OBSERVATIONS ON THE SURVIVAL OF NATIVE AND EXOTIC PLANT SPECIES IN RANGE TRIAL PLANTINGS IN SOUTHERN ARIZONA

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by

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OBSERVATIONS ON THE SURVIVAL OF NATIVE AND EXOTIC PLANT SPECIES IN RANGE TRIAL PLANTINGS IN SOUTHERN ARIZONA

Introduction

The establishment of vegetative cover on certain areas of the southwestern range lands presents a difficult problem. Before progress can be made in the establishment of vegetation, it is necessary to determine what plants have the drought-resistant qualities which will enable them to survive the periods of low precipitation and high evaporation common to the desert grasslands of the Southwest.

The objective of this study was to determine species of native and exotic grasses, herbs and shrubs which are adapted for artificial reseeding of problem areas in need of a vegetative cover in the southwest. Observations were made on the ease of establishment, rate of growth, survival, and ability to spread.

The determination of suitable species is logically a first step in solving the problem of establishment of a vegetative cover by artificial reseeding. After these species have been determined, major effort can be concentrated on methods of establishment; most effective moisture conserving devices which facilitate establishment; and range management practices necessary to maintain and improve initial stands.

This paper does not attempt to cover methods of establishment and management practices, although it does touch upon methods of establishment used on the Tucson City Farm.

The determination of adaptable species has a highly practical application and fills a need growing greater each year. Ranchers and stockmen are making an increasing number of inquiries concerning the desirable species to plant on depleted desert grassland ranges in southern Arizona and southern New Mexico. County Agents, Extension Service specialists, and the field technicians of state and federal agencies interested in revegetation must be able to base their recommendations on proven species.

The trial of promising exotic species is of particular importance, since little is known of the adaptation of these introduced plants to southwestern conditions. In some cases promising species for revegetation in this region have not been used in their native habitat. For example, Lehmann lovegrass[1] (Eragrostis Lehmanniana), an exotic grass imported from South Africa, has given good results in desert grassland plantings in southern Arizona and southern New Mexico. Technical men acquainted with this grass in South Africa, have upon visiting the Soil Conservation Service Nursery at Tucson, reported Lehmann lovegrass is considered a weed or an invader species in their country, among the first to come in on fallow land or disturbed soil. There, it has not been used in revegetation work and is not considered of particular value.

1. The common names used in this paper are those published in Standardized Plant Names, 2nd Ed. Compiled by Harlan P. Kelsey and William A. Dayton 675 pp. Harrisburg, Pa. 1942.

In other cases, adaptability to alkaline soils, eroded desert soils, water-spreading areas, and various sites, has not been determined in the native country. The determination of the adaptation of the exotic species is therefore of primary importance.

An important point in the selection of any species for a given site is the time required to make significant growth under the range of soil and moisture conditions which will obtain. The climatic conditions of Southern Arizona and Southern New Mexico are such that summer growing species must become sufficiently established thru the summer months to survive the severe drought period in late spring and early summer, then resume growth with the advent of the summer rains. The time required under those conditions which prevail for a bunchgrass to make a strong, robust clump, or for a stoloniferous or rhizomatous grass to make a sod, is a factor that should be considered in determining the suitability of the species. It will be seen that these characteristics must be determined through careful observations for more than one season.

Review of Literature

Reports of reseeding work undertaken on desert and desert grassland ranges in the Southwest are few in number, although there are numerous publications dealing with revegetation in the Intermountain Region. Stewart and others (12), Price (9), and Forsling and Dayton (4) have reported on artificial revegetation trials with brome grasses and wheat grasses, species

which are not adapted to desert grassland plantings in the Southwest. The earliest recorded attempt at revegetation in Southern Arizona was undertaken by Dr. David Griffiths in 1900 and 1901 (5), and continued by J. J. Thornber through 1910 (13). Extensive trials were conducted in New Mexico by C. P. Wilson (15) in February, 1931, and reported by Wilson and others in 1936 (16). Experiments in reseeding on the Jornada Range were reported by Cassidy in 1937 (3). Cassidy and Glendenning in a recent publication (2) have discussed the subject of revegetation of semi-desert ranges in some detail, and in this publication have touched upon the selection of species and reseeding methods. Parker and McGinnies have covered the field broadly.[1] They have based their selection of certain species adapted in the area referred to as "Range 1" in their publication, on the cooperative work at the Northwest Station (Santa Rita Desert Tank) on the Santa Rita Range Reserve near Tucson, Ariz. These reseeding tests were carried on by the Soil Conservation Service Nursery Division in cooperation with the Southwest Forest & Range Experiment Station. In this paper the writer has described additional exotic species which have given promise, as well as presented additional evidence on the survival and adaptation of species listed by Parker and McGinnies. Savage (11) describes the use of native and exotic grasses in range reseeding in the Southern Great Plains. Two exotics, weeping lovegrass and Lehmann lovegrass, are discussed briefly.

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1. Parker, K.W., and McGinnies, W.G. Reseeding Southwestern Ranges, Research Notes, Southwestern Forest & Range Experiment Station, Note No. 86 5 pp. June 1940 (mimeographed)

No report is available on the results of Griffiths' planting, but J. J. Thornber, who continued Griffiths' work, reported only a scattering of grass on the better of the plots at the end of the second year (13). According to Dr. Thornber:

> "The failure of the above experiments is all the more pronounced when it is recalled that both the summer and winter rainy seasons were quite up to the average. Although these were followed by a remarkably dry year which was a severe test for any but well established drought resistant species."

Extensive trials were conducted by C. P. Wilson in 1931 (15), some of which were reported by Wilson and others in 1936 (16). Many of the same species tested by the writer were planted in plots located throughout southern and central New Mexico at State College, Temporal, Roswell, Whitewater, and Estancia. No information is available on the plots planted in the desert grassland type.

Cassidy and Glendenning (2) make this statement concerning the possibility of successful reseeding on semi-desert range:

> "The chances for successful reseeding of semi-desert range depend to a large degree on moisture conditions and the extent of range deterioration as well as on the amount of control that can be exercised over livestock, rodents, and erosion."

Bridges (17) reports successful reseeding on the College Ranch at Las Cruces, New Mexico, under ten inches of rainfall. Species which have shown most promise to date are Rothrock grama, Lehmann lovegrass, and Boer lovegrass.

Close contact with the trial plantings of the Soil Conservation Service Nursery Division has broadened the scope of observations possible in this study. In 1937 the Nursery Division initiated trial plantings at the Tucson City Farm,

the Wilshaw Ranch at Patagonia, and at the Santa Rita Desert Tank. The writer has conducted the planting operations and observations on the areas in the vicinity of Tucson since the summer of 1938, has visited most of the plantings reported upon by Marshall and Downs,[1] and has worked with species discussed by E. L. Flory.[2] He has made observations on many of the areas planted in Southern Arizona by the Soil Conservation Service, the Indian Service, and the Extension Service in cooperation with the Soil Conservation Nursery.

The subject of mechanical aids to establish vegetation is discussed by Cassidy and Glendenning (2) and by Rowalt and specialists of the Soil Conservation Service (10). The latter state, "Contour furrowing is considered by many to be one of the more effective soil and moisture conservation practices now employed in the Southwest."

Rowalt considers percolaters of rock, brush, or a combination, effective checks to erosion on land sloping not more than 10 feet to the 100 in which gullies have not formed. He describes the use of water spreaders constructed of earth, rock, brush, or a combination of these materials to spread water that is concentrated in gullies and arroyos.

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1. Marshall, Charles G. & Downs, J.A. Preliminary Progress Report - Plant Observational Project, Summer 1938, U.S.D.A. Soil Conservation Service Nursery Division, Albuquerque, N.M., July 1939 58 pp. (mimeographed).

2. Flory, E.L. Preliminary Observations on Artificial Revegetation, Native and Exotic Grasses Suitable for Use in Soil and Water Conservation, U.S.D.A. S.C.S. Feb. 11, 1939 Albuquerque, N.M. 40 pp. (mimeographed).

Glendenning has obtained good results with mulch on eroded desert grassland soils.[1,2] Mulch has the disadvantages of high cost of handling, difficulty of spreading evenly, and a tendency to blow off the area where it is spread. Blowing may be reduced by disking the mulch into the soil; however, some mulches do not seem to be as effective when handled in this manner. The use of mulch can be justified on critical sites, particularly where material is readily available.

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1. Glendenning, George E., Litter Aids Germination of Grass Seeds and Establishment of Grass Seedlings. Research notes, Southwestern Forest & Range Experiment Station, Note No. 7, 2 pp. March 1937 (mimeographed).

2. Comparison of the Effects of Various Kinds of Artificial Litter upon the Germination of Grass Seeds. Research Notes, Southwestern Forest & Range Experiment Station, Note No. 61, 3 pp. July 1939, (mimeographed).

Experimental Procedure and Results

The plantings from which the observations reported in this paper were made were located on the desert and desert grassland types in southern Arizona and New Mexico at elevations from 2300 to 4500 ft. The desert grassland type includes the vegetation on the foothills, mesas and valleys in southeastern Arizona below the level of the oak woodland and above the creosote desert. It is characterized by mixed stands of blue, hairy, and slender gramas, and curly mesquite at the higher elevations. Rothrock and black grama, three awns, and cottongrass predominate at lower elevations with tobosa on the flats and swales. Burroweed, snakeweed and mesquite have replaced grasses over much of this type.

Desert areas considered in this paper are those bordering on the desert grassland. They are characterized by creosote bush, mesquite, cactus, and needle grama on the coarse-textured soils and mesquite and saltbush on the finer textured, compact, alkaline soils.

Observations were made at four planting sites in southern Arizona: the Tucson City Farm, the Santa Rita Desert Tank on the Santa Rita Range Reserve, Sonoita, and Pearce. Information gathered from plantings on the Papago Indian Reservation, the Williamson Valley near Prescott, the College Ranch at Las Cruces, and from field plantings in the Sulphur Springs Valley has been used to support the selection and range of species adapted to particular sites.

Rainfall on the plantings averaged from nine inches at Las Cruces, New Mexico, to 14 inches at Sonoita, Arizona.

Plantings were made in rod rows and in broadcast plantings. Soil and moisture conservation measures in the form of contour furrows, contour corrugations, low dikes or ridges, subsoiling, water-spreading and mulching were used in conjunction with the seedings. Planting was done by hand or with a cyclone seeder.

Observations were taken at the time of emergence, after emergence, at the end of the growing season, prior to the spring and summer drought period, and after the summer rains began. Ocular observations were made on the height, growth, percentage of stand, and number of volunteers appearing. More frequent observations were possible on the Tucson City Farm plot as it was close to the Nursery.

Site A - Tucson City Farm

This plot is located adjacent to the 35 acres of City Farm land occupied by the Soil Conservation Service Nursery. The plot consists of 17 acres, of which about 4 acres were planted yearly in 1938, 1939, and 1940. In 1938 the 17-acre plot was contour furrowed and additional contours have been added from time to time.

The plot may be divided into two different general types of soil: a sandy loam, and a silt loam comprising the heavier soil which makes up the greater part of the area. In parts of the area this silt loam is characterized by highly-dispersed

impermeable, alkaline areas, on which scarcely any vegetation can secure a foothold. These areas occur on the steeply-sloping northeast corner of the plot and on the gently-sloping southern half of the plot. The western half of the area is rather flat and has a sandy to silt loam soil which is more permeable than the soil on the slope and supported a good growth of weeds.

Precipitation records beginning with July 1938 were kept for three years on the area and are given in Table I. Runoff water from the slope to the east of the plot was diverted by a ditch, but broke over in 1938 and 1939. This resulted in broken contours, as well as in additional runoff water reaching the flat below the slope. For two successive years, in 1939 and 1940, the Santa Cruz River overflowed its banks and covered the flat area with flood water. Upon receding this left a light deposit of silt in 1939 and a deposit up to one inch thick over much of the area in 1940. The area is fenced from livestock; in the fall of 1938, a rabbit-proof fence was erected around the plot.

The planting in the summer of 1938 included row plantings and broadcast plots. The row plantings were seeded in contour furrows made with a plow followed by a border disk. Seed scattered by hand in the furrow strips, along the side of the ridge, was lightly covered with a rake.

