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Growth Seed Yields, and Seedling Production of Native Prairie Plants In Various Habitats of The Mixed Prairie

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GROWTH, SEED YIELDS, AND SEEDLING PRODUCTION OF NATIVE PRAIRIE PLANTS IN VARIOUS HABITATS OF THE MIXED PRAIRIE

being

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by

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A C K N O W L E D G M E N T S

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INTRODUCTION

The native vegetation of the mixed prairie of west-central Kansas was subjected to the worst drought on record during the period 1933 to 1939 inclusive. Data secured from the United States Weather Bureau reveal the fact that precipitation during this period of drought was far below normal. The rainfall deficit as reported by Albertson and Weaver (1942) was nearly 35 inches for this 7-year period. Other climatic factors such as wind movement, relative humidity, and temperature were equally abnormal.

The extreme drought period greatly modified the vegetation of the mixed prairie and the short-grass disclimax. The basal cover in these two types of vegetation before the drought ranged between 65 and 95 per cent. During the 7 years of deficient rainfall, however, this cover was reduced to nearly zero in many places and an average cover of 1 to 20 per cent was common (Weaver and Albertson, 1940). The direct causes of loss in vegetation were deficient soil moisture, overgrazing and dust carried by wind from cultivated fields and deposited upon the prairie vegetation. The reduction of plant cover resulted in large denuded areas that became extremely susceptible to wind erosion. As range depletion became more extensive the need for a sound conservation program in relation to soil erosion, range management and revegetation became evident.

The native vegetation has proved to be the best adapted to mid-west Kansas and should therefore be used for re-establishing depleted areas.

These conditions have presented many problems for research men.

Some of these problems pertain to variation in growth, yield of seed and mortality rate of seedlings of native prairie plants in various habitats of the mixed prairie. These problems are of vital importance in re-establishing the vegetation in west-central Kansas. The study of basal cover of plants over a period of years will reveal the species best adapted for revegetation. The amount of seed produced by native prairie plants, as well as the ability of the seedlings to ecise, indicates to some extent their value in relation to re-establishing a native plant cover on abandoned cultivated fields and denuded range land.

The term seed yield often referred to in grass production is confusing. Prairie grasses often produce numerous flower stalks and the florets attain natural size, but caryopses do not develop within the florets. The use of the word "seed" for both spikelets and florets, regardless of whether or not they contain caryopses, has made data on grass seed yield difficult to interpret. The number of caryopses per hundred florets is the most accurate method of determining grass seed yield and is the only method of ascertaining the real value of a seed crop.

The present research is concerned with determining the yield of seed in pounds per acre, and the number of seedlings produced in relation to basal cover, habitat and climatic conditions.

RELATED STUDIES

The mixed prairie was first recognized as a distinct plant association by Clements (1920) who described its nature and range, also the grouping

of dominants. Albertson (1937) divided the mixed prairie near Hays, Kansas, into three types. The short grasses occupy the high level land. Little bluestem and its associates are most common on the hillsides and big bluestem dominates the lowlands and ravines.

Weaver and Albertson (1940) made a study of the deterioration of grass land that covered a large area of the midwestern plains. The research included representative grazing lands in western Kansas and Nebraska, portions of southwestern South Dakota, eastern Wyoming and Colorado, and the Panhandle of Oklahoma. In many places it was difficult to distinguish denuded pasture from weedy cultivated land.

Albertson and Weaver (1942) made a thorough study of the native vegetation of western Kansas during 7 years of extreme drought. In many cases the mesic plants disappeared completely and even the most xeric species were reduced greatly in number. They grouped the results according to the conditions to which the area was subjected at the time of the initial quadrating. The conditions were classified as light dusting and moderate grazing, light dusting and over-grazing, heavy dusting and moderate grazing, and heavy dusting and over-grazing.

The yield of grass seed in pounds per acre obtained from the caryopsis count affords limited reference material. Branson (1939) made an analysis of seed production of several species of native Kansas grasses by counting the caryopses per 100 florets.

Fultz (1936) made a study of grass seed on the acre basis. There was a yield of 32.5 pounds of tops which, when threshed, produced 3.4 pounds of pure seed.

Buffalo grass, growing in close association under dry land conditions such as is common in pastures throughout the western part of Kansas, normally produces but a small quantity of seed from year to year. In favorable years, however, good seed crops may be produced (Wenger, 1939-1940).

Riegel (1940) made a study of the variations in the growth of blue grama grass (Bouteloua gracilis) from seed produced in various sections of the Great Plains Region. The grass of the central section produced the greatest number of caryopses per hundred florets for two seasons.

Blake (1935) examined the seeds of western wheat grass (Agropyron smithii) and found that many of the glumes were empty. By discarding the empty glumes the per cent germination was considerably higher.

Savage (1935) found in tracing the history of perennial seedlings in the prairie, that few widely scattered seedlings were discovered. For the seedling which attained temporary establishment, the principal immediate cause of death was drought.

Sporobolus cryptandrus seeds which mature in the late summer or early fall are produced in enormous numbers. Ten thousand mature seeds have been obtained from a single closed panicle. Their total weight was only 0.7 gram (Weaver and Hansen, 1939).

Gates (1941) has drawings of 145 grass, forb, and ruderal seedlings of Kansas, useful for identifying young plants.

To the investigator's knowledge, no one has determined the yield of grass seed in pounds per acre by counting the caryopses per 100 florets, or the pounds of forb and ruderal seed produced per acre for the various plants of the mixed prairie.

ENVIRONMENTAL CONDITIONS

Precipitation

Data on climatic conditions were secured from the United States Weather Bureau, Hays, Kansas. The average annual precipitation for 1939 was 7.84 inches below the recorded normal (Table I). The fall drought, extending from August to the end of December, was the most severe on record for this time of year. Rainfall during May, July and September was 2.46, 2.13 and 1.85 inches, respectively, below normal (Fig. 1). For June and August it barely exceeded normal.

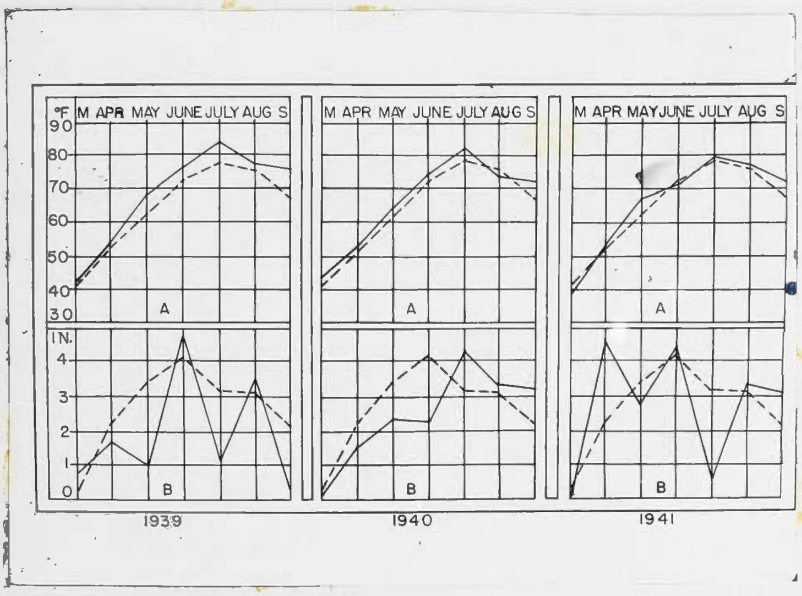


FIG. 1. (A) Normal monthly mean temperature (broken line) and monthly mean temperature (solid line); (B) mean monthly rainfall (broken line) and monthly rainfall (solid line) for growing season of 1939, 1940, and 1941 at Hays, Kansas.

TABLE I. Monthly and annual precipitation (P) for the years 1939, 1940, and 1941 with departure (D) from the normal. Hays, Kansas.

Period	Normal	1939		1940		1941	
		P	D	P	D	P	D
Jan.	0.33	0.48	-0.15	0.72	-0.39	1.08	-0.75
Feb.	0.82	1.05	-0.23	0.35	-0.47	0.85	-0.03
March	0.93	0.98	-0.05	0.83	-0.10	0.58	-0.35
April	2.29	1.65	-0.64	-1.57	-0.72	4.61	-2.32
May	3.46	1.00	-2.46	-2.41	-1.05	2.86	-0.60
June	4.10	4.71	-0.61	-2.36	-1.74	6.40	-2.30
July	3.17	1.04	-2.13	4.21	-1.04	0.63	-2.54
August	3.14	3.53	-0.39	3.30	-0.16	4.14	-1.00
Sept.	2.27	0.42	-1.85	3.14	-0.87	3.02	-0.75
Oct.	1.35	0.18	-1.37	0.62	-0.93	2.35	-0.80
Nov.	1.01	0.11	-0.90	2.58	-1.57	0.54	-0.47
Dec.	0.62	0.70	-0.08	0.82	-0.20	1.07	-0.45
Total	23.69	15.85	-7.84	22.91	-.78	28.13	-4.44

During 1940, precipitation was approximately normal. From February to the closing days of June, the precipitation for each month was below normal, and from the beginning of July to the end of September it was above normal.

Precipitation for 1941 was 4.44 inches above normal. Rainfall during the growing season was above normal for April, June and August and only slightly below during March and May. For July, however, it was 2.54 inches below normal.

Temperature

The mean annual temperature for 1939 was 3.1° F. above normal. During the months of September and December, new high temperatures were established which were 6.5 and 6.2° F. respectively, above normal (Table II).

TABLE II. Average monthly and mean annual temperature (T) and departure from normal (D) at Hays, Kansas.

Period	Normal	1939		1940		1941	
		P	D	P	D	P	D
Jan.	29.8	37.0	-7.2	13.6	-16.2	31.3	-1.5
Feb.	32.5	28.7	-3.8	33.0	-0.5	32.7	-0.2
March	42.0	43.2	-1.2	44.4	-2.4	39.0	-3.0
April	52.6	53.7	-1.1	54.0	-1.4	54.0	-1.4
May	62.0	68.6	-6.6	63.2	-1.2	66.8	-4.8
June	72.6	75.4	-2.8	74.6	-2.0	71.6	-1.0
July	78.6	84.7	-6.1	82.4	-3.8	78.8	-0.2
August	77.4	78.0	-0.6	75.4	-2.0	78.3	-0.9
Sept.	68.5	75.2	-6.5	71.4	-2.7	71.6	-2.9
Oct.	56.0	59.7	-3.7	63.1	-7.1	57.0	-1.0
Nov.	43.5	43.0	-0.5	38.6	-4.9	44.2	-0.7
Dec.	31.0	37.2	-6.2	34.5	-3.5	35.6	-4.6
Total	53.9	57.0	-3.1	54	-0.1	55.1	-1.2

The mean annual temperature for 1940 was approximately normal. The two extremes for this year were January, being 16.2° F. below normal, and October, 7.1° F. above normal. The mean annual temperature for 1941 was 1.2° F. above normal. The mean monthly temperature of May and December was 4.8 and 4.6° F., respectively, above normal. The temperature for the remaining ten months deviated but slightly from normal.

Water Content of Soil

The amount of soil moisture available for plant growth for the three seasons determined from samples, taken to a depth of 5 feet once each month during the growing season, are shown in Table III. The percentage of soil moisture above the hygroscopic coefficient is considered to be the amount of water available for plant growth.

In 1939, a small amount of available moisture was present in the top

12 inches in April but to only a depth of 6 inches during May and June. The moisture content was below the point of availability for the full depth of 5 feet in July but 3.5 inches of rainfall in August restored considerable available moisture in the top 6 inches.

The total rainfall of 1.6 inches in April and 2.4 in May 1940 penetrated to a depth of 12 inches and available moisture was maintained to this depth for the two months. The small amount of rainfall during June failed to supply the needs of the struggling vegetation and no available moisture was present to the depth of 5 feet when determinations were made at the end of the month. The precipitation during July was 4.2 inches and furnished available soil moisture for plant growth to a depth of 12 inches. Vigorous growth of vegetation during August depleted the supply of available moisture except in the top 6 inches. Continued growth in September reduced the amount of available moisture to zero.

Rainfall during the growing season of 1941 was sufficient to furnish excellent growing conditions for the drought stricken vegetation. Rainfall during April (4.6 inches) penetrated to a depth of 3 feet. The amount received during May was sufficient to maintain available moisture to the same depth as in April. The total of 6.4 inches in June restored available moisture to 5 feet. This amount was quickly used by the rapidly growing prairie plants and available moisture was present in only the top 12 inches when moisture determinations were made. The rainfall of 4.2 inches in August penetrated to 24 inches and when the last soil moisture determinations were made in September, available moisture extended to 12 inches.

TABLE III. Percentage of available soil moisture in moderately grazed short-grass type at Hays, Kansas, for the growing seasons of 1939, 1940, and 1941.

Depth (inches)	1939						1940					
	A	M	J	J	A	S	A	M	J	J	A	S
0-6	6.2	0.5	2.9	-3.4	-4.2	-2.2	7.3	4.0	-5.3	13.3	1.5	-2.4
6-12	4.6	-0.7	-0.2	-1.8	-2.5	-2.6	1.3	0.6	-1.2	1.3	0.0	-1.4
12-24	-0.4	-1.6	-1.3	-2.2	-1.8	-1.4	-2.5	-2.1	-1.7	-1.2	-0.5	-0.9
24-36	-2.3	-1.5	-0.1	-1.3	-1.5	-0.8	-1.7	-2.3	-1.8	-1.9	-2.7	-1.4
36-48	-1.2	-1.5	-0.3	0.5	0.3	-0.1	-0.5	-0.6	-0.6	-0.4	-2.0	-1.5
48-60	-0.4	-1.1	1.8	1.3	0.5	0.3	0.9	1.4	0.0	-0.6	-1.2	-0.5

Depth (inches)	1941					
	A	M	J	J	A	S
0-6	19.2	24.0	16.9	0.3	20.2	6.5
6-12	15.8	18.8	14.9	1.5	17.2	5.1
12-24	11.9	13.7	8.3	-1.5	2.1	-0.3
24-36	0.8	3.8	6.8	-1.8	-1.9	-3.5
36-48	-2.1	-0.6	4.3	-2.5	-2.9	-3.1
48-60	-2.6	0.1	2.2	-2.7	-1.4	-2.8

EXPERIMENTAL PROCEDURE

Locating the Study Areas

The three climax types of vegetating include the short grasses that grow primarily on the highland, the little bluestem on the hillsides and the big bluestem on the lowlands. In addition to these three types, are two others of considerable importance due to biotic and climatic disturbances.

Frequently, farmers, for one reason or another, have abandoned large areas of cultivated land and allowed the vegetation on these areas to seek its own course from year to year. The area considered in this study was cultivated for the last time in 1919. Successive waves of plant populations in this area resulted in a fairly stable cover of Sporobolus cryptandrus and Buchloe dactyloides in 1939.

Intense dusting of 1935 moved an enormous amount of earth from parched cultivated fields and deposited it on other fields and grass lands. The depth of layer varied greatly depending upon distance from the source of supply, topography, and nature of vegetation. When a good cover of native vegetation, or a depleted weedy one offered obstruction to the dust laden wind, a layer of dust .5 to 2 inches in depth was deposited over the entire area.

Dust drifts and mounds sometimes 2 to 3 feet or more in height were formed (Weaver and Albertson, 1940). The area considered in this study was small and was bordered on three sides by cultivated fields. Before the period of drought and dust storms, the vegetation was composed of mixed grasses with big bluestem (Andropogon furcatus) common throughout.

The cause of death in the native vegetation by intermittant dusting, resulted in successive waves of annual weeds, followed by a fairly stable cover of Bouteloua gracilis, Buchloe dactyloides and Sporobolus cryptandrus.

On June 8, 1939, a unit area of four 1-meter permanent quadrats forming a grid, was staked out for each area in the five different habitats. All quadrats were labeled with a tin plate denoting location and number of each. The ungrazed area of mixed prairie was divided into the three different types, short-grass type, little bluestem type, and big bluestem type. The variation in the little bluestem was so great, that it seemed advisable to divide it into three subdivisions--one on the upper slope, one on the mid-slope, and one on the lower slope.

The area dusted from nearby cultivated fields was divided into badly, moderately and lightly dusted areas. Quadrats on the revegetation area were located so as to include the two dominant grasses sand dropseed (Sporobolus cryptandrus) and buffalo grass (Buchloe dactyloides). Studies of the vegetation were made continuously throughout the three growing seasons.

Study of Basal Cover

Each quadrat was charted with a pantograph in mid-June or early July for each year during the period of study. The planimeter was used to determine the per cent basal cover of each species of native grass found.

A representative quadrat from each grid studied was photographed for the last two seasons of the research.

Studies of Seed Yield

Each year the ripened seed from all species was collected from the west half of each grid. The east half was left for other studies. The seed from each species was placed in a paper sack, that was labeled corresponding to the quadrat from which it was gathered, and stored in a dry place.

To determine the seed yield of grasses in pounds per acre for each year, the entire sample was poured out on a piece of paper. One hundred representative florets were then selected by taking a few from each portion of the sample. The hundred florets selected were spread in a single layer on a glass plate and illuminated from below by an electric light. Empty florets were transparent, while those containing caryopses, unopened anthers or smut were opaque. All florets appearing to contain caryopses were examined with tweezers in order to eliminate those diseased or with unopened anthers.

The hundred representative florets taken from the entire sample were weighed after which the florets containing caryopses were separated from the empty florets. The percentage weight of caryopses in the hundred florets was then determined and from this percentage, the total weight of caryopses in the meter quadrat was calculated. The yields in pounds per acre were calculated for each species from the gram weight in each meter quadrat.

