been used widely in reseeding in Southwestern ranges, although 15 inches of annual precipitation is the lower limit at which it has been successful

(Reynolds and Springfield, 1953). It is quite well adapted to ponderosa pine and pinyon-juniper vegetation types.

Eckert *et al.* (1961) tested Crested wheatgrass along with several other grasses in Nevada ranges with precipitation of about nine inches. They found that the wheatgrass survived only in bottom sites subject to stream overflow and a seasonal high water table.

Curly Mitchellgrass [*Astrebla lappacea* (Lindl.) Domin.] and hoop Mitchellgrass (*Astrebla elymoides* F. Muell.)[2] which are from northeastern Australia were also tested. The soil of their native region is a brown or gray clay of calcareous and volcanic origin and the precipitation varies from 10 to 30 inches (Roe, 1940).

Turkestan bluestem was also seeded in the area. It originated from Mediterranean Europe and is widespread through southern and central Europe and Asia. This grass was first introduced and tested in Texas (Swallen, 1950); since then, several reseeding trials have been made in the Southwest with good success. McGinnies *et al.* (1963) pointed out that a precipitation of 15 inches or more was required to establish Turkestan bluestem stands in Colorado upland plains. Anderson *et al.* (1957) reported 14 inches of annual rainfall as the lower limit to seed this grass in the Arizona desert grassland. Lavin and Pase (1963) obtained good to excellent stands of Turkestan

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[2] This specific name was obtained from Jackson (1895).

bluestem in a burned Arizona chaparral site with about 23 inches of mean-annual precipitation. Turkestan bluestem palatability is a variable characteristic according to the different strains of the species.

Lehmann and weeping lovegrass which were two of the most important grasses in this study were introduced from South Africa. Meredith (1955) determined their major area of distribution to be in the Orange Free State and Transvaal which has a range of annual precipitation from 10 to 35 inches. Lehmann and weeping lovegrasses are often found as components of a subclimax grassland deteriorated by intensive grazing.

Burning of lovegrass ranges has been recommended to remove old growth and increase utilization (Meredith, 1955; Scott, 1952). Bews (1918), in a description of the Veld vegetation types wrote: "It has already been pointed out that the grasses (Sporobolus-Eragrostis) are deep rooted, xerophitic, hard and wiry, farmers are usually very positive that they must burn to get young shoots, otherwise cattle will not eat the grasses."

Valentine (1945) discussed the results of seeding trials in New Mexico using introduced lovegrasses. He reported that weeping lovegrass was unsuited in desert grassland but excellent in the more humid Northeastern region. Lehmann lovegrass had a greater ability to occupy the desert grassland site after initial reseeding or at least until other native species become established through natural reseeding.

Crider (1945) analyzed the revegetation trials made by the Soil Conservation Service in Arizona desert grassland using Lehmann, weeping and Boer lovegrasses. Weeping lovegrass was found to be the most resistant to low temperatures. However, it cannot be established in areas where the average annual precipitation is less than 15 inches. Lehmann lovegrass is the least cold resistant but it can thrive where the annual precipitation is 10 to 12 inches and where four to six inches fall in the summer.

Kincaid _et al._ (1959) studied the relationship between Lehmann lovegrass, velvet mesquite, and the native grasses in a desert grassland site where mesquite trees were thinned to densities of 0, 9, 16 and 25 trees per acre from the original population of 385 trees per acre. They found that Lehmann lovegrass was not affected by densities of 25 trees or less per acre, but that native grasses were reduced by even low densities of mesquite. They reported Lehmann lovegrass spreading into native grass areas due to its ability to compete and its low grazing preference. However, Cable and Tschirley (1961) reported that Lehmann lovegrass increased its forage yield about three times when dense mesquite was sprayed with herbicides.

Cable and Bohning (1959) investigated the degree of utilization of native grasses and Lehmann, Boer and Wilman (Eragrostis superba Peyr.) lovegrasses. They found Lehmann lovegrass was the least utilized species until the late spring, although in general the difference in utilization between native and introduced species was not significant.

Humphrey (1958b) evaluated the results of Lehmann lovegrass seedings in Arizona grazing lands. He found that the principal advantages of this grass are easy establishment and green forage production in the cool season. However, he also reported that since Lehmann lovegrass has a low grazing preference it can displace native grasses of better quality. Utilization reports by Crider (1945) generally showed that cattle had a higher preference for weeping than for Lehmann lovegrass. Scott (1952), however, reported that weeping lovegrass is not regarded as an useful forage grass in South Africa because it develops a high fiber content early in the season.

Williams (1964) analyzed an area in southern Arizona seeded with Lehmann lovegrass 22 years earlier. He concluded that: (a) water and wind are the principal agents that spread Lehmann lovegrass seed, (b) selective grazing between Lehmann lovegrass and native species was not found to be a factor in the spread of the lovegrass, (c) dense stands of other grasses or mesquite were effective in decreasing

Lehmann lovegrass invasion, and (d) the spread of Lehmann lovegrass is restricted to years of abundant precipitation.

DESCRIPTION OF THE STUDY AREA

Location

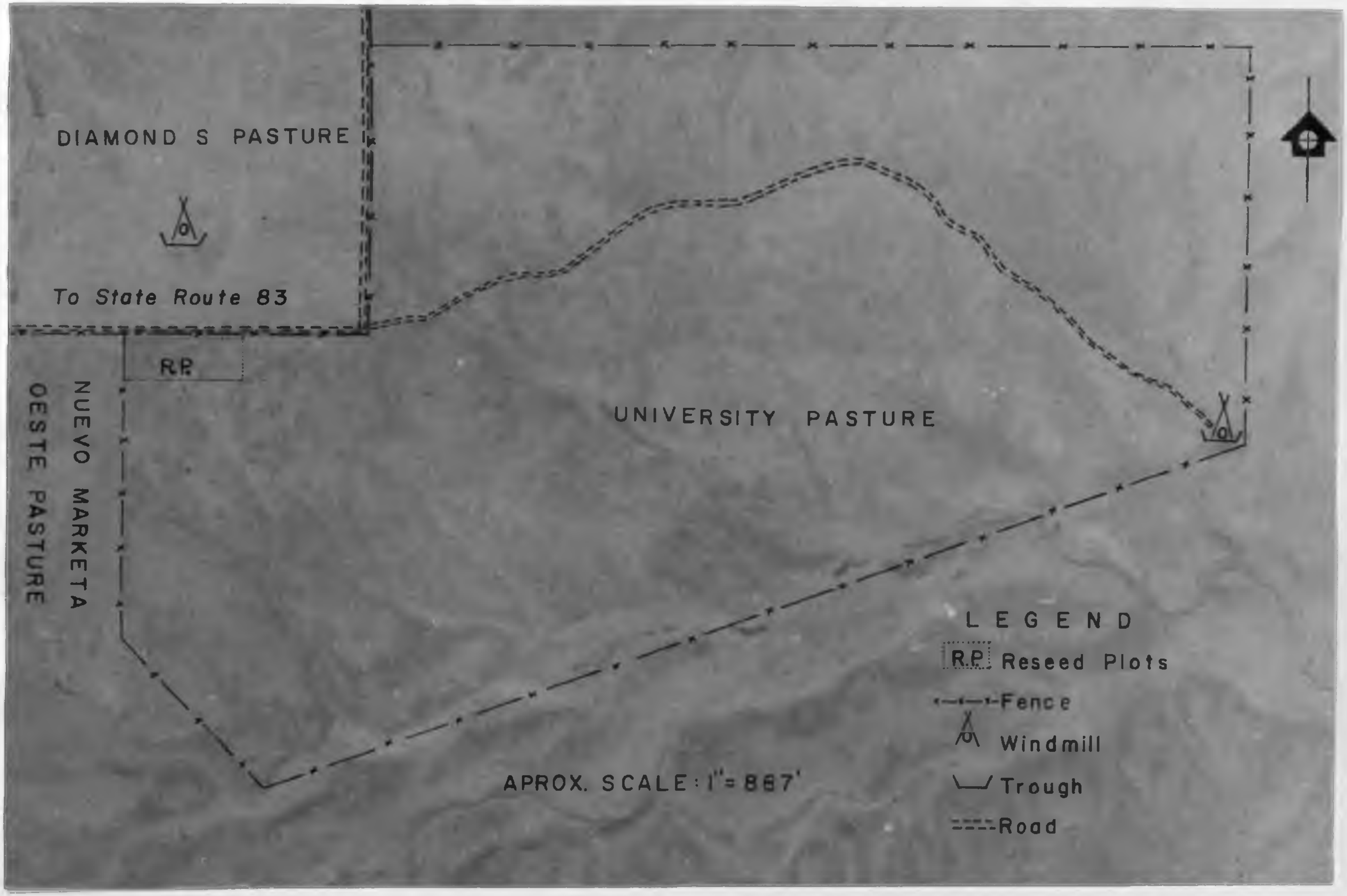
The study area is located about two miles northeast of Sonoita, Santa Cruz County, Arizona, in Section 8, R17E, T20S of the Gila and Salt River Meridian. It is in the northwest corner of the 380-acre University Pasture on the Douglas Ranch (Figure 1).[1] The north fence and unpaved road separate this part of the University Pasture from the Diamond S Pasture of the Curly Horse Ranch. The west fence is the boundary line with the Nuevo Marketa Oeste Ranch. The reseeded plots have a total surface of 2.3 acres and lie approximately 1.2 miles from the water supply of the pasture which is located in its southeastern corner.

Soil

The study area is at an elevation of about 4,750 feet, and presents a general aspect of rolling hills with gentle slopes. The reseeded plots are located 400 feet below the crest of a hill and slope

[1] When the reseeding work was made, this pasture belonged to the R. C. Larrimore Ranch.

Figure 1. Photographic map of the study area.


DIAMOND S PASTURE
To State Route 83
R.P.
NUEVO MARKETA
OESTE PASTURE
UNIVERSITY PASTURE
APROX. SCALE: 1" = 867'
LEGEND
R.P. Reseed Plots
Fence
Windmill
Trough
Road

to the north and east. The soil is developed from alluvium from the Santa Rita Mountains to the west and the Canelo Hills to the south. There is neither appreciable erosion nor deposition of new material.

The soil of the reseeded plots and the vicinity is classified as the Bernardino gravelly clay loam series,[2] a deep, well-drained reddish-brown soil. The textural analysis (from 9 samples taken at 1 to 12 inches depth) showed the following percentages: sand 53%, silt 21% and clay 26% (Table 1). Topsoil texture is a sandy clay loam.

The chemical analysis shows it has a pH value of 7.1, available NO_3^- 10 ppm, $PO_4^{=}$ 1 ppm, and total soluble salts 280 ppm.

Climate

Climatic records are not available in the study area; therefore, information was obtained from the nearest stations.