Forty-one species of grasses, herbs, and shrubs were planted along the contour furrows in 30-foot lengths. The seed beds on the broadcast plots were prepared by light disking. The plots were seeded by hand, mulched with straw,

TABLE I

MONTHLY PRECIPITATION AT THE TUCSON CITY FARM, SANTA RITA DESERT TANK AREA, AND SONOITA PLANTINGS 1938 - 1940

1938	Tucson City Farm	Santa Rita	Sonoita
July	.78	1.36	
Aug.	2.37	2.27	
Sept.	.70	.23	
Oct.	.00	.00	
Nov.	.07	.06	
Dec.	1.07	.63	
1939			
Jan.	.42	.35	
Feb.	1.61	1.03	
Mar.	.54	.12	
April	.03	.32	
May	.00	.00	
June	.00	.39	
July	.77	2.36	
Aug. (Flood)	2.01	2.83	4.32
Sept.	1.83	1.25	.84
Oct.	.00	.50	1.54
Nov.	.88	.23	.88
Dec.	.31	.42	.56
YEARLY TOTAL	8.30	9.80	8.14
1940			
Jan.	.70	.16	.40
Feb.	1.76	1.81	1.04
Mar.	.02	.00	.00
April	.18	.24	.00
May	.50	.10	.?
June	1.02	2.03	3.90
July	.56	2.36	3.08
Aug. (Flood)	1.43	3.83	5.07
Sept.	1.75	3.33	2.74
Oct.	.35	.93	.13
Nov.	2.02	.58	1.43
Dec.	3.04	2.31	3.56
YEARLY TOTAL	13.33	17.68	21.35

MONTHLY PRECIPITATION
TUCSON CITY FARM
1938 - 1940

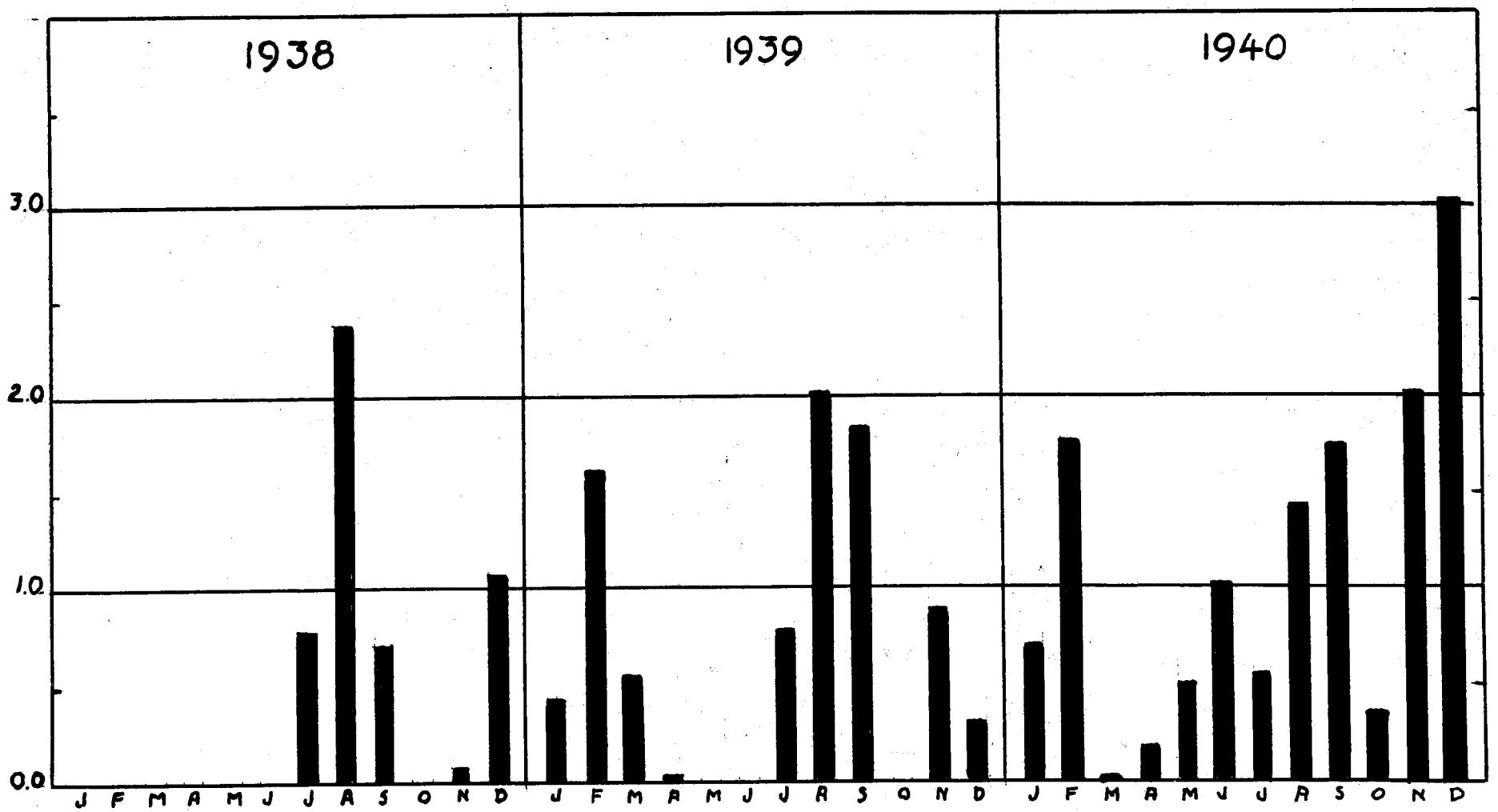

TABLE I a.

MONTHLY PRECIPITATION
SANTA RITA DESERT TANK PLANTING
1938 - 1940

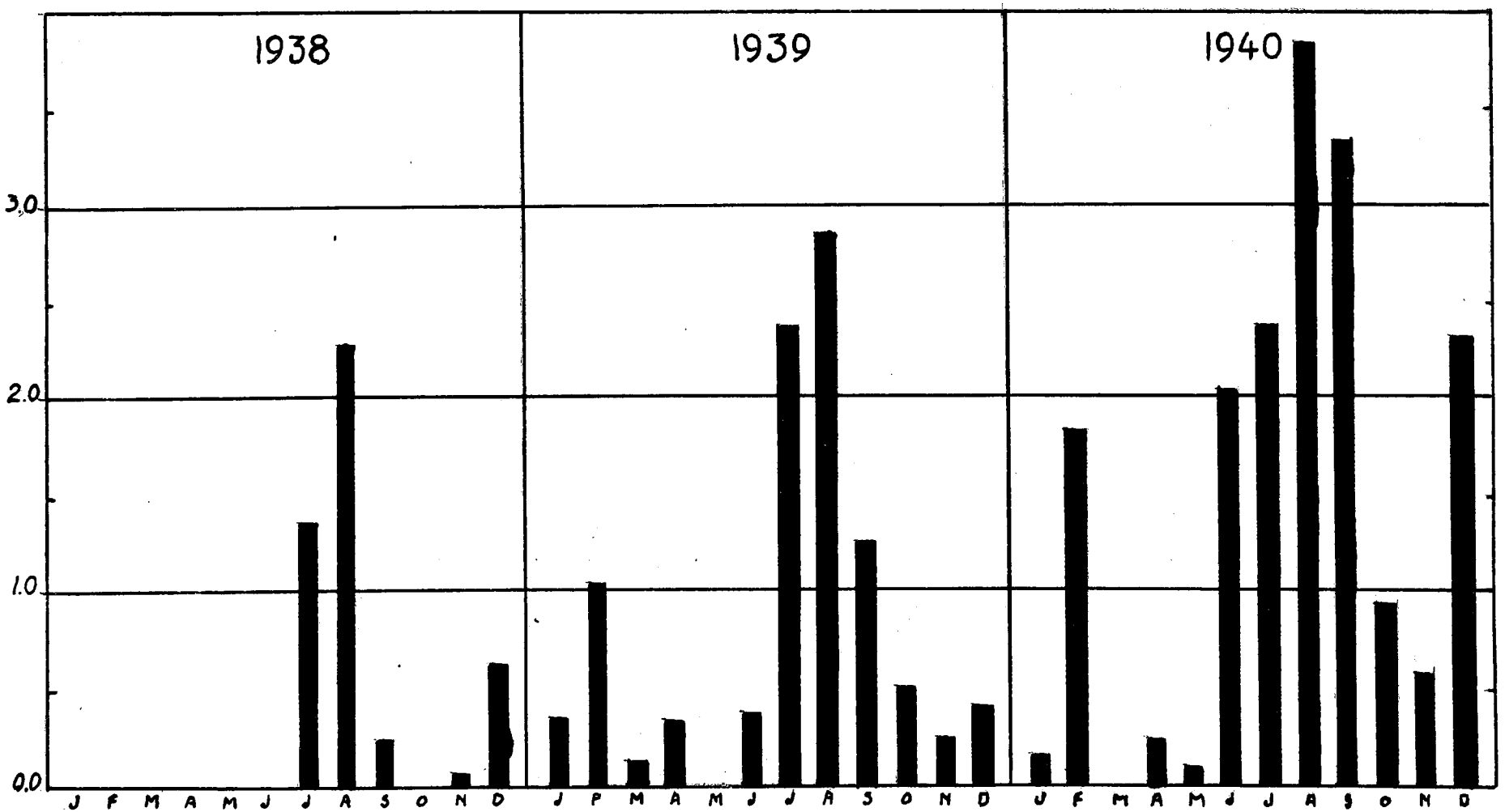

TABLE I b.

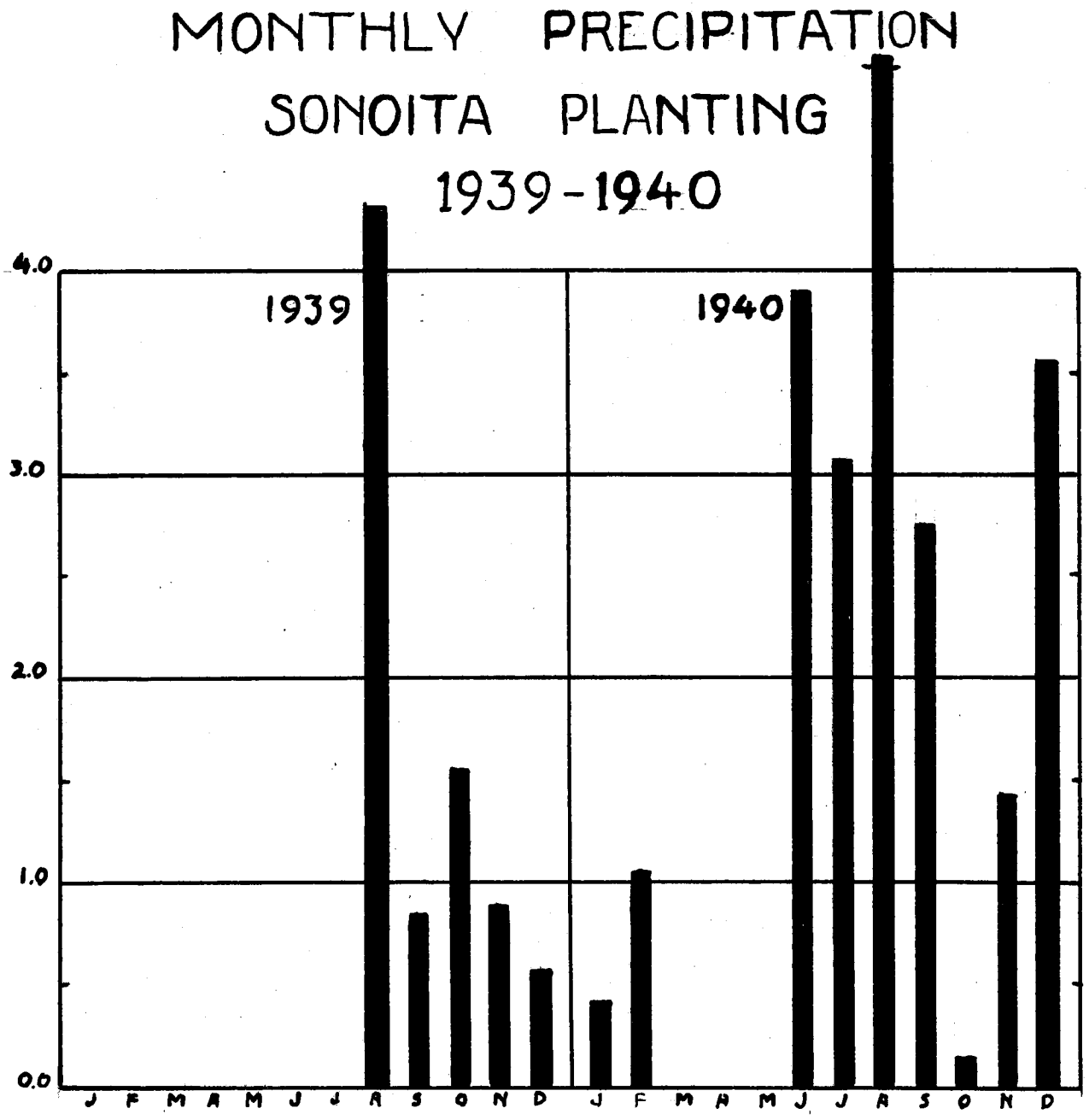
MONTHLY PRECIPITATION
SONOITA PLANTING
1939-1940
1939
1940
4.0
3.0
2.0
1.0
0.0
J F M A M J J A S O N D
J F M A M J J A S O N D

TABLE I c.

and finally run over lightly with a disk to fix the mulch. The broadcast plots varied in size from 20 x 40 feet to 1/20 acre. The species planted and the observations on emergence, growth, and survival are given in Tables II and III. A discussion of the species showing promise in these plantings appears on pages 28 to 51.

In the winter of 1938-39, grass, shrub, and herb species were planted on the flat silt loam area with two purposes in mind: primarily to test out species which would germinate only in cool weather and make their best growth at that time; secondly, to determine whether seed of summer growing species would lie over and emerge with the summer rains. The species planted, emergence, growth and survival are given in Table IV. The results of this planting closely parallel those of the 1938 summer planting.