RESULTS

Cover of Vegetation on Different Types

The results of this study are divided into three major divisions.

1. The basal cover of the native grasses, the number of forbs and the number of ruderals on each type of vegetation.

2. The yield of seed in pounds per acre of each species of grass forbs and ruderals on each type of vegetation.

3. The number and fate of seedlings of native grasses on each type of vegetation.

The results of each are discussed in the order listed above. The basal cover of each species of grass in each type of native vegetation at Hays, Kansas, is discussed for 1939, 1940, and 1941.

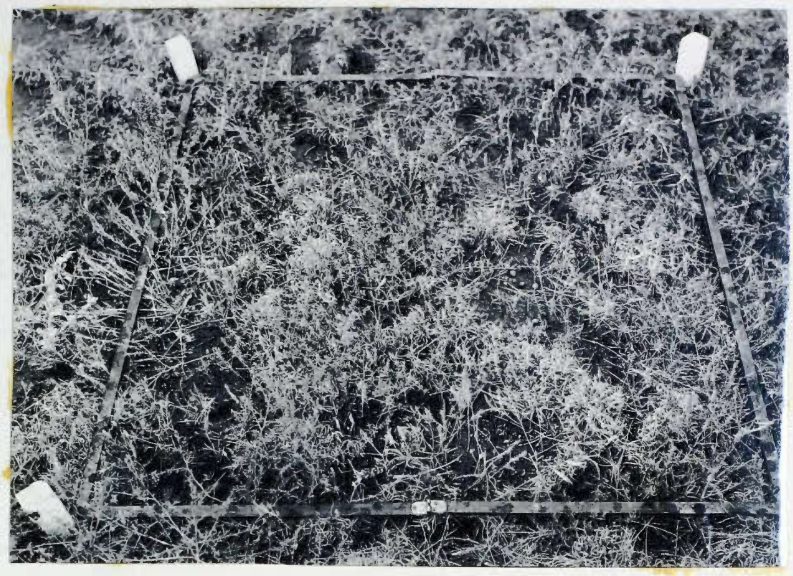
THE SHORT-GRASS TYPE

The major species of grass in the vicinity of the area of the four quadrats studied were Buchloe dactyloides and Bouteloua gracilis. Minor species were Aristida longiseta and A. purpurea; Agropyron smithii was found growing in buffalo wallows and other slight depressions.

Average Basal Cover of Each Species for Each Year

A typical quadrat of the unit area for 1940 and 1941 is shown in Figure 2. In 1940 the cover of 12 per cent was equally divided between the two dominants. During the following year buffalo grass increased to 14.2 per cent and blue grama grass to 15.8 per cent, making a total cover of 30 per cent. All quadrats of the unit area were charted in mid-June, 1939, 1940, and 1941. The average basal cover of grasses in 1939 was 31.7 per cent, of which 27.5 per cent was Bouteloua gracilis, 4.2 was Buchloe dactyloides, with only a trace of Sporobolus cryptandrus.

In June, 1940, the average basal cover was reduced to 11.6 per cent. The cover of Bouteloua gracilis and Buchloe dactyloides was 8.2 and 3.5 per cent, respectively, with Sporobolus cryptandrus increasing to nearly 1 per cent.



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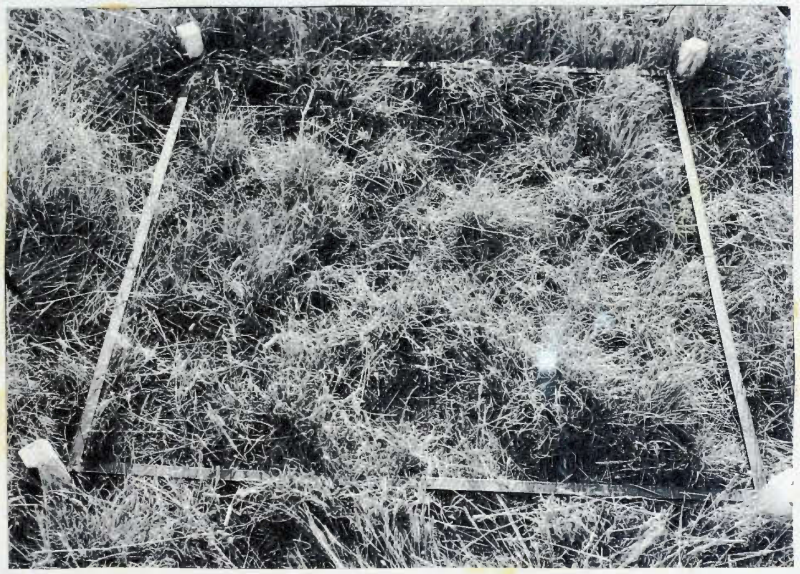

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FIG. 2. (A) Meter quadrat in an ungrazed short-grass type near Hays, Kansas, in June 1940. (B) The same quadrat in June 1941.

Due to improved climatic conditions the grasses had increased in cover when charted in June, 1941. The average total cover of the four quadrats was 29.1 per cent, of which 11.7 per cent was Buchloe dactyloides and 17.4 was Bouteloua gracilis (Table IV).

In order to show in more detail the position of each species of grass during the period of study, a representative quadrat is shown for each of the years, 1939, 1940, and 1941 in Figure 3.

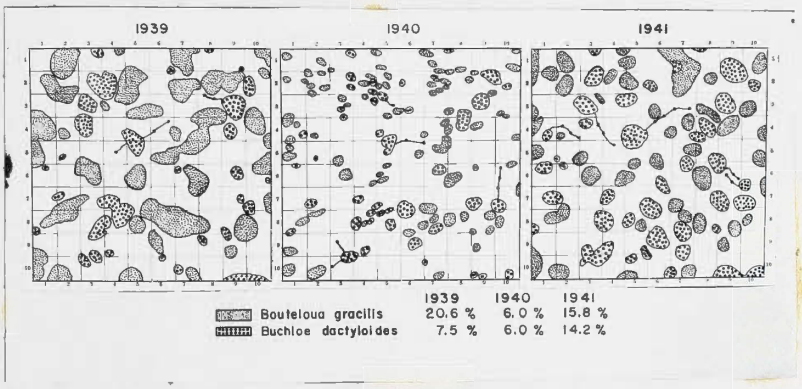


FIG. 3. A representative meter quadrat in ungrazed short-grass type near Hays, Kansas, charted in June 1939, 1940, and 1941.

The quadrats charted in 1939 showed fairly evenly distributed bunches of Bouteloua gracilis ranging from 2 to 16 inches in diameter. In 1940 the bunches had died out in the center, reducing the large bunches to many small ones located on the periphery of the original bunches. When charted in 1941, an enormous increase of cover was shown. The small bunches had united forming larger ones with diameters ranging from 2 to 10 inches. These large bunches were evenly distributed throughout the quadrat.

TABLE IV. Average per cent basal cover of each species of grass in each quadrat on the short-grass type for 3 years. Hays, Kansas.

Quadrat Number	Per cent of basal cover for each species											
	Buchloe dactyloides			Bouteloua gracilis			Sporobolus cryptandrus			Total cover		
	1939	1940	1941	1939	1940	1941	1939	1940	1941	1939	1940	1941
S1--1	1.6	1.6	8.5	24.2	8.2	13.0	0.0	0.1	0.1	25.8	9.7	21.6
S1--2	3.6	3.7	11.4	36.6	11.1	25.4	0.1	0.2	0.2	40.3	15.0	37.0
S1--3	4.3	2.6	12.2	28.4	7.8	15.6	0.0	0.0	0.2	32.7	10.4	28.0
S1--4	7.5	6.0	14.2	20.6	6.0	15.8	0.0	0.0	0.0	28.1	12.0	30.0
Average	4.2	3.5	11.7	27.5	8.2	17.4	T	0.1-	0.1+	31.7	11.6	29.1

The cover of Buchloe dactyloides in 1939 was distributed evenly throughout the quadrat in small bunches from 2 to 4 inches in diameter. In 1940 it suffered a small loss. The size of the tufts became less in most cases but remained constant in some. In some cases the cover increased slightly. In 1941 the old bunches had increased considerably in diameter and new ones were formed from stolons of the previous year. The numerous runners produced early in 1941 accounted for a marked increase in cover at the end of the growing season.

Forbs of Short-grass Type

The species of forbs common in the type surrounding the unit area studied were Malvastrum coccineum, Opuntia humifusa, and Psoralea tenuiflora. Some less common species were Allium nuttallii, Ambrosia psilostachya, Allionia linearis and Gaura coccinea.

The number of forbs was determined when this area was charted in mid-June 1939, 1940, and 1941. The total number of forbs per grid of 4 square meters in 1939 was 3 plants of Malvastrum coccineum. When charted in 1940, the same 3 plants were present and 2 plants of Psoralea tenuiflora and 1 plant of Allium nuttallii appeared for the first time. The same 6 plants were still alive when the area was charted in June, 1941 (Table V).

In order to show in more detail the position and number of each species of forbs during the period of study, a representative quadrat is shown for each of the years (Figure 4). This study indicates that Malvastrum coccineum is very drought-resistant as the same 3 plants lived through the period of study. In 1940, 2 plants of Psoralea tenuiflora

TABLE V. Number of plants of each species of forbs in each quadrat on the short-grass type for 3 years. Hays, Kansas.

Quadrat Number	Number of forbs for each species											
	Malvastrum coccineum			Psoralea tenuiflora			Allium nuttallii			Total number		
	1939	1940	1941	1939	1940	1941	1939	1940	1941	1939	1940	1941
S1--1	0	0	0	0	0	0	0	1	1	0	1	1
S1--2	3	3	3	0	2	2	0	0	0	3	5	5
S1--3	0	0	0	0	0	0	0	0	0	0	0	0
S1--4	0	0	0	0	0	0	0	0	0	0	0	0
Total	3	3	3	0	2	2	0	1	1	3	6	6

were charted and the same 2 were again present in 1941.

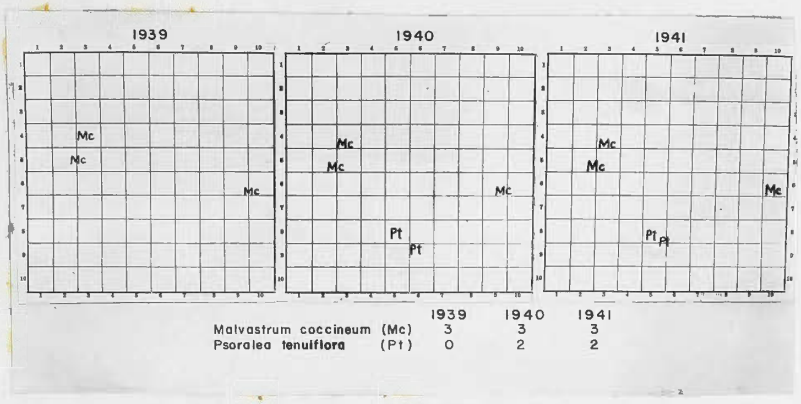


FIG. 4. A representative meter quadrat of forbs in ungrazed short-grass type near Hays, Kansas, charted in June 1939, 1940, and 1941.

Ruderals of Short-grass Type

The total number of ruderals in the unit area of study of 4 square meters was listed in mid-June 1939, 1940, and 1941 (Table VI). The species common in the vicinity around the area were also mentioned.

In 1939, the only ruderal found in the grid was 20 stems of Hordeum pusillum. Other species in the vicinity were Salsola pestifer, Helianthus annuus, Chenopodium album, Plantago spinulosa, P. purshii, Lappula occidentalis, Lepidium densiflorum, Solanum rostratum, Hedeoma hispida, and Sophia pinnata.

The number of plants of each species found in any abundance in 1940 in the unit area of four quadrats was: Lepidium densiflorum 985 plants, Plantago purshii 83 plants, Lappula occidentalis 83 plants, Salsola pestifer 47 plants, Hordeum pusillum 22 plants, Chenopodium album 11 plants, and only 1 plant of Solanum rostratum. Species in the surrounding area

TABLE VI. Number of plants of each species of ruderals in each quadrat on the short-grass type for 3 years, Hays, Kansas.

Species	Quadrat number														
	S1 - 1			S1 - 2			S1 - 3			S1 - 4			Total ruderal in grid		
	1939	1940	1941	1939	1940	1941	1939	1940	1941	1939	1940	1941	1939	1940	194
Chenopodium album	0	6	0	0	1	0	0	2	0	0	2	0	0	11	0
Festuca octoflora	0	0	25	0	0	3	0	0	15	0	0	10	0	0	53
Hedeoma hispida	0	0	0	0	0	0	0	0	12	0	0	0	0	0	12
Hordeum pusillum	20	9	120	0	7	900	0	0	500	0	6	1000	20	22	252
Lappula occidentalis	0	80	0	0	3	0	0	0	0	0	0	0	0	83	0
Lepidium densiflorum	0	210	0	0	225	0	0	300	0	0	250	0	0	985	0
Plantago purshii	0	18	13	0	15	2	0	20	0	0	30	25	0	83	0
Plantago spinulosa	0	0	3	0	0	5	0	0	600	0	0	250	0	0	858
Salsola pestifer	0	15	0	0	7	0	0	14	0	0	11	0	0	47	0
Solanum rostratum	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0
Total	20	338	171	0	259	910	0	366	1127	0	299	1285	20	1242	342

in 1940 were Helianthus annuus, Hedeoma hispida, Plantago spinulosa and a few scattered plants of Festuca octoflora.

The total number of plants of each species in this area of study in 1941 were found as follows: Hordeum pusillum 2520 plants, Plantago spinulosa 858 plants, Festuca octoflora 53 plants, Plantago purshii 40 plants, and only 12 plants of Hedeoma hispida. Other species in the vicinity were Lappula occidentalis, L. heterosperma, Helianthus annuus, Salsola pestifer, Sophia intermedia and Chenopodium album.

The shift in abundance of ruderals from one season to another is quite evident as indicated by the study. In 1939, Hordeum pusillum was the principal weed in the grid, but in the surrounding area there was an enormous amount of Lappula occidentalis. In 1940 this area was covered with an abundance of Lepidium densiflorum, but Hordeum pusillum formed a dense cover in 1941. In many short-grass areas the number of stems of little barley ranged from 120 to 1000 per square meter.

THE LITTLE-BLUESTEM TYPE

The dominant species throughout this type was Bouteloua curtipendula. Its associates on the upper-slope were Bouteloua hirsuta and Sporobolus pilosus of approximately equal rank. The latter two were more prevalent during drought. On the mid-slope, Bouteloua curtipendula and Andropogon furcatus were dominant. The latter was outranked more than 3 times. The more xeric Bouteloua hirsuta and Sporobolus pilosus were practically nil in this area. On the lower-slope, Andropogon furcatus was second in rank. Bouteloua hirsuta and Sporobolus pilosus ranked third and fourth respectively.

A few scattered tufts of Aristida longiseta, A. purpurea, and Sporobolus cryptandrus were observed in this type. Buffalo grass was growing in areas scattered throughout this type and Agropyron smithii was found growing around the base of inclines.

Studies on this type were made on 3 representative areas of four quadrats each. One unit area was located on thin soil near the upper side of the slope. The second was located near the center, and the third near the lower edge of the slope. The cover in each unit area on the different slopes was charted for three seasons. The average total cover for the three years on the upper, middle, and lower slopes was 8.9, 27.3 and 20.2 per cent, respectively.

In 1939, the average basal cover on the upper slope was 13.1 per cent. It decreased to 4.9 in 1940, and then increased to 8.9 in 1941. The cover on the mid-slope for 1939 was 37.3 per cent. In 1940 it was reduced to 14.1 per cent, but in the following year it had increased to 30.7 per cent. On the lower slope the cover in 1939, 1940, and 1941 was 26.3, 10.4, and 24.0 per cent respectively.

Basal Cover of Each Species of Grass

Upper Slope

The average cover of each species on the upper slope in 1939, 1940, and 1941 is given in Table VII. The average cover for Bouteloua curtipendula for three seasons was 4.4 per cent in 1939, only .7 per cent in 1940, and then increased to 1.8 per cent in 1941. The average cover of Bouteloua hirsuta in 1939, 1940, and 1941 was 4, 1.6 and 3.7 per cent

TABLE VII. Average per cent basal cover of each species of grass in each quadrat of little-bluestem type, upper slope for 3 years. Hays, Kansas.

Quadrat Number	Average per cent of cover for each species											
	Andropogon furcatus			Andropogon scoparius			Bouteloua curtipendula			Bouteloua hirsuta		
	1939	1940	1941	1939	1940	1941	1939	1940	1941	1939	1940	1941
S3-1	0.0	0.0	0.0	0.0	0.1	0.0	4.2	0.4	2.2	2.9	.6	2.2
S3-2	0.0	0.0	0.2	1.3	0.0	0.0	2.8	0.4	.5	4.5	1.1	2.5
S3-3	1.1	.5	1.6	0.0	0.0	0.0	6.7	0.6	2.4	4.2	2.1	4.5
S3-4	2.0	.6	2.0	0.8	0.4	1.0	3.8	1.4	2.3	4.6	2.6	5.8
Average	1.0	.2/	1.0	.5/	0.1/	.2/	4.4	.7	1.8	4.0	1.6	3.7

Quadrat Number	Sporobolus pilosus			Average total cover		
	1939	1940	1941	1939	1940	1941
S3-1	4.2	2.5	2.4	11.3	3.9	6.8
S3-2	3.8	2.3	2.1	12.4	3.8	5.3
S3-3	5.7	4.0	4.2	17.7	7.2	12.7
S3-4	0.0	0.0	0.0	11.2	5.0	11.1
Average	3.4	2.2	2.1	13.1	4.9	8.9

respectively. The cover of Sporobolus pilosus averaged 3.4 per cent in 1939. It was reduced to 2.2 per cent in 1940, which was the lightest for any species in this area, and further reduced to 2.1 per cent in 1941. In 1939 Andropogon furcatus and A. scoparius were present in small scattered tufts. In 1940 these two species were reduced to almost nil. In 1941 the cover of Andropogon furcatus was 1 per cent and that of A. scoparius only .2 per cent.