Precipitation

Precipitation records were taken from Elgin which has an elevation[3] of 4,900 feet and is located about 7 miles southeast

[2] Personal communication with Dr. Stanley W. Buol, Department of Agricultural Chemistry and Soils, University of Arizona, Tucson.

[3] Elgin Station was located at 4,900 feet in 1939 and from November 1957, to December 1963. From January 1940 to October 1957 it was at 4,730 feet.

TABLE 1.--Analysis of soil texture of 9 soil samples taken from the study area at a depth of from 1 to 12 inches.

Soil sample	Reseeded plot	Soil texture			Soil classification
		Sand	Silt	Clay	
		Percent			
1	5-W	66	15	19	Sandy clay loam
2	5-W	55	18	27	Sandy clay loam
3	5-E	50	29	31	Sandy clay loam
4	5-E	52	33	15	Sandy clay loam
5[a]	14-E	55	21	24	Sandy clay loam
6	14-E	47	17	36	Sandy clay loam
7	14-W	54	16	30	Sandy clay loam
8	14-W	50	23	27	Sandy clay loam
9[a]	9-W	49	21	30	Sandy clay loam
Average		53	21	26	Sandy clay loam

[a]Analysis made by the Laboratory of Agriculture Chemistry and Soils, University of Arizona, Tucson.

from the University Pasture. Total annual and average precipitation are presented in Figure 2, and monthly averages in Figure 3.

The average precipitation in the 25-year period from 1939 to 1964 was 13.8 inches. In 1939, when the first reseeding was done, the rainfall was 12.46 inches, which is 1.5 inches below the period's average. Next year when six plots were reseeded again, the precipitation was 20.4 inches, one of the highest during the period. A two-year drought occurred from 1942 through 1943 but the driest year was 1953 when only about one-third of the average rainfall was recorded.

Monthly average distribution shows a rainfall concentration in the late summer months of July and August. About 25 perçent of the total precipitation falls in August and about 60 percent of the total is concentrated in July, August and September.

Temperature

Temperature records were available at Fort Huachuca which is at an elevation of 4,664 feet and is located about 20 miles southeast from the study area. Maximum mean and minimum monthly temperatures, based on data from 1957-1963, are presented in Figure 4. Minimum temperatures usually occurred in January. The lowest temperature recorded has been 1° F. Maximum temperatures usually occurred in June. The highest temperature recorded in the station's history was 105° F. The limit of frost killing temperatures

Figure 2. Annual precipitation from 1939-1963 at Elgin, Arizona located 7 miles southeast of the study area (U. S. Weather Bureau, 1939-63). Missing data was interpolated for January, 1948.

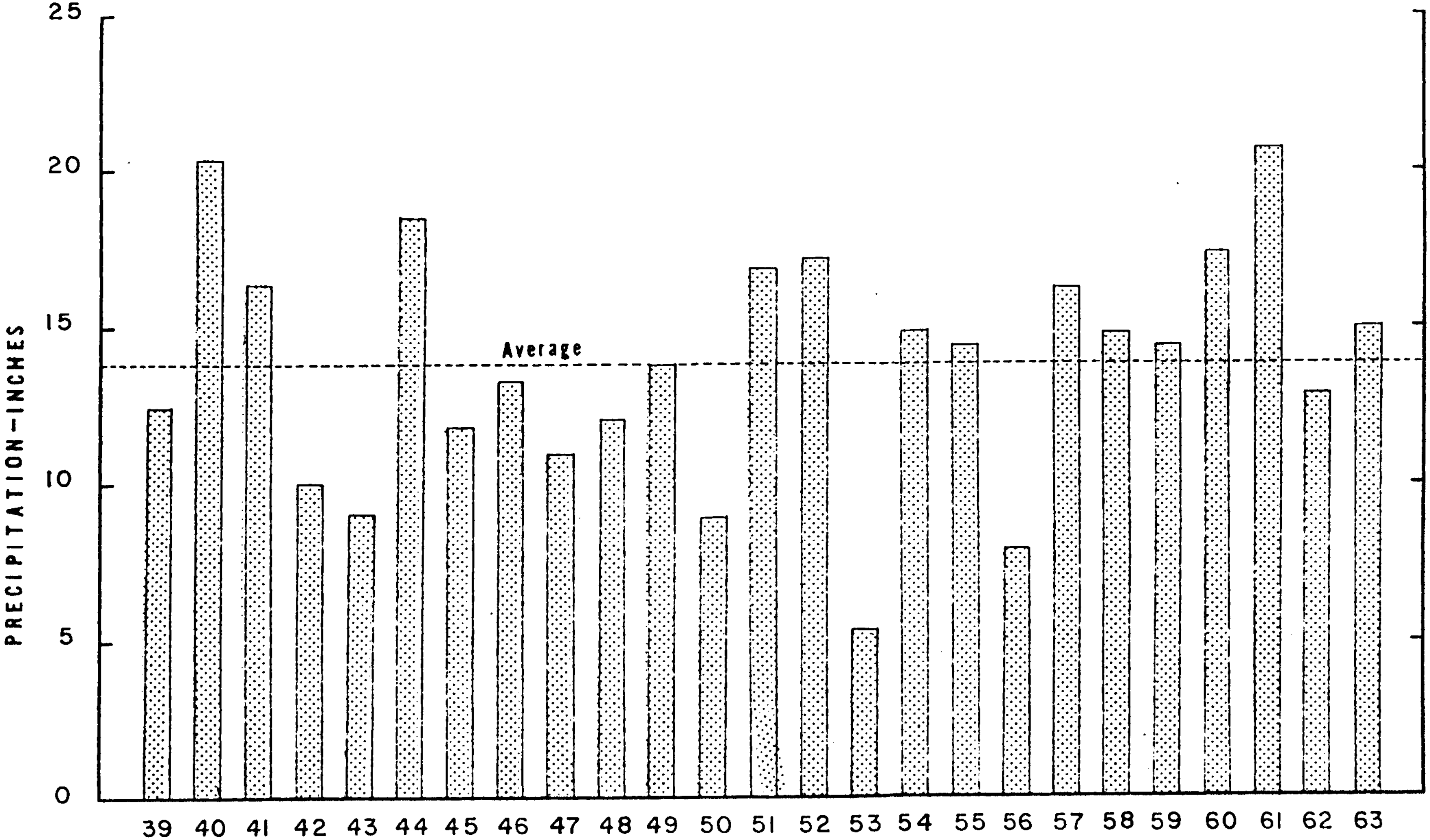

PRECIPITATION-INCHES
25
20
15
10
5
0
Average
39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63

Figure 3: Distribution of average monthly precipitation from 1939-1963 at Elgin, Arizona located 7 miles southeast of the study area (U. S. Weather Bureau, 1939-1963). Missing data were interpolated for January, 1948.

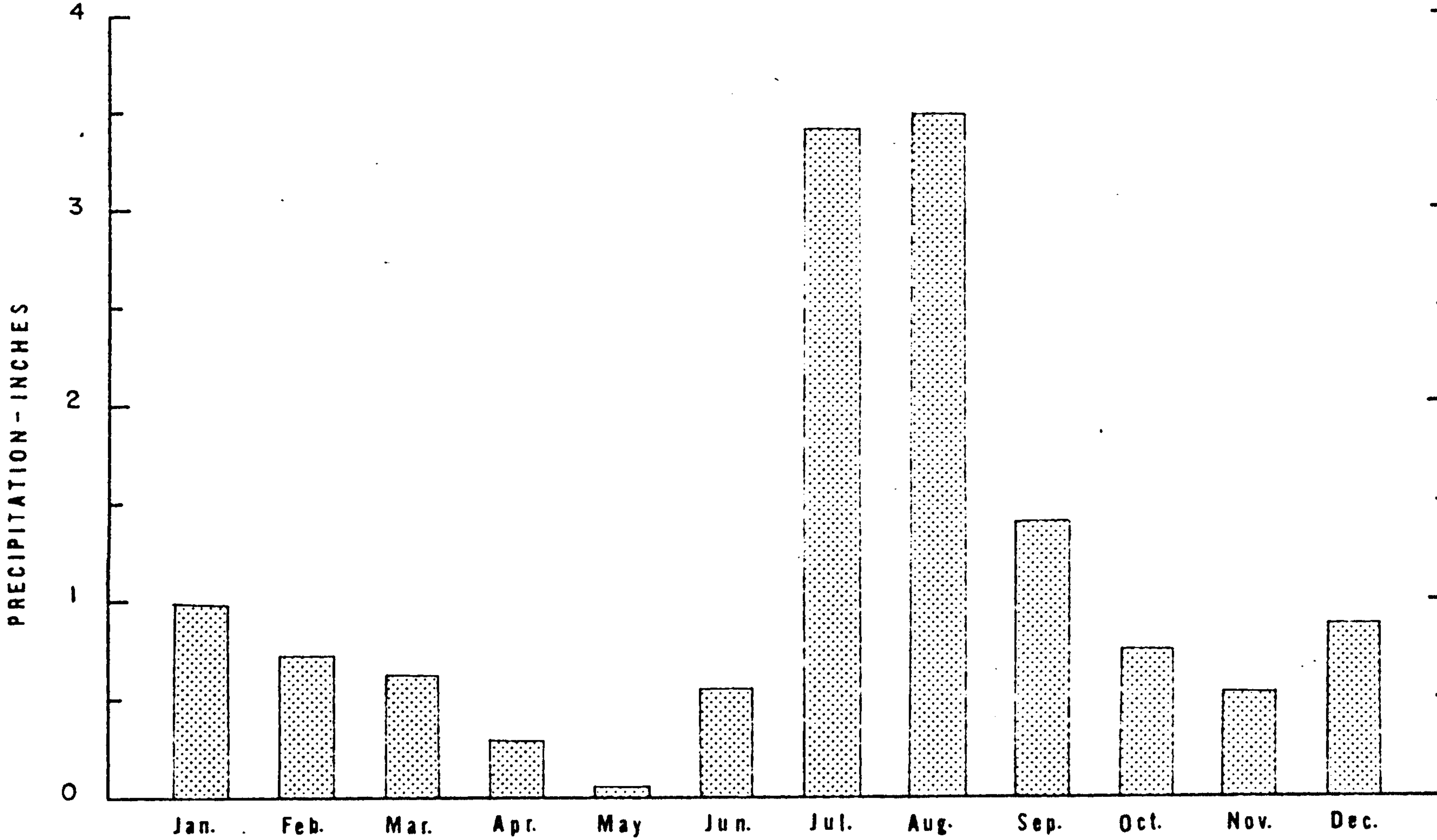
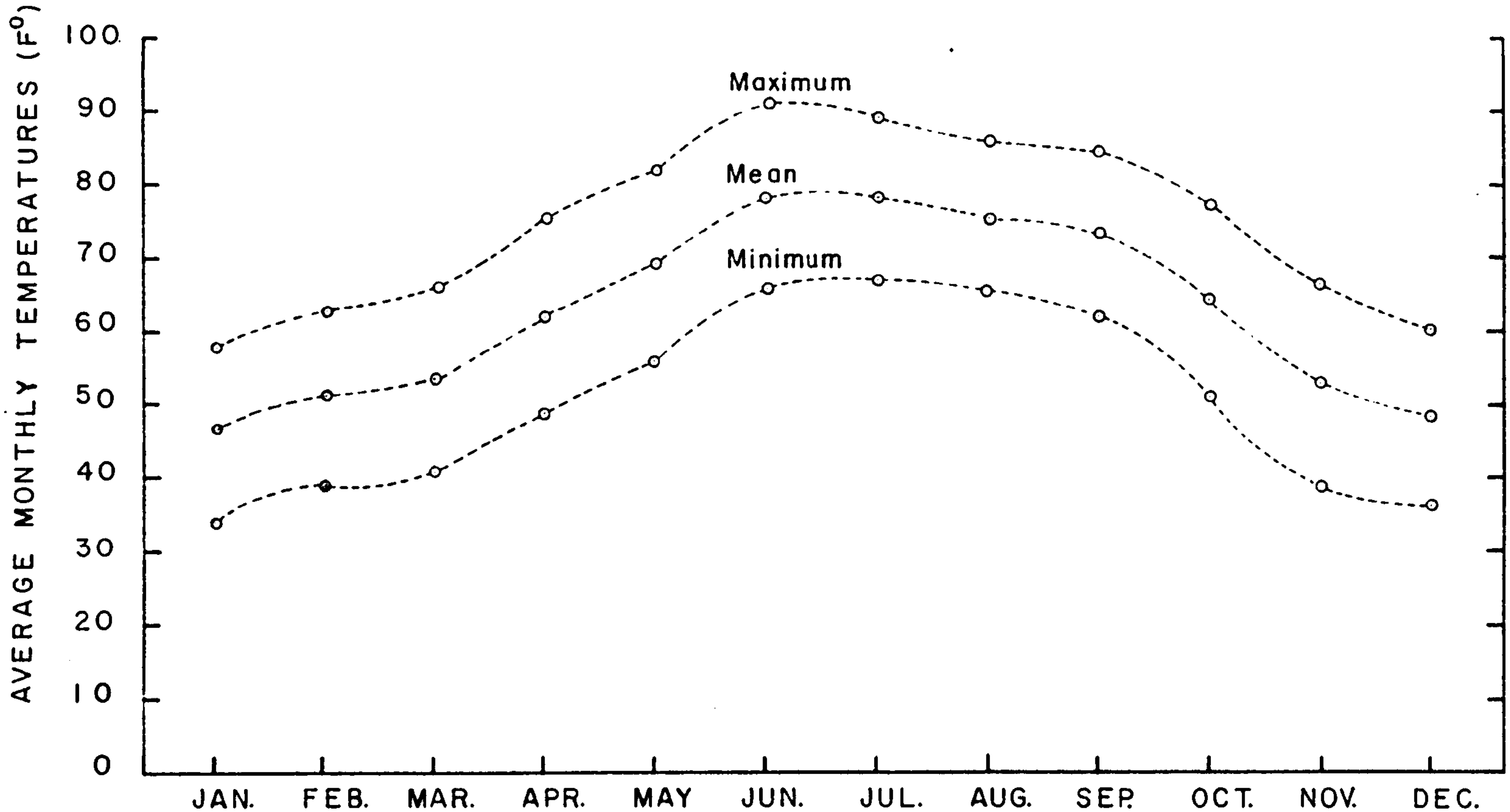