Observations were made on the value of threshed straw containing some seed, as a means of securing a stand of grass on denuded impermeable sloping soil. The straw was scattered between contour furrows. Results were good along the furrows proper, but the mulch washed and blew off the areas between the furrows. Species which gave best results from mulching were whiplash pappusgrass (Pappophorum mucronulatum), Lehmann lovegrass, big sacaton, green sprangletop, sand dropseed, Rothrock grama, and Arizona cottongrass.

In the summer of 1939 a mixture of grass, herb, and shrub seed was planted on the sloping area lying east of the flat. Four different methods of seed bed preparation were

TABLE II - EMERGENCE, GROWTH, AND SURVIVAL OVER A THREE YEAR PERIOD, OF SPECIES BROADCAST ON MULCHED PLOTS ON A DESILTING AREA ON THE TUCSON CITY FARM - - - PLANTED JULY 1938

SPECIES	EMERGENCE	GROWTH	SURVIVAL	HEIGHT	SEED PRODUCTION	VOLUNTEERS PRODUCED	VIGOR
Astrebla lappacea	Good	Very good - quick recovery with moisture following dry period.	Plants thrifty after 3 yrs.	24" culm with 16"-20" basal leaves.	Good	Numerous	Thrifty
Bouteloua Rothrockii	Good	Little first year, but firmly rooted	Died out in summer of 1940.	12" - 16"	Good	Moderate	Weak
Chloris Berroi	Good	Slow	Stand reduced in 1939; none left in spring of 1940.	4" - 6"	None	None	Weak
Eragrostis curvula	Good	Moderate in seedling stage.	Plants died out entirely in early summer 1939. A few survived in most favorable spots along contour. These died in 1941.	Seedlings 6" - 8"; Mature plants with culms 48" tall.	Good	None	Weak
Eragrostis Lehmanniana	Good	Moderate	Very good up to early summer of 1939. About 60% of the stand died out.	Culms 24" to 30"	Good	Numerous	Thrifty
Eragrostis chloromelas	Poor	Moderate	Original plants are alive after 3 yrs. and thrifty.	Culms 30" tall	Good	None	Thrifty
Panicum antidotale	Good	Rapid	Original plants are alive after 3 yrs.	72"	Good	Numerous	Thrifty
Panicum obtusum	Poor	Moderate	Original plants are alive after 3 yrs.	17"	Poor	From runners taking root	Thrifty
Pentzia incana	Fair	Very slow, 3"-6" first season.	Died out second summer.	3" - 6"	Flowered	None	Crowded out by weeds.
Sporobolus cryptandrus (treated)	Good	A thick stand made 1"-2" the first year, stood still the second season, then died out.	Plants died out after 2 yrs. existence as small seedlings.	2" - 3"	None	None	Weak
Sporobolus cryptandrus (untreated)	Fair	Moderate growth	Died out in third year.	16" - 24"	Good	None	Moderate
Sporobolus airoides	Poor	Moderate	Original plants alive after 3 yrs.		Good	None	Thrifty
Trichachne californica	Good	Good	Original plants alive after 3 yrs.	16" - 24"	Good	Numerous	Thrifty

TABLE III - EMERGENCE, GROWTH, AND SURVIVAL OVER A THREE YEAR PERIOD, OF SPECIES PLANTED IN CONTOUR FURROWS - - - PLANTED JULY 1938
ON A DESILTING AREA ON THE TUCSON CITY FARM

SPECIES	EMERGENCE	GROWTH	SURVIVAL	HEIGHT	SEED PRODUCTION	VOLUNTEERS PRODUCED	VIGOR
Atriplex canescens	Poor	Slow	Good - oldest plants 3 yrs. old	24"-36" after 3 yrs.	None	None	Moderate
Atriplex semibaccata	Poor	Moderate	Good - oldest plants 3 yrs. old	24" by second year	Yes	None	Weak
Astrebla elymoides	Good	Vigorous	Good - oldest plants 3 yrs. old	24" by second year	1st growing season	Undetermined	Thrifty
Astrebla lappacea	Good	Vigorous	Good - oldest plants 3 yrs. old	36"-40" 2nd year	1st growing season	Undetermined	Thrifty
Bouteloua curtipendula	Good	Very weak	Small seedlings died late summer 1938, one thrifty plant after three years.	33"	Yes	None	Weak
Bouteloua gracilis	Fair	Slow	Few plants in 1939, none in 1940.		None		
Bouteloua Rothrockii	Good	Vigorous	Died out the summer of 1940.	12" - 18"	1st growing season	None	
Cenchrus biflorus	Good	Vigorous	Behaved as an annual. Few large plants survived first and second years.	12"	1st growing season, seeded every year.	Yes, a few	Moderate
Chloris Berroi	Fair	Slow	Small seedlings died first season, larger plants died second year.	6" - 8"	None	None	
Erodium cicutarium	Poor	Insignificant				None	Weak
Eragrostis brizantha	Good	Vigorous	All but a few plants died by the second year. None were alive the third year.	16" - 24" at maturity.	1st growing season	Undetermined	Weak
Eragrostis curvula	Good	Good growth first year, but failed to head.	Small seedlings dead May 1939, largest seedlings died summer of 1939.	36"-40" at maturity.	None	None	
Eragrostis Lehmanniana	Fair	Washed out					
Eragrostis chloromelas	Good	Moderate, no heads 1st yr.	Two fairly weak plants after three years.	24"	2nd growing season	None	Weak
Heteropogon contortus	Good	Very good the first year.	Few weak plants after three years.	18" - 24"	1st growing season	None	Weak
Hilaria Belangeri	Fair	Good, but little volume.	Died out in summer of 1940 after drought.	6"	1st growing season	Undetermined	Moderate
Hilaria mutica	Fair	Slow, grew in moist depressions, along contour.	A few plants were alive in spring of 1940; died out in the early summer of 1940.	12"	None	None	Weak
Muhlenbergia Porteri	Poor	Very slow	Died out in second summer.	4"-6" slender stems	None	None	Weak
Menodora scabra	Fair	Very slow	The stand died out partially the first year, and completely the second year.	6" - 8"	None	None	Weak
Menodora scoparia	Poor	Very slow	Gradually died out to a few plants by 1940.	6" - 12"	Third year	None	Weak
Oryzopsis miliacea	Good	Good; died in spring.	Died out during early summer before rainy season.				
Panicum antidotale	Good	Vigorous	Seedlings too small to make seed heads died out badly. Larger plants and especially old plants are very drought resistant; oldest plants three years old.	40" culms 16" leafy basal growth	Second year	None	Thrifty
Pentzia incana	None						
Panicum obtusum	Fair	Good - larger plants headed. No runners were produced first season.	Good - tops die back, but root and crowns are very drought resistant; oldest plants three years old.	17"	A few heads on larger plants the first year.	None	Thrifty
Pappophorum mucronulatum	Fair	Good	Very good, oldest plants three yrs. old.	34" culms 12-16" leafy growth	First year	None	Thrifty
Phalaris tuberosa	None						
Setaria macrostachya	Fair	Moderate	A good stand was reduced to a few plants in early summer of 1939. These died the following early summer of 1940.	4" - 6"	None	None	Moderate
Sporobolus contractus	Good	Slow	A good stand thinned out to a few plants in early summer of 1939.	30" culms in 1940, 12" basal leaves	Second year	None	Weak
Sporobolus cryptandrus	Good	Moderate	A fair stand died out in summer of 1939.		First year	None	Weak
Sporobolus Wrightii	Fair	Slow	A fair stand died out in summer of 1939.		None	None	Weak
Sporobolus airoides	Slow	Very slow	A few plants with little growth were found in the spring of 1940.	2" tall in 1940.	Third year	None	Moderate
Schismus barbatus	None	Moderate	Plant died out in spring - annual	2" - 4"	Yes	Yes	Weak
Trichachne californica	Fair	Good	A light stand survived three years.	30" - 36" culms, 14" leafy basal growth.	First year	Yes	Thrifty

TABLE IV EMERGENCE, GROWTH, AND SURVIVAL OVER A THREE YEAR PERIOD OF SPECIES PLANTED IN CONTOUR FURROWS ON AN ERODED FLAT ON THE TUCSON CITY FARM - - PLANTED DECEMBER 1938

SPECIES	EMERGENCE	GROWTH	SURVIVAL	HEIGHT	SEED HEADS PRODUCED	VOLUNTEERS PRODUCED	VIGOR
Atriplex canescens	Poor	2"-4" 1st year; 8"-16" 2nd year.	Alive after three years.	12" - 16"	None	None	Moderate
Atriplex semibaccata	None						
* Bouteloua Rothrockii	Fair	Fairly good	No original plants	15" - 20"	Yes	Yes, good stand	Thrifty
* Bouteloua curtipendula	Poor	Few plants, died second summer					
* Cenchrus biflorus	Good	Rapid	Few original plants left.	7"	Yes	Yes, good stand	Moderate
Chloris Berroi	None						
Erodium cicutarium	Good	Good	Annual	12" - 18"	Yes	Yes	
* Eragrostis brizantha	Good	Slow	Alive after three years.	20"	Yes	Yes, a few.	Weak
Eragrostis curvula	None						
* Eragrostis Lehmanniana	Good	Very good	Good after three years.	22"	Yes	Yes	Thrifty
Eurotia lanata	Fair	6" - 12" first year.	Died second winter.				
* Hilaria mutica	Poor	Fair	Alive after three years.	12"	Few	None	Moderate
Menodora scoparia	Good	2"-3" first year; 3"-4" 2nd yr.	Alive after three years.	10" - 12"	Yes	None	Moderate
* Muhlenbergia Porteri	Poor	Slow	Died 1st and 2nd years.	3" - 4"	None	None	
Oryzopsis miliacea	Good	Fair during first spring.	Died in early summer	2" - 3"	None	None	
* Panicum antidotale	Good	Slow the first year.	Alive after three years.	36" - 40"	Yes	None	Thrifty
* Panicum obtusum	Fair	Slow first year, 3" growth forming rhizomes.	Alive after three years.	12" - 16"	Few	Runners rooted	Thrifty
Phalaris tuberosa	Good	Good the first spring	Died during early summer.	2" - 3"	None	None	
Schismus barbatus	Good	Fair during spring	Annual	2" - 3"	Yes	Yes	Weak
* Setaria macrostachya	Fair	Slow first year.	Few plants lived 3 years.	16"	Yes	None	Weak
* Sporobolus cryptandrus	Good	Slow	Died out early summer of second year.	3" - 4"	None	None	
* Trichachne californica	Good	Slow first year.	Died out early in second summer.	Few inches	None	None	

* These species did not germinate until the summer rains.

used in duplicate on the slope. These were:

1. Plot disked lightly, seed broadcast, and firmed with a cultipacker.
2. Plot corrugated, seed broadcast; not covered.
3. Plot disked lightly, seeds broadcast, mulched and firmed with the cultipacker.
4. Plot corrugated, seed broadcast, mulched with straw; mulch cut in with disk harrow.

These treatments were duplicated on plots 5, 6, 7, and 8. An odd plot left over was given the same treatment as plots 4 and 8 but the mulch was left on the surface.

In each of the above operations the corrugations were shallow furrows from four to six inches deep. They were made with a Farmall tractor using small furrowing shovels on the cultivating attachments. The mulch consisted of threshed straw of whiplash pappusgrass (Pappophorum mucronulatum), bush muhly (Muhlenbergia Porteri), and plains bristle grass (Setaria macrostachya). The mulch was scattered with hand labor and cut in by running over it with an open disk harrow.

The species planted and the amounts of seed used in the mixture planted on the Tucson City Farm in July 1939 were:

Astrebla elymoides	2 lbs.
Astrebla lappacea	2½ lbs.
Atriplex canescens	2½ lbs.
Atriplex semibaccata	½ lb.
Bouteloua curtipendula	1/8 lb. cary.
Bouteloua Rothrockii	¼ lb.
Chloris Berroi	2½ lb.
Eragrostis brizantha	¼ lb.
Eragrostis curvula	½ lb.
Eragrostis intermedia	1/16 lb. cary.
Eragrostis Lehmanniana	½ lb.
Hilaria mutica	1/8 lb. cary.
Menodora scabra	½ lb.
Menodora scoparius	¼ lb.
Onobrychis chorassanica	1/16 lb.
Panicum antidotale	¼ lb.
Pentzia incana	½ lb.
Plantago sp.	1/8 lb.

Setaria macrostachya	$2\frac{1}{2}$ lbs.
Sporobolus cryptandrus	$\frac{1}{4}$ lb.
Trichachne californica	$2\frac{1}{2}$ lbs.
Tripteris pachypteris	1 lb.

TOTAL 20 lbs. per acre

Astrebla elymoides, Astrebla lappacea, Atriplex semibaccata, Eragrostis brizantha, Panicum antidotale, Setaria macrostachya and Trichachne californica were largely confined to the strip at the base of the contour dike where moisture conditions were better. Bouteloua Rothrockii, Eragrostis lehmanniana, and Atriplex canescens were distributed over the slope between the contours, but made better growth in the strip at the base of the dikes.