Details of the relative position of each species are shown in a representative quadrat on the upper slope for 1939, 1940, 1941 (Figure 5). The bunches of Andropogon furcatus ranging from 2 to 4 inches in diameter are limited to a small area in one corner in 1939. In 1940 they were reduced to 3 small tufts averaging about 2 inches in diameter. In 1941 this number had increased to 4 bunches each averaging nearly 3 inches in diameter.

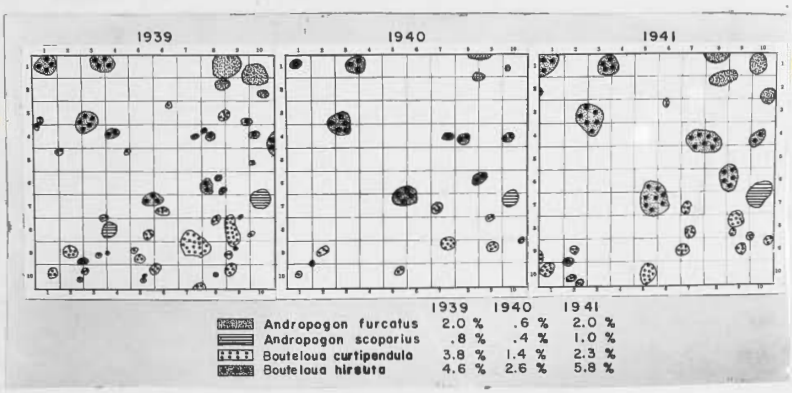


FIG. 5. A representative meter quadrat in ungrazed little-bluestem type, upper slope near Hays, Kansas, charted in June 1939, 1940, and 1941.

Two small bunches of Andropogon scoparius, each approximately 3 inches in diameter were located on opposite sides of the quadrat in 1939.

In 1940 only 1 bunch remained and it was reduced in size. The one tuft left in 1941 had increased to about 4 inches in diameter.

In 1939 two large bunches of Bouteloua curtipendula, approximately 4 inches in diameter were located in the lower right corner of the quadrat. These two bunches were surrounded by many small bunches that varied from 1 to 2 inches in diameter. In 1940 many of the small bunches had died out and the large bunches were reduced to approximately 2 inches in diameter. In 1941 they had made only a slight increase in diameter.

Bouteloua hirsuta was the dominant species in this quadrat. In 1939 the bunches ranged from 1 to 3 inches in diameter and were evenly distributed throughout the meter square. In 1940 the poorly established small bunches had disappeared but the larger ones had increased in diameter. In 1941 it made the greatest gain of all species in the quadrat. Most of the bunches more than doubled in diameter.

Middle Slope

The dominant species on the mid-slope was Bouteloua curtipendula. In 1939 its average cover was 26.5 per cent. Of the total cover of 14.1 per cent in 1940, 12.3 per cent was Bouteloua curtipendula (Table 8). The ideal climatic conditions of 1941 stimulated an enormous increase of plant cover in western Kansas. In July, 1941, the cover of Bouteloua curtipendula had increased to 25.1 per cent. The co-dominant species was Andropogon furcatus. It had an average cover of 7.3 per cent in 1939. In 1940 it was 1 per cent and then increased to 4.7 per cent in 1941. Grasses present in small amounts in 1939 were Andropogon scoparius, Bouteloua hirsuta, and Sporobolus pilosus. These grasses were reduced

TABLE VIII. Average per cent basal cover of each species of grass in each quadrat on little-bluestem type, middle slope for 3 years. Hays, Kansas.

Quadrat number	TOTAL PER CENT OF COVER FOR EACH SPECIES											
	Andropogon furcatus			Andropogon scoparius			Bouteloua curtipendula			Bouteloua hirsuta		
	1939	1940	1941	1939	1940	1941	1939	1940	1941	1939	1940	1941
S2--1	6.1	0.1	2.6	0.1	0.0	0.0	24.8	8.6	21.9	1.5	1.1	1.5
S2--2	8.5	1.2	5.0	0.0	0.0	0.0	24.7	7.9	22.6	1.6	1.6	1.1
S2--3	8.8	1.2	8.2	0.2	0.1	0.2	25.8	15.0	24.7	0.2	0.0	0.0
S2--4	6.0	0.7	3.1	0.4	0.0	0.0	31.9	17.7	31.5	.1	0.9	0.0
Average	7.3	1.0	4.7	0.1/	0./	0.1-	26.5	12.3	25.1	1.0	.5/	1.0

Quadrat number	Sporobolus pilosus			Average total cover		
	1939	1940	1941	1939	1940	1941
S2--1	0.0	0.0	0.0	32.5	9.8	26.0
S2--2	0.5	0.3	0.2	35.3	11.0	28.9
S2--3	0.0	0.0	0.0	35.0	16.3	33.1
S2--4	0.0	0.0	0.0	38.4	19.3	34.6
Average	0.1/	0.1-	0./	37.3	14.1	30.7

to a scanty cover in 1940. In 1941 Andropogon scoparius made a slight gain, but Bouteloua hirsuta and Sporobolus pilosus were reduced to almost zero.

A representative quadrat on the middle slope for 1939, 1940, and 1941 is shown in Figure 6. In 1939 bunches of Andropogon furcatus were distributed irregularly throughout the quadrat. The bunches ranged from approximately 1 to 4 inches in diameter. In 1940 they had decreased in number and also in diameter. In 1941 there was a significant gain and the cover was more than trebled.

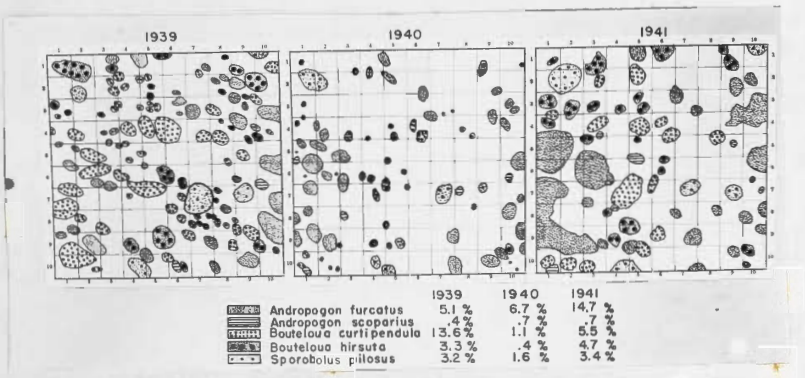


FIG. 6. A representative meter quadrat in ungrazed little bluestem type, middle slope near Hays, Kansas, charted in June, 1939, 1940, and 1941.

One bunch of Andropogon scoparius around 2 inches in diameter inhabited one corner of the meter square in 1939. In 1940 it was reduced to zero and was not present in 1941.

In 1939 large bunches of Bouteloua curtipendula ranging from 5 to 12 inches in diameter dominated this quadrat. Its 31.9 per cent cover compared to the 38.4 per cent of the whole area proves its ability to

thrive under drought. In 1940 the bunches were reduced in diameter from 1 to 4 inches but no significant reduction in number occurred. In 1941 the cover had increased by the union of small bunches through growth forming larger ones that ranged from 4 to 11 inches in diameter. These large bunches were scattered evenly throughout the quadrat.

Only 2 tufts of Bouteloua hirsuta were found in 1939. In 1940 these two bunches had made a slight gain. The following year they were further increased.

Lower Slope

Bouteloua curtipendula was the most common species on the lower slope with an average cover of 11.1, 2.6, and 5.7 per cent respectively in 1939, 1940, and 1941 (Table 9). Andropogon furcatus had a cover of 4.6 per cent in 1939. It was slightly reduced to 3.4 per cent in 1940, but was the leading species in 1941, having a cover of 8.3 per cent. The cover for Bouteloua hirsuta in 1939, 1940, and 1941 was 3.3, .9, and 2.9 per cent respectively. Sporobolus pilosus was 2.2 per cent in 1939, reduced to 1.2 per cent in 1940, and increased to 1.7 per cent in 1941. In 1939 Bouteloua gracilis and Panicum virgatum had a cover of 1.8 per cent each. In 1940 Bouteloua gracilis was reduced to 1.1 per cent and Panicum virgatum to a mere trace. The average cover for Andropogon scoparius in 1939, 1940, and 1941 was 1.4, .3, and .7 per cent respectively.

A representative quadrat on the lower-slope for 1939, 1940, and 1941 is shown in Figure 7. Bunches of Andropogon furcatus varying from a single stem to 4 inches in diameter, were distributed evenly throughout the quadrat in 1939. In 1940 it made a slight gain as a few bunches

TABLE IX. Average per cent basal cover of each species in each quadrat of little-bluestem type, lower slope for 3 years. Hays, Kansas.

Quadrat Number	Per cent of basal cover for each species											
	Bouteloua gracilis			Andropogon furcatus			Andropogon scoparius			Bouteloua curtipendula		
	1939	1940	1941	1939	1940	1941	1939	1940	1941	1939	1940	1941
S4--1	3.7	2.3	7.6	3.6	1.9	4.9	2.5	0.0	1.3	8.2	3.7	6.4
S4--2	0.0	0.0	0.0	4.3	1.2	5.3	0.8	0.1	0.4	9.6	3.2	5.2
S4--3	0.0	0.0	0.0	5.1	6.7	14.7	0.4	0.7	0.7	13.6	1.1	5.5
S4--4	3.4	2.0	3.2	5.4	4.1	8.4	2.1	0.3	0.3	13.3	2.3	5.7
Average	1.8	1.1	2.7	4.6	3.4	8.3	1.4	0.3	.7	11.1	2.6	5.7

Quadrat Number	Bouteloua hirsuta			Panicum virgatum			Sporobolus pilosus			Average total cover		
	1939	1940	1941	1939	1940	1931	1939	1940	1941	1939	1940	1941
S4--1	2.2	0.0	0.3	2.3	1.4	4.3	1.1	0.8	0.9	23.6	10.1	25.7
S4--2	5.5	2.8	4.6	0.3	0.0	0.0	2.6	1.9	1.5	23.1	9.2	17.0
S4--3	3.4	0.5	4.7	0.0	0.0	0.0	3.2	1.6	3.2	25.7	10.6	29.0
S4--4	2.3	0.3	2.2	4.0	2.1	3.6	1.9	0.6	1.1	32.9	11.7	24.5
Average	3.3	.9	2.9	1.8	.9	1.9	2.2	1.2	1.7	26.3	10.4	24.0

increased in diameter. In 1941 it more than doubled its cover. Numerous small bunches appeared, which no doubt grew from dormant rhizomes, stimulated by the excessive spring moisture.

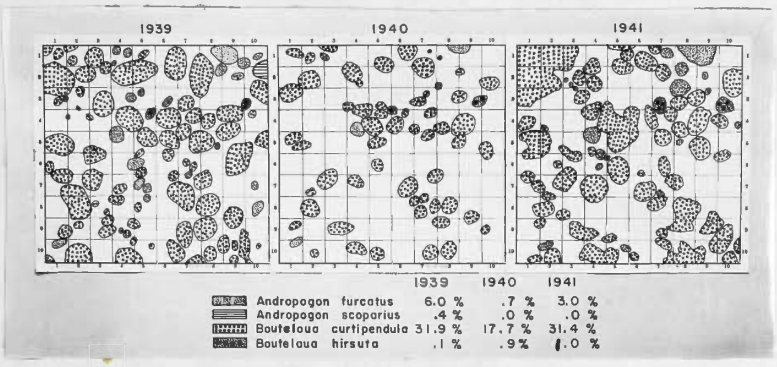


FIG. 7. A representative meter quadrat in ungrazed little bluestem type, lower slope near Hays, Kansas, charted in June, 1939, 1940, and 1941.

In 1939 Andropogon scoparius was represented by 2 small tufts. In 1940 the bunches were reduced in size but the average cover was increased by the appearance of new bunches. The following year it failed to increase its cover.

Bouteloua curtipendula was evenly distributed throughout the quadrat by bunches varying from 2 to 5 inches in diameter, 1939. In 1940 it suffered a severe loss and decreased from 13.6 to 1.1 per cent. The large bunches were reduced in diameter and many of the smaller ones had disappeared. In 1941 it increased by the uniting of small bunches.

In 1939 three bunches of Bouteloua hirsuta approximately 3 inches in diameter were spaced at equal distances across the quadrat. Many smaller bunches were equally intermingled with other species. In 1940 this species suffered considerable loss by the large bunches being

reduced to nil. During the following year however, some gain was made by the enlargement of the old bunches.

The cover of Sporobolus pilosus was composed of 1 bunch approximately 5 inches in diameter and 3 bunches nearly 3 inches in diameter when charted in 1939. The following year all the bunches were reduced to approximately half their former diameters. In 1941 the increase was sufficient to approximately double the cover of 1940.

Forbs of Little-bluestem Type

The principal species of forbs growing throughout the little bluestem type are as follows: Ambrosia psilostachya, Amorpha canescens, Echinacea angustifolia, Liatris punctata, Meriolix serrulata, Psoralea tenuiflora, P. esculenta, Sideranthus spinulosus, Asclepiodora decumbens, Tetraneuris stenophylla, Thelesperma gracile, Lygodesmia juncea, Acerates viridiflora, Asclepias pumila, A. tuberosa, Pentstemon albidus, Solidago rigida, S. glaberrima, Morongia uncinata, Cheirinia aspera, Aster oblongifolius, A. fendleri, A. multiflorus, Opuntia humifusa, Yucca glauca, Petalostemon oligophyllum, P. purpureum, and Parosela enneandra. Forbs that are usually found on brows of hills are Evolvulus pilosus, Scutellaria resinosa, Tragia ramosa, Arenaria texana, Houstonia augustifolia, Lesquerella ovalifolia, Megapterium fremontii, and Paronychia jamesii. There are also many less common species growing in this type.

The variation in total number of plants per grid of 4 square meters in the study area on the upper slope is given in table 10 for each species. In 1939 Thelesperma gracile, with 40 plants was the most abundant forb in

TABLE X. Number of plants of each species of forbs in each quadrat of little-bluestem type, upper slope for 3 years. Hays, Kansas.

Species	Quadrat number														
	S3-1			S3-2			S3-3			S3-4			Total for grid		
	'39	'40	'41	'39	'40	'41	'39	'40	'41	'39	'40	'41	'39	'40	'41
Asclepias pumila	0	0	0	0	0	0	0	0	0	1	0	6	1	0	6
Cheirinia aspera	9	3	34	6	0	24	1	1	0	2	0	17	18	4	75
Echinaceae angustifolia	2	2	2	1	0	0	4	1	4	1	1	1	8	4	7
Galpinsia lavandulaefolia	2	0	0	0	0	0	1	0	1	8	0	3	11	0	4
Gutierrezia sarothrae	0	0	0	0	0	0	1	0	4	0	0	0	1	0	4
Liatris punctata	5	2	2	3	1	0	5	2	4	2	1	2	15	6	8
Lithosperma linearifolium	2	5	7	0	1	3	2	4	5	5	9	7	9	19	22
Lesquerella ovalifolia	1	0	4	2	0	1	2	0	2	8	4	2	13	4	9
Meriolix serrulata	6	6	10	10	6	12	2	4	11	4	6	4	22	22	37
Morongia uncinata	1	1	1	0	0	0	1	2	2	2	2	2	4	5	5
Psoralea tenuiflora	0	0	2	1	2	2	0	0	1	0	0	1	1	2	6
Paronychia jamesii	0	0	0	1	0	0	0	0	0	3	0	0	4	0	0
Tetraneuris stenophylla	6	0	0	3	3	0	2	1	0	2	0	0	13	4	0
Thelesperma gracile	3	0	2	3	3	2	5	1	8	29	8	23	40	12	35
All others	0	0	1	2	2	3	0	0	0	0	1	2	2	3	6
Total	37	17	63	32	18	47	26	16	42	67	32	70	190	85	224

this area. In 1940 this number was reduced to 12 scattered plants but optimum growing conditions in 1941 restored the number of this species to 35 plants per grid in this area. The next most abundant forb was Meriolix serrulata. The 22 plants charted in 1939 were still present in 1940 but this number was increased to 37 in 1941.

The biennial, Cheirinia aspera, was represented by 18 plants in 1939. This number was reduced to only 4 in 1940 but the abundant surface soil moisture in the fall of this year was conducive to a high rate of germination of the seed of this species and 75 plants were present when charted in June of 1941. The number of plants of Liatris punctata, Lesquerella ovalifolia and Echinacea angustifolia, all important forbs of this habitat, was 15, 13, and 8 respectively in 1939. All were reduced in number during the next year and made only slight gains in 1941. Lithospermum linearifolium was the only forb of any importance to increase in number during all years. In 1939 only 9 plants were found in the 4 meter quadrats. This number was doubled in 1940 and only slightly increased to 22 in 1941. The variation in number of plants of the other species of this study area may be found by referring to table 10.

The variation in total number of plants for each species in the study area on the middle slope is given in table 11. In 1939 Liatris punctata, with 17 plants was the most abundant forb in this area. In 1940 this number was reduced to 5 plants but in 1941 it gained to 6 plants in this area. The next most abundant forb was Amorpha canescens. The 11 plants charted in 1939 were still present in 1940. This number was increased to 13 in 1941. Moroncia uncinata was represented by 9 plants in 1939. The

TABLE XI. Number of plants of each species of forbs in each quadrat of little-bluestem type, middle slope for 3 years. Hays, Kansas.