4
3
2
1
0
PRECIPITATION - INCHES
Jan.
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.

Figure 4. Average monthly maximum, minimum and mean temperatures for 1957-1963 at Fort Huachuca, Arizona located 20 miles southeast of the study area. Data were taken from records furnished by U. S. Army Weather Station at Fort Huachuca, Arizona.



AVERAGE MONTHLY TEMPERATURES (F°)
100
90
80
70
60
50
40
30
20
10
0
Maximum
Mean
Minimum
JAN.
FEB.
MAR.
APR.
MAY
JUN.
JUL.
AUG.
SEP.
OCT.
NOV.
DEC.

is in late March and the early fall frost generally comes about the middle of November (Sellers, 1960).

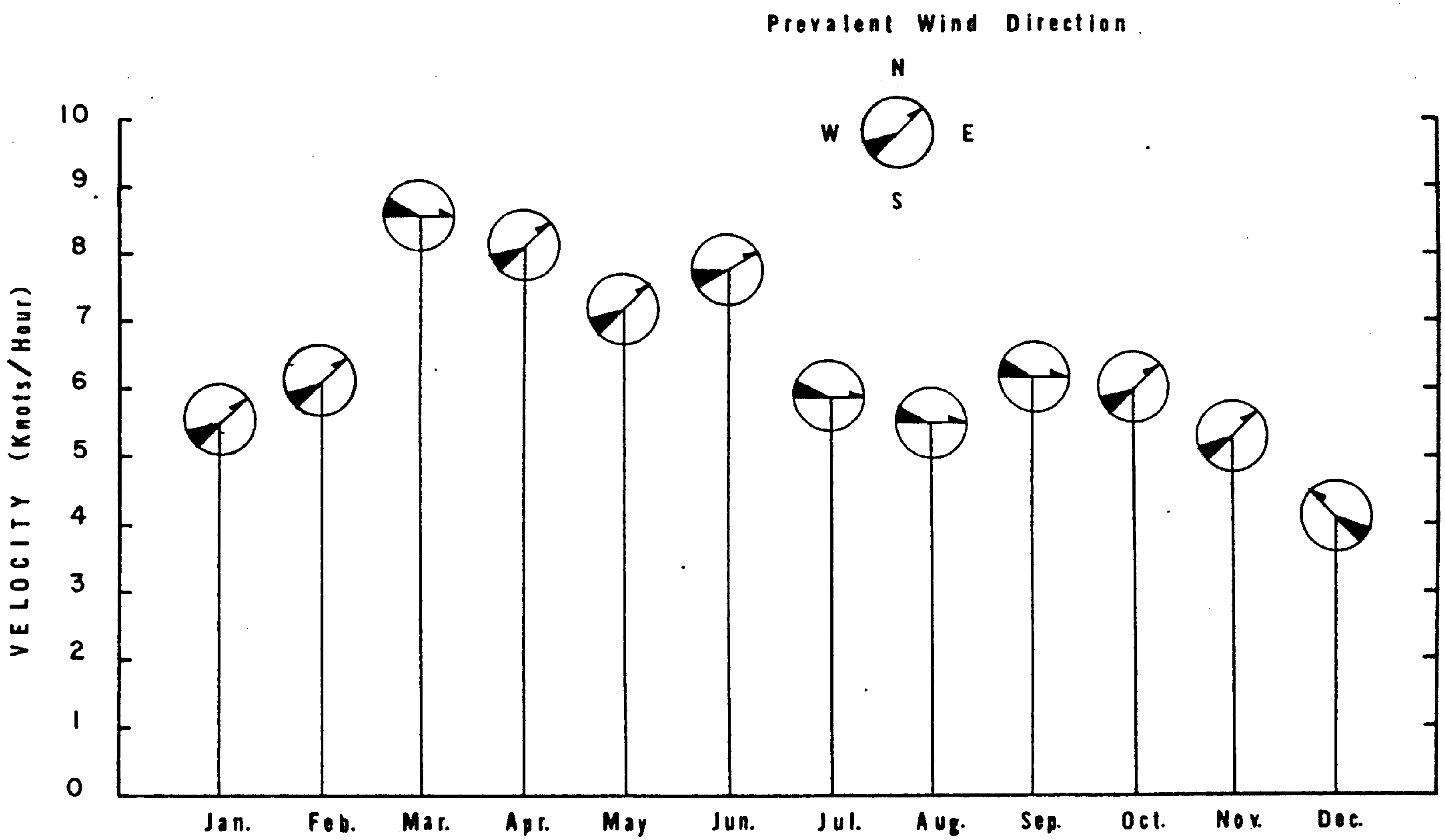
Wind

Average monthly wind velocities and the prevailing direction are summarized in Figure 5. Dominant wind direction during the year is from the southwest and west. December is the only month with prevailing wind direction toward the west. The higher wind velocities occur during the spring and the lowest ones during mid summer and winter.

The Fort Huachuca Weather Station is very close to the Huachuca Mountains. Undoubtedly, temperature and wind characteristics were affected by these particular topographic conditions, making them somewhat different from those present in the Sonoita country farther from mountain masses. Precipitation at Elgin is more typical of the study area because of the similarity in elevation and general physiography.

Vegetation

The study area is an almost pure stand of grass where the dominant native genera are *Bouteloua*, *Hilaria* and *Aristida* (Humphrey, 1958a). The dominant perennial grasses are curly mesquite, blue grama, sideoats grama, sprucetop grama, black grama, spidergrass


Prevalent Wind Direction
N
W
E
S
10
9
8
7
6
5
4
3
2
1
0
VELOCITY (Knots/Hour)
Jan.
Feb.
Mar.
Apr.
May
Jun.
Jul.
Aug.
Sep.
Oct.
Nov.
Dec.

(Aristida ternipes Cav.), poverty threeawn, cane beardgrass (Andropogon barbinodis Lag.) and Rothrock grama. Sixweeks threeawn (Aristida adscensionis L.) and sixweeks grama (Bouteloua barbata Lag.) are two of the most important annual grasses. Two of the more prevalent perennial forbs are Cirsium neomexicanum Gray and Gaura coccinea (Nutt). Aplopappus gracilis (Nutt) Gray is one of the more important late summer annual forbs.

The principal shrubs are velvet mesquite, soaptree (Yucca elata Engelm.), sotol (Dasylirion wheeleri Wats.) and beargrass (Nolina microcarpa Wats.). The mesquite is usually restricted to bottom lands and drainages. However, it is frequently one of the early pioneer invader plants into the upland grasslands. The other two species frequently act as increasers under overgrazing.

On the north slopes, with higher soil moisture, sideoats grama is the most abundant species. On the south slopes, more xeric species such as curly mesquite are dominants.

An ocular estimation of the vegetative composition[4] made before the 1939 seeding showed Aristida spp. 35 percent, curly mesquite 30 percent, blue grama 25 percent, hairy grama 5 percent, and sideoats

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[4] Information about the original study unless otherwise indicated was obtained from the archives of the Plant Material Center (S. C. S.), Tucson, Arizona, and from the personal communications and field notes of Mr. Louis P. Hamilton.

grama 5 percent. Traces of loco weed (*Astragalus nothoxys* Gray) were also observed.