Interpretation of results on the methods of establishment tried are made difficult by uncontrolled factors. The amounts of runoff received varied with the slope and with breaks in the contour borders. Also the mulch of pappusgrass used on the Tucson City Farm contained seed which produced a good stand of grass. The competition of the pappusgrass may have affected the density of the Lehmann lovegrass and Rothrock grama. In general it was apparent that the disked areas sealed over quickly causing nearly complete runoff. The mulched areas had better stands on the lower half of the border than the unmulched; the stands were more evenly distributed over the border, and were of greater density where corrugations were used. All borders had good stands along a strip at the base of the contour border where there was good penetration.

No winter planting was made in 1939-40. In the summer of 1940, a slightly different mixture of grasses, shrubs, and herbs was planted in the area directly south of the flat. This planting lay partially in the highly-dispersed impermeable soil and partially in light sandy soil. Resulting emergence in the heavy soil was light except where water was concentrated behind contour dikes or was held in the contour furrows.

Species included in this mixture planted on the slope in July 1940 were:

Aeluropus littoralis
Astrebla lappacea
Atriplex canescens
Atriplex semibaccata
Bouteloua Rothrockii
Cenchus biflorus
Enchylaena tomentosa
Eragrostis brizantha
Eragrostis curvula
Eragrostis chloromelas
Eragrostis Lehmanniana
Menodora scabra
Onobrychis chorassanica
Onobrychis vulgaris
Panicum antidotale
Pappophorum mucronulatum
Pentzia incana
Setaria macrostachya
Sporobolus cryptandrus
Trichachne californica

In the 1940 planting Astrebla lappacea, Atriplex semibaccata, Bouteloua Rothrockii, Eragrostis brizantha and Eragrostis Lehmanniana again showed the greatest emergence and survival. Eragrostis chloromelas a species not included in the former planting did well; Atriplex canescens, Panicum antidotale, Setaria macrostachya, Trichachne californica and Menodora scabra gave very poor results.

From the results of the plantings of individual species as given in Table II, III and IV and from the results in seeding mixtures planted on the slope in 1939 and 1940 species judged suitable to water-spreading and water-retention areas in this type of site are:

Andropogon barbinodis	Hilaria mutica
Astrebla elymoides	Panicum antidotale
Astrebla lappacea	Panicum obtusum
Atriplex canescens	Pappophorum mucronulatum
Atriplex semibaccata	Setaria macrostachya
Eragrostis brizantha	Sporobolus Wrightii
Eragrostis chloromelas	Trichachne californica
Eragrostis Lehmanniana	

On areas where silt deposition is not a factor, Rothrock grama, spike and sand dropseed, curly mesquite, and rough menodora may be included.

Rothrock grama and Lehmann lovegrass showed the greatest survival on the portions of the area having the least accumulation of moisture.

Black, slender, blue, and hairy gramas, Chloris Berroi, India sandbur (Cenchrus biflorus), winterfat, tanglehead, and bush muhly failed to survive and are considered unadapted.

Smilo grass (Oryzopsis miliacea) and Harding grass (Phalaris tuberosa), both species which germinate and grow in cool weather, failed to survive. These species planted in December 1938 were well rooted and had four inches to six inches growth the following April, but they died out during the hot, dry months of May and June. These above species, together with bulbous barley (Hordeum bulbosum) appear to be

the most promising perennial grasses for winter and early spring pasture in the southern part of the region, and might be established in range plantings in the fall during years of exceptional winter and spring rainfall such as occurred in 1904, 1914, 1940-41. However, the fall and spring of 1938-1939 and 1939-40 were not greatly below normal, and the perennial fall-spring growing grasses failed to become established from winter plantings in those years. Annuals such as Filaree, Indian wheat, and Mediterranean grass (*Schismus barbatus*), made little growth in fall and winter plantings in 1938 and 1939, although they made luxuriant growth on the range in 1940-41.

Site B

Northwest Station, Santa Rita Range Reserve (Desert Tank)

This plot is located 100 yards east of the stock tank constructed by the Southwestern Forest & Range Experiment Station on that part of the Santa Rita Experimental Range known as the Northwest Station or Desert Tank Area. The average precipitation for the area is nearly ten inches. The plot selected is subject to sheet and minor gully erosion from water draining off a gentle slope east of the plot.

This water concentrates in small drainage ways and flows across the area with sufficient force to wash out contour furrows. Efforts were made to divert the water around the

plot by building dikes and diversion channels, but these were inadequate and broke under the impact of the runoff allowing the water to flow across the plot. Before planting, the sparse vegetation consisted of annual three-awn and six-weeks needle grama, cactus, mesquite, desert hackberry, and wolf berry, with remnants of bush muhly, Rothrock grama, and spike dropseed. The north half of the plot is Commoro soil. This soil is a sandy loam to a depth of three feet. It has a gravelly loam surface, is quite open and fairly uniform, has good penetration, and likewise loses surface moisture rapidly. The south half of the plot has lost the top-soil leaving an impermeable surface. This soil has a compact clay loam surface soil underlaid with a layer of clay from one to three feet. A sandy layer extends below this depth. Penetration is poor, but the moisture is retained if the surface is broken up so penetration can take place.

The plot was contour-furrowed before the planting was made, and was seeded in July, 1938. Additional plantings were made in the winter of 1938-1939 and the summer of 1939. In the summer of 1940, a mixture of the more promising species, as indicated by previous trials, was planted in contour furrows west of and adjacent to the original plot. The species planted, and data on emergence and survival are given for the 1938, 1939, and 1940 plantings in Table V. An analysis of Table V indicates that of those planted the following grasses are best adapted under the conditions of soil and rainfall present at the Santa Rita Desert Tank Area:

TABLE V - EMERGENCE, GROWTH, AND SURVIVAL OVER A THREE YEAR PERIOD OF SPECIES PLANTED ON A WATER SPREADING AREA AT THE SANTA RITA DESERT TANK NEAR TUCSON, ARIZONA - - - - PLANTED JULY and DECEMBER 1938

SPECIES	EMERGENCE	GROWTH	SURVIVAL	HEIGHT or SPREAD	SEED PRODUCED	VOLUNTEERS PRODUCED	VIGOR
Atriplex canescens	Good	Slow 1st year, 4" - 6"	Small number alive after three years; not very thrifty.	16" - 24"	None	None	Weak
Atriplex semibaccata	None						
Astrebla elymoides	Good	Good	Reduced to a few plants the first summer.	30"	Yes	Few	Moderate
Astrebla lappacea	Good	Good	Original stand alive after 3½ yrs.	18"	Yes	Few	Moderate
Bouteloua curtipendula	Good	Slow first year	Many died first spring.	12" - 18"	Yes	None	Moderate
Bouteloua eriopoda	Good	Good	Crowded out by Lehmann lovegrass in second year.	8" - 10"	Heads	None	Moderate
Bouteloua filiformis	Fair	Insignificant	Plants alive after two years.	8" - 12"	Few	None	Weak
Bouteloua gracilis	Good	Good	Plants alive after 3½ years.	24"	Yes	None	Thrifty
Bouteloua hirsuta	Fair	Insignificant	Good	8"	Not recorded	None	Weak
Bouteloua Rothrockii	Good	Good	Reduced to light stand; second year thickened up.	24"	Yes	Yes	Moderate
Cenchrus biflorus	Good	Rapid	Larger plants lived second year, small plants died first winter.	6" - 10"	Yes	Yes	Weak
Erodium cicutarium	Fair	Insignificant	Annual	2" - 3" spread	Few	Few	
Eragrostis brizantha	Good	Good	Alive and thrifty after 3 years.	24" - 30"	Yes	Prolific in depressions.	Thrifty
Eragrostis curvula	Good	Good	Fair, larger plants alive after four years; small plants died.	36" - 40"	Yes	Few	
Eragrostis Lehmanniana	Good	Good	Original row has good stand, but largely of volunteers.	30"	Yes	Numerous in bare eroded soil as well as in depressions.	Thrifty
Eragrostis chloromelas	Good	Good	Alive after 3½ years.	36"	Yes	Yes, fairly numerous	Thrifty
Heteropogon contortus	Good	Good in places, many plants small.	Stand was much reduced second summer. Light stand lived thru 3½ yrs.	12" - 18"	Yes	Few	Moderate
Hilaria Belangeri	Poor	Fair, no runners.	The few plants established have lived through 3½ years.	4" - 6"	Yes	Few	Moderate
Hilaria mutica	Poor	A few plants made good growth.	Poor, seedlings volunteering below, died out the second season.	2" - 3" (seedlings)	Yes	Failed to survive.	Moderate
Muhlenbergia Porteri	None						
Menodora scabra	Good	Very slow first year	Good, alive after 3½ years.	18"	Yes	Prolific	Thrifty
Oryzopsis miliacea	Yes, in winter.	Slow	Died first spring.	2" - 3"	None	None	
Panicum antidotale	Good	Slow at first, but vigorous the second year.	Alive and thrifty after 3½ yrs.	60" - 64"	Yes	Fairly numerous	Thrifty
Pentzia incana	None from seed				Numerous volunteers	From transplants	Thrifty
Panicum obtusum	None						
Pappophorum mucronulatum	Good	Fair, not thrifty, but in a slick site where there is no penetration.	Alive after three years.	18" - 24"	Yes	None	Moderate
Phalaris tuberosa	Good	Slow at first.	Died the first spring.	2" - 3"	None	None	
Sporobolus contractus	Good	Good	Alive and thrifty after 3½ yrs.	12" - 30"	Yes	Yes	Thrifty
Sporobolus cryptandrus	Good	Good	Alive and thrifty after 3½ yrs.	24" - 30"	Yes	None	Thrifty
Setaria macrostachya	Good	Good	Alive after four years, but not thrifty; no penetration in this area.	18" - 24"	Yes	Few	Moderate
Trichachne californica	Good	Good	Alive and thrifty after 3½ yrs.	14" - 16"	Yes	None	Thrifty

Bouteloua eriopoda	Panicum antidotale
Bouteloua Rothrockii	Setaria macrostachya
Eragrostis brizantha	Sporobolus contractus
Eragrostis chloromelas	Sporobolus cryptandrus
Eragrostis Lehmanniana	Trichachne californica

Atriplex canescens, Menodora scabra and Menodora scoparia were the only non-grass species to survive.

Tanglehead showed an excellent initial establishment at the Santa Rita Desert Tank, but the stand was definitely reduced by drought in 1939. In view of the prevalence and natural increase of this grass on a nearby range this fact was surprising. On the basis of their experience on other parts of the Santa Rita Range, where there is a 12 inch rainfall, Cassidy and Glendenning (2) have recommended the planting of tanglehead.

Cenchrus biflorus gave little promise at the Desert Tank Area. It was noted that the parent plants, well established in 1938, produced seed and died the following spring. There was only a trace of seedlings the following year, and none were found in the drainage below. Hilaria mutica, although very poor in the row where it was planted, showed a few two-year old plants in the row and numerous seedlings in the drainage below. An analysis of Table V shows the same unpromising results with spring annuals, and perennial species having a fall, winter, and spring growing season, as were obtained on the City Farm.

The rows planted in January, 1939, as well as those planted in July, 1939, were in shallow contour furrows providing less favorable moisture retention than those of the 1938 summer

plantings. It is a strong indication that whiplash pappus-grass (Pappophorum mucronulatum) is somewhat drought resistant, since it was the only species out of the 39 planted in July, 1939, to maintain the original stand and make significant growth that year.

Site C - Sonoita Experimental Area

This plot situated in the rolling grassland northeast of Sonoita was selected in cooperation with the Department of Animal Husbandry of the University of Arizona, the Southwest Forest & Range Experiment Station, and the Soil Conservation Service. It is located on the R. C. Larrimore Ranch three miles north of Sonoita, Arizona. The area was under cultivation 23 years ago, and had regained a partial stand of native grasses at the time the plots were planted. The vegetation which had a range in density from .2 to .5 consisted of three-awn species 50%, curly mesquite 20%, blue grama 16%, and hairy grama 12%. There was a scattering of side-oats grama, sand dropseed, Texas timothy, vine mesquite, and cane bluestem. The soil is a well-developed loam and gravelly clay with a heavy-textured subsoil. Moisture is retained in the surface soil only a short time. The plot slopes to the north and east, and receives runoff from 300 feet of slope above the plot.

Two methods of planting were used on the area. In one, broadcast strips were seeded, and in the other contour furrows

were seeded. One-tenth acre strips were planted to native and exotic grasses and mixtures for comparative palatability studies.

In the strip plantings the seed bed was prepared by undercutting the sod with a blade which passed beneath the surface three to four inches. The strips were then disked to cut up the scattered patches of sod sufficiently for a seed bed. Four-foot strips of undisturbed vegetation were left between the planted strips. The fine seed was broadcast with a Cyclone seeder and rolled with a cultipacker. The coarse seed was hand broadcast. Short contour rows were planted for species tests. Seed was scattered by hand in the bottom and sides of the furrow at the base of the ridge, then covered with a rake. The species planted, emergence, and survival are given in Table VI.

An analysis of this table indicates certain definite adaptabilities in some species and lack of adaptability in other species. As would be expected from the native vegetation, the grama grasses did well with the exception of black grama. The lovegrasses, (Eragrostis Lehmanniana, curvula, and chloromelas) came up with good stands, survived, and made good growth. Green sprangletop (Leptochloa dubia) made a good showing in this plot.