Q Species	Quadrat number														
	S2-1			S2-2			S2-3			S2-4			Total for grid		
	1939	1940	1941	1939	1940	1941	1939	1940	1941	1939	1940	1941	1939	1940	1941
Asclepias pumila	0	1	2	4	3	2	0	0	3	0	1	0	4	5	7
Amorpha canescens	2	2	2	6	5	8	1	2	1	2	2	2	11	11	13
Echinaceae angustifolia	2	2	3	0	0	0	0	0	0	2	2	2	4	4	5
Liatris punctata	3	1	0	7	3	2	4	0	2	3	1	2	17	5	6
Morongia uncinata	1	0	0	3	2	2	2	5	5	3	5	5	9	12	12
Psoralea tenuiflora	0	0	5	0	0	1	0	4	5	1	0	1	1	4	12
Tetraneuris stenophylla	0	0	0	2	0	0	1	2	3	0	3	1	3	5	4
Thelesperma gracile	0	1	9	0	5	10	0	0	0	0	1	2	0	7	21
all others	0	1	1	1	0	1		2	2	0	1	1	1	4	5
Total	8	8	22	23	18	26	8	15	21	11	16	16	50	57	85

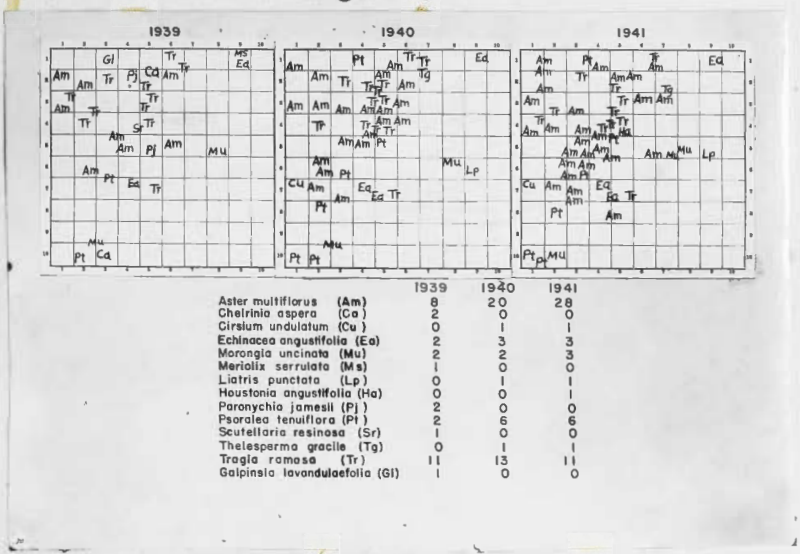
12 plants charted in 1940 were still present in 1941.

The number of plants of Asclepias pumila, Echinacea angustifolia, and Tetraneuris stenophylla, all important forbs of this area, was 4, 4, and 3 respectively in 1939. Echinacea angustifolia remained the same for the next year, while the other two made slight gains. In 1941 Tetraneuris stenophylla showed a slight reduction and the remaining two made a small gain. Thelesperma gracile was the only forb of any importance that made a tremendous gain during the period of study. In 1939 it was absent from the area, but in 1940, 7 plants were present and in 1941 it increased greatly to 21 plants.

The variation in total number of plants for each species in the study area on the lower slope is given in table 12. Aster multiflorus made the greatest increase of all forbs in this area for each season of study. In 1939, 12 plants were present. This number was increased to 25 per grid in 1940 and then to 35 in 1941. The total number of plants of Psoralea tenuiflora was 11 in 1939, 30 in 1940, and 23 in 1941. The decrease in number in 1941 was due to the continued attack of walking sticks. In 1939 Tragia ramosa with 22 plants was the most abundant forb in this area. In 1940 this number was increased to 29 plants and in 1941 it was reduced to 28 plants. The next most abundant forb was Echinacea angustifolia. Of the 17 plants charted in 1939, only 9 were present in 1940, and the same number was present in 1941. Morongia uncinata was represented with 16 plants in 1939. This number was increased to 21 the following year and decreased to 20 per 4 square meters in 1941. The

variation in number of plants of the other species of this study area may be found by referring to table 12.

The relative position of each species during the study is shown in a representative quadrat of the little-bluestem type for each of the years 1939, 1940, and 1941 (Figure 8).



	1939	1940	1941
Aster multiflorus (Am)	8	20	28
Chelrinia aspera (Ca)	2	0	0
Cirsium undulatum (Cu)	0	1	1
Echinacea angustifolia (Ea)	2	3	3
Morongia uncinata (Mu)	2	2	3
Meriolix serrulata (Ms)	1	0	0
Liatris punctata (Lp)	0	1	1
Houstonia angustifolia (Ha)	0	0	1
Paronychia jamesii (Pj)	2	0	0
Psoralea tenuiflora (Pt)	2	6	6
Scutellaria resinosa (Sr)	1	0	0
Thelesperma gracile (Tg)	0	1	1
Tragia ramosa (Tr)	11	13	11
Galpinsia lavandulaefolia (Gl)	1	0	0

FIG. 8. A representative meter quadrat of forbs on ungrazed little-bluestem type for 3 years, Hays, Kansas.

Ruderals of Little-Bluestem Type

Comparatively few ruderals were present in the little-bluestem type. The most common ones throughout the area were Hedeoma hispida, H. longiflora, Festuca octoflora, Salsola pestifer, Chenopodium album, Helianthus annuus, Sophia intermedia, Lappula occidentalis and Lepidium densiflorum. The greatest number of plants for any species in one quadrat was in 1940 when 20 plants of Lappula occidentalis were found in one quadrat on the upper slope. The usual number, however, was from 1 to 3 per meter quadrat.

TABLE XII. Number of plants of each species of forbs in each quadrat of little-bluestem type, lower slope for 3 years. Hays, Kansas.

Species	Quadrat number														
	S4-1			S4-2			S4-3			S4-4			Total for grid		
	'39	'40	'41	'39	'40	'41	'39	'40	'41	'39	'40	'41	'39	'40	'41
Aster multiflorus	8	20	28	4	5	7	0	0	0	0	0	0	12	25	35
Cheirinia aspera	2	0	0	6	0	7	3	0	27	2	8	0	13	8	34
Echinaceae angustifolia	2	3	3	6	4	2	4	1	0	5	1	4	17	9	9
Galpinsia lavandulaefolia	1	0	0	0	0	0	1	0	0	2	0	4	4	0	4
Liatris punctata	0	1	1	1	3	1	1	0	0	0	0	0	2	4	2
Morongia uncinata	2	2	3	8	8	6	2	5	6	4	6	5	16	21	20
Meriolix serrulata	1	0	0	2	2	1	0	0	0	0	0	0	3	2	1
Psoralea tenuiflora	2	6	6	4	15	9	4	6	6	1	3	2	11	30	23
Paronychia jamesii	2	0	0	1	1	0	0	0	0	1	0	0	4	1	0
Scutellaria resinosa	1	0	0	0	0	1	0	0	0	1	0	4	2	0	5
Thelesperma gracile	0	1	1	1	2	11	0	0	1	0	0	0	1	3	13
Tragia ramosa	11	13	11	8	11	12	3	5	5	0	0	0	22	29	28
All others	0	1	2	1	0	0	2	1	1	1	2	0	4	4	3
Total	32	47	53	42	51	57	20	18	46	17	20	19	111	136	177

Big-Bluestem Type

The lower slopes and ravines where the soil is more moist, are dominated by big-bluestem and its associates. It was not feasible to use a pantograph in determining basal cover of these tall grasses. Hence, the plants were listed in stems per square meter.

The dominant species of grasses and sedges in this type are Andropogon furcatus, Sporobolus hookeri, Carex gravida, Agropyron smithii, and Bouteloua curtipendula. Sub-dominant species are Sorghastrum nutans, Panicum virgatum, Elymus virginicus, E. canadensis, and Andropogon saccharoides. Species of grasses occasionally inhabiting this type are Bouteloua gracilis, Buchloe dactyloides, and Sporobolus cryptandrus.

The average number of stems per quadrat in this type was 838 in 1939, 706 in 1940, and 943 in 1941. This indicates a considerable reduction of cover in 1940. The big increase in 1941 was no doubt due to the great amount of rainfall. The shift of cover for each species during the period showed least decrease for the more xeric species and in some cases they even increased. However, the more mesic species were greatly reduced in number.

Average Number of Stems of Each Species

The number of stems of Andropogon furcatus per meter quadrat was 436 in 1939, 327 in 1940 and 475 in 1941. For Agropyron smithii, it was 16 in 1939, reduced to 12 in 1940 and then increased to 19 in 1941. Bouteloua curtipendula was relatively scarce in this area and only 6 stems were present in 1939, 5 in 1940 and 12 in 1941. Carex gravida was also

materially affected by the drought of 1939 and 53 stems were present in that year, 20 stems in 1940 and 42 stems in 1941. Sporobolus hookeri gradually increased for all three years. The number of stems per square meter of this species for 1939, 1940, and 1941, was 327, 342, and 395 respectively (Table 13).

Shift of Species in Representative Quadrat for Each Year

In order to show in more detail the position of each species of grass during the period of study, a representative quadrat is shown for each of the years 1939, 1940, and 1941 (Figure 9). In 1939 Andropogon furcatus was distributed fairly evenly throughout the quadrat. In 1940 the stems had decreased in nearly every square decimeter but in 1941 it made an enormous increase. In 1939 stems of Agropyron smithii were scattered sparingly among the other species. The number of stems decreased in two of them during the next year; however, in 1941 it increased by reappearing in places vacated the year before.

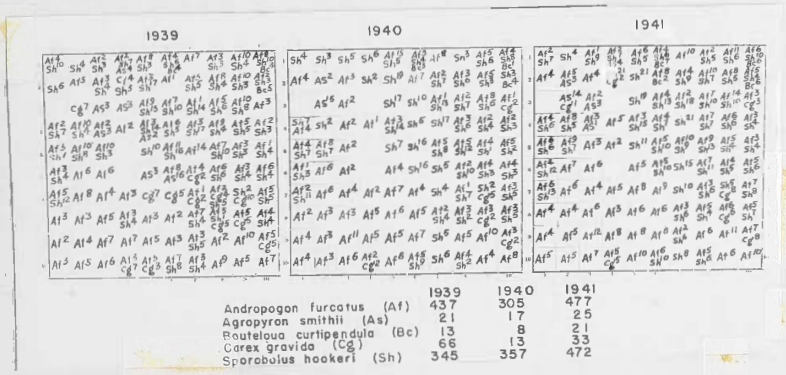


FIG. 9. A representative meter quadrat in ungrazed big-bluestem type near Hays, Kansas, charted in July 1939, 1940, and 1941.

Bouteloua curtipendula was confined to one corner in 1939. In 1940

TABLE XIII. Number of stems of each species of grass charted in a meter quadrat of big-bluestem type for 3 years. Hays, Kansas.

Species	Year	Quadrat number S5-1	S5-2	S5-3	S5-4	Average number
Andropogon furcatus	1939	453	470	437	384	436
	1940	320	401	305	283	327
	1941	502	480	477	443	475
	Average	415	450	406	370	410
Agropyron smithii	1939	10	24	21	10	16
	1940	8	18	17	5	12
	1941	12	27	25	15	19
	Average	10	23	21	10	16
Bouteloua curtipendula	1939	8	0	13	5	6
	1940	5	0	8	8	5
	1941	13	0	22	14	12
	Average	9	0	14	9	8
Carex gravida	1939	0	2	66	145	53
	1940	0	0	13	68	20
	1941	0	8	33	127	42
	Average	0	3	37	113	38
Sporobolus hookeri	1939	319	420	345	226	327
	1940	352	430	357	231	342
	1941	399	465	472	246	395
	Average	356	438	391	234	329

it had made a small reduction and in 1941 it was present in the same decimeters but had increased in number of stems. Carex gravida inhabited an area near one side of the quadrat in 1939. In 1940 it took an enormous loss; in many decimeters it had entirely disappeared. The increase in 1941 was made by adding stems in decimeters already inhabited. Sporobolus hookeri was present in large bunches throughout the unit area in 1939. In 1940 it increased throughout the quadrat displacing Carex gravida in numerous cases. The following year it increased in the decimeters where it was found the year before, but in most instances it did not inhabit new areas.

Forbs of Big-bluestem Type

The grid staked out in this type was devoid of forbs, although many were growing in the vicinity. The common forbs were Vernonia baldwini, Salvia pitcheri, Gaura parviflora, Aster multiflorus, Psoralea tenuiflora, Verbena stricta and Amorpha canescens. Some species less common were Ratibida columnaris, Glycyrrhiza lepidota, Helianthus maximiliani, Lythrum alatum, Kuhnia glutinosa, Lippia cuneifolia, Callirrhoe involucrata, Ambrosia psilostachya, Onosmodium occidentale, Solidago mollis, S. rigida, Cirsium undulatum, Silphium interegrifolium and S. laciniatum.

Ruderals of Big-bluestem Type

Debris of soil and dead plants washed down from above and covered much of the vegetation, creating many bare areas. These were usually populated with myriads of ruderals such as Helianthus annuus, Chenopodium album, Salsola pestifer, Euphorbia marginata, Sophia intermedia, and S.

pinnata. Some less common ruderals were Hordeum pusillum, Croton texensis, C. monanthogynus, Erigeron canadensis, Lappula heterosperma, and L. occidentalis.

Ruderals were absent in this grid in 1939. In 1940, 29 plants of Chenopodium album, 30 of Lappula occidentalis, and 6 of Sophia intermedia were listed. The only ruderal present in 1941 was 1 plant of Galium aparine.

The Revegetation Type

The dominant grasses in this area consisted of Sporobolus cryptandrus and Buchloe dactyloides, therefore a representative area of three quadrats was staked out for each species. Sub-dominant grasses in the vicinity of the grids consisted of Bouteloua gracilis, Aristida longiseta, Chloris verticillata, and occasionally a clump of Bouteloua curtipendula. Scattered patches of Agropyron smithii inhabited the depressions.

Buchloe dactyloides Area

The average total cover on the Buchloe dactyloides grid was 86.5 per cent in 1939. This was reduced to 74.4 per cent in 1940 and then increased to 89.9 per cent in 1941. The average cover of the dominant was 85.1 per cent in 1939. There was a significant loss in 1940 when the cover was only 73.1 per cent. In 1941, however, the cover was increased to 89.2 per cent (Table 14).

The per cent cover of Sporobolus cryptandrus was negligible, being 1.2, 1.1, and .5 respectively in 1939, 1940, and 1941. Only a trace of Aristida longiseta was found in any of the three years.

In 1939, a representative area in the Buchloe dactyloides grid had a

TABLE XIV. Average per cent basal cover of each species of grass in each quadrat of Buchloe dactyloides area for 3 years. Hays, Kansas.

Quadrat number	Per cent of basal cover for each species											
	B. dactyloides			Sp. cryptandrus			A. longiseta			Total cover		
	1939	1940	1941	1939	1940	1941	1939	1940	1941	1939	1940	1941
A2-3	78.6	52.2	89.9	0.0	0.0	0.0	.4	.3	.4	79.0	52.5	90.3
A2-4	85.9	81.3	87.6	2.4	1.9	1.2	0.0	0.0	0.0	88.3	83.2	88.8
A2-5	90.8	85.9	90.2	1.3	1.5	.3	.2	.1	.2	92.3	87.5	90.7
Average	85.1	73.1	89.2	1.2	1.1	.5	.2	.1	.2	86.5	74.4	89.9

well sodded turf with small bare areas scattered throughout the quadrat (Figure 10). One small clump of Aristida longiseta nearly 2 inches in diameter was growing near the border line. In 1940, the cover had decreased greatly and the dense mat had divided into irregular patches ranging from approximately 2 to 12 inches in diameter. The Aristida longiseta suffered only a slight reduction. In 1941 the scattered patches of Buchloe dactyloides had increased through stolon growth and had formed a heavy turf with an occasional open space. The Aristida made only a slight increase in diameter.

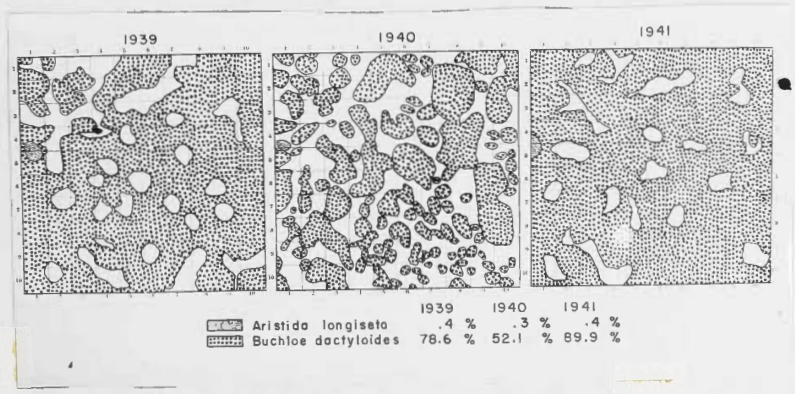


FIG. 10. A representative meter quadrat in ungrazed revegetation type, buffalo grass area near Hays, Kansas, charted in June 1939, 1940, and 1941.

Sporobolus cryptandrus Area

The average total cover in the Sporobolus cryptandrus area for 1939, 1940, and 1941 was 32.9, 21.3, and 25.0 per cent respectively (Table 15).