Livestock Grazing

The University Pasture has been grazed by cattle, usually mother cows and calves, since the early 1930's. This pasture was managed under a rotation system[5] prior to the first reseeding treatment, and for a few years thereafter. During the rotation period 72 head utilized the pasture for periods of about one month at three-month intervals. Since the period of rotation the pasture has been grazed with a variable number of stock, from 17 to 22 animals year long.[6] This is essentially the same number of animal unit months previously supported by the pasture.

The adjacent Diamond S and Nuevo Marketa Oeste pastures have about the same acreage as the University Pasture. Unfortunately, the stocking history is not known because of the lack of records and the ownership changes.

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[5] Personal communication with Mr. Ernest Hussmann.

[6] Personal communication with Mr. James S. Douglas.

Original Study

The original reseeding study was a cooperative project among the University of Arizona, Soil Conservation Service, Southwest Forest and Range Experimental Station and Mr. R. C. Larrimore, the ranch owner. The objectives of the study were to obtain information on native and exotic grasses with respect to their: (a) adaptation to grassland range types in southern Arizona, (b) forage production, (c) relative palatability, (d) erosion resistant properties, (e) growth habits, (f) resistance of grazing by cattle, and (g) use in the abandoned plowed-over lands.

The study was designed originally as a test for 7 introduced grasses and 4 native grasses which were planted on July 12 and 13, 1939. Five of the exotic grasses were planted separately, a mixture of 2 exotic grasses (Mixture No. 1) and a mixture of 7 exotic and 3 native grasses (Mixture No. 2) (Table 2). They were seeded in plots 218 feet long by 10 feet wide (Figure 6). The plots were bordered on each side by a similar sized plot seeded on one side to blue grama and the other with sideoats grama. This gave a total of 17 plots. Strips of native sod 4 feet wide were left between plots. The single species and mixtures to be planted on each specific plot were determined by random selection. All treatments were replicated on an adjacent area.

TABLE 2.--Species and mixtures seeded July 12 and 13, 1939.

Species	Rate per acre (pounds)	Form of seed	Method of seeding
Bouteloua gracilis[a]	2.5	caryopses	cyclone seeder
Bouteloua curtipendula[a]	2.5	caryopses	cyclone seeder
Eragrostis curvula	5.0	caryopses	cyclone seeder
Eragrostis lehmanniana	unknown	unknown	unknown
Mixture No. 1[b]	unknown	unknown	by hand
Panicum antidotale	10	clean seed	cyclone seeder
Chloris berroi	20	in glumes	by hand
Agropyron desertorum	12	in glumes	cyclone seeder
Mixture No. 2[c]	11	mixed seed	unknown

[a]Native grasses.

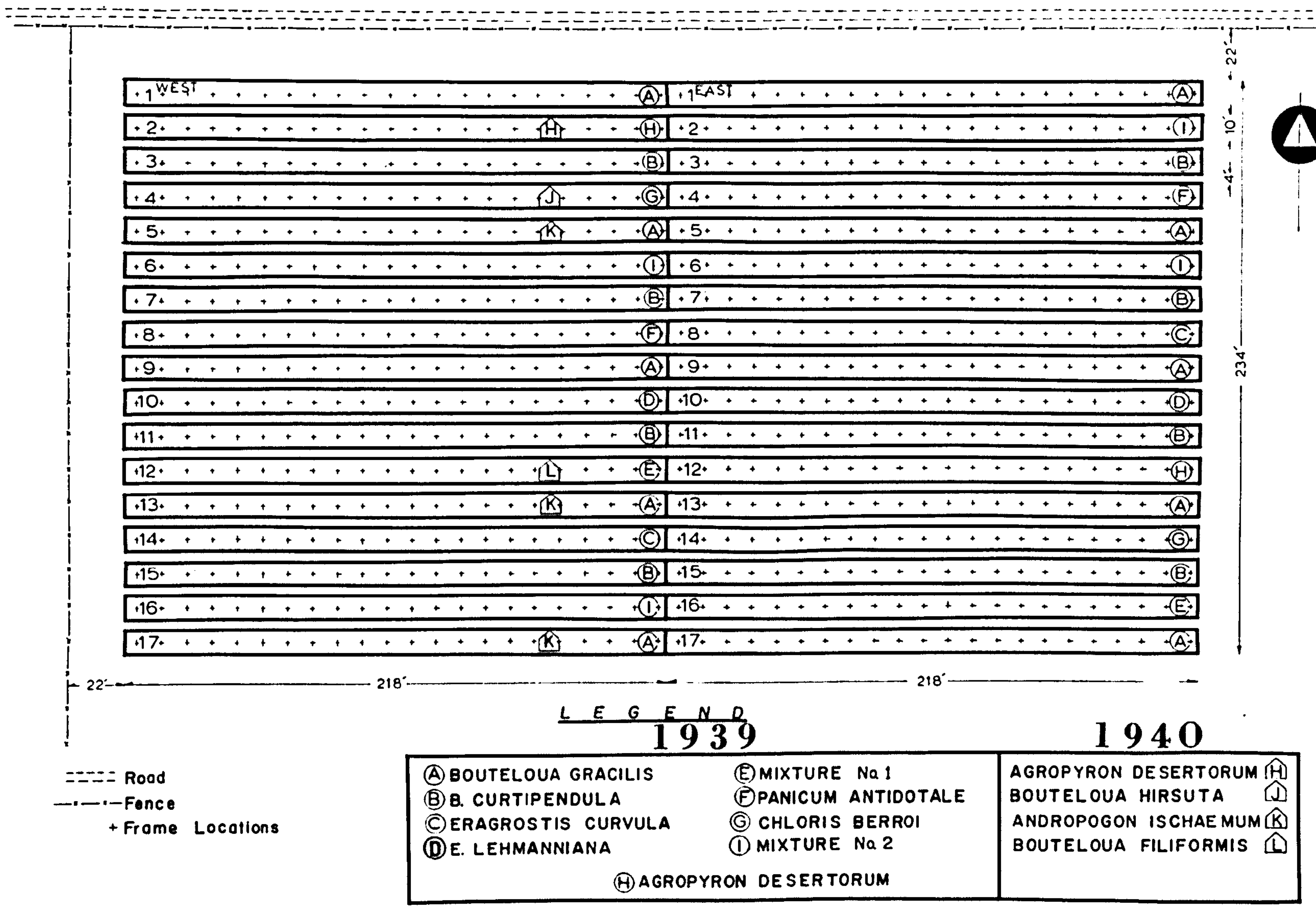
[b]Species in mixture no. 1;

Species	Ratio in mixture (parts)
Astrebla lappacea	12.5
Astrebla elymoides	8.0

[c]Species in mixture no. 2;

Species	Ratio in mixture (parts)
Bouteloua gracilis[a]	8.0
Bouteloua curtipendula[a]	9.0
Hilaria belangeri[a]	8.0
Eragrostis lehmanniana	5.0
Astrebla lappaceae	40.0
Astrebla elymoides	32.0
Panicum antidotale	16.0
Chloris berroi	32.0
Agropyron desertorum	20.0

Figure 6. Diagram of the reseeded plots and sampling locations in the study area. Chart shows the original seedings made in 1939 and reseedings made in 1940.



WEST
EAST
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
22'
10'
4'
234'
218'
LEGEND
1939
1940
Road
Fence
+ Frame Locations
Ⓐ BOUTELOUA GRACILIS
Ⓑ B. CURTIPENDULA
Ⓒ ERAGROSTIS CURVULA
Ⓓ E. LEHMANNIANA
Ⓔ MIXTURE No. 1
Ⓕ PANICUM ANTIDOTALE
Ⓖ CHLORIS BERROI
Ⓘ MIXTURE No. 2
Ⓗ AGROPYRON DESERTORUM
AGROPYRON DESERTORUM H
BOUTELOUA HIRSUTA J
ANDROPOGON ISCHAEMUM K
BOUTELOUA FILIFORMIS L

Seedbeds were prepared by means of a sod cutter which passed a 3-foot blade under the soil at a depth of 3 to 4 feet. A single-gang disc harrow was pulled behind the sod cutter in order to break up the sod and to provide some soil for the seedbed. Seeding methods and amount of grass used are listed in Table 2. The seed was covered by running a cultipacker both parallel to and at right angles to the direction of the plantings.

The following year six plots with seeding failures were reseeded with either crested wheatgrass,[7] Turkestan bluestem, slender grama or hairy grama (Table 3). The seedbed in the 1940 seedings was prepared with a border disc partially open. The seed was not covered but it rained immediately after planting.

All plots were closed to grazing for about one year, but were apparently grazed thereafter.

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[7] Crested wheatgrass [Agropyron desertorum (Fisch.) Schult] was identified in the original study as Agropyron cristatum (L.) Gaertn.

TABLE 3.--Plots and species reseeded July 26, 1940.

Plot number	Species seeded in 1939	Species seeded in 1940
2-W	Agropyron desertorum	Agropyron desertorum
4-W	Chloris berroi	Bouteloua hirsuta
5-W	Bouteloua gracilis	Andropogon ischaemum
12-W	Astrebla lappacea and Astrebla elymoides	Bouteloua filiformis
13-W	Bouteloua gracilis	Andropogon ischaemum
17-W	Bouteloua gracilis	Andropogon ischaemum

SAMPLING METHOD AND PROCEDURES

Sampling Method

Vegetative composition and plant basal area were determined by using the point-plot method. This method was originated by L. Cockayne in 1926 and later modified by Levy and Madden (1933). It is based on the mathematical concept of the homogenity of an unit area. If enough points are taken, an accurate vegetative picture may be reproduced.

Several studies have been made to compare the point-plot with other methods. Schultz et al. (1961), comparing the line intercept, line points, loop, ten-point frame and Bitterlich plot methods using artificial populations, found that the final mean recorded with the point-plot gave more accurate estimates of population parameters than any of these methods. Troxel (1962) reported that the point-plot method, when compared with the three-step method, gave the most reliable evaluation of density and composition and that a great number of species was detected. Brun and Box (1963) in a comparison of the accuracy of the line intercept and point-plot techniques found no statistically significant differences between the two methods. However, they found that the point-plot was 1.86 and 5.67 times faster for estimating ground cover with the same degree of accuracy in two different vegetation types. The aforementioned reports indicate that the point-plot method generally has more advantages over other methods in sampling open desert vegetation.

Levy and Madden reported that in charting a pasture dominant species were detected with 100 points and 400 to 500 were necessary for the subdominants. More points are needed under more xeric conditions. Whitman and Siggeirson (1954) concluded that 3, 600 basal contact points are the minimum acceptable for surveying a 300 to 500 foot area of native grass vegetation in South Dakota. Troxel (1962) took 43, 500 points in 1, 090 acres and 124, 800 points in 12, 605 acres in the Arizona desert grassland.