Species found adapted in these trials under the soil and moisture conditions of the Sonoita plot are:

TABLE VI - EMERGENCE, GROWTH, AND SURVIVAL OVER A THREE YEAR PERIOD OF SPECIES PLANTED IN CONTOUR FURROWS ON SLOPING LAND IN THE SONOITA AREA - - - - PLANTED JULY 1939

SPECIES	EMERGENCE	GROWTH	SURVIVAL	HEIGHT	SEED OR SEEDHEADS PRODUCED	VOLUNTEERS PRODUCED
Atriplex canescens	Poor	Good	Alive after three years	24"	None	
Astrebla elymoides	Poor	Not thrifty	Died second summer	4" - 5"		
Astrebla lappacea	Fair	Not thrifty	Died second summer	4" - 5"	None	
Andropogon scoparius	Fair	Slow	Died second summer	24"	Yes	None
Andropogon ischaemum	Good	Good	Alive after three years	18" - 24"	Yes	None
* Bouteloua chondrosioides	Fair	Weak	Died out second year	4" - 6"	Yes	None
* Bouteloua curtipendula	Fair	Slow	Alive after three years	8" - 10"	Yes	None
Bouteloua eriopoda	Poor	Very slow	Died second season	2" - 3"	None	
* Bouteloua filiformis	Good	Good	Alive after three years	6" - 8"	Yes	Yes
* Bouteloua gracilis	Poor	Very slow	Good	2" - 3"	Yes	None
* Bouteloua hirsuta	Good	Good	Alive after three years	6" - 8"	Yes	
* Bouteloua Rothrockii	Good	Rapid	Only few seedlings third year	12"	Yes	Few
Cenchrus biflorus	Good	Rapid	A few lived over and produced a few seedlings	8" - 10"	Yes	Few
Chloris Berroi	Poor	Little	Died out in second year	6"	Yes	None
Eragrostis chloromelas	Good	Good	Alive and thrifty after three yrs.	30"	Yes	Alive
Eragrostis curvula	Good	Good	Alive and thrifty after three yrs.	36"	Yes	None
Eragrostis Lehmanniana	Good	Good	Alive and thrifty after three yrs.	30"	Yes	Few
* Hilaria Belangeri	Fair	Slow	Alive after three yrs.,little growth	3" - 4"	Yes	None
Hilaria mutica	Poor	Slow	Died second year	2" - 3"	None	
Leptochloa dubia	Good	Good	Alive after three years.	36"	Yes	None
Menodora scabra	Good	Very slow, defoliated by insects second year	Alive after three years, but not thrifty.	6"	Yes	None
Menodora scoparia	Good	Very slow, defoliated by insects.	Alive after three years, but not thrifty.	6"	Yes	None
Panicum antidotale	Good	Slow	Stand reduced second year. Plants remaining are not thrifty.	30"	Yes	None
* Sporobolus cryptandrus	Fair	Very slow	Died second summer.		None	
Setaria macrostachya	Good	Good	Thrifty for two years, but died out badly the third year.	15" - 18"		
Trichachne californica	Fair	Moderate	Died out during the third summer, leaving only a few plants.	10" - 12"	Yes	None

* Native on the area.

Andropogon barbinodis	Eragrostis curvula
Bouteloua curtipendula	Eragrostis chloromelas
Bouteloua filiformis	Hilaria Belangeri
Bouteloua hirsuta	Leptochloa dubia
Bouteloua Rothrockii	Menodora scabra
Eragrostis Lehmanniana	Menodora scoparius

Setaria macrostachya

Species promising in alluvial bottom land soils and water-spreading areas which are definitely not adapted on the Sonoita area are:

Astrebla elymoides
Astrebla lappacea
Hilaria mutica
Panicum antidotale

The planting in the 1/10 acre strips demonstrated the advantages of the exotic lovegrasses, Eragrostis Lehmanniana and Eragrostis curvula, insofar as quick establishment is concerned.

Site D - Pearce Area

This plot situated on the K. A. Roth property one-half mile north of Pearce, Arizona, along the Pearce-Willcox Highway was planted by the Extension Service of the University of Arizona in the summer of 1939. The area selected is a typical sheet-eroded flat, largely barren of any vegetation. The soil is compacted and impermeable, and, judging from adjacent vegetation, once supported a stand of tobosa grass. Shallow contour furrows made with a walking plow failed to hold back runoff water from an extensive drainage above. The natural spreading of this runoff water resulted in excellent emergence over the plot in portions of nearly every contour. Later observations

during the second and third year showed a high mortality in portions of the contour rows which were drained off by breaks in the contours. Table VII gives the emergence, growth, and survival for the Pearce planting.

It will be seen from an examination of this table that, once established, many of our native and exotic species will make good growth on badly-eroded, compact soils on which little growth occurs without moisture conservation practices accompanied by reseeding. Also, it is of note that spread from seed was significant on this plot.

Species which were found adapted in these trials under the soil and moisture conditions of the Pearce plot are:

Atriplex canescens
Astrebla elymoides
Astrebla lappacea
Andropogon barbinodis
Bouteloua curtipendula
Bouteloua Rothrockii
Chloris Berroi
Eragrostis chloromelas
Eragrostis curvula
Eragrostis Lehmanniana
Hilaria mutica
Panicum antidotale
Panicum obtusum
Pentzia incana
Setaria macrostachya
Sporobolus airoides
Sporobolus Wrightii
Trichachne californica

TABLE VII - - EMERGENCE, GROWTH, AND SURVIVAL OVER A TWO YEAR PERIOD OF SPECIES PLANTED IN CONTOUR FURROWS ON AN ERODED FLAT NEAR PEARCE, ARIZONA - - PLANTED JULY 1939

SPECIES	EMERGENCE	GROWTH	SURVIVAL AFTER THREE YEARS	SPREAD FROM SEED *	VIGOR
Andropogon scoparius	Fair	Good	Good	Yes	Moderate
Andropogon barbinodis	Good	Good	Good	Yes	Thrifty
Astrebla elymoides	Good	Good	Good	Yes	Thrifty
Astrebla lappacea	Good	Good	Good	Yes	Thrifty
Atriplex canescens	Fair	Good	Good	None	Thrifty
Bouteloua curtipendula	Good	Good	Good	None	Thrifty
Bouteloua eriopoda	Good	Good	Dying out	None	Moderate
Bouteloua gracilis	Good	Good	Good	None	Moderate
Bouteloua Rothrockii	Good	Good	Poor	None	Weak
Chloris Berroi	Good	Good	Good	Yes	Thrifty
Eragrostis chloromelas	Good	Good	Good	Yes	Thrifty
Eragrostis curvula	Good	Good	Dying out	None	Weak
Eragrostis Lehmanniana	Good	Good	Good	Yes	Thrifty
Hilaria Jamesii	Fair	Good	Good	None	Thrifty
Menodora scabra	Good	Slow	Fair		Moderate
Muhlenbergia Porteri	None		None		
Oryzopsis hymenoides	None				
Panicum antidotale	Good	Good	Good	Yes	Thrifty
Panicum obtusum	Good	Good	Good	None	Thrifty
Pentzia incana	Fair	Fair	Good		Thrifty
Phalaris tuberosa	Good	Fair	Dying out	None	Weak
Setaria macrostachya	Good	Good	Good	None	Thrifty
Sporobolus airoides	Good	Good	Good	None	Thrifty
Sporobolus cryptandrus	Good	Good	Dying out	None	Thrifty
Sporobolus Wrightii	Good	Good	Good	None	Thrifty
Trichachne californica	Good	Good	Good	None	Thrifty
Tripteris pachypteris	Fair	Fair	Fair	None	Thrifty

* Last observation made end of third summer.

DISCUSSION OF RESULTS

Sites

The sites adapted for reseeding may, for convenience, be divided into groups such as:

(1) desilting areas and water-spreading areas on alluvial bottom lands, swales and eroded flats

(2) well-drained slopes, mesas, and plains.

Desilting areas and alluvial bottom lands in the southern part of the region generally have little slope, but may have well-defined drainage courses. The soil tends to be alkaline. These areas are generally characterized by mesquite with scattered shrubs of wolfberry, graythorn, and saltbush, and have a heavy growth of careless weed and purslane following the summer rains. These areas were often originally occupied by sacaton and tobosa grass. The Tucson City Farm is an example of such a site. Other areas in the desert grassland have no well-defined drainage courses and have a gentle slope which is frequently sheet-eroded. These areas are characterized by remnants of Rothrock grama, black grama, and bush muhly, with cane bluestem, plains bristle grass, and cottongrass generally found in depressions and swales. Where sheet erosion has not progressed, poverty three-awn (*Aristida divaricata*) and burroweed are predominant with annual six-weeks needle grama, and annual three-awn where there is

sufficient summer moisture. The areas generally have scattered plants of creosote bush, cactus, and mesquite. The Santa Rita Desert Tank Area is an example of such a site. Many of the heavier textured soils, formerly tobosa areas, are now eroded flats. These areas are typified by the Pearce site.

The well-drained slopes and mesas are characterized by a mixture of grama grasses, dropseeds, three-awns, curly mesquite grass, and half shrubs, chiefly burroweed or broom-weed. The College Ranch planting at Las Cruces and the Sonoita area are examples.

The selection of criteria of adaptability of plant species suitable for reseeding on southwestern ranges presents a complex problem. In this study adaptability is considered on the basis of sites which represent extensive acreages in problem areas. Within these sites on problem areas there are gradations of moisture due to topography, soil type, and vegetation, all of which affect the retention and penetration of moisture. It will be seen, therefore, that limits of elevation and rainfall except in their broad aspects cannot be used as satisfactory criteria for the site. In determining the adaptability of any given species for a typical site the conditions immediately affecting that species were considered. Primary consideration was given to what may be called the "end moisture result".

Factors which were considered in reaching this end result were:

Slope:

Did it add to the runoff the species received or drain off water excessively?

Effectiveness of moisture conservation measures:

Did contour furrows break draining water from the row?

Soil conditions:

Did puddled soil prevent penetration?

Was alkali unduly heavy?

Was topsoil eroded excessively?

Vegetation:

Was weed competition excessive?

Any one or combination of these factors act to determine the "end moisture result".

This resultant moisture condition may be considered in a practical sense to represent equally favorable, less favorable, or occasionally more favorable conditions than are attained under field conditions encountered where effective soil and moisture conservation practices have been employed.

Having taken this result into account, the selection depended upon the performance and survival of the species on the area studied. This performance is based upon experience with the species under nursery and field conditions. It takes into account the purpose the plant is to serve, the rate of emergence, percentage of germination, seedling vigor, rate of growth, production of seed, and ability to reseed itself. No set standards can be given for these qualities; they must

be measured in terms of the potential of each species and the consideration of whether there is a better species to use where a deficiency is apparent.

From a practical aspect it is this: Certain critical areas require and justify reseeding to establish a vegetative cover. If there is no one species or combination of species which will satisfy all the desired requirements there must be a choice of those which appear to most nearly meet the desired performance. These are the species which are considered as adapted in this paper.

The selection of species listed below is based on the results of the plantings at the Tucson City Farm, Santa Rita Desert Tank Area, Sonoita, and Pearce areas. It is supported by information secured from the planting of the Animal Husbandry Department of the University of New Mexico in cooperation with the Nursery Division at State College, New Mexico, and widely scattered plantings of the Soil Conservation Service and Indian Service in southern Arizona. Adaptability of species tried in representative sites in these plantings is given in Table VIII. Observations taken on the above plantings indicate the following species are adapted to the planting of alluvial bottom lands, swales, and desilting areas in the desert grassland and adjacent desert types:

Andropogon barbinodis
Atriplex canescens
Astrebla lappacea
Astrebla elymoides
Eragrostis chloromelas
Eragrostis Lehmanniana
Hilaria mutica
Panicum obtusum
Panicum antidotale
Pappophorum mucronulatum
Setaria macrostachya
Trichachne californica

TABLE VIII - - ADAPTABILITY OF SPECIES TRIED IN RANGE TRIAL PLANTINGS ON REPRESENTATIVE SITES IN THE DESERT GRASSLAND RANGES OF SOUTHERN ARIZONA AND NEW MEXICO - 1938 - 1941