TABLE XV. Average per cent basal cover of each species of grass in a meter quadrat of Sporobolus cryptandrus area for 3 years. Hays, Kansas.

Quadrat number	Per cent basal cover for each species											
	Sp. cryptandrus			B. gracilis			A. longiseta			Total cover		
	1939	1940	1941	1939	1940	1941	1939	1940	1941	1939	1940	1941
C-1	19.0	18.0	15.2	10.7	7.7	12.8	.5	.6	1.1	30.2	26.3	29.1
C-2	36.1	21.9	29.6	0.0	0.0	0.0	.9	.8	.4	37.0	22.7	30.0
6-2	30.6	15.0	16.0	0.0	0.0	0.0	0.0	0.0	0.0	30.6	15.0	16.0
Average	28.5	18.3	20.2	3.5	2.5	4.2	.5	.5	.5	32.9	21.3	25.0

On this type the average cover for the dominant in 1939, 1940, and 1941 was 28.5, 18.3, and 20.2 per cent respectively. Bouteloua gracilis was relatively scarce and had a cover of only 3.5 per cent in 1939, 2.5 per cent in 1940, and 4.2 per cent in 1941. Aristida longiseta maintained a cover of .5 per cent throughout the three consecutive seasons.

In 1939, large irregular bunches of Sporobolus cryptandrus from 8 to 16 inches in diameter were intermingled with many small tufts ranging from approximately 1 to 2 inches in diameter. In 1940, the large bunches had died out in the center, forming numerous small bunches on their periphery. Some of the small clumps had entirely disappeared. In early July 1941, the cover had made a slight increase by the small bunches uniting and the single ones enlarging in diameter (Figure 11).

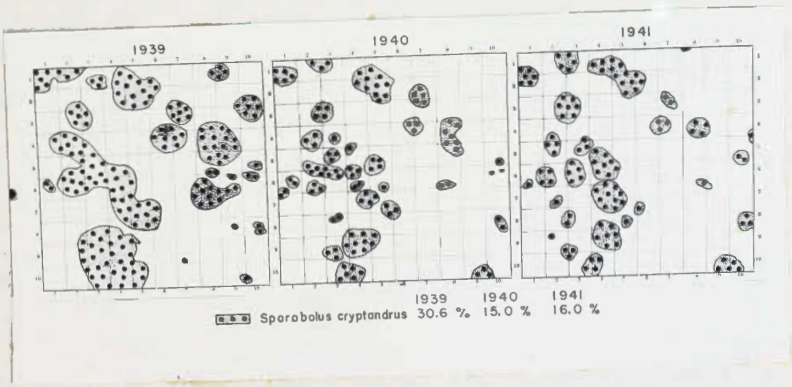


FIG. 11. A representative meter quadrat in ungrazed revegetation type, sand dropseed area, near Hays, Kansas, charted in June 1939, 1940, and 1941.

The most common forbs inhabiting the revegetation type were Ambrosia psilostachya, Psoralea tenuiflora, Cheirnia aspera, Gaura coccinea, Callirrhoe involucrata, and Malvastrum coccineum. The less common species were Verbena bracteosa, V. bipinnatifida, Salvia lanceolata, Specularia perfoliata, and Lygodesmia juncea. The open cover on the Sporobolus cryptandrus area encouraged the invasion of a greater number of forbs, than did the closed cover of Buchloe dactyloides.

Forbs of Buchloe dactyloides Area

Of the 4 forbs found in the Buchloe area in 1939, there were 2 of each species of Ambrosia psilostachya and Psoralea tenuiflora. Of the 4 forbs in 1940, 3 were Ambrosia psilostachya and 1 Psoralea tenuiflora. Of the 20 forbs in 1941, 17 were Ambrosia psilostachya and 3 were Psoralea tenuiflora (Table 16).

Forbs of Sporobolus cryptandrus Area

Of the 8 forbs found in the Sporobolus area in 1939, 1 was Ambrosia psilostachya, 4 were Psoralea tenuiflora, and 3 were Malvastrum coccineum. Of the 11 forbs in 1940, 3 were Ambrosia psilostachya, 2 were Psoralea tenuiflora, 3 were Malvastrum coccineum, and 1 each of Verbena bracteosa, V. bipinnatifida and Salvia lanceolata. Of the 17 forbs in 1941, 8 were Ambrosia psilostachya, 3 were Psoralea tenuiflora, 5 Malvastrum coccineum, and 1 Verbena bracteosa (Table 16).

In order to show in more detail the position of each species of forbs during the period of study a representative quadrat is shown for each of the years 1939, 1940, and 1941 (Figure 12). It indicates that the Psoralea

TABLE XVI. Total number of forbs in 3 quadrats of Buchloe dactyloides area and Sporobolus cryptandrus area of the revegetation type for 3 years. Hays, Kansas.

Species	BUCHLOE DACTYLOIDES AREA. Total number of forbs											
	A2-3			A2-4			A2-5			Total number		
	1939	1940	1941	1939	1940	1941	1939	1940	1941	1939	1940	1941
Ambrosia psilostachya	0	0	0	0	0	9	2	3	8	2	3	17
Psoralea tenuiflora	0	0	0	1	0	1	1	1	2	2	1	3
Total	0	0	0	1	0	10	3	4	10	4	4	20

	SPOROBOLUS CRYPTANDRUS AREA. Total number of forbs											
	C-1			C-2			6-2			Total number		
	1939	1940	1941	1939	1940	1941	1939	1940	1941	1939	1940	1941
Ambrosia psilostachya	0	0	1	1	3	7	0	0	0	1	3	8
Psoralea tenuiflora	2	1	1	2	1	2	0	0	0	4	2	3
Malvastrum coccineum	3	3	3	0	0	0	0	0	2	3	3	5
Verbena bracteosa	0	0	0	0	0	0	0	1	1	0	1	1
Verbena bipinnatifida	0	1	0	0	0	0	0	0	0	0	1	0
Salvia lanceolata	0	0	0	0	1	0	0	0	0	0	1	0
Total	5	5	5	3	5	9	0	1	3	8	11	17

tenuiflora was fairly stable, while the Ambrosia psilostachya shifted considerably.

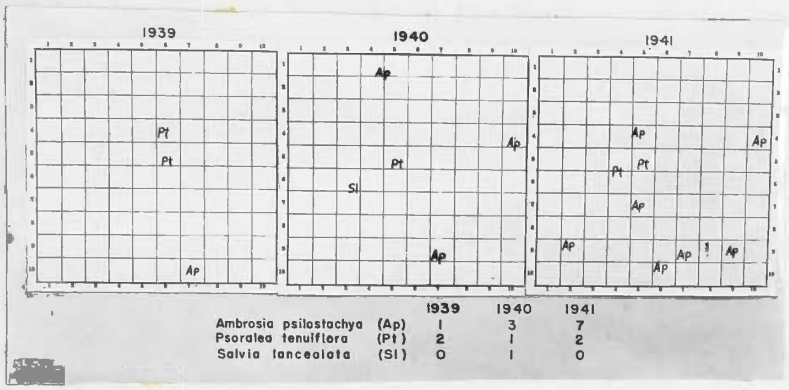


FIG. 12. A representative meter quadrat of forbs in ungrazed revegetation type for 3 years, Hays, Kansas.

Ruderals of Revegetation Type

The most common ruderals ranging throughout the revegetation type were Hordeum pusillum, Solanum rostratum, Lappula occidentalis, L. heterosperma, Helianthus annuus, Salsola pestifer, Plantago purshii, P. spinulosa, Lepidium densiflorum, Chenopodium album, and Sophia intermedia. Some less common species were Schedonnardus paniculatus, Panicum capillare, Euphorbia marginata, Croton texensis, and Physalis lanceolata.

The total number of ruderals per meter quadrat for each season on the Sporobolus area was 100 in 1939, 197 in 1940, and 3700 in 1941.

The total number of plants per square meter for each species during the study period in the Sporobolus area was as follows: Hordeum pusillum 100 in 1939, 175 in 1940 and 3700 in 1941. Six Solanum rostratum plants appeared in 1940 but there were none in 1939 and 1941. There were 13 plants of Salsola pestifer in 1940. Two plants of Lappula occidentalis were found only in 1940.

The total number of ruderals on the Buchloe dactyloides area for the study period was 2 in 1939, 258 in 1940 and 747 in 1941. This variation in number of ruderals for the three years would indicate that they are regulated by the amount of moisture.

The number of plants for each species in the buffalo grass area was considerably less than in the sand dropseed area. Two plants of Panicum capillare were found in 1939 but none thereafter. In 1940 there were 230 stems of Hordeum pusillum, and 747 in 1941. Twenty-six plants of Sophia intermedia were found in 1940 and only 2 plants of Lappula occidentalis.

THE DUSTED TYPE

The principal grasses in this type were Buchloe dactyloides and Bouteloua gracilis. Some less common species were Sporobolus cryptandrus, Aristida longiseta, and Agropyron smithii. By 1941 Andropogon furcatus was frequently found inhabiting the low places.

The cover on the badly, moderately, and lightly dusted areas in the dusted type, portrayed considerable variation in composition of cover. The average per cent cover was lowest on the badly dusted, and greatest on the lightly dusted area.

Dusted Types

The average basal cover for a grid of 4 quadrats in each area for the three years was: badly dusted 14.8 per cent, moderately dusted 24.5 per cent, and lightly dusted 30.1 per cent.

Badly Dusted

The total average cover for this area in 1939, 1940, and 1941 was 10, 7.6, and 25.6 per cent respectively.

The average per cent of basal cover for each species on this area during the study period was 9.8 per cent for Bouteloua gracilis in 1939, 7.1 per cent in 1940, and 24.3 per cent in 1941. The cover for Sporobolus cryptandrus for 1939, 1940, and 1941 was .2, .4, and 1.3 per cent respectively (Table 17).

On the badly dusted area in 1939 the bunches of Bouteloua gracilis, approximately 2 to 8 inches in diameter, were widely scattered throughout the quadrat (Figure 13). In 1940 the bunches were reduced in diameter and some of the smaller ones had disappeared. In 1941 the diameter of the large bunches had increased to nearly 13 inches. In 1939 and 1940 Sporobolus cryptandrus had a cover of .1 per cent for each season. In 1941 the one bunch had increased to approximately 3 inches in diameter.

Moderately Dusted

The total average cover on this area was 27.9 per cent in 1939, 18.2 per cent in 1940, and 27.4 per cent in 1941, (Table 18).

The average basal cover for Bouteloua gracilis in this area was 22.3 per cent in 1939. It was reduced to 17.5 per cent in 1940, and increased to 20.1 per cent in 1941. The cover for Buchloe dactyloides was 3.1 per cent

TABLE XVII. Average percentage of basal cover of each species of grass found in a meter quadrat in badly dusted area for 3 years. Hays, Kansas.

Badly dusted	¼Per cent basal cover of each species								
	Bouteloua gracilis			Sporobolus cryptandrus			Total cover		
Quadrat no.	1939	1940	1941	1939	1940	1941	1939	1940	1941
C1-1	6.1	3.9	17.9	.1	.1	.9	6.2	4.0	18.8
C1-2	11.2	8.3	23.3	.3	.3	.8	11.5	8.6	24.1
C1-3	14.1	10.3	35.7	0.0	0.0	0.0	14.1	10.3	35.7
C1-4	7.8	6.2	20.4	0.5	1.2	3.5	8.3	7.4	23.9
Average	9.8	7.1	24.3	.2	.4	1.3	10.0	7.6	25.6

TABLE XVIII. Average percentage of basal cover of each species of grass found in a meter quadrat in the moderately dusted area for three years. Hays, Kansas.

Moderately dusted	Per cent basal cover of each species								
	Bouteloua gracilis			Buchloe dactyloides			Total cover		
Quadrat no.	1939	1940	1941	1939	1940	1941	1939	1940	1941
C3-1	15.2	13.0	30.4	7.0	5.9	18.6	32.2	18.9	49.0
C3-2	21.1	15.0	29.4	1.8	2.2	7.2	22.9	17.2	36.6
C3-3	27.4	18.8	5.6	3.5	1.4	2.4	30.9	20.2	8.0
Average	22.3	17.5	20.1	3.1	2.5	7.3	27.9	18.2	27.4

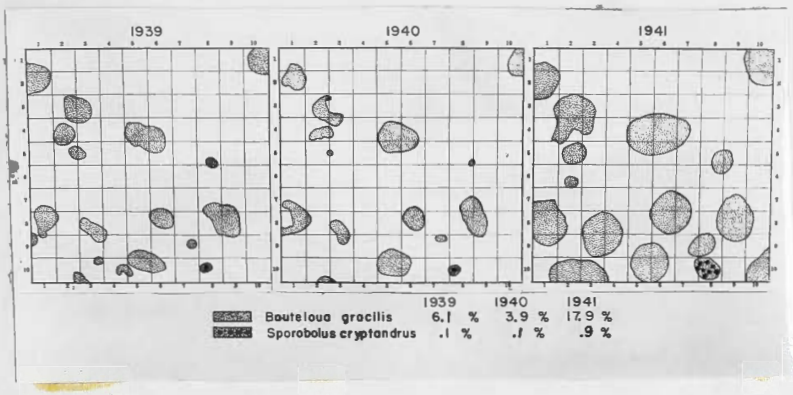


FIG. 13. A representative meter quadrat of grasses on a badly dusted area near Hays, Kansas, Charted in June 1939, 1940, and 1941.

in 1939, 2.5 per cent in 1940, and 7.3 per cent in 1941.

The bunches of Bouteloua gracilis ranged from 2 to 8 inches in diameter on this area in 1939 (Figure 14). They were spaced at fairly equal distances throughout the quadrat. In 1940 the large bunches were divided into many small bunches ranging from 1 to 3 inches in diameter. Many of the small tufts had died, hence the cover was greatly reduced. The increase in 1941 was due to the uniting of small bunches and the increase in diameter of single ones. In 1939 small bunches of buffalo grass were scattered throughout the quadrat. In 1940 these small bunches increased in diameter which slightly increased the total cover. In 1941 the increase of cover was due to the bunches increasing in diameter to

approximately 2 to 6 inches. New bunches were formed from runners produced during 1940.

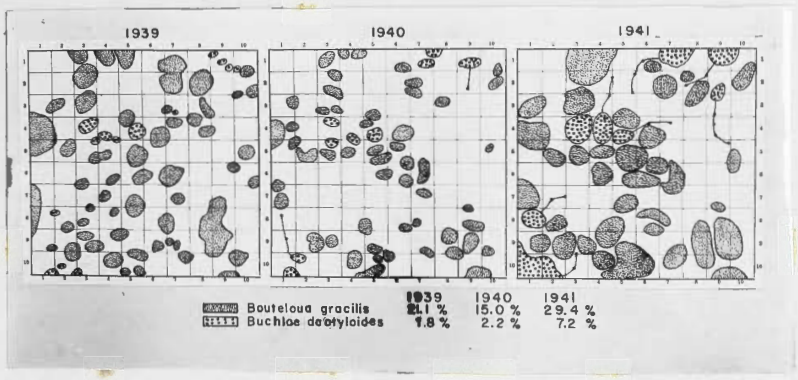


FIG. 14. A representative meter quadrat of grass on a moderately dusted area for 3 years, Hays, Kansas.

Lightly Dusted

The total average cover for this area was 37.7 per cent in 1939. It decreased to 22.4 per cent in 1940, and then greatly increased to 40.4 per cent in 1941 (Table 19).

The average basal cover for Bouteloua gracilis for the same years was 25, 15.2 and 23.8 per cent respectively. For Buchloe dactyloides the cover was 12.5 per cent in 1939, 7.2 per cent the following year, and 16.3 per cent in 1941.

The cover of Bouteloua gracilis on this area in 1939 was composed of large irregular bunches from 2 to 16 inches in diameter (Figure 15).

TABLE XIX. Average percentage of basal cover of each species of grass found in a meter quadrat in the lightly dusted area for 3 years. Hays, Kansas.

Lightly dusted	Per cent basal cover of each species								
	Bouteloua gracilis			Buchloe dactyloides			Total cover		
Quadrat no.	1939	1940	1941	1939	1940	1941	1939	1940	1941
C2-1	30.1	18.4	23.8	2.0	1.6	4.6	32.1	20.0	28.4
C2-2	22.2	14.8	27.7	15.3	6.6	18.6	37.5	21.5	46.3
C2-3	27.2	15.8	25.7	11.9	6.9	15.9	39.1	22.7	41.6
C2-4	20.5	11.9	18.1	21.8	13.8	27.3	42.3	25.7	45.4
Average	25.	15.2	23.8	12.5	7.2	16.3	37.7	22.4	40.4

In 1940 the large bunches had died out in the center producing numerous bunches on the periphery of old bunches. Many of the small clumps had disappeared. In 1941 the numerous small clumps had united and the diameter of single bunches was greatly increased. The diameter of the bunches at this time ranged from approximately 2 to 15 inches.

The Buchloe dactyloides cover in 1939 was represented by 1 large bunch approximately 16 inches in diameter surrounded by numerous small clumps. In 1940 the large patch had divided into many small bunches. Many of the small clumps present the year before were absent. In 1941 the increase in cover was due largely to the increase in size of each tuft.