The apparatus used for field sampling in this study is a ten-point steel frame, 60 centimeters tall with two horizontal bars which have 10 holes, 91 millimeters apart (Figure 7). In each hole there were ten 90-centimeter-long pins (welding rods 4. 8 millimeters diameter) which could be moved vertically. Magnets were placed between the vertical bars to hold the pins yet allow easy movement.

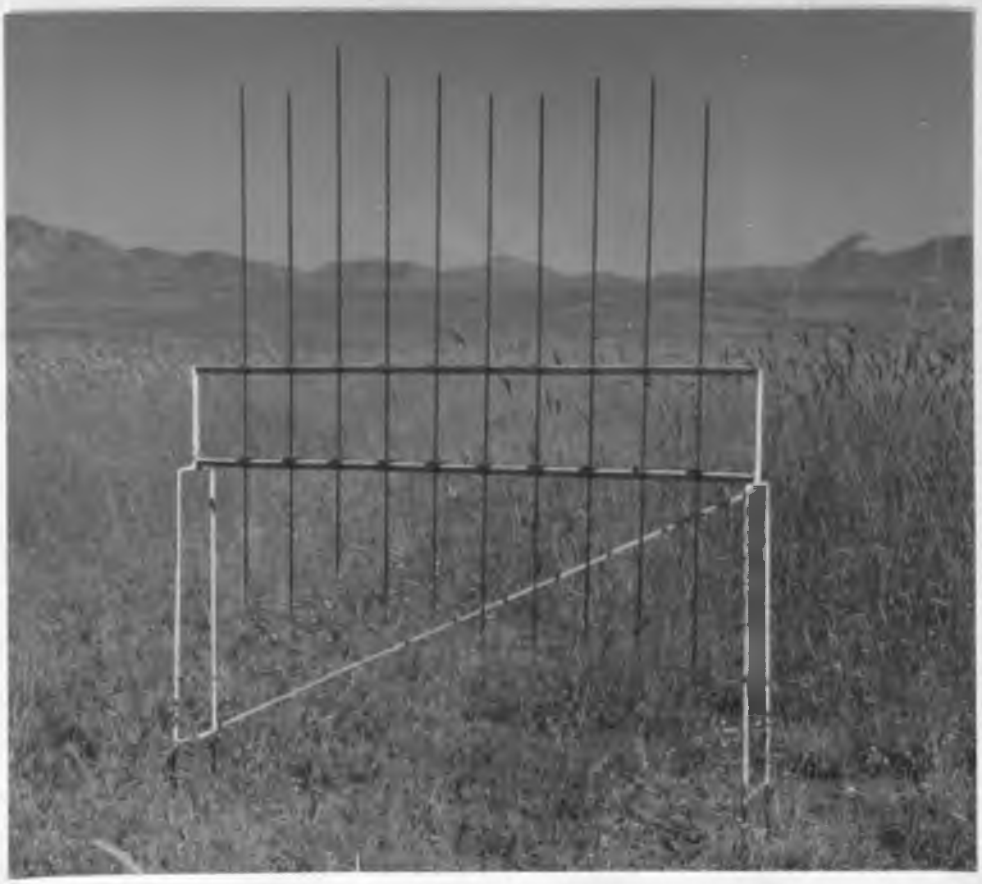


Figure 7. Point-plot frame used in the study.

Sampling Procedures

Reseeded Area

The sampling design consisted of lines run length-wise down the middle of each plot. "Frame locations" were marked at 10-foot intervals along this line (Figure 6). The first of these was located 5 feet west of the west border of the west replication; the last was 7 feet east of the east border of the east replication. Each pair of plots had 44 of these "frame locations" giving a total of 748 "frame locations" and 7,480 points on the 17 lines. On each pin-point location, the basal area intercept of all annual and perennial species was read. The reseeded area was sampled during August, 1963. Data from both the reseeded and outside areas were analyzed statistically using standard analysis of variance techniques as described in Snedecor (1962).

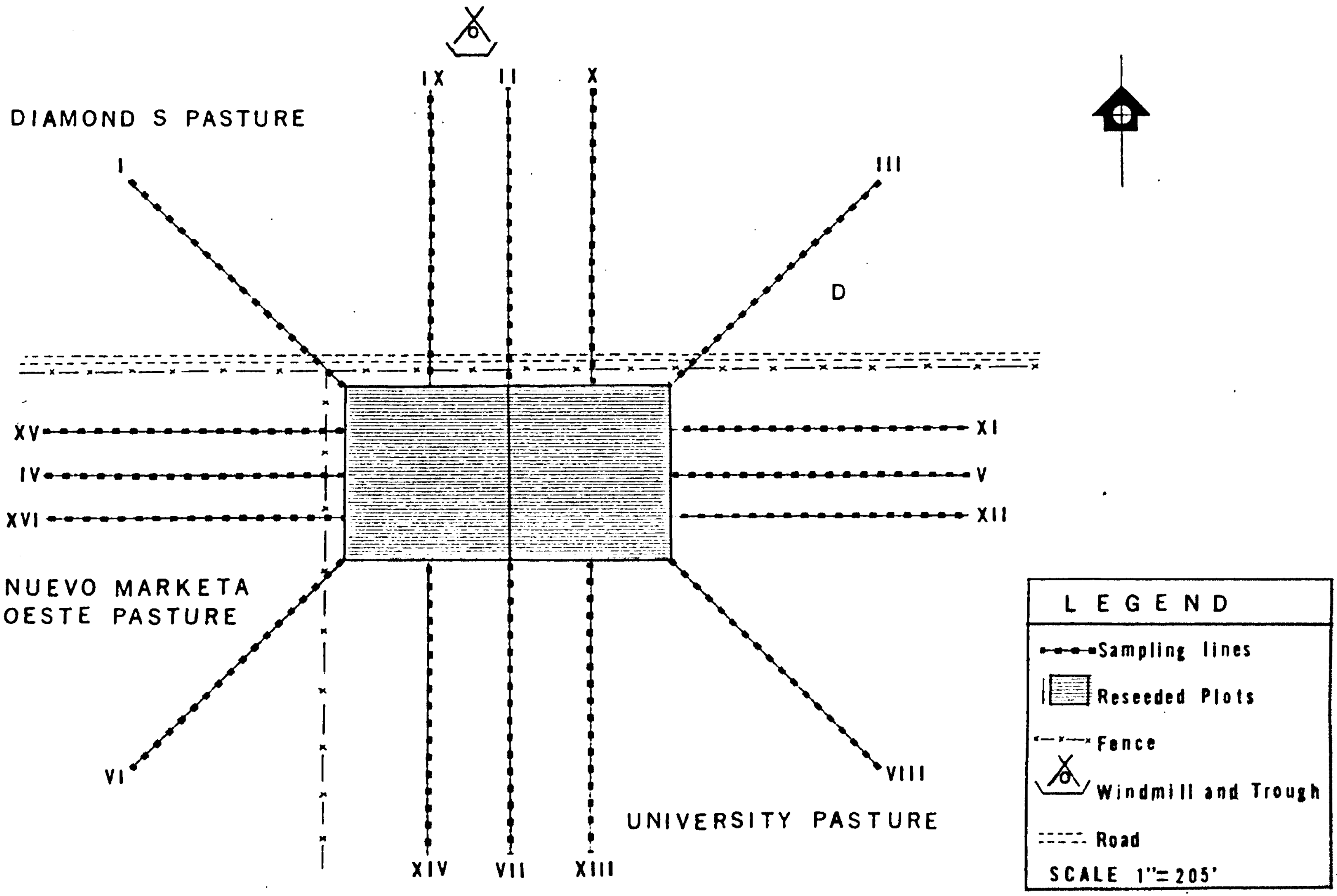
Outside Reseeded Area

Vegetative composition and basal area density of plants spreading outside the plot were determined by sampling 16 transect lines. Each line was 400 feet long with 40 "frame locations" at 10-foot intervals; a total of 400 points were recorded per line. Eight lines were sampled during August, 1963 and the other eight during May, 1964. The sampling-line characteristics are listed in Table 4, and they are located in a diagram (Figure 8).

TABLE 4.--Sampling lines outside the reseeded area.

Line number	Direction	Pasture location	Date sampled
I	N 45 W	Diamond S	August 1963
II	N	Diamond S	August 1963
III	N 45 E	Diamond S	August 1963
IV	W	Nuevo Marketa Oeste	August 1963
V	E	University	August 1963
VI	S 45 W	Nuevo Marketa Oeste	August 1963
VII	S	University	August 1963
VIII	S 45 E	University	August 1963
IX	N	Diamond S	May 1964
X	N	Diamond S	May 1964
XI	E	University	May 1964
XII	E	University	May 1964
XIII	S	University	May 1964
XIV	S	University	May 1964
XV	W	Nuevo Marketa Oeste	May 1964
XVI	W	Nuevo Marketa Oeste	May 1964

Figure 8. Diagram of the sampling lines (I-XVI) outside the reseeded plots.


DIAMOND S PASTURE
NUEVO MARKETA OESTE PASTURE
UNIVERSITY PASTURE
D
I
II
III
IV
V
VI
VII
VIII
IX
X
XI
XII
XIII
XIV
XV
XVI
LEGEND
Sampling lines
Reseeded Plots
Fence
Windmill and Trough
Road
SCALE 1"= 205'

RESULTS

Survival and Spread on Reseeded Plots

Lehmann lovegrass and Turkestan bluestem were the only exotic grasses able to survive in the University Pasture plots. All the native reseeded grasses except slender grama were found in the reseeded area; however, it was not possible to determine if they are descendants from the reseeded ones or if they came from the original plants in the area.

Plots were grouped according to the species or species mixture seeded on them. Recent information about basal density and vegetative composition of these plot groups is presented in Table 5. A statistical analysis of basal point-hits of the six reseeded species on the 34 plots showed a significant dominance of Lehmann lovegrass and curly mesquite in the vegetative community and that Lehmann lovegrass was the more abundant of the two. Early conditions in 1939 and 1940 are presented in Table 6.

The data also show no significant difference in basal density of sideoats grama between plots seeded to this species and plots seeded to other species.

Blue grama presents a different pattern than sideoats grama. The average basal density of 2.0 percent in plots seeded

TABLE 5.--Average percentage basal density and vegetative composition of the species found in the reseeded plots.