SPECIES PLANTED	DESILTING AREAS AND ALLUVIAL BOTTOMLAND IN THE LOWER DESERT GRASSLAND		WATER SPREADING AND WATER RETENTION AREAS IN THE LOWER DESERT GRASSLAND					OPEN SLOPES AND MESAS IN THE UPPER DESERT GRASSLAND	
	Tucson City Farm July 1938	Tucson City Farm December 1938	Tucson City Farm July 1939	Tucson City Farm July 1940	Santa Rita Desert Tank 1938	Pearce, Ariz. July 1939	Papago Reservation 1938 and 1940	Sonoita, Ariz. July 1939	Las Cruces, New Mexico 1938-1941
Atriplex canescens	yes	yes	yes	no	yes	yes	undetermined	undetermined	no
Atriplex semibaccata	undetermined*	undetermined	yes	yes	no	undetermined	undetermined	undetermined	no
Astrebla elymoides	yes	undetermined	yes	yes	yes	yes	undetermined	no	no
Astrebla lappacea	yes	undetermined	yes	yes	yes	yes	undetermined	no	no
Bouteloua curtipendula	no	undetermined	no	undetermined	yes	yes	undetermined	yes	yes
Bouteloua eriopoda	no	undetermined	undetermined	undetermined	yes	yes	undetermined	undetermined	yes
Bouteloua filiformis	no	undetermined	undetermined	undetermined	undetermined	undetermined	undetermined	yes	no
Bouteloua gracilis	no	undetermined	undetermined	undetermined	yes	yes	undetermined	yes	yes
Bouteloua hirsuta	no	undetermined	undetermined	undetermined	undetermined	undetermined	undetermined	yes	no
Bouteloua Rothrockii	no	yes	yes	yes	yes		yes	yes	yes
Cenchrus biflorus	no	yes	no	no	no	undetermined	no	no	no
Chloris Berroi	no	undetermined	no	undetermined	no	yes	undetermined	no	no
Erodium cicutarium	no	yes	yes	yes	no	undetermined	undetermined	undetermined	no
Eragrostis brizantha	yes	yes	yes	yes	yes	undetermined	undetermined	yes	undetermined
Eragrostis curvula	no	no	no	no	yes	no	no	yes	no
Eragrostis chloromelas	undetermined	undetermined	undetermined	yes	yes	yes	yes	yes	yes
Eragrostis Lehmanniana	no	no	yes	yes	yes	yes	yes	yes	yes
Eurotia lanata	no	no	undetermined	undetermined	no	undetermined	undetermined	undetermined	no
Heteropogon contortus	no	undetermined	undetermined	undetermined	yes	undetermined	undetermined	undetermined	no
Hilaria Belangeri	undetermined	undetermined	undetermined	undetermined	undetermined	undetermined	undetermined	yes	no
Hilaria mutica	yes	yes	undetermined	undetermined	no	yes	undetermined	no	yes
Menodora scabra & scoparia	no	yes	yes	no	yes	yes	no	yes	no
Muhlenbergia Porteri	no	no	undetermined	undetermined	no	undetermined	undetermined	undetermined	yes
Oryzopsis miliacea	no	no	undetermined	undetermined	no	undetermined	undetermined	no	no
Panicum antidotale	yes	yes	yes	undetermined	yes	yes	yes	no	yes
Panicum obtusum	yes	yes	undetermined	undetermined	no	yes	undetermined	undetermined	no
Pappophorum mucronulatum	yes	undetermined	yes	no	yes	undetermined	yes	undetermined	undetermined
Phalaris tuberosa	no	no	undetermined	undetermined	no	no	undetermined	no	no
Schismus barbatus	no	no	undetermined	undetermined	no	undetermined	no	undetermined	no
Setaria macrostachya	no	no	no	no	yes	yes	no	yes	yes
Sporobolus airoides	yes	undetermined	undetermined	undetermined	undetermined	yes	undetermined	undetermined	undetermined
Sporobolus contractus	yes	undetermined	undetermined	no	yes	undetermined	undetermined	undetermined	undetermined
Sporobolus cryptandrus	no	undetermined	yes	no	yes	yes	undetermined	undetermined	undetermined
Sporobolus Wrightii	yes	undetermined	undetermined	undetermined	no	yes	undetermined	undetermined	undetermined
Trichachne californica	yes	no	yes	no	yes	yes	yes	yes	no

*Species are marked undetermined where they were not included in the planting, or if planted the results were inconclusive.

The work of Thornber and Griffiths (13) has demonstrated the desirability of Andropogon barbinodis, though it was not outstanding in trials reported in this study. Eragrostis curvula and Bouteloua curtipendula, though they may not be expected to survive on sites subjected to severe conditions, seem adapted in areas having favorable moisture, and once the seedlings are established, they will withstand considerable drought. Though satisfactory stands of Eragrostis curvula have not lived, a few plants established on the Tucson City Farm planting lived for three years.

The species adapted to desilting areas and alluvial bottomlands may be expected to survive on water-spreading areas on eroded flats in the desert grassland as well. In addition to the species listed above, other species seem adapted to these better-drained eroded flats. These are:

Bouteloua Rothrockii	Bouteloua eriopoda
Bouteloua curtipendula	Sporobolus cryptandrus
Bouteloua filiformis	Sporobolus contractus

Species which appear adapted to well-drained slopes, mesas, and plains in the desert grassland type are:

Bouteloua eriopoda	Eragrostis chloromelas
Bouteloua filiformis	Eragrostis curvula
Bouteloua gracilis	Eragrostis Lehmanniana
Bouteloua hirsuta	Hilaria Belangeri
Bouteloua Rothrockii	Leptochloa dubia

Sporobolus cryptandrus

All the above species may be used on areas having 12 to 14 inches rainfall. For areas in the lower desert grassland

having 10 to 12 inches and under, Rothrock grama, Lehmann lovegrass, and Boer lovegrass may be the only species to survive. Rothrock grama is more likely to die out than the other two species, although it tends to reseed itself to some extent.

Species Studied

Exotic Species

Although this paper has dwelt at greater length upon the exotic than upon the native species, their importance should not be over-estimated. They are considered in more detail in this paper, since less is generally known of their characteristics, whereas there are numerous publications on the native species. It must be borne in mind that the exotic species have been under trial for too short a period of years to recommend their use too strongly and without qualification.

Curly Mitchell grass:-

Curly Mitchell grass (*Astrebla lappacea*) and Hoop Mitchell grass (*Astrebla elymoides*) have thrived and spread in moderately alkaline clay loam soils on the Tucson City Farm (Fig. 1) and have survived and made satisfactory growth in sandy loam soil at the Santa Rita Desert Tank area. These grasses are growing on a sheet-eroded flat near Lordsburg, New Mexico, where they were planted in 1939. They have not proven adaptable on well-drained slopes of the desert grassland in the Sonoita planting.

Plate i.

Fig. 1. Curly Mitchell grass growing on an alluvial bottom-land near Tucson, Arizona. These plants have replaced a dense stand of careless weed in two seasons and have taken over an adjacent plot of Rothrock grama.

Both species are introduced bunch grasses from Australia. Dr. H. C. Trumbull, in charge of range investigation at the University of Adelaide, Australia, has reported this bunch grass is a climax grass on the Black Grassland Plains of Australia, where it grows in fertile soil with 16 to 20 inches of rainfall. Under conditions in Southern Arizona, it is a leafy bunch grass attaining a height of two feet. The seed is borne in tough spikelets of which there are about 75,000 per pound. These spikelets are usually well filled with caryopses, and this offsets to a great extent the relatively small number of spikelets per pound. Total seed production per acre is low. Ten degrees above zero is considered the minimum temperature that Mitchell grasses can withstand.

The Mitchell grasses appear suitable for planting in central and southern Arizona and New Mexico at elevations from 2400 to 4500 feet on desilting and water-spreading areas, alluvial bottom lands and eroded flats in heavy soils. They should not be planted on light soils or mesas where moisture is deficient.

Lehmann lovegrass:-

Lehmann lovegrass (Eragrostis Lehmanniana) is a perennial bunch grass having a tufted leafy base during the winter and spring. In the growing season erect leafy stems are produced 24 to 30 inches tall. From four to twelve inches of leafy growth was produced by plants of this species in a spring when adjacent Rothrock grama was dormant, or had from two to six

inches of leafy growth. The basal part of the bunch stays green especially in mild winters, and growth takes place early in the spring if moisture is present. The principal growing period is during the summer rains, at which time a heavy growth of seed is matured. Under conditions of drought, Lehmann lovegrass in open stands has a tendency to produce stolons which take root under favorable moisture conditions. These prostrate stems occur under grazing in open stand; and have even produced seed under these conditions. Rooting at the nodes has been observed along gullies where the grass has been washed over and stems have become partially covered. Spread from layering is not appreciable in thick stands, but significant spread from seed has been observed repeatedly.

Lehmann lovegrass has been grazed under various conditions; palatability of the young growth is apparent from observations on areas grazed by cattle and horses, (Fig. 2). Stock pastured the 100-acre seeding on the McKinney Ranch near Courtland, Arizona, the year around, particularly in the early spring. The period of greatest use appears to be in the spring at the time when there is little growth of perennial grama grasses, and stock are dependent on spring annuals to a large extent. This ability to furnish good forage at this time of year when green feed is scarce makes it a valuable addition to the southwestern ranges. In the Sonoita pasture where the native grama grasses were utilized ten per cent through the fall, winter, and spring of 1940,

Fig. 2. Grazed portion of an irrigated seed production block of Lehmann lovegrass on the Soil Conservation Nursery, Tucson, Arizona.

Photograph by R. A. Darrow.

Lehmann lovegrass was utilized 35 per cent. Fig. 3 taken August 30, 1940, of the row at Pearce, Arizona, showing the seed crop matured under grazing indicates that other grasses are preferred during the summer growing season.

Lehmann lovegrass is a prolific seed producer, and under range conditions with favorable moisture, produces a spring crop of seed as well as the usual crop following the summer rains. Seed production is readily handled, and quantities of seed should be available as a demand for this seed develops. Since this grass has winter-killed during severe winters of six to eight degrees below zero at Albuquerque, New Mexico, and during the winter of 1941-42 at Holbrook, Arizona, it is likely that the Williamson Valley near Prescott is its northern limit in Arizona. In this valley it may be expected to freeze during severe winters. On the College Ranch at Las Cruces, New Mexico, the small plot observed in October, 1938, was reported by Bridges (17) to be growing well in 1941. Plantings established in 1939 and 1940 are making good growth at the same site. A planting was made on the west slope of the Catalina foothills east of U. S. Highway 80 in 1938. The soil, which is Palo Verde gravelly loam, is low in organic matter, and surface moisture disappears rapidly. Lehmann lovegrass and Rothrock grama emerged, although very patchy, and survived to a greater degree than 54 other species tried.

Fig. 3. A row of Lehmann lovegrass in a contour furrow established on a denuded tobosa flat near Pearce, Arizona. Photo taken at the end of the second growing season.

The place of Lehmann lovegrass is foremost in the four sites studied in detail (Figures 4, 5, 6, & 7). The writer has observed this grass in numerous other plantings and has received unpublished reports on its establishment in trial plantings. Scattered patches in one planting and rather well-defined 1/5 acre strips in another planting have been observed in sandy loam soil 16 miles east and 11 miles west of Sells, Arizona. These plots are located in a region with 10-12 inches of rainfall on the Papago Indian Reservation where the natural vegetation is mostly mesquite, cactus, and annual grass, Rothrock grama and black grama having been grazed out. The above plots were planted by the Indian Service in 1938. An excellent stand of Lehmann lovegrass was obtained in one of the same areas in the late summer of 1940 where it was planted in mixture with native and exotic grasses.

Noticeable natural spread was observed from a 100-foot row planted on the Santa Margarita Ranch in the Altar Valley in 1938. J. T. Rigden reported in April of 1940 that this planting reseeded and spread in the plot open to grazing, as well as in the protected plot. The soil is a sandy loam with black grama once predominating. It receives 15 to 17 inches of rainfall yearly.

Lehmann lovegrass has made good growth and spread to adjacent contour furrows at Pearce, Arizona, in plantings made by the Extension Service of the University of Arizona in the summer of 1939.

Fig. 4. Lehmann lovegrass established along a contour furrow on an alluvial bottomland near Tucson, Arizona. The shrubs are saltbush (*Atriplex polycarpa*).

Fig. 5. Lehmann lovegrass growing on an alluvial bottomland near Tucson, Arizona. Weeping lovegrass died out here during the first dry season following planting.

Fig. 6. Mixed stand of grasses on denuded flat on the Desert Tank Area, Santa Rita Range Reserve, Tucson, Arizona. Principal species are Lehmann lovegrass, weeping lovegrass, and Rothrock grama. Photograph taken at end of first growing season.

Fig. 7. A strip of Lehmann lovegrass established on sloping desert grassland range near Sonoita, Arizona. Native grasses are principally blue and hairy grama and poverty three-awn.

Fig. 8. Lehmann lovegrass growing in contour furrows on a water-spreading area near Courtland, Arizona. Seed was broadcast across a ten foot strip. Light grazing was provided the year around in this pasture. Note the spread between the contour furrows. Photograph taken at end of second growing season.

Lehmann lovegrass with some weeping lovegrass was established in contour strips near Courtland, Arizona, in a 100-acre pasture (Fig. 8). This pasture was once black grama range, but at the time the planting was made the vegetation present was chiefly Rothrock grama, three-awn and burroweed. The planting was made in 1939 and was lightly grazed the first season. The Lehmann lovegrass is spreading between the contours, and where there was a good spread of water over the area a solid stand has resulted.

Trial plantings made by the Extension Service in cooperation with the Soil Conservation Service Nursery Division, in the Big Chino Valley, east of Prescott, have fair stands of Lehmann lovegrass (Fig. 9). It was the only species to survive in 1938 in an adjacent planting. In trial plantings made by the Research Division of the Soil Conservation Service, it has been established and is growing in small plots at the Freeman Flat demonstration area near Safford, Arizona. A planting of Lehmann lovegrass was made in 1937 on light textured soil on a loamy mesa near Safford, Arizona. During the summers of 1939 and 1940, there was a noticeable increase in this stand, under protection from grazing.