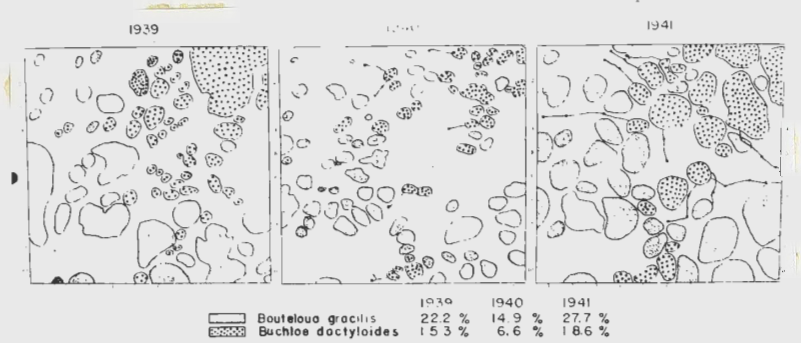


FIG. 15. A representative meter quadrat of grass on a lightly dusted area for 3 years, Hays, Kansas.

Forbs of Dusted Type

Comparatively few species of forbs were found in the dusted type. The

common ones present in the surrounding area were Malvastrum coccineum, Ambrosia psilostachya, and Salvia lanceolata. Some less common species were Psoralea tenuiflora, Lygodesmia juncea, and Gaura coccinea.

The only forb present in the study area was Malvastrum coccineum. It proved to be very drought resistant as it increased in number each season. In 1939 there was an average of 14 plants per grid. In 1940 the number had increased to 17, and further increased to 21 in 1941. Of the 14 mallows in 1939, 8 were on the moderately dusted area and 6 were in the lightly dusted area. In 1940, 7 of the forbs were on the moderately dusted area, and 10 were in the lightly dusted area. Of the 24 in 1941, 9 were in the moderately dusted area and 12 were in the lightly dusted area. The badly dusted area was devoid of forbs during the period of study. To further show the position of each plant during the study period, a representative quadrat for the dusted type is shown in Figure 16. Four plants of Malvastrum coccineum were present in 1939. Five plants were present in 1940. The following year the same 5 plants were present in addition to the 2 new ones that had appeared.

Ruderals of Dusted Type

Species of ruderals commonly found on the dusted type surrounding the study area were Hordeum pusillum, Chenopodium album, Lappula occidentalis, Lepidium densiflorum, Sophia pinnata, S. intermedia, Salsola pestifer, Panicum capillare, Mollugo verticillata, Plantago purshii, Helianthus annuus, Amaranthus retroflexus, A. graecizans, Chamaesyce glyptosperma, C. serpens, Hedeoma hispida and Festuca octoflora.

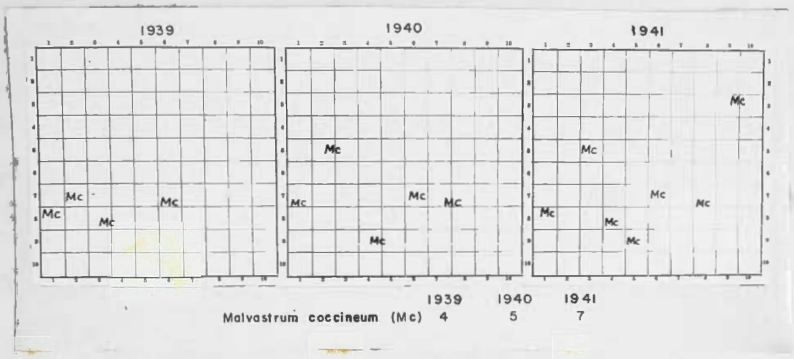


FIG. 16. A representative meter quadrat of forbs on dusted type near Hays, Kansas, charted in June 1939, 1940, and 1941.

The shift of dominance in this type varied considerably in the different dusted areas. Dominant species on the badly dusted area for 1939, was Lappula occidentalis; it changed to Chenopodium album in 1940, and to Hordeum pusillum in 1941 (Table 20).

The leading species for the moderately dusted area was Hordeum pusillum for all three years. In 1941 as many as 9000 stems were present in a single quadrat. Other species of ruderals listed in this area throughout the study period were Lappula occidentalis, Chenopodium album, Salsola pestifer, Lepidium densiflorum, Plantago purshii, Hedeoma hispida and Sophia pinnata.

Hordeum pusillum was the leading species in the lightly dusted area for all three years. Other species common in this area are the same as those mentioned above, except Festuca octoflora that appeared only in 1940.

TABLE XX. Total number of plants of each species of ruderals in 4 meter quadrats of each area of the dusted type. Hays, Kansas.

Species	1939	1940	1941
BADLY DUSTED			
Chenopodium album	157	1283	0
Hordeum pusillum	0	15	478
Lappula occidentalis	945	4	0
Lepidium densiflorum	0	12	0
Mollugo verticillata	0	0	265
Panicum capillare	0	0	115
Sophia pinnata	0	4	0
Salsola pestifer	0	0	5
Average total	1102	1318	863
MODERATELY DUSTED			
Chenopodium album	38	7	0
Hedeoma hispida	0	4	0
Hordeum pusillum	1000	1750	20500
Lappula occidentalis	195	135	0
Lepidium densiflorum	0	11	0
Plantago purshii	0	5	0
Salsola pestifer	0	1	0
Sophia pinnata	0	1	0
Total	1229	1930	20500
LIGHTLY DUSTED			
Chenopodium album	61	40	0
Festuca octoflora	0	14	0
Hedeoma hispida	0	7	0
Hordeum pusillum	530	965	10250
Lappula occidentalis	370	430	0
Lepidium densiflorum	0	21	0
Sophia pinnata	951	1518	10250
Total	951	1518	10250

SEED YIELD ON DIFFERENT TYPES

The seed yield for each species in each habitat varied greatly for the different years. Variation was also apparent for each species in each habitat during each year. It was evident throughout the three years of study that the fluctuation in seed yield was governed by various environmental factors. The high temperature, deficient rainfall, high wind velocity and deficient soil moisture in 1939 reduced the seed yield in many species to nil. The reduction in plant cover due to drought in the fall of 1939 also decreased the yield in 1940. Improved climatic conditions in 1941, however, produced remarkable increases in the seed yields of most of the species studied. The dense growth of Hordeum pusillum in the open cover of short grass decreased the light greatly and was very detrimental to the yield of native plants in these areas.

The damage to seed by insects was quite evident in 1939. Entire plants of Morongia uncinata and Psoralea tenuiflora were eaten by walking sticks. During this same season, grasshoppers destroyed many flower heads of Bouteloua gracilis, B. curtipendula, and Buchloe dactyloides. The grasshoppers also damaged large quantities of seed in 1940 and 1941. Many larvae of other insects were found feeding upon the seed of various plants when the harvest was made. While threshing Lesquerella ovalifolia seed in 1941, many of the pods which were devoid of seed, contained small white larvae.

The feeding of rodents was evident on Tragia ramosa as many pods were broken open and the seeds were eaten. Many burs of Buchloe dactyloides had been torn apart and the seed destroyed.

The combination of all environmental factors resulted in variation of seed production for each season during the period of research.

Short Grass Type

The average total yield of seed in pounds per acre for each of the three years was 6.6 pounds in the dry year of 1939, 481.4 pounds in 1940, and 326.9 pounds per acre in 1941.

Of the 6.6 pounds per acre produced in 1939, 3.6 pounds was grass seed and the remaining 3 pounds was ruderal seed. The total yield in 1940 was 481.4 pounds per acre. Of this amount, the grasses produced 14.4 pounds, the forbs 58 pounds, and the ruderals 409 pounds. Out of 326.9 pounds in 1941, 30.4 pounds was grass seed, 79 pounds was forb seed and 217.5 pounds was ruderal seed. A large number of ruderals was listed for 1940 which did not appear in 1939 and 1941 which accounts for the greater seed yield of 1940.

The total cover for the period was 33.5 per cent in 1939, 12.5 per cent in 1940, and 29.3 per cent in 1941 (Table 21).

The average yield of Buchloe dactyloides seed on this type in 1939 was 2.1 pounds per acre on a cover of 2.6 per cent. In 1940 an average seed yield of 3.2 pounds was harvested from a cover of 2.7 per cent. The following year 6.6 pounds of seed were produced from a basal cover of 9.9 per cent. The average number of caryopses per bur was 1 in 1939, 1.5 in 1940, and two in 1941 (Table 22). This variation in number correlates closely with the amount of precipitation and available soil moisture for the respective seasons.

The average seed yield of Bouteloua gracilis was considerably less than

TABLE XXI. The average percentage of basal cover and pounds of seed per acre of each species of grass found in two 1-meter quadrats in the short-grass type for three years. Hays, Kansas.

Species	1939		1940		1941	
	Cover	Yield	Cover	Yield	Cover	Yield
Buchloe dactyloides	2.6	2.1	2.7	3.2	9.9	6.6
Bouteloua gracilis	30.4	1.5	9.7	11.2	19.2	23.8
Sporobolus cryptandrus	.5	0.0	.1	0.0	.2	0.0
Total	33.5	3.6	12.5	14.4	29.3	30.4

that of Buchloe dactyloides in ratio to per cent of cover. This was at least partly due to the diminutive size of the Bouteloua gracilis caryopses. One thousand seed weighed only .447 gram, which is approximately one million seed per pounds. The seed yield of Bouteloua gracilis in 1939 was only 1.5 pounds per acre from a cover of 30.4 per cent. In 1940, it yielded 11.2 pounds from a cover of 9.7 per cent. The following year a yield of 23.8 pounds per acre was harvested from a cover of 19.2 per cent (Table 21). The variation in seed yield each year was due to variations in the number of spikes produced and in the number of caryopses per hundred florets. The caryopses count for 1939, 1940 and 1941 was 1, 12, and 18 respectively per hundred florets (Table 22). Branson (1939) found an average of 1 caryopis per hundred florets on high land.

A small tuft of Sporobolus cryptandrus on this area failed to produce seed.

TABLE XXII. Number of caryopses per hundred florets determined from 1000 florets for the years 1939, 1940, 1941. Hays, Kansas.

Habitat	Species	Average yield		
		1939	1940	1941
Short grass	Bouteloua gracilis	1	12	18
	*Buchloe dactyloides	1	1.5	2
	Hordeum pusillium	15	18	22
Little bluestem	Andropogon furcatus	0	0	25
	Andropogon scoparius	0	24.1	48.3
	Bouteloua curtipendula	4	12.1	22.3
	Bouteloua gracilis	3.6	21	33
	Bouteloua hirsuta	15.9	32.2	41.2
	Panicum virgatum	72.4	70.2	89
	Sporobolus pilosus	83.4	88	91.3
Big bluestem	Agropyron smithii	0	0	96
	Andropogon furcatus	0	0	31.2
	Bouteloua curtipendula	0	0	27.1
	Sporobolus hookeri	0	0	98.2
Revegetation	*Buchloe dactyloides	2	3	3.2
	Sporobolus cryptandrus	94	91	97
	Hordeum pusillum		20	23
Dustbd	Bouteloua gracilis	4	25	38
	*Buchloe dactyloides	1.6	2.2	2.8
	Hordeum pusillum	18	23	17

* Number of caryopses per bur determined on basis of 100 burs.

Yield of Forbs

The only forb on this area in 1939 was Malvastrum coccineum and it failed to produce seed. The average number of forbs per meter quadrat on this area in 1940 was only .5 plant of Allium nuttallii, which produced at the rate of 50 pounds of seed per acre. In 1941 the same number of plants produced 70 pounds of seed per acre. The average number of Psoralea tenuiflora in 1940 was 1 plant per meter which produced 8 pounds of seed per acre. The following year the same number of Psoralea tenuiflora produced 9 pounds of seed. The average number of Malvastrum coccineum for the three years was 1.5 plants per square meter which failed to produce seed during the period of study (Table 23).

Yield of Ruderals

Chenopodium album was absent in 1939, but in 1940 an average of 3.5 plants per square meter produced 14 pounds of seed per acre (Table 24). These plants, approximately seven inches high, were rather small for this species. In 1941 this species failed to inhabit the grid. Festuca octoflora was absent the first two years. In 1941, however, there were 14 plants per square meter that produced 9 pounds of seed per acre.

The number of caryopses per hundred florets of Hordeum pusillum was 15 in 1939, 18 in 1940, and 22 in 1941. The average seed yield for 10 Hordeum pusillum plants was three pounds per acre in 1939. In 1940, 8 per meter quadrat yielded 3 pounds of seed per acre, and in 1941, 510 plants produced 20 pounds of seed. The Lappula occidentalis was not present in 1939 and 1941, but in 1940 it was represented with an average of 41.5 plants per meter that produced 40 pounds of seed per acre.

TABLE XXIII. Average number of forbs per meter square and pounds of seed per acre for each species in 2 quadrats in the short-grass type for 3 years. Hays, Kansas

Species	1939		1940		1941	
	Number	Yield	Number	Yield	Number	Yield
Allium nattallii	0	0	.5	50	.5	70
Malvastrum Coccineum	1.5	0	1.5	0	1.5	0
Psoralea tenuiflora	0	0	1	8	1	9
Total	1.5	0	3.0	58	3.0	79

TABLE XXIV. Average number of ruderals per square meter and pounds of seed per acre for each species in 2 quadrats in the short-grass type for 3 years. Hays, Kansas.

Short-grass Type	1939		1940		1941	
	Number	Yield	Number	Yield	Number	Yield
Chenopodium album	0	0	3.5	14.0	0	0
Festuca octoflora	0	0	0	0	14.0	9.0
Hordeum pusillum	10.0	3.0	8.0	3.0	510.0	200.0
Lappula occidentalis	0	0	41.5	40.0	0	0
Lepidium densiflorum	0	0	217.5	333.0	0	0
Plantago purshii	0	0	18.0	9.0	7.5	5.5
Plantago spinulosa	0	0	0	0	4.0	3.0
Salsola pestifer	0	0	11.0	5.0	0	0
Solanum rostratum	0	0	.5	2.5	0	0
Total	10.0	3.0	299.0	406.5	535.5	217.5

Lepidium densiflorum was absent from the area in 1939 and 1941. In 1940, however, an average of 217.5 plants per meter square produced at the rate of 333 pounds of seed per acre. Plantago purshii did not inhabit the area in 1939 but the following year 18 plants yielded 9 pounds of seed per acre. In 1941 the number of these plants was 7.5 and they produced 5.5 pounds of seed. Plantago spinulosa first appeared in 1941 with 4 plants per meter with an acre yield of 3 pounds of seed. Salsola pestifer was not present in 1939 nor in 1941, but in 1940, 11 stunted plants on a square meter produced 5 pounds of seed per acre. The only year Solanum rostratum appeared was 1940 when only .5 plant per meter yielded 2.5 pounds of seed per acre.

Little-bluestem Type

The total seed yield for all locations on the little-bluestem type for the years 1939, 1940, and 1941 was 129.9, 225.8, and 834.9 pounds per acre, respectively. Of the 129.9 pounds of seed produced in 1939, 35.6 pounds was grass, 94.3 pounds was forbs and the ruderal yield was zero. Of the 225.8 pounds produced in 1940, 36.0 pounds was grass seed, 184.8 pounds was forbs and 5 pounds was ruderals. The 834.9 pounds per acre produced in 1941 comprised 129.8 pounds of grass seed and 705.1 pounds of forb seed. No ruderal seed was produced.

The average yield per acre of grass seed on the upper slope was 10.7 pounds in 1939, 16.7 pounds in 1940, and 23.2 pounds per acre in 1941 (Table 25). For the middle slope the average seed yield for grasses in 1939, 1940, and 1941 was 13.3, 12, and 53.6 pounds per acre respectively (Table 26). On the lower slope, the yield for 1939 was 11.6 pounds, the

TABLE XXV. The average percentage of basal cover and pounds of seed per acre of each species of grass found in two 1-meter quadrats in the little-bluestem type, upper slope, for 3 years. Hays, Kansas.

Species	1939		1940		1941	
	Cover	Yield	Cover	Yield	Cover	Yield
Andropogon furcatus	0	0	0	0	.2	0
Andropogon scoparius	.6	0	.5	.1	0	0
Bouteloua curtipendula	3.5	2.0	.4	.4	1.3	4.2
Bouteloua hirsuta	3.7	1.5	.9	1.0	2.3	4.6
Sporobolus pilosus	4.0	7.2	2.4	15.0	2.3	14.4
Sporobolus cryptandrus	0	0	0	0	.1	0
Total	11.8	10.7	4.2	16.7	6.2	23.2

TABLE XXVI. The average percentage of basal cover and pounds of seed per acre for each species of grass in two 1-meter quadrats in the little-bluestem type, middle slope, 3 years. Hays, Kansas.

Species	1939		1940		1941	
	Cover	Yield	Cover	Yield	Cover	Yield
Andropogon furcatus	7.3	0	.6	0	3.8	3.5
Andropogon scoparius	.1	0	0	0	0	0
Bouteloua curtipendula	24.8	12.1	8.3	10.1	22.3	48.4
Bouteloua hirsuta	1.6	1.2	1.4	1.8	1.3	1.6
Aristida longiseta	.1	0	.3	.1	.2	.1
Sporobolus pilosus	.2	0	.1	0	.1	0
Total	34.1	13.3	10.7	12.0	27.7	53.6

following year the yield was 7.3 pounds and in 1941 it increased to 53.0 pounds per acre (Table 27).

Andropogon furcatus did not produce seed in this area during the first two years. In 1941, however, the average number of caryopses at all locations was 25 per hundred florets. No caryopses were produced by this species during any of the years on the upper slope, but on the middle slope, an average cover of 3.8 per cent produced 3.5 pounds of seed per acre. On the lower slope, 5.1 per cent cover produced 13.3 pounds of seed.

Andropogon scoparious failed to yield seed during the dry year of 1939, but in 1940 the number of caryopses averaged 24.1 per hundred florets on the upper slope where the underlying limestone was exposed in most places. The yield for this species was only .3 pound per acre on a cover of .5 per cent. In 1941 this species produced seeds on only the lower slope. In average cover of .8 per cent produced 1 pound of seed per acre.