Vegetation composition	Reseeded plots																							
	B. grac. 7 plots		*B. curt.* 8 plots		*E. curv.* 2 plots		*E. lehm.* 2 plots		Mix. 1 1 plot		*P. ant.* 2 plots		*C. berr.* 1 plot		*A. des.* 2 plots		Mix. 2 4 plots		*B. hir.* 1 plot		*B. fil.* 1 plot		*A. isch.* 3 plots	
	B.D.	V.C.	B.D.	V.C.	B.D.	V.C.	B.D.	V.C.	B.D.	V.C.	B.D.	V.C.	B.D.	V.C.	B.D.	V.C.	B.D.	V.C.	B.D.	V.C.	B.D.	V.C.	B.D.	V.C.
	Percent																							
Reseeded perennial grasses																								
Eragrostis lehmanniana	2.1	27.0	1.9	19.7	1.6	20.0	1.1	15.3	0.9	10.4	2.7	60.0	2.3	20.2	2.5	19.6	2.3	23.3	3.2	17.2	0.9	11.8	1.2	11.7
Hilaria belangeri	1.0	13.0	1.8	18.8	2.7	32.5	0.2	3.0	6.0	69.8			2.3	20.2	2.7	21.4	2.9	30.2			1.4	17.6	1.2	11.7
Andropogon ischaemum	0.1	1.3	0.8	8.4	0.4	5.4	0.7	9.2							1.4	10.7	0.5	5.6	6.8	36.7	3.2	41.1	2.5	25.4
Bouteloua gracilis	2.0	26.0	0.8	8.4	0.2	2.7	0.2	3.0					0.4	3.5	0.4	3.6	0.8	7.9	1.4	7.3	0.4	5.9	2.1	20.9
Bouteloua hirsuta			0.9	9.4	0.2	2.7	0.9	12.2			0.2	5.0	1.3	11.4	2.5	16.0	0.1	0.9	1.4	7.3				
Bouteloua curtipendula	0.3	3.9	0.6	6.6	0.7	7.0	0.4	6.0			0.2	5.0	0.9	7.9	0.4	3.6	0.5	5.6					0.7	7.3
Subtotal	5.5	71.2	6.8	71.3	5.8	70.3	3.5	48.7	6.9	80.2	3.1	70.0	7.2	63.2	9.9	74.9	7.1	73.5	12.8	68.5	5.9	76.4	7.7	77.0
Other perennial grasses																								
Andropogon barbinodis			0.4	4.0	0.4	5.4	0.9	12.0	0.4	4.7			0.4	3.5	0.9	7.1	0.8	7.9	1.8	9.9	0.9	11.8		
Aristida ternipes	0.6	8.0	0.4	4.0	0.4	5.4	0.2	3.0			0.2	5.0			0.2	1.8	0.3	3.3	0.4	2.4			0.1	1.4
Lycurus phleoides	0.1	1.3	0.4	4.0									0.9	7.9	0.2	1.8	0.1	0.9	0.9	4.8				
Hilaria mutica																			0.9	4.8			0.1	1.4
Panicum obtusum			0.1	0.9			0.2	3.0							0.2	1.8								
Subtotal	0.7	9.3	1.3	12.9	0.8	10.8	1.3	18.0	0.4	4.7	0.2	5.0	1.3	11.4	1.5	12.5	1.2	12.1	4.0	21.9	0.9	11.8	0.2	2.8
Annual grasses																								
Aristida adscensionis	0.3	3.9	0.1	0.9	0.4	5.4	0.4	6.0			0.2	5.0					0.3	3.3						
Bouteloua aristidoides	0.5	6.3	0.5	5.2	0.4	5.4	0.4	6.0	0.9	10.4			2.0	17.5	0.4	3.6							1.2	7.3
Panicum capillare			0.1	0.9			0.2	3.0					0.9	7.9					0.9	4.8			0.3	2.8
Subtotal	0.8	10.2	0.7	7.0	0.8	10.8	1.0	15.0	0.9	10.4	0.2	5.0	2.9	25.4	0.4	3.6	0.3	3.3	0.9	4.8			1.5	10.1
Perennial forbs																								
Sida procumbens			0.1	0.9	0.2	2.7	0.2	3.0																
Cirsium neomexicana																	0.1	0.9						
Evolvulus arizonicus	0.1	1.3																						
Subtotal	0.1	1.3	0.1	0.9	0.2	2.7	0.2	3.0									0.1	0.9						
Annual forbs																								
Portulaca oleracea									0.4	4.7					0.4	3.6			0.4	2.4			0.1	1.4
Euphorbia albomarginata	0.6	8.0	0.6	6.1	0.4	5.4	1.0	15.3			0.9	20.0			0.7	5.4	0.7	7.0	0.4	2.4	0.4	5.9	0.7	7.3
Aplopappus gracilis			0.1	0.9													0.2	2.3			0.4	5.9	0.1	1.4
Franseria confertifolia			0.1	0.9													0.1	0.9						
Subtotal	0.6	8.0	0.8	7.9	0.4	5.4	1.0	15.3	0.4	4.7	0.9	20.0			1.1	9.0	1.0	10.2	0.8	4.8	0.8	11.8	0.9	10.1
Total	7.7	100.0	9.7	100.0	8.0	100.0	7.0	100.0	8.6	100.0	4.4	100.0	11.4	100.0	12.9	100.0	9.7	100.0	18.5	100.0	7.6	100.0	10.3	100.0

B.D. = percent of basal density. V.C. = percent of vegetative composition.

TABLE 6.--Reports on the Condition of the Reseeded Plots (S. C. S. Field Notes).

Plot	Species	Stand November 6, 1939
1-E, 1-W	Bouteloua gracilis	
2-W	Agropyron desertorum	None
2-E	Mixture No. 2	Scattered
3-E, 3-W	Bouteloua curtipendula	
4-E	Panicum antidotale	Thick at east end
4-W	Chloris berroi	Scattering, some headed
5-E, 5-W	Bouteloua gracilis	
6-E, 6-W	Mixture No. 2	
7-E, 7-W	Bouteloua curtipendula	
8-E	Eragrostis curvula	Good-excellent, 6-10 plant/sq. yd.
8-W	Panicum antidotale	Excellent, 6-8 plant/sq. yd.
9-E, 9-W	Bouteloua gracilis	
10-E, 10-W	Eragrostis lehmanniana	Good-very good, 5-10 plants/sq. yd.
11-E, 11-W	Bouteloua curtipendula	
12-E	Agropyron desertorum	None
12-W	Mixture No. 1	Scattering - fair, 5 plants/sq. yd.
13-E, 13-W	Bouteloua gracilis	
14-E	Eragrostis curvula	Fair-good, 2 plants/sq. yd.
14-W	Chloris berroi	Scattered - fair, some headed
15-E, 15-W	Bouteloua curtipendula	Fair-good, 1 plant/sq. yd.
16-E	Mixture No. 1	Scattering - fair, 5 plants/sq. yd.
16-W	Mixture No. 2	All of them, traces of Astrebla
17-E, 17-W	Bouteloua gracilis	Seedlings at the upper end

TABLE 6--Continued

Stand July 26, 1940	Stand November 21, 1940
Replanted to A. desertorum	None
	Fair E. lehmanniana and E. curvula
	Fair 2" basal leaves
	Thin 6-12" growth
Replanted B. hirsuta	Only Bouteloua seedlings
5-W replanted A. ischaemum	Only a light stand of B. gracilis
	E. lehmanniana 20-24", E. curvula 12-18" Hi. be.
	Fair
	Good. Eaten off 3-6"
	12-24" growth with headed plants
	Scattered plants
	Excellent, 28" tall, 3" basal growth
	Scattered plants 3-4"
	None
Replanted B. filiformis	Occasional Astrebla, no B. filiformis
13-W replanted A. ischaemum	No A. ischaemum found
	Light stand 12-16" growth
	None
	Fair 3-5" basal growth
	E. lehmanniana light; few plants E. curvula
17-W replanted A. ischaemum	Scattering of B. gracilis; no A. ischaemum

to blue grama is generally two to ten times greater than other plots not seeded to blue grama.

Of the three plots seeded to blue grama (1939) and reseeded to Turkestan bluestem a year later, the average basal density of blue grama was also about 2.1 percent.

Hairy grama was seeded only in one plot in 1940. The basal density on this plot was 1.4 percent which is the same value found for hairy grama in the plot seeded with Chloris berroi and less than the average (2.5 percent) for plots seeded to crested wheatgrass.

Although only a small amount of curly mesquite was included in Mixture No. 2 (Table 2), it became the most abundant of the native grasses on all the plots (Table 5). Its average basal density on the various plots varies from 4.1 percent to zero. In general, the heaviest stands occurred where reseeded species failed. Curly mesquite has a basal density of 2.9 percent in the four plots seeded with Mixture No. 2; this percentage is very close to the average of all 34 plots. It was noticed that there was a higher frequency of curly mesquite in the southern plots which had a slight degree of slope and probably less available moisture than the northern plots which were more nearly level and perhaps received slightly more moisture.

Lehmann lovegrass, the most dominant plant in the vegetation of the reseeded area, demonstrated a high ability to spread from its original area located in the south part of the plot series (Figure 6). In fact, its original seeded area was increased about 20 times. The average basal density on plots seeded to Lehmann lovegrass is 1.1 percent. However, there are 7 plot groups where Lehmann lovegrass density is almost twice that of those seeded to this species. This grass generally had more dense stands in the strips where the soil was disturbed in 1939 and again in 1940. For instance, the plot seeded to crested wheatgrass in 1939 and a year later to hairy grama had the highest basal area density of Lehmann lovegrass (3.2 percent).

Turkestan bluestem is the second of the exotic grasses and the third plant in order of importance in the reseeded area (Table 5). Data show it has a relatively high basal density of 2.5 percent on plots where this grass was seeded. However, its basal density is even higher in the surrounding area, particularly on adjacent plots that were disturbed and reseeded in 1940 following seeding failures in 1939.

Of the other native vegetation that invaded the reseeded area, the dominant grass species is cane bluestem (or beardgrass) which is 5.6 percent of the total vegetative composition and averages about 0.6 percent basal density. Apparently the density has been increasing in the last 20 years (Figures 9a and 9b). Cane bluestem population does not show any particular pattern of distribution among the plots.

Figure 9a. Fenceline contrast between the east end of the reseeded plots (right) and the open pasture (left) on August 26, 1943 (U. S. Forest Service photograph).

Figure 9b. The same area September 29, 1963.

Spidergrass is another native plant well distributed in the area, but is even less abundant than cane bluestem.

Annual grasses and forbs comprise about nine percent of the total population and average about 0.8 percent basal density. Sixweeks threeawn and sixweeks grama are the most frequent annual grass species encountered. The annual forbs are generally more evenly distributed. Whitemargin spurge (*Euphorbia albomarginata* Torr. and Gray) was found in almost all the plots with a range of variation from 1.5 to 20 percent of the composition and an average basal density of about 0.5 percent. However, it is possible that an overestimation of this plant was made because of its procumbent habit and the method of measurement.

Annual vegetation appeared to be more abundant in the reseeded plots than in the outside area, although this cannot be ascertained completely because of the season involved in sampling the outside area.

Perennial forbs are quite scattered and only three species were detected. Of these, *Sida procumbens* Sw. had the highest frequency.

Spread of Reseeded Grasses Outside the Plot

The spreading ability of the reseeded grasses was determined by 16 transect lines distributed in 3 pastures (Figure 8). The results obtained are presented in Table 7.