Lehmann lovegrass may be planted at elevations from 2000 to 4500 feet on water-spreading areas, alluvial bottom lands and eroded flats in desert grassland areas and desert types bordering on the desert grassland type. A fair degree of success may attend its reseeding on gentle slopes and mesas

Fig. 9. Lehmann lovegrass on a mesa near Prescott, Arizona.

Photograph by J. T. Rigden.

in the lower desert grassland, but unless there are moisture conditions to support a natural stand of Rothrock grama, the success in establishing Lehmann lovegrass or any other perennial grass is problematical.

Weeping lovegrass:-

Weeping lovegrass (Eragrostis curvula) is a perennial bunch grass having erect culms four feet tall with dense tufts of basal leaves commonly 20 inches long at maturity. Growth takes place in early spring as in Lehmann lovegrass, and the plants remain green late in the winter in the southern part of the region. Weeping lovegrass is cold-hardy to a minimum of about 15 degrees below zero, having survived at Logan, Utah; Woodward, Oklahoma; Shiprock, New Mexico; and Albuquerque, New Mexico.

There is an increasing amount of evidence that weeping lovegrass is quite palatable to beef cattle and horses although not relished by dairy cows. On the Soil Conservation Nursery, tough, basal leaves of mature plants were not eaten at the end of the growing season, but the younger portions of the plant in the center were eaten (Figures 10 & 11). Seedlings were cropped close to the ground. One and two-year old plants were cropped within one to three inches of the ground where stock had access to them in the planting at Pearce and at the Sonoita area. In the latter area cattle utilized the species 85 per cent through the summer, winter, and spring in a pasture in which the native grama grasses were utilized only ten per cent. Weeping lovegrass was cropped

Fig. 10. An ungrazed portion of the irrigated seed production block of weeping lovegrass on the Soil Conservation Nursery, Tucson, Arizona.

Photograph by R. A. Darrow.

Fig. 11. Grazed portion of an irrigated seed production block of weeping lovegrass on the Soil Conservation Nursery. The centers of the bunches were taken and young seedlings were cropped close to the ground. At the time of pasturing, the bunches were mature and the basal leaves had become dry, tough, and unpalatable. Photograph by R. A. Darrow.

within two to three inches of the ground during mid-October in a pasture where it had been grazed during the summer and fall in the Sulphur Springs Valley. It has been reported from the Dust Bowl region that stock have taken it during the growing season in preference to blue grama.

Weeping lovegrass (Fig. 12) has produced good stands and made good growth during the first growing season, but it has proven less drought-resistant than Lehmann lovegrass. A thick stand of seedlings growing on the City Farm planting in 1938 died with the early summer drought in 1939. Plants established in the mixed planting in the summer of 1939, were found only occasionally in 1940. The row growing in a contour furrow at the Santa Rita Desert Tank area has lived through four seasons. There has been some spread from seedlings there, but it is not significant. At the Extension Service planting at Pearce on a bare sheet-eroded flat, formerly covered with tobosa grass, weeping lovegrass established in a very thick stand in contour furrows made vigorous growth and seeded in 1939. The writer observed the row in the summer of 1940 after it had been grazed. At this time many of the clumps were dead and only part of the remaining ones showed life. At the plot on the College Ranch at Las Cruces, New Mexico, where the annual rainfall is 8", the density of weeping lovegrass was reduced below that of Rothrock grama, Lehmann lovegrass, and Boer grass (Eragrostis chloromelas). At the Sonoita area and on the McKinney Ranch near Courtland the stand of weeping lovegrass has maintained itself and appears well adapted.

Fig. 12. Weeping lovegrass growing on alluvial bottomland near Tucson, Arizona. Photograph taken at the end of the second growing season.

Weeping lovegrass may be planted in the upper areas of the desert grassland type, but below 4000 feet and under 12 inches of rainfall it should be used only as a special-place grass in moist sites.

Kimberly lovegrass:-

Kimberly lovegrass (Eragrostis brizantha), (Fig. 13), is similar in appearance to Lehmann lovegrass. The stems are less fine, and the spikes are broader and more dense than Lehmann lovegrass. At the Santa Rita plot this lovegrass volunteered in depressions and numerous plants were observed taking hold along with Lehmann lovegrass on bare sheet-eroded areas.

Boer lovegrass:

Boer lovegrass (Eragrostis chloromelas) is a perennial bunch grass similar in appearance to weeping lovegrass, but having shorter, less slender, glaucous leaves and a more compact panicle, (Fig. 14). Basal growth remains green through the winter at lower elevations to a greater extent than in the weeping lovegrass. Boer lovegrass is more drought resistant than weeping lovegrass. Less is known of its palatability, but grazing on the row at Pearce indicates it was utilized to the same degree as was weeping lovegrass. It is adapted to seed production under cultivation, but the crops harvested from nursery plots have fluctuated widely in the quantity harvested from year to year.

Boer lovegrass has received less attention in trial plantings than weeping lovegrass. In the planting at the City Farm it was observed to have survived in broadcast plantings

Fig. 13. Volunteer plants of Eragrostis brizantha on the Santa Rita Desert Tank, Santa Rita Range Reserve near Tucson, Arizona. Plants are two years old.

Fig. 14. Boer lovegrass growing in a depression along a contour furrow near Tucson, Arizona. This grass has proved more drought-resistant than weeping lovegrass.

where weeping lovegrass died out. Likewise, at Las Cruces, it was reported by Bridges (17) to have survived better than weeping lovegrass. At the Santa Rita Desert Tank volunteer seedlings were fairly numerous in contour furrows below the original row.

Boer lovegrass appears suited to planting in the same situations as Lehmann lovegrass, but may not be expected to grow in thick stands.

Giant panicum:-

Giant panicum (Panicum antidotale) is a robust perennial bunch grass introduced from Australia. The grass is characterized by a heavy clump which has erect branching culms from four to six feet tall bearing terminal seed heads, (Fig. 15). The culms become tough and cane-like at maturity. Giant panicum is one of the most promising exotic grasses tested. Its adaptability appears similar to that of the Mitchell grasses. Giant panicum made good growth on a strata of Gila fine sand overlain with a thin layer of silt on the bottom land of the City Farm plot. Here it grew to a height of five feet and produced a crop of seed from which numerous volunteers were observed the following year. Despite the fact that giant panicum is a robust, vigorous growing leafy grass, once the plants are well established they can withstand protracted periods of drought.

An observation made on the grass in 1940 on the City Farm illustrates its endurance under drought and its quick recovery when it secures moisture. After little more than two inches

Fig. 15. A clump of giant panicum growing near the Desert Tank on the Santa Rita Range Reserve. Notice the height and volume of this one plant compared to the vigorous native spike dropseed on either side.

of rain from February through early August there was no apparent evidence of life in the crowns of the two year old plants. Following the August flood, the crowns put out new vigorous growth which reached a height of six feet and produced a heavy crop of seed by September. This grass made good growth at the Santa Rita Desert Tank plot. Seed washed down from the plantings above volunteered profusely on the bank of the stock tank. Giant panicum formed solid stands along the contour row, and seedlings volunteered in adjacent rows. At Sonoita it proved unadapted on the grama grasslands, where it made a stunted growth, and only a few plants produced seed. At the Pearce planting on heavy soil it was an outstanding grass. Here it grew three feet high and matured seed the first season.

The plant is much more drought resistant than its vigorous, succulent appearance during the growing season would indicate. Ample evidence exists showing giant panicum is highly palatable when young, and even the tough canes are consumed when feed is scarce. Figures 16 and 17 taken on the Soil Conservation Nursery show growth before grazing and after the leaves have been stripped from plants. Fig. 18 shows mature plants in the row on the Pearce planting closely grazed within one or two inches of the ground. Plants in the Sonoita plantings were grazed closely in 1938. At the time a fence was removed from an established planting of giant panicum in a pasture along the Sonoita Creek near Patagonia, the growth was five feet high and equal to that of Johnson grass growing

Fig. 16. An irrigated seed production block of giant panicum on the Soil Conservation Nursery, Tucson, Arizona, before grazing by cattle and horses. Growth is aftermath following the harvesting of the seed crop.

Photograph by R. A. Darrow.

Fig. 17. Irrigated seed production block of giant panicum after grazing. At the time of grazing the plants were mature, and the canes had become hard and tough. Under range conditions these canes have been consumed.

Photograph by R. A. Darrow.

Plate xvi

Fig. 18. Giant panicum grass along a contour furrow on a denuded tobosa flat near Pearce, Ariz. This grass stood three feet high and matured seed the previous season. It was more closely grazed than any other of twenty-six grasses in the plot except plains bristle grass. The planting recovered and made thrifty growth after being grazed.

along with it. When the plot was visited in the summer of 1940, the clumps had been continually grazed for two summers, and, although they were cropped nearly to the ground, were still alive. Hay of giant panicum fed to steers in the feeding lot at the University Farm was eaten as readily as good Sudan grass hay. J. C. Elms of Phoenix has reported that dairy cattle on his ranch at Rittenhouse, Arizona, ate young gian panicum growing adjacent to alfalfa. Furthermore, his foreman reported that the stock left the alfalfa in favor of this grass. Horses, however, grazed Johnson grass in preference to giant panicum on the City Farm. A field at Florence, Arizona, has been used for feed for a number of years. Giant panicum is readily handled for seed production, and, unlike many members of the genus Panicum, the seed ripens sufficiently uniformly to harvest with machinery and is of good quality. This grass is less winter hardy than weeping lovegrass, and does not make thrifty growth at elevations above 4500 feet.

Though giant panicum may not be expected to grow in thick stands, the volume of forage produced growing as scattered bunches justifies including it in mixture for planting on desilting areas, water-spreading areas, alluvial bottom lands, and eroded flats in the desert grassland area from 2000 to 4500 ft. This species is not adapted to coarse-textured soil on slopes and mesas.

Native Species

Fourwing salt bush:-

Fourwing saltbush (*Atriplex canescens*) seems to vary widely in the degree it is used by stock, but in general it is accepted as highly desirable forage by stockmen and county agents. The U. S. Forest Service considers it to be one of the most valuable forage shrubs on arid sites in the Southwest (14). Plants have lived in the clay soil of the Santa Rita plot under ten inches of rainfall, but this appears to be the lower limit for the species for this soil type and elevation. Seedlings have grown rapidly in the heavy bottom land and on the lighter soil on the slope on the City Farm area under conditions of moderate alkalinity. Fourwing saltbush made rapid growth in the Sulphur Springs Valley on soils formerly supporting tobosa grass, (Fig. 19).

Seedlings planted in 1934 by the Soil Conservation Service at Duncan, Arizona, and at Porter Springs near Safford, Arizona, are thrifty and have made good growth. The latter site is on gravelly loam on a gentle slope where tobosa grass was formerly the principal vegetation.

Fourwing saltbush appears adapted for seeding on water-spreading areas, alluvial bottomlands and eroded flats, and on slopes and mesas having not under 12 inches of rainfall in the desert grassland type.

Plate xvii.

Fig. 19. Fourwing saltbush seedlings growing in contour furrows on a denuded tobosa flat near Pearce, Arizona. Age ten months.

Photograph by J. T. Rigden.

Rothrock grama:-

Crowfoot or Rothrock grama (Bouteloua Rothrockii) has produced good stands and made good growth from seedings, but the duration of the life of the original plants has been short. The concensus of opinion of field men who have observed Rothrock grama is that in unfavorable years it is a summer annual, although it will survive for several years if moisture conditions are favorable. It has reseeded from plantings, but none have been observed in which the original stand has been maintained through volunteer seedlings. The density of the Rothrock grama stand in the contour rows was reduced as much as 60-80% of the amount which would be supported without crowding in the row. This occurred under ten to twelve inches of rainfall on Palo Verde gravelly loam, Commoro sandy loam, and Gila loam soils. Thornber and Griffiths (13) included this species in their planting, and found that, although good stands were obtained, they failed to survive. Extensive areas of this grass lie in the Sulphur Springs Valley between the Chiricahua Mountains and the Dragoon Mountains. The fluctuation in density of these areas from year to year has been noted. D. A. Anderson, in an unpublished study made by the Research Division of the Soil Conservation Service, has reported the annual character of Rothrock grama in dry years. On the bottom land of the City Farm plot the species has been observed to die out completely, which suggests a lack of adaptability to overflow areas and bottom lands or water spreading areas where silt is deposited.

Cassidy and Glendenning (2) list Rothrock grama as a species satisfactory for revegetation. Bridges (17) reports an excellent stand of Rothrock grama was established in 1939 at Las Cruces, although it is not commonly found on adjacent ranges. This stand is still very good after two years growth. Fig. 20 shows a stand of grass composed mainly of Rothrock grama and Lehmann lovegrass on sandy loam soil at the Santa Rita Desert Tank.

An opinion has been expressed by some field men planning revegetation plantings in Southern Arizona that Rothrock grama may be expected to grow, wherever it is adapted, from seed present in the soil. They contend that only moisture is necessary to secure good stands of Rothrock grama in many areas, and in such areas planting this species is not justified. This contention seems to be borne out on parts of the Papago Indian Reservation. In plantings made by the writer, Rothrock grama has been the only species that has been established in stands comparable to those of Lehmann lovegrass.