Bouteloua curtipendula produced an average of 4 caryopses per hundred florets in 1939. In 1940, it was 12.1 per hundred florets and in 1941 the average number was increased to 22.3 caryopses per hundred florets. On the upper slope in 1939, a cover of 3.5 per cent for this species produced 2.0 pounds of seed per acre. In 1940 a meager cover of .4 per cent produced only .4 pounds, and in 1941 a cover of 1.3 per cent produced 4.2 pounds of seed per acre. On the middle slope in 1939 a cover of 24.8 per cent produced 12.1 pounds of seed. In 1940, the cover was reduced to 8.3 per cent and produced 10.1 pounds. In 1941 the yield was 48.4 pounds per acre on a cover of 22.3 per cent. On the lower slope in 1939 an average cover of 6.9 per cent produced 2.2 pounds of seed per acre. In 1940 a slightly decreased cover of 2.5 yielded only 1.1 pounds of seed, and the following

TABLE XXVII. The average percentage of basal cover and pounds of seed per acre for each species of grass in two 1-meter quadrats in the little-bluestem type, lower slope, for 3 years. Hays, Kansas.

Species	1939		1940		1941	
	Cover	Yield	Cover	Yield	Cover	Yield
Andropogon furcatus	3.9	0	1.6	0	5.1	13.3
Andropogon scoparius	1.7	0	.1	0	.8	1.0
Aristida longiseta	.5	.2	.2	.1	.4	.3
Bouteloua curtipendula	6.9	2.2	2.5	1.1	5.8	13.2
Bouteloua gracilis	1.8	1.1	1.2	1.8	5.8	4.1
Bouteloua hirsuta	2.8	1.0	.4	.3	2.4	6.8
Panicum virgatum	1.4	3.5	.7	2.0	2.2	6.1
Sporobolus cryptandrus	.1	0	0	0	0	0
Sporobolus pilosus	1.9	3.6	.8	2.0	1.4	8.2
Total	21.0	11.6	7.5	7.3	21.9	53.0

year a cover of 5.8 per cent produced 13.2 pounds of seed per acre.

The average number of caryopses per hundred florets for Boutelcua hirsuta was 15.9 in 1939. Branson (1939) counted 17 caryopses per hundred florets. In 1940 it was 32.2 per hundred florets and in 1941 an average of 41.2 caryopses was found. During the season of 1939, the average cover on the upper slope was 3.7 per cent producing 1.5 pounds of caryopses per acre. In 1940 a .9 per cent cover produced one pounds of seed, and in the following year 2.3 per cent cover yielded 4.6 pounds of seed per acre. On the middle slope in 1939, a cover of 1.6 per cent produced 1.2 pounds of caryopses. In 1940, 1.8 pounds per acre was produced on a cover of 1.4 per cent, and in 1941 a cover of 1.3 per cent produced 1.6 pounds of seed. On the lower slope the cover of this species for 1939 was 2.8 per cent, producing 1 pound of seed. The following year an average cover of .4 per cent produced .3 pounds of seed and in 1941 a 2.4 per cent cover yielded 6.8 pounds per acre.

The average caryopses count per hundred florets for Boutelcua gracilis on the lower slope was 3.6 in 1939, 21 in 1940, and 33 in 1941. An average cover of 1.8 per cent produced 1.1 pounds of seed in 1939. The following year a cover of 1.2 per cent gave a yield of 1.8 pounds and in 1941 a cover of 3.8 per cent produced 4.1 pounds of seed per acre.

The average number of caryopses per hundred florets for Sporobolus pilosus in 1939, 1940, and 1941 was 83.4, 88, and 91.3 per cent respectively. The average cover for two quadrats on the upper slope in 1939 was 4.0 per cent and it produced 7.2 pounds of seed. In 1940, a cover of 2.4 per cent yielded 15 pounds and a cover of 2.3 per cent the following

year produced 14.4 pounds of seed per acre. It failed to produce seed on the middle slope during the period of study. For the lower slope, a cover of 1.9 per cent gave a yield of 3.6 pounds of caryopses in 1939. The following year a cover of .8 per cent produced 2 pounds and in 1941 a cover of 1.4 per cent gave an average seed yield of 8.2 pounds per acre.

The average cover of Sporobolus cryptandrus and Aristida longiseta was almost nil. The seed yield was too negligible to get an accurate count.

The caryopses count for Panicum virgatum for 1939, 1940, and 1941 was 72.4, 70.2 and 89 respectively per hundred florets. Its only place of habitation was on the lower slope. In 1939 an average cover of 1.4 per cent produced 3.5 pounds of seed. In 1940 a cover of .7 per cent gave a yield of 2 pounds and a cover of 2.2 per cent in 1941 yielded 6.1 pounds of seed per acre.

Number of Forbs and Yield of Seed

Upper Slope

The total average seed yield of the 2 quadrats for 1939, 1940, and 1941 was 65.3, 51.6 and 204.4 pounds per acre respectively.

In 1939, Cheirinia asper produced at the rate of 22 pounds of seed per acre from 7.5 plants per square meter (Table 28). The following year an average of 1.5 plants produced 6 pounds per acre and in 1941 a seed yield of 65 pounds per acre was harvested from 29 plants per meter quadrat. Echinacea angustifolia produced 7 pounds of seed from 1.5 plants in 1939. The following year 1 plant produced at the rate of 6.2 pounds of seed per acre. However, in 1941, the same plant produced at the rate of 10.6 pounds of seed per acre. Lesquerella ovalifolia did not

TABLE XXVIII. Average number of forbs per meter square and pounds of seed per acre of each species in 2 quadrats on the little bluestem type, upper slope, for 3 years. Hays, Kansas.

Species	1939		1940		1941	
	Number	Yield	Number	Yield	Number	Yield
Cheirinia aspera	7.5	22.0	1.5	6.0	29.0	65.0
Echinacea angustifolia	1.5	7.0	1.0	6.2	1.0	10.6
Lesquerella ovalifolia	1.5	0	0	0	2.5	10.0
Liatris punctata	4.0	14.0	1.5	6.1	1.0	5.0
Lithospermum linearifolium	1.0	4.0	3.0	10.0	5.0	28.0
Meriolix serrulata	8.0	13.8	6.0	9.3	11.0	67.0
Morongia uncinata	.5	0	.5	.0	.5	9.8
Psoralea tenuiflora	.5	0	1.0	0	2.0	0
Paronychia jamesii	.5	4.5	0	0	0	0
Thelesperma gracile	0	0	1.5	9.0	2.0	9.0
Tetraneuris stenophylla	4.5	0	3.0	5.0	0	0
Total	29.5	65.3	19.0	51.6	54.0	204.4

yield seed the first two years but in the third year 2.5 plants produced 10 pounds of seed per acre. Liatris punctata produced 14 pounds of seed per acre from 4 plants in 1939. In 1940 the seed yield was 6.1 pounds from an average of 1.5 plants per meter, and in 1941, 1 plant produced 5 pounds of seed. The yield of Lithospermum linearfolium in 1939 was 4 pounds of seed from 1 plant per meter square. In 1940, 3 plants gave a yield of 10 pounds and in 1941, 5 plants produced at the rate of 28 pounds of seed per acre. In 1939 the evening primrose (Meriolix serrulata) produced 13.8 pounds of seed from 8 plants per meter square. The following year 6 plants gave a yield of 9.3 pounds and in 1941, 67 pounds of seed were harvested from 11 plants. The first two years Morongia uncinata pods were eaten by walking sticks, a species of insects belonging to the order Orthoptera. The third year an average of .5 plant produced 9.8 pounds of seed per acre. Paronychia jamesii produced 4.5 pounds of seed from an average of .5 plant in 1939 but this plant perished during the severe fall drought of this year. Thelesperma gracile failed to produce seed in 1939. The following year an average of 1.5 plants produced 9 pounds of seed per acre. In 1941, 9 pounds of seed was harvested from 2 plants. In 1939 Tetraneuris stenophylla did not yield seed. In 1940, 3 plants produced 5 pounds of seed, however, in late July all plants of this species in the study area died.

Species of plants inhabiting the two study quadrats on the upper slope that did not produce seed were Psoralea tenuiflora, Galpinsia lavandulaefolia, Hymenopappus corymbosus, Evolvulus pilosus, Psoralea esculenta, and acerates viridflora.

Middle Slope

The average total seed yield in pounds per acre for the two study quadrats in 1939, 1940, and 1941 was 0, 64.2, and 169.7 pounds, respectively (Table 29).

In 1939 Amorpha canescens failed to produce seed. In 1940, 3.5 plants produced 22.2 pounds of seed, and in 1941, 5 plants produced 30.7 pounds of seed per acre. Echinacea angustifolia did not produce seed the first year. The next year 1 plant produced 9 pounds and the following year 12 pounds were produced from an average of 1.5 plants per meter. Liatris punctata failed to yield seed during the first year, but in 1940, 2 plants produced 8 pounds and in 1941, 1 plant yielded 5 pounds of seed per acre. Meriolix serrulata did not appear the first two years, but in 1941, an average of .5 plant per meter were present and produced 4 pounds of seed. In 1939 the Morongia uncinata pods were eaten by walking sticks. The following year 1 plant produced 5 pounds of seed and in 1941 the same number of plants yielded 21 pounds of seed per acre. Thelesperma gracile did not yield seed in 1939, but the next year 20 pounds of seed was produced from 3 plants and in 1941 an average of 9.5 plants produced 97 pounds of seed per acre.

Species, charted in this area of two quadrats, that did not yield seed during the study period were Psoralea tenuiflora, Tetraneuris stenophylla, Acerates viridiflora, Asclepias pumila, and Cheirinia aspera.

Lower Slope

The total average seed yield from the two study quadrats in 1939, 1940, and 1941 was 29, 69, and 307 pounds respectively. (Table 30).

TABLE XXIX. Average number of forbs per meter square and pounds of seed per acre of each species in 2 quadrats on the little bluestem type, middle slope, for 3 years. Hays, Kansas.

Species	1939		1940		1941	
	Cover	Yield	Cover	Yield	Cover	Yield
Amorpha canescens	4	0	3.5	22.2	5.0	30.7
Echinacea angustifolia	1	0	1.0	9.0	1.5	12.0
Liatris punctata	5	0	2.0	8.0	1.0	5.0
Meriolix serrulata	0	0	0	0	.5	4.0
Morongia uncinata	2	0	1.0	5.0	1.0	21.0
Psoralea tenuiflora	0	0	0	0	3.0	0
Thelesperma gracile	0	0	3.0	20.0	9.5	97.0
Tetraneuris stenophylla	1	0	0	0	0	0
Total	13	0	10.5	64.2	21.5	169.7

TABLE XXX. Average number of forbs per meter square and pounds of seed per acre of each species in 2 quadrats of the little bluestem type, lower slope for 3 years. Hays, Kansas.

Species	1939		1940		1941	
	Number	Yield	Number	Yield	Number	Yield
Cheirinia aspera	4.0	13	0	0	3.0	30
Aster multiflorus	6.0	0	12.0	21	17.5	130
Cirsium undulatum	0	0	1.0	0	1.0	4
Echinacea angustifolia	4.0	12	5.0	13	1.0	4
Galpinsia lavandulaefolia	.5	0	0	0	0	0
Houstonia angustifolia	0	0	0	0	.5	2
Liatris punctata	.5	0	2.0	10	1.0	9
Morongia uncinata	5.0	0	5.0	7	4.0	8
Merlolix serrulata	1.5	2	1.0	0	.5	5
Psoralea tenuifloria	3.0	0	10.5	0	7.5	5
Thelesperma gracile	.5	0	1.5	8	6.0	45
Tragia ramosa	9.5	0	12.0	10	11.5	15
Scutellaria resinosa	.5	2	0	0	.5	0
Total	35.0	29	40.0	69	54.0	307

The average number of 4 plants per meter of Cheirnia aspera in 1939 yielded 13 pounds of seed. The following year it was absent, but in 1941, 3 plants produced an average acre yield of 30 pounds of seed. Aster multiflorus was represented by 6 plants in 1939, but failed to produce seed. The following year 12 plants produced 21 pounds of seed and in 1941 an average of 17.5 plants produced 180 pounds of seed per acre. Cirsium undulatum did not produce seed the first two years but in 1941, 1 plant produced 4 pounds of seed. In 1939, Echinacea angustifolia was represented by 4 plants per meter and produced 12 pounds of seed. In 1940, the 3 plants produced 13 pounds of seed, and in 1941, 1 plant yielded 4 pounds of seed per acre. Houstonia angustifolia first appeared in 1941 and produced only 2 pounds of seed from an average of .5 plant per meter. Liatris punctata did not produce seed the first year. In 1940, however, 2 plants produced 10 pounds of seed and in 1941, 9 pounds of seed were harvested from 1 plant. In 1939 the green pods of Morongia uncinata were consumed by the same type of insect that destroyed the pods in the other locations. The following year 5 plants gave a yield of 7 pounds of seed per acre, and during 1941, 4 plants produced 8 pounds of seed per acre.

In 1939, an average of 1.5 plants per meter of Meriolix serrulata produced 2 pounds of seed. The following year it did not yield seed, but in 1941, an average of .5 plant per meter produced 5 pounds of seed per acre. The Psoralea tenuiflora seed was eaten by walking sticks the first two seasons, but in 1941 a seed yield of 5 pounds per acre was threshed from 7.5 plants. Thelesperma gracile failed to yield seed the first year.

However, in 1940, 8 pounds of seed were harvested from an average of 1.5 plants and in 1941, the seed crop from 6 plants was 45 pounds per acre. Tragia ramosa was destroyed by rodents in the first year. In 1940, a seed yield of 10 pounds was harvested from 12 plants. In 1941, an average of 11.5 plants yielded 15 pounds of seed per acre. Scutellaria resinosa produced seed only during 1939 when an average of .5 plant per meter produced 2 pounds of seed per acre.

Species of plant in the study quadrats on the lower slope that failed to yield seed during the entire study period were Galpinsia lavandulaefolia, Paronychia jamesii, and Psoralea esculenta.

Number and Seed Yield of Ruderals

The species of ruderals found growing in the little-bluestem type were limited to three. Lappula occidentalis was the only one producing seed. In 1940 an average of 11.5 plants on the upper slope produced 5 pounds of seed per acre.

Big-bluestem Type

The seed yield in this type during 1939 was extremely low. The drought caused the succulent grasses to wither and dry up when only approximately 16 inches high.

In 1940 the seed crop was destroyed by livestock, hence no data were secured.

The abundant seed yield in 1941 was no doubt due to the ideal climatic

conditions prevailing throughout the growing season. Sporobolus hookeri, with an average of 98.2 caryopses per hundred florets, yielded at the rate of 909.3 pounds of seed per acre from 432 stems per meter square (Table 31). Andropogon furcatus, with an average of 31.2 caryopses per hundred florets, produced 50.5 pounds of caryopsis bearing seed from 491 stems. The caryopses count in Agropyron smithii was unusually high for this year and with 96 caryopses per hundred florets, the yield from 19.5 stems per square meter was 70.5 pounds per acre. Bouteloua curtipendula, though having only an average of 27.1 caryopses per hundred florets, was above normal for this species and yielded at the rate of 12.5 pounds of seed per acre from 6.5 stems. Carex gravida produced 26.4 pounds of seed from 4 stems. However many of the seeds had shattered before harvest.

Forbs were absent from the study area throughout the period of research.

The severe drought of 1939 greatly reduced the cover in this area in 1940 and large open spaces were common in which the invading ruderals could grow. During this season an average of 14.5 plants of Chenopodium album produced 61 pounds of seed per acre. Lappula occidentalis yielded at the rate of 3 pounds of seed per acre from 15 plants and Sophia pinnata yielded a similar amount from 3 plants per meter square.

Revegetation Type

The average total seed yield of all the grasses on the Buchloe dactyloides area in 1939 was 31.2 pounds per acre. Of the 78.6 pounds per acre of seed produced in 1940, 30.6 pounds were grass seed and 48 pounds were furnished by ruderals. Of the 282.6 pounds of seed in 1941 the grasses

TABLE XXXI. Average number of stems per square meter and pounds of seed per acre of each species of grass in 2 quadrats of big bluestem type for 3 years. Hays, Kansas.

Habitat	Species	1939		1940		1941	
		No. stems	Yield	No. stems	Yield	No. stems	Yield
Big-	Andropogon furcatus	461.5	0.0	360.5	0.0	491.	50.5
	Andropogon smithii	17.	0.0	13.	0.0	19.5	70.5
bluestem	Bouteloua curtipendula	4.	0.0	2.5	0.0	6.5	12.5
	Carex gravida	1.	0.0	0	0.0	4	26.4
	Sporobolus hookeri	369.5	0.0	391.	0.0	432	909.3
	Total	853.0	0.0	767.0	0.0	953.0	1069.2

produced 82.6 pounds, the forbs yielded 100 pounds and ruderals 100 pounds per acre.

The only two grasses inhabiting the buffalo grass area were Aristida longiseta and Buchloe dactyloides. The cover of Aristida was less than 1 per cent, thus making the seed yield too negligible for an accurate count. A heavy turf of buffalo grass occupied the greater per cent of this area. The average number of caryopses per bur for the study period 1939, 1940, and 1941 was 2, 3, and 3.2 respectively. In 1939 an average cover of 78.6 per cent produced 31.2 pounds of seed. The next year a cover of 52.2 per cent yielded 30.6 pounds and in 1941 a cover of 89.5 per cent produced 82.6 pounds of seed per acre (Table 32).