TABLE 7.--Average percentage, basal density and vegetative composition of the University, Diamond S and Nuevo Marketa Oeste pastures.

Vegetation	University		Diamond S		Nuevo Marketa Oeste	
	Basal density	Vegetative composition	Basal density	Vegetative composition	Basal density	Vegetative composition
	Percent					
Reseeded perennial grasses						
Bouteloua gracilis	1.6	23.3	1.6	28.4	4.9	54.0
Hilaria belangeri	2.6	37.4	2.3	41.5	0.8	9.1
Bouteloua curtipendula	0.7	10.7	0.1	0.9	0.4	5.0
Eragrostis lehmanniana	0.8	11.2	0.1	2.0	0.1	0.7
Bouteloua hirsuta	0.3	4.3	0.1	0.9		
Andropogon ischaemum	0.1	1.0			0.1	0.7
Subtotal	6.1	87.9	4.2	73.7	6.3	69.5
Other perennial grasses						
Bouteloua chondrosioides	0.1	0.5			1.4	15.7
Bouteloua eriopoda					0.9	9.9
Sporobolus cryptandrus	0.1	1.0	0.1	2.0		
Andropogon barbinodis	0.3	4.3	0.7	12.2		
Lycurus phleoides	0.3	3.9	0.1	1.9		
Enneapogon desvauxii			0.2	3.6	0.3	3.5
Aristida ternipes	0.1	1.4	0.2	3.8	0.1	1.4
Bouteloua rothrockii	0.1	0.5				
Panicum obtusum	0.1	0.5				
Tridens pulchellus						
Subtotal	1.1	12.1	1.3	23.5	2.7	30.5
Perennial forbs						
Evolvulus sericeus			0.2	2.8		
Subtotal			0.2	2.8		
Total vegetation	7.2	100.0	5.7	100.0	9.0	100.0

In general, exotic grasses did not move outside the plots to any great extent. Lehmann lovegrass had a basal density of 0.8 percent and comprised 11.2 percent of the vegetative composition in the University Pasture. This is less than half the basal density of the reseeded plots. Lehmann lovegrass plants were found about 300 feet east of the plots and 400 feet south of the plots although they were groups of a few plants which were not detected by the transect lines.

In the Diamond S Pasture, Lehmann lovegrass had less density than in the University Pasture. Basal density was 0.1 percent and comprised about 2 percent of the vegetative composition. However, it was observed that Lehmann lovegrass moved farther in this pasture. Isolated small colonies were observed about 800 feet north of the reseeded area.

On the Nuevo Marketa Oeste Pasture only one hit of Lehmann lovegrass was recorded, and its distribution is restricted to the area close to the division fence with the University Pasture. About 150 feet west of the fence was the limit of Lehmann lovegrass observed in this direction.

Turkestan bluestem was even a poorer spreader than Lehmann lovegrass. Two hits were recorded in the University Pasture, none in the Diamond S and only one in the Nuevo Marketa Oeste Pasture. Again it was not possible to determine if the native reseeded grasses spread from the reseeded plants or from the indigenous ones.

Nuevo Marketa Oeste Pasture had the highest average total plant basal density of 9.0 percent. The University Pasture was second with 7.2 percent basal density and Diamond S was lowest with 5.8 percent. The average basal density of the three pastures was 6.9 percent compared to an average of 7.8 percent for the 34 reseeded plots (Table 8). The three pastures have very similar environmental characteristics; therefore, the principal cause of differences in vegetative cover obviously was their specific management methods.

Nuevo Marketa Oeste Pasture shows not only a higher percentage of basal density but also a different vegetative composition. Black grama and sprucetop grama together are about 25 percent of the total vegetative composition. These species are relatively scarce in the other pastures.

Grass Utilization

The available data of exotic-grass utilization are in agreement with previous information reported about introduced lovegrass in the Southwest. Crider (1945) summarized the utilization observations taken by the Soil Conservation Service personnel in the study area during 1940 and 1941. He reported that weeping lovegrass was abundant at that time. It evidently disappeared sometime between August 1943 (Figure 10) and August 1963.

TABLE 8.--Average percentage of basal density and vegetative composition of the reseeded plots and the outside areas (University, Diamond S and Nuevo Marketa Oeste pastures).

Vegetation measured	Areas measured: Reseeded plots: Basal density	Reseeded plots: Vegetative composition	Outside areas: Basal density	Outside areas: Vegetative composition
	Percent			
Reseeded perennial grasses				
Eragrostis lehmanniana	2.0	25.4	0.4	5.7
Hilaria belangeri	1.8	22.7	2.1	29.7
Andropogon ischaemum	1.0	13.1	trace[a]	0.7
Bouteloua gracilis	1.0	12.3	2.4	34.2
Bouteloua hirsuta	0.6	7.3	0.1	2.2
Bouteloua curtipendula	0.5	5.8	0.5	6.6
Subtotal	6.9	86.6	5.5	79.1
Other perennial grasses				
Andropogon barbinodis	0.5	5.6	0.2	2.4
Aristida ternipes	0.3	4.2	0.1	1.1
Lycurus phleoides	0.1	1.8	0.2	2.4
Hilaria mutica	trace[a]	0.6		
Panicum obtusum	trace[a]	0.5	trace[a]	0.2
Bouteloua chondrosioides			0.4	5.1
Bouteloua eriopoda			0.2	3.3
Sporobolus cryptandrus			0.2	3.3
Enneapogon desvauxii			0.1	2.0
Bouteloua rothrockii			trace[a]	0.2
Tridens pulchellus			trace[a]	0.2
Subtotal	0.9	12.7	1.4	20.2
Perennial forbs				
Sida procumbens	trace[a]	0.5		
Cirsium neomexicana	trace[a]	0.1		
Evolvulus arizonicus	trace[a]	0.1		
Evolvus sericeus			trace[a]	0.7
Subtotal	trace[a]	0.7	trace[a]	0.7
Total	7.8	100.0	6.9	100.0

[a]Below 0.1 percent.

Figure 10. An aspect of the exotic grass utilization on August 26, 1943. Arrow points to a heavy cropping of weeping lovegrass. On the left plants of Lehmann lovegrass are lightly grazed. (U. S. Forest Service photograph).

Observations taken in 1940-41 (Table 9) show big differences in utilization between grasses. In March, 1941, weeping lovegrass had 80 percent utilization, Lehmann lovegrass 30 percent, and the native grasses averaged only 10 percent utilization. Selective utilization between weeping and Lehmann lovegrass is also shown in Figure 11. The higher palatability of the introduced grasses resulted from the fact that the basal portion of the leaves and stems of Lehmann and weeping lovegrasses remain green and succulent during the cold season; consequently, they are more palatable than native grasses which usually are dry.

During the summer of 1963 and the winter of 1963-64 qualitative observations were made on utilization of the two exotic grasses present, Lehmann lovegrass and Turkestan bluestem. Lehmann lovegrass was found to be consumed by cattle at a very low rate during the summer and native grasses were preferred. In the winter the situation is reversed. Lehmann lovegrass is still green at this time (Figure 11a) and is grazed more heavily (Figure 11b).

Turkestan bluestem is consumed very little throughout the year. A few grazed plants were observed during the late spring and early summer. Ranch personnel have also observed this situation for several years.

TABLE 9.--Utilization of weeping and Lehmann lovegrasses in comparison with the native perennials in the winter and spring of 1940-41 (from Crider, 1945).

Date of examination	Weeping lovegrass	Lehmann lovegrass	Native species
October 1	a	none	slightly
October 14	30%	none	slightly
October 28	35	5%	less than 10% each
November 27	40	10	less than 10% each
December 28	65	15	less than 10% each
January 11	70	15	less than 10% each
January 25			
March 7	80	30	10% each
April 1	none	none	none
May 1	none	none	none

[a]Mainly the seed stalks were utilized.

Figure 11a. Lehmann lovegrass plant showing green basal leaves on March 29, 1964.

Figure 11b. Lehmann lovegrass plant heavily grazed by cattle on May 10, 1964.

DISCUSSION

Results obtained in this study in general support the conclusions from previous reseeding trials made with introduced and native grasses in the southwestern desert grassland.

Some Factors Affecting Seedling Establishment

Some of the principal factors involved in seedling establishment are available moisture, ability to compete with native plants, and protection from grazing.

Precipitation in 1939 was 1.5 inches below the 25-year average while in 1940 it was 6.5 inches above this average. Rainfall distribution within these years generally followed the normal pattern; about 50 percent of the annual precipitation was recorded in July, August and September. Therefore, a rainfall-stress year was not the limiting factor in the grass seedlings establishment.

The importance of seedbed preparation, which affects the available moisture and the ability of reseeded plants to compete with native vegetation, is well recognized as a factor in the success of reseeding practices (Anderson et al. 1957, Barnes and Anderson, 1944; Bridges, 1942; Douglas et al., 1960; Hamilton, 1959). However, seedbed preparation was not a variable in this study since the reseeded areas were given similar treatment both years.

Grazing undoubtedly had an effect on seedling success. The reseeded area was closed to cattle until the fall of 1940 (the exact date is unknown). The reseeded plots in 1939 had about one year of protection, but the six plots reseeded in 1940 were free from grazing only about two months after reseeding. The early grazing following the 1940 plantings obviously had an important effect in the grass seedling establishment since almost all the literature that has been written about range reseeding in the Southwest recommends at least one-and-a-half or preferably two years of seedling protection from grazing.

Evaluation of the Reseeded Native Grasses

The results obtained from the native reseeded grasses are difficult to evaluate because all of them except slender grama were present in the site before seeding. However, all available information indicates that the vegetative stand was quite open (Figure 10a) in most of the pasture prior to the reseeding operation. Unfortunately, this information is based on only visual estimations.

Sideoats grama and curly mesquite were the only native species which showed fair to good stands in 1939 and 1940. Blue grama and other native grasses seeded did not have very much success during the early period following seeding, and the plots were reported bare or with only scattered plants.

The results obtained 23 years later show a very different picture from the early condition reported. Today curly mesquite, which is one of the desert grassland species more efficient in the use of water (McGinnies and Arnold, 1939), is the second dominant plant in the reseeded plots. Even though this grass was seeded at a low rate in Mixture No. 2 it was able to spread rapidly since the seeding.

In 1963 blue grama had an average basal density of 2.0 percent (which represents up to 26 percent of the vegetative composition) in the plots where it was seeded. This was as might be expected greater than in adjacent plots where it was not seeded. Some of the other seeded native grass species, however, had a higher percentage basal density in some plots where they were not seeded than in plots where they were seeded.