Rothrock grama may be planted in the same sites as Lehmann lovegrass. Indications are that it will behave as an annual on slopes and mesas in the lower elevation and rainfall areas of the desert grassland except during favorable years. It may be expected to reseed itself to some degree under these conditions, but not sufficiently to maintain a good stand.

Black grama:-

Black grama (Bouteloua eriopoda), although highly successful in a rod row planting at the Santa Rita Desert Tank area

Fig. 20. Mixed grasses on a denuded flat at the Desert Tank Area on the Santa Rita Range Reserve near Tucson, Arizona. Stand is composed principally of Rothrock grama, Lehmann lovegrass, and weeping lovegrass. Planted July 24, 1940. Photograph taken October 1940.

in 1938, and later established in the mixture in 1940, has generally given poor stands from reseeding. In the opinion of the writer, these poor results may be due largely to the difficulty of securing viable seed. Average quality seed as it is collected with machine strippers contains only a small percentage of fertile florets. This seed may have as high as 90% inert matter. In order to secure a good stand with seed of this quality, the amount per acre which would have to be sowed would be prohibitive.

Since successful reseeding with black grama is difficult because of the low quality of seed which can be obtained, use of available seed should be confined to seeding its natural range.

Side-oats grama:-

Side-oats grama (Bouteloua curtipendula) has been used widely in past years. This species was among those tried by Griffiths and Thornber (13) in 1900. It is one of the few range grasses available on the commercial market. The writer has made numerous inquiries on its establishment in plantings and has received reports of only mediocre results. Growth on the City Farm plantings was fair, but this observation is based on only a small number of plants. A good stand in the row at the Santa Rita Desert Tank thinned out markedly the first year during the dry season, and the remaining plants have made little growth in the succeeding three seasons. In the planting at Pearce, Arizona side-oats grama has done well; good

establishment is reported by J. T. Rigden from a planting made in the Chino Valley near Prescott, Arizona, in 1940.

Fifth-acre strips of side-oats and blue grama were planted at Sonoita in the cooperative utilization study. Although 2½ pounds of caryopsis per acre were broadcast, only a scattering of seedlings resulted, whereas in the same plot Lehmann lovegrass planted at the rate of 5 lbs. per acre gave a dense strip across the plot (Fig. 7). The rate of growth of these two grama grasses in this planting was very slow. At the close of the first season after a total of seven inches of summer rainfall, side-oats grama and blue grama seedlings had only one to two inches growth and could be distinguished only with difficulty. At the end of the second growing season, only a few of the larger plants of side-oats and blue grama had produced seed heads. Robust native plants of side-oats grama and blue grama were growing in adjacent strips, thus indicating the soil factor was not limiting their growth. It would appear that side-oats grama and blue grama are inherently slow growing the first two years in any but the most fertile soils.

Side-oats grama appears adapted to the same sites and range as weeping lovegrass,namely in the upper limits of the desert grassland.

Slender grama:-

Slender grama (Bouteloua filiformis) is a longer-lived species than Rothrock grama, and where there is sufficient moisture may be a better grass. It is reported by the Soil

Conservation Service at San Antonio, Texas, to be more easily established than side-oats or blue grama. Growth is more rapid the first and second seasons. Fair establishment of this species was observed in a mixture in contour rows along the Courtland-Pearce highway in the summer of 1940. It was somewhat surprising to note volunteers in the contours on the City Farm from the mulch scattered on impermeable silt loam soil.

Slender grama is found associated with Rothrock grama in the upper desert grassland areas. Seeding should be confined to those areas in which it normally grows.

Tobosa grass:-

Tobosa grass (Hilaria mutica) is one of the best species for control of erosion in the swales and flats in the southern part of the region. Establishment in trial plantings has been generally unsuccessful. Tobosa grass planted in a mixture on the City Farm plot in 1938 was noted with good growth in the summers of 1939 and 1940 and 1941. A planting in the Santa Rita contour row was partially washed out in 1938. However, a few of the seedlings grew and matured seed. In 1940 numerous seedlings were observed growing along the small gully below the original planting. The number of the plants established and the number of seedlings observed was too small to be of significance for erosion control, but did indicate that natural spread may take place through reseeding under not too favorable conditions. A factor largely contributing toward

the failure of tobosa grass seedlings to become established is the low quality of the seed generally found; a large percentage of the clusters may be entirely sterile.

Tobosa grass is adapted as a valuable soil binder in desilting areas, water-spreading areas, eroded flats and swales in the desert grassland from 2400 to 4500 ft. Seeding of this species should be confined to the finer-textured, somewhat compact soils.

Green sprangletop:-

Green sprangletop (Leptochloa dubia) has not generally been considered a species suitable for revegetation use due to its low to moderate palatability and restricted distribution. It is commonly associated with the grama grasses in gravelly soils, and is among the first species to come in on disturbed soils. In the fall of 1938, threshings of this species were distributed over a sheet-eroded, bare flat of silt loam soil on the City Farm. At the end of the next season, there was a good stand of sprangletop along the contours where the mulch had lodged. At the Sonoita planting, it was one of the outstanding species in the contour rows. Its apparent ease of establishment together with ease of securing good seed should make it desirable for planting.

Green sprangletop appears suitable for reseeding slopes and mesas in the upper desert grassland areas.

Twinberry:-

Rough Menodora (Menodora scabra) and Broom Menodora (Menodora scoparius) together with fourwing saltbush have been

the only shrubs successfully established in the trial plantings of this study. Seed planted at the Santa Rita Desert Tank area in 1938 produced a few plants which matured. Numerous seedlings which had spread markedly in the drainage below were noted in the summer of 1941. Good stands came up and made four to six inches of growth at Pearce and Sonoita, but in each case were defoliated by insects during the first summer. When it was planted in a mixture in the summer of 1939 on the Tucson City Farm, twinberry made good growth on sandy loam soil and matured seed the following season.

Although twinberry appears adapted to planting in desert grassland areas on slopes and mesas and well-drained water-spreading areas, its growth is so slow and attacks by insects and rodents are so common that it is questionable whether its planting can be recommended.

Vine mesquite grass:-

Vine mesquite grass (Panicum obtusum) is a desirable native grass for erosion control. Field technicians have reported numerous failures from seeding of this species; it failed to emerge from plantings made at Sonoita and at the Santa Rita Desert Tank. Few plants are required to make a favorable showing, and when this is considered, the stands obtained on the City Farm, though they appeared good, were actually very light. The low quality of the seed generally found and consequent light stand obtained is partially offset by the rapidity with which the plants spread from stolons

under favorable conditions. However, much of the stoloniferous growth dies back during the winter, the prostrate stems remaining alive only where the nodes become rooted. The most outstanding planting of vine mesquite grass was observed at the Extension Service plot near Pearce. Here on a sheet-eroded tobosa flat, vine mesquite grass spread four feet the first season. Growth comparable to this has been observed at the Santa Rita Desert Tank reservoir where along the bank of the gully leading to the reservoir, a clump of vine mesquite grass spread fifteen feet in one season. Likewise, the small patch at the lower end of the tank promises to sod the spillway from the tank in three seasons if it is protected from grazing. Vine mesquite grass was observed to recover quickly following the flood on the City Farm after the prolonged drought of February to August in 1940. During these five months only 2.1 inches of rainfall were recorded. The stubby crowns and rhizomes below ground appeared nearly dead before the flood, but following it they made rapid growth and set a small number of seed heads. A good stand resulted in the summer of 1939 on the City Farm from a seeding made the previous January.

Vine mesquite grass is adapted to reseeding of desilting areas, water-spreading areas, swales and eroded flats in the same sites as giant panicum and tobosa grass.

Whiplash pappusgrass:-

Whiplash pappusgrass (Pappophorum mucronulatum) is generally found growing in swales, depressions, and borrow

pits in the southern part of the region. This grass was one of the outstanding grasses in the Tucson City Farm planting in 1939. It spreads rapidly from the windblown seed. Fig. 21 shows whiplash pappusgrass growing in mixture with Lehmann lovegrass along a contour border on the City Farm.

The widespread belief that it is quite unpalatable makes its use questionable, although there are doubtless areas where the less palatable species would prove desirable. Its palatability during the growing season on the Papago Reservations is without question according to J. J. Thornber, who relates that this grass was abundant on the reservation a number of years ago in swales and depressions along with feather grass. Lawrence Roberson, who made a range survey recently on the Papago Reservations, reports a palatability of 60% for this grass and states it is readily eaten.

Whiplash pappusgrass appears adapted for reseeding water-spreading areas, desilting areas, swales, and eroded flats in the lower areas of the desert grassland.

Dropseeds:-

Spike dropseed (Sporobolus contractus) and sand dropseed (Sporobolus cryptandrus) are two common native grasses which furnish good summer and fall forage. Broadcast plantings of sand dropseed on the City Farm plot gave good stands, but, although the plants matured, they did not produce much volume. A good stand was established at the Santa Rita Desert Tank plot; native volunteers of spike dropseed have come in on this

Fig. 21. Whiplash pappusgrass growing along a contour dyke on the Tucson City Farm planting near Tucson, Arizona. Straw mulch containing seed was scattered on the area in October 1938. The picture was taken October, 1940. Note bare area above contour.

area. These species did not survive in the Sonoita planting, although they occur in mixture with the grama grasses. Sand dropseed made good growth at the Pearce planting.

Spike dropseed and sand dropseed appear adapted to reseeding on well-drained water-spreading areas, eroded flats, slopes and mesas in the desert grassland areas from 2400 to 4500 feet. They are a component of vegetation at higher elevations and may be planted in short grass and sagebrush types.

Plains bristlegrass:-

Plains bristlegrass (Setaria macrostachya) produced volunteers on the flooded flat on the Tucson City Farm, but the plants died out along the contour. This grass made a good growth at the Santa Rita Desert Tank area, the Sonoita Area, and in the Pearce planting it was one of the outstanding species. Poor emergence may generally be attributed to poor seed as the percentage of fertile spikelets produced is very low.

Plains bristlegrass appears adapted to water-spreading areas, swales, and eroded flats in the desert grassland from 2400 to 4500 ft. elevation.

Arizona cottongrass:-

Arizona cottongrass (Trichachne californica) had good survival at the plots on the City Farm and the Santa Rita Desert Tank plantings. On the flooded plot of the City Farm, plants made thrifty growth and numerous volunteers came up

from the seed. Losses have been high in the young seedling stage, but once established, cottongrass withstands severe drought and produces an abundance of fertile seed. It is the outstanding native grass in the Sells planting. Here well defined strips of thrifty plants may be seen four years after planting.

Arizona cottongrass is found associated with plains bristlegrass and is adapted to the same sites.

SUMMARY

Observations on the survival of native and exotic plant species in range trial plantings in Southern Arizona are reported in this study. The objective of the study was the determination of plant species adaptable for reseeding of problem areas in Southern Arizona and New Mexico in need of a vegetative cover.

The experimental procedure and the results of the plantings are given for a three year period at the Tucson City Farm, the Santa Rita Desert Tank, and the Sonoita areas in Pima County, and the Pearce planting in Cochise County, Arizona. Supporting information is reported from plantings at San Vicinte Pasture near Sells in Pima County; the Williamson Valley near Prescott in Yavapai County; Arizona, from the College Ranch at Las Cruces, New Mexico; and from field plantings in the Sulphur Springs Valley.

A description of promising native and exotic species and their performance on the nursery and in trial range plantings is given.

On the basis of studies of field plots and observation of a number of plantings throughout Southern Arizona and Southern New Mexico, species are listed according to the type of site which is to be planted. These sites and the species which

appear adapted under each are as follows:

1. Water spreading areas such as desilting areas, alluvial bottom lands, swales, and eroded flats:

Arizona cottongrass	Lehmann lovegrass
Boer lovegrass	Mitchell grasses
Cane bluestem	Plains bristle grass
Fourwing saltbush	Tobosa grass
Giant panicum	Vine mesquite grass

Whiplash pappusgrass

Side-oats grama and weeping lovegrass may be added where moisture conditions are good. Rothrock grama, slender grama, black grama, curly mesquite, and spike and sand dropseed may be added on well drained sites, but are not considered suitable for desilting areas.

2. Well drained slopes and mesas:

Arizona cottongrass	Lehmann lovegrass
Black grama	Plains bristlegrass
Blue grama	Rothrock grama
Boer lovegrass	Sand dropseed
Curly mesquite grass	Slender grama
Green sprangletop	Side-oats grama
Hairy grama	Weeping lovegrass

Weeping lovegrass may be expected to survive only in favorable sites. Giant panicum, tobosa and the Mitchell grasses failed to make satisfactory growth on this type of site.

Reseeding under arid conditions in the desert and desert grassland type may on occasion give results without seed bed preparation, or without any provision to prevent runoff by means of water retention or increased penetration; however this practice is more than likely doomed to failure and should be discouraged.

Although trials reported in this paper indicate the possibility of successful reseeding when adequate moisture conservation practices have been used, it should be emphasized that proper range management to conserve the vegetation and topsoil is all important.

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