TABLE XXXII. The average percentage basal cover and pounds of seed per acre of each species of grass in two 1-meter quadrats on Buchloe dactyloides area for 3 years. Hays, Kansas.

Species	1939		1940		1941	
	Cover	Yield	Cover	Yield	Cover	Yield
Aristida longiseta	0.4	0.0	0.3	0.0	0.4	0.0
Buchloe dactyloides	78.6	31.2	52.2	30.6	89.5	82.6
Total	79.0	31.2	52.5	30.6	89.9	82.6

In the Sporobolus cryptandrus area in 1939 the total average seed yield was 184 pounds per acre. The grass seed yield was 172 pounds, the forbs zero, and the ruderals 12 pounds per acre. Of the 126 pounds of seed produced in 1940, 87 pounds were grass seeds, 39 pounds were ruderal seeds

but the forbs again failed to produce. During 1941 the total seed yield was 437 pounds. Of this amount the yield of grass seed was 163 pounds, that of forbs 24 pounds and for ruderals it was 250 pounds per acre.

The abundant seed yield, of Sporobolus cryptandrus during the extreme drought of 1939, helps to explain the successful invasion of this species, throughout the mixed prairie during the period of prolonged drought.

During the study period, Sporobolus cryptandrus produced myriads of tiny red seeds. A thousand of these seeds weighed only .091 gram or approximately 5 million seeds per pound. The number of caryopses per hundred florets in 1939, 1940, and 1941 was 94, 91, and 97, respectively. In 1939 a cover of 24.8 per cent produced 172 pounds. In 1940 a cover of 16.5 per cent yielded 87 pounds of seed and the following year 163 pounds per acre were harvested from a cover of 17.5 per cent. The amount of rainfall had but little effect on the seed yield of this species, as most of the seeds mature within the sheath and the flower clusters are protected from hot winds (Table 33).

TABLE XXXIII. Average percentage basal cover and pounds of seed per acre for each species of grass in two 1-meter quadrats on Sporobolus cryptandrus area.

Species	1939		1940		1941	
	Cover	Yield	Cover	Yield	Cover	Yield
Aristida longiseta	0.2	0.0	0.3	0.0	0.5	0.0
Sporobolus cryptandrus	24.8	172.0	16.5	87.0	17.5	163.0
Total	25.0	172.0	16.8	87.0	18.0	163.0

Forbs of Revegetation Type

The only forb that produced seed in the Buchloe dactyloides area was Ambrosia psilostachya and the only year it appeared in this area was 1941 with a density of 9 plants per square meter that yielded 100 pounds per acre of seed.

The only season during which forbs produced seed in the Sporobolus cryptandrus area was 1941. Ambrosia psilostachya produced 15 pounds per acre of seed from an average of .5 plant and Verbena bracteosa produced 9 pounds of seed from approximately the same number of plants.

Ruderals of Revegetation Type

The ruderals of the Buchloe dactyloides area failed to yield seed in 1939. In 1940, however, Hordeum pusillum, with a caryopses count of 20 per hundred florets, produced 30 pounds of seed per acre from an average of 67.5 plants per meter. The following year 225 plants per meter produced at the rate of 100 pounds of seed per acre, with a caryopses count of 23 per hundred florets. In 1940 Lappula occidentalis yielded 2 pounds of seed from 1 plant per meter. The next year it was not present in this area. In 1940 Plantago purshii produced 1 pound of seed from an average of 1.5 plants and an average of 12.5 plants of Sophia pinnata yielded 15 pounds of seed per acre.

The seed yield of ruderals in the Sporobolus cryptandrus area was much greater than in the buffalo grass area. This was due to the more open cover in the Sporobolus type. Hordeum pusillum was the only ruderal

present in 1939 and 1941. The caryopses count for it in 1939, 1940, and 1941, was 18, 23, and 17, respectively, per hundred florets. The seed yield for Hordeum pusillum in 1939 was 12 pounds per acre from 50 plants per meter. The following year an average of 62.5 plants yielded 18 pounds of seed and in 1941, 150 plants yielded 250 pounds of seed per acre. In 1940, Lappula occidentalis produced 3 pounds of seed from an average of .5 plant. The same year Salsola pestifer yielded at the rate of 2 pounds of seed per acre from 6 plants per square meter and Solanum rostratum produced 16 pounds of seed from 3½ plants.

Dusted Type

The average total seed yield for this type in 1939, 1940, and 1941 was 276.2, 485.8, and 1605.8 pounds per acre respectively.

On the badly dusted portion the average total yield was 89.9 pounds in 1939, 106.3 pounds in 1940, and 168.3 pounds per acre in 1941.

The moderately dusted area had a total yield of 192.7, 317.8, and 629.7 pounds per acre, respectively, for 1939, 1940, and 1941.

The total yield on the lightly dusted area in 1939 was 63.6 pounds. The following year it was 161.7 pounds and in 1941, 807.3 of seed per acre were harvested.

The abundant yield in 1941 was due to the heavy stand of Hordeum pusillum. Bouteloua gracilis also produced more seed than during 1939 and 1940.

The average caryopses count per hundred florets for Bouteloua gracilis on this type for 1939, 1940, and 1941 was 4, 25, and 38, respectively. Similar figures for Buchloe dactyloides was 1.6, 2.2, and 2.8 for the same

three years.

Seed Yield of Each Species of Grass on the Badly Dusted Area

In 1939, Bouteloua gracilis with an average cover of 8.6 per cent failed to produce ripened seed as grasshoppers consumed the immature spikes. In 1940 a 6.1 per cent cover yielded 8.5 pounds of seed per acre (Table 34). The next year an average of 20.1 per cent cover produced numerous spikes that averaged 3.3 cm. in length and yielded 51 pounds of seed per acre.

TABLE XXXIV. The average percentage of basal cover and pounds of seed per acre for species of grass on two 1-meter quadrats in the badly dusted area for 3 years. Hays, Kansas.

Species	1939		1940		1941	
	Cover	Yield	Cover	Yield	Cover	Yield
Bouteloua gracilis	8.6	0.0	6.1	8.5	20.1	51.0
Sporobolus cryptandrus	.1	0.0	0.3	0.0	1.7	0.0
Total	8.7	0.0	6.4	8.5	21.8	51.0

Seed Yield of Each Species of Grass on the Moderately Dusted Area

The average cover of Bouteloua gracilis in 1939 was 18.2 per cent which produced 2.4 pounds of seed per acre (Table 35). In 1940 the cover was decreased to 13.9 per cent but the yield was 4.8 pounds of seed. The following year the limited number of spikes that were able to overtop the dense debris of Hordeum pusillum yielded 11.7 pounds of seeds per acre from a cover of 29.9 per cent.

The cover of Buchloe dactyloides on this area in 1939 was 4.4 per cent, but it failed to produce seed, due to the absence of any pistillate plants.

In 1940 a cover of 4.5 per cent was charted. It also failed to produce for the same reason as in 1939. In 1941 a cover of 12.8 per cent yielded 2 pounds of seed. This was the first year that pistillate plants were present.

TABLE XXXV. The average percentage basal cover and pounds of seed per acre of each species of grass in two 1-meter quadrats on the moderately dusted area for 3 years. Hays, Kansas.

Species	1939		1940		1941	
	Cover	Yield	Cover	Yield	Cover	Yield
Bouteloua gracilis	18.2	2.4	13.9	4.8	29.9	11.7
Buchloe dactyloides	4.4	0.0	4.5	0.0	12.8	2.0
Sporobolus cryptandrus	0.7	0.0	0.4	0.0	0.6	0.0
Total	23.3	2.4	18.8	4.8	43.3	13.7

Seed Yield of Each Species of Grass on the Lightly Dusted Area

In 1939, Bouteloua gracilis, with an average basal cover of 26.1 per cent, produced 2.8 pounds of seed (Table 36). The following year it yielded 7.2 pounds of seed from 16.6 per cent cover. In 1941 a cover of 25.8 per cent yielded 32.1 pounds of seed per acre. It is significant that during 1941 the short grasses had to compete with Hordeum pusillum that averaged 2,250 stems per square meter.

In 1939, Buchloe dactyloides, with a cover of 8.6 per cent, produced 4.8 pounds of seed per acre. The following year 3.9 pounds were harvested from a 4.1 per cent cover. The next year 11.6 per cent cover yielded 4.2 pounds of seed per acre.

TABLE XXXVI. The average percentage basal cover and pounds of seed per acre of each species of grass in two 1-meter quadrats on the lightly dusted area for 3 years. Hays, Kansas.

Species	1939		1940		1941	
	Cover	Yield	Cover	Yield	Cover	Yield
Bouteloua gracilis	26.1	2.8	16.6	7.2	25.8	32.1
Buchloe dactyloides	8.6	4.8	4.1	3.9	11.6	4.2
Total	34.7	7.6	20.7	11.1	37.4	36.3

Forbs of the Dusted Type

The badly dusted area was devoid of forbs during the study period. The other areas contained Malvastrum coccineum which failed to yield seed during the three successive years.

Ruderals of the Dusted Type

Badly Dusted Area

In 1939, the production from an average number of 40 plants per square meter of Chenopodium album was 9.9 pounds of seed and in 1940, 304 plants produced 91 pounds of seed per acre (Table 37). The following year this species was absent. Hordeum pusillum was not present the first year. In 1940, however, an average of 2.5 plants produced 1 pound of seed and the following year 114 plants yielded 99 pounds of seed per acre. Lappula occidentalis produced 80 pounds of seed from an average of 22.5 plants in 1939. The next year 2 plants produced 8.8 pounds of seed per acre. In 1940, Lepidium densiflorum yielded 5 pounds of seed from an average of 2.5 plants. This was the only year this

TABLE XXXVII. Average number of ruderals per meter square and pounds of seed per acre of each species on 2 quadrats of each dusted area for 3 years. Hays, Kansas.

	1939		1940		1941	
Badly dusted area	Number	Yield	Number	Yield	Number	Yield
Chenopodium album	40.0	9.9	304.0	91.0	0	0
Hordeum pusillum	0	0	2.5	1.0	114.0	99.0
Lappula occidentalis	22.5	80.0	2.0	5.8	0	0
Lepidium densiflorum	0	0	2.5	5.0	0	0
Mollugo verticillata	0	0	0	0	112.5	0
Panicum capillare	0	0	0	0	30.0	18.8
Sophia pinnata	0	0	2.0	2.0	0	0
Total	62.5	89.9	313.0	97.8	256.5	117.8
Moderately dusted area						
Chenopodium album	8.0	2.7	1.5	1.0	0	0
Hedeoma hispida	0	0	1.5	0	0	0
Hordeum pusillum	300.0	94.0	500.0	161.0	2250	616
Lappula occidentalis	57.5	23.6	40.0	38.0	0	0
Salsola pestifer	1.5	0	3.5	13.0	0	0
Total	367.0	120.3	346.5	213.0	2250	616
Lightly dusted area						
Chenopodium album	11.5	3.6	17.5	9.6	0	0
Festuca octoflora	0	0	7.0	1.0	0	0
Hedeoma hispida	0	0	1.5	0	0	0
Hordeum pusillum	60.0	21.3	95.0	57.5	2750	771
Lappula occidentalis	110.0	31.1	150.0	56.0	0	0
Lepidium densiflorum	0	0	6.0	9.0	0	0
Sophia pinnata	0	0	5.0	6.0	0	0
Total	181.5	56.0	282.0	139.1	2750	771

species was present in the area. The only year Panicum capillare produced seed was in 1941 when 30 plants yielded 18.8 pounds per acre. In 1940, Sophia pinnata produced at the rate of 2 pounds of seed per acre from 2 plants per square meter.

Moderately Dusted Area

In 1939, 8 plants of Chenopodium album produced 2.7 pounds of seed. The following year the production from an average of 1.5 plant per meter was 1 pound of seed. During both years the plants were approximately 6 inches in height. With a caryopses count of 18 per hundred florets, Hordeum pusillum produced 94 pounds of seed from 300 spikes in 1939. The following year the same number of spikes produced 161 pounds of seed and the last year 2,250 spikes produced 616 pounds of seed per acre. In 1939, Lappula occidentalis produced 23.6 pounds of seed from an average of 57.5 plants per meter. The following year 40 plants produced 38 pounds. The only year Salsola pestifer produced seed was in 1940 when an average of 3.5 dwarf plants yielded 13 pounds per acre.

Lightly Dusted Area

In 1939, Chenopodium album produced 3.5 pounds of seed from an average of 11.5 plants per meter. The following year 17.5 plants produced 9.6 pounds of seed per acre. The plants during this year were scarcely more than 6 inches high and many failed to produce seed. In 1940, Festuca octoflora produced 1 pound of seed from 7 plants. During 1939, Hordeum pusillum produced at the rate of 21.3 pounds of seed per acre from 60 spikes per meter. The following year 95 spikes yielded 57.5 pounds of seed and in 1941, 2,750 spikes produced 771 pounds per acre.

In 1939, Lappula occidentalis yielded 31.1 pounds of seed from 110 plants. The following year 150 plants produced 56 pounds of seed. The only year Lepidium densiflorum produced was in 1940 when 6 plants yielded 9 pounds of seed. This same year 5 plants per square meter of Sophia pinnata produced at the rate of 6 pounds of seed per acre.

SEEDLINGS ON DIFFERENT TYPES

The information gathered from the study of seed yields, shows that most prairie species produce large quantities of seed. A number of these seed were no doubt sterile. Blake (1935) states that viability of most forb seeds was less than 15 per cent, although in some species it was at least 50 per cent. Fultz (1936) states that certain range grasses give 70 to 90 per cent germination. Many of the seeds that germinate and grow, fail to produce mature plants. The mortality rate among seedlings is controlled by various factors of the habitat.

In this study the seedlings present in each area were charted in June, 1939. The same areas were again studied in June, 1940, and 1941, at which time determination was made of the seedling survival from the previous year and also the number of new seedlings present for the current year. The final study was made during the summer of 1942 to determine the survival of seedlings from 1941.

Short-grass Type

No seedlings of perennial grasses were found in this habitat during either of the three years. Two seedlings of Psoralea tenuiflora were the only forbs present in June, 1939. Both survived the drought of that year

and became permanently established in this location. In 1940 this area failed to yield a single seedling. In 1941, however, eight seedlings were present in this area, only one of which survived. One seedling of Malvastrum coccineum and four seedlings of Opuntia humifusa perished in the July drought. Of the three Psoralea tenuiflora charted in 1941, only one survived until 1942. Of the ten seedlings charted during the study period only three survived (Table 38).

Little-bluestem Type

Upper Slope

There were 36 grass seedlings charted on this type in 1939. One was Andropogon scoparius, 23 were Bouteloua curtipendula, 8 were B. hirsuta, and 4 were Sporobolus pilosus. Enough soil moisture was available for germination and growth from April to the middle of July. During the latter part of July and all of August, however, soil moisture was deficient. Associated with the drought were myriads of grasshoppers that devoured the tender seedlings. The combined effect of drought and grasshoppers resulted in the death of all grass seedlings. The low seedling population of 1940 was evidently due to the low seed yield produced during the dry season of 1939.

In 1940, ten seedlings were charted; nine were Bouteloua curtipendula and one was B. hirsuta. All nine of the Bouteloua curtipendula succumbed to environmental factors. The one B. hirsuta seedling became established and was present in June, 1941. At this time it had increased to a diameter of approximately two inches. In August, 1942, it had increased its basal cover to approximately three inches in diameter. Increased precipitation in 1941 greatly increased the number of seedlings of prairie plants. Of the 190

TABLE XXXVIII. Number of seedlings present in 4 meter quadrats of the short-grass type and number surviving each year for three years. Hays, Kansas.

Species	1939		1940		1941		Total	
	Number present	Number survived	Number present	Number survived	Number present	Number survived	Number present	Number survived
Malvastrum coccineum	0	0	0	0	1	0	1	0
Opuntia humifusa	0	0	0	0	4	0	4	0
Psoralea tenuiflora	2	2	0	0	3	1	5	3
Total	2	2	0	0	8	1	10	3

grass seedlings charted, 112 were Bouteloua curtipendula, 75 were B. hirsuta, and only three were Sporobolus pilosus. When charted in August, 1942, 14 of the Bouteloua curtipendula seedlings had survived. The diameter of these year-old plants varied from 1 to 2.5 inches. Of the 75 seedlings of Bouteloua hirsuta, 52 survived and measured approximately one to two inches in diameter. The two surviving Sporobolus pilosus plants had a basal diameter of approximately two inches (Table 39).

Forb Seedlings on Upper Slope

Thirty forb seedlings were charted in 1939, of which, 12 were Cheirinia aspera, one was Echinacea angustifolia, one was Lithospermum linearifolium, ten were Lesquerella ovalifolia, three were Liatris punctata, two were Theloserma gracile, and one was Tetraneuris stenophylla. When charted in 1940, only two Cheirinia aspera and one Liatris punctata had survived (Table 39).

Rodents had destroyed numerous seedlings by gnawing them off below the surface of the ground. Grasshoppers fed on the small seedlings and often destroyed many of them. These adverse biotic and climatic factors reduced the number of seedlings to almost nil.

In 1940, 568 seedlings were charted and 118 of these were present the following year. This number was distributed among 16 different species but Cheirinia aspera was present in far greater numbers than were any of the others.

In June, 1941, a total of 245 seedlings were found. Of this number 84 were present in the summer of 1942. The relatively small number of forb seedlings in 1941 was due primarily to the high rate of mortality of

TABLE XXXIX. Number of seedlings present in 4 meter quadrats of the little bluestem type on the upper slope and the number surviving each year for 3 years. Hays, Kansas.

Species	1939		1940		1941		Total	