The average basal density in 1963 in plots seeded to blue grama in 1939 and to Turkestan bluestem the following year (because of the 1939 seeding failure) was not significant. This may have been due to the possibility that the seed provided in 1939 did not germinate until the third or fourth year after seeding. Wolff (1951) reported that the average longevity period of blue grama seed in storage is about 4 years, but longevity in the soil is probably less. Rodents may also be an important factor in seeding success of all species. A more acceptable possibility is that the introduced seed failed, and blue grama seed from native plants in the vicinity invaded the open spaces. This conjecture can also be applied to all the native grasses seeded except sideoats grama and curly mesquite which had some success in the early years following the seeding. It is likely that the present sideoats grama and curly mesquite stands are descendants, at least partially, of the artificially seeded plants.

Seeding of mixtures of seeds is considered to have several advantages over seeding one species alone (Springfield and Reynolds, 1951; Hull et al., 1950; McWilliams and Cleave, 1960). However, in this study the seeded mixtures did not have any apparent advantages over seeding of a single species. This was true for both the native and the exotic grasses.

Evaluation of the Reseeded Exotic Grasses

The two Australian Mitchell grasses in Mixture No. 1 were rated fair in establishment the first year (1939) with a reported stand of about 5 plants per square yard (Table 6). However, by November 6, 1940 only occasional plants were observed in the plot. In 1963, there was not a single Mitchell grass plant in the reseeded area. The established plants probably did not set seed; this is a condition that frequently occurs in their native area of north Australia (Roe, 1940). It is also possible that these grasses failed because the low rainfall and sandy soils of the reseeded area is very unlike their native area where the rainfall varies from 10 to 30 inches and the soils are high in clay.

Chloris berroi seedlings were also observed in 1939, but were not found in 1940. Blue panic was reported present in both 1939 and 1940, and even some headed plants were observed. However, both of these species disappeared before 1963, apparently because their water requirements are higher than the average moisture available in the study area.

Crested wheatgrass, which was added to the reseeding species list at the request of Mr. Larrimore the ranch owner at that time also was a complete failure.

Springfield and Reynolds (1951) pointed out that 15 inches of rainfall was the lower limit for successful crested wheatgrass seeding. On the other hand, Eckert *et al.* (1961) reported that this grass can be seeded in sites of less than 10 inches, but that it should be restricted to the bottom lands subjected to stream overflow. Neither of these conditions is present on the reseeded area; therefore, it is logical that crested wheatgrass seedlings were not even established.

The Turkestan bluestem seed utilized probably is a variety very similar to El Kan which was described by McGinnies *et al.* (1963) as a grass very easily established but relatively unpalatable compared with the native species. Obviously it is not the variety described by Nixon (1949) as a palatable grass for all kinds of livestock. Anderson *et al.* (1957) reported that Turkestan bluestem seeded in Arizona is very similar to the King Ranch variety; however, this variety was reported by McGinnies *et al.* (1963) as fairly palatable, while that in the University Pasture is very unpalatable.

Weeping lovegrass had fair to excellent establishment in 1939 with about 6 to 10 plants per square yard. In 1940 the stand was observed good to light. Also weeping lovegrass, together with Lehmann lovegrass, was a dominant grass in the plots seeded with Mixture No. 2. The last indication of the presence of weeping lovegrass in the area is a photograph taken by the Forest Service on August 26, 1949 (Figure 11). Weeping lovegrass disappeared some time between that date and 1963, probably during the dry years 1950 or 1953 when the rainfall was 5.3 inches, almost one-third of the regional average. Crider (1945) described weeping lovegrass as a cold resistant species. Therefore, it is suggested that moisture stress rather than low temperatures, together with the reported abusive utilization rate by cattle, killed the weeping . .

lovegrass. Valentine (1945) also found that weeping lovegrass was unsuited for the lower desert grassland.

Observations in Table 9 and Figure 11 indicated that weeping lovegrass had about 80 percent utilization during the winter and spring of 1940-41. However, Scott (1952) stated that weeping lovegrass is not a palatable species in South Africa because of its high fiber content.

Lehmann lovegrass became the most abundant plant on the reseeded plots. Good stands with an average of 5 to 10 plants per square yard were observed in November 1939, and an excellent stand with 28-inch tall plants was reported in November 1940. A photograph taken on August 26, 1943 (Figure 12a) showed a densely populated Lehmann lovegrass strip in contrast to the bare surrounding area.

The ability of Lehmann lovegrass to become easily established has been commonly observed since the introduction of the grass in the Southwest. An important characteristic supporting this ability is the indifference of this grass to the day length in producing seed, reported by Whyte et al. (1959). Also, Lehmann is a prolific seed producer which helps account for its ability to spread (Crider, 1945). It seems to be a very well adapted species in the desert grassland, although in its native ranges of South Africa it usually thrives at higher precipitation zones of about 19 inches (Acocks, 1953).

Figure 12a. Plot 16-E with Lehmann lovegrass on August 26, 1943 (U. S. Forest Service photograph).

Figure 12b. The same area 20 years later on September 29, 1963.

Crider (1945) stated that low temperature is a very important factor in survival of Lehmann lovegrass in the desert grassland. Boyle (1945) determined 15° F. as the lowest temperature at which it could survive. However, low temperature is probably not a limiting factor in the study area since Lehmann lovegrass was able to survive there for 24 years. This conclusion is also supported by the fact that the monthly average minimum temperature in January registered at Fort Huachuca is only 30° F.

Lehmann lovegrass in South Africa is classified as an invader species (Meredith, 1955) which forms a secondary vegetative stage when the grassland of _Themeda_ sp. is degraded by misuse. Humphrey's opinion (1958b), based on Lehmann's aggressiveness and low palatability, indicated the potential danger that Lehmann lovegrass will become another invader plant along with burroweed [_Aplopappus tenuisectus_ (Greene) Blake.] and mesquite, displacing better native grasses in the desert grassland. Kincaid _et al._ (1959) found reduction of native grasses because of the characteristics of Lehmann lovegrass cited above. However, in the studied site it was found that Lehmann lovegrass became dominant only when the native sod was destroyed, and that it was not able to displace the native grasses when they were not removed. Even under conditions of overgrazing such as in the Diamond S Pasture which is a sacrifice area near to the water, the selective grazing did not result in a dominance of Lehmann lovegrass.

In the Nuevo Marketa Oeste Pasture, which had a dense cover of native grasses, Lehmann lovegrass moved only a short distance into the pasture and only isolated plants became established, despite the fact that the prevalent wind direction all year, except in December (Figure 5), is toward this pasture. Williams (1964) found a similar behavior of Lehmann lovegrass. He also assumed that Lehmann's spreading is restricted to years with above average precipitation. Therefore, under different conditions of higher mean temperature and rainfall it is possible that Lehmann's aggressiveness may be increased.

Lehmann lovegrass was observed to spread farthest toward the north; however, the basal density of this grass was not great in any direction compared to the density of native grasses outside the plots. (Table 7). Williams (1964) attributed the spread of lovegrass to wind and water. In the present case the prevalent wind direction is from the west and southwest (Figure 5); therefore, wind direction could have also been a cause. The influence of water runoff as a vehicle which moved the seed seems questionable in this case because of the slight degree of slope. Grazing animals also possibly had some effect in transporting seeds toward the north in the Diamond S Pasture since grazing was greatest in this direction. Probably a more critical factor affecting spread of Lehmann lovegrass, however, is the competition from native grasses (Kincaid et al., 1959). The Diamond S Pasture where Lehmann lovegrass spread about 800 feet to the north had a percent basal density of only 5.8, while the University Pasture where Lehmann lovegrass spread about 400 feet to the south had a percent basal area of 7.2. The dominant direction of the agents of transportation is probably of secondary importance, and the most important factor is competition from native grasses.

Palatability of Lehmann lovegrass is generally low. Its utilization is predominantly during the winter and spring seasons because it is green at that time when other grasses are dry. During the summer and early fall native grasses are more palatable (Stanley and Hodgson, 1938). Lehmann's low palatability is also common in South Africa where they burn the grassland with several objectives, one of them being to improve its utilization (Bews, 1918; Scott, 1952; Meredith, 1955). Another means of improving the palatability was demonstrated by Holt and Wilson (1961). They increased the utilization of Lehmann lovegrass three, four and five times by applications of 25, 50 and 100 pounds of nitrogen per acre, respectively. Bentley (1964) found a significant increase in the crude protein content due to nitrogen fertilization and probably the palatability was increased in proportion to the protein (Stanley and Hodgson, 1938).

The results obtained by this study show that reseeding of native grasses in general was not successful. At the present time there is not a significant difference between the native grass population in the reseeded plots and the average outside area (Table 8). The majority of the present grass plants probably came from the indigenous plants established in the area before the reseeding operation. Their seeds were spread and the seedlings were able to thrive under lighter grazing pressure. Therefore, artificial seeding of the University Pasture apparently was unnecessary. But under different conditions where there is a total absence of natural seed sources, the value of providing seed from outside sources can be vindicated.

Turkestan bluestem had some success in the reseeded area despite the fact that it was not able to spread outside. It seems to be a good grass to be used in erosion control but because of its low palatability, the strain used in this study would be almost worthless as a forage plant.

Lehmann lovegrass has several advantages and disadvantages as a grass to be seeded in the Southwest. The seeding of Lehmann lovegrass is not necessary in sites similar to the University Pasture where there are remnants of good native species, but it can be justified on desert grassland ranges with only scattered sources of desirable grass seed. In addition to its easy establishment, Lehmann provides soil protection and green forage production during the critical cool period.

SUMMARY

A vegetative analysis was made (summer 1963 and the spring of 1964) by using the point-plot method in a desert grassland site near Sonoita, Arizona, where 34 plots were seeded to various native and exotic grasses in 1939 and 1940 (by a joint team of Soil Conservation Service, Forest Service, University of Arizona and Mr. R. C. Larrimore).

The results obtained by this study were:

1. All the native grasses seeded, except slender grama, were found in the plots. However, it was not possible to determine whether the plants resulted from the reseeding or from native plants in the adjacent area. Blue grama showed a higher population on its reseeded plots; however, some other species had a greater population on adjacent plots where they were not seeded than on the plots where they were seeded. Apparently reseeding of native grasses was not justified in this site.

2. The exotic grasses--curly Mitchell grass, hoop Mitchell grass, blue panic, Chloris berroi, and crested wheatgrass--were not able to survive on the reseeded strips.

3. Weeping lovegrass was well established and utilized by cattle at a high rate. It disappeared sometime between August 1943 and August 1963.

4. Turkestan bluestem survived in the site and spread only in the area near its original plots; it was not able to move outside the reseeded area. Palatability of the Turkestan bluestem strain used in this study is so low that it is worthless for grazing.

5. Lehmann lovegrass was the dominant species in the 34 plots. However, it did not spread to become an important species into the community outside of the reseeded plots. Apparently Lehmann lovegrass is dominant only when the native sod was disturbed by mechanical means. Palatability is low during the growing season and high in the spring and winter when the grass remains green.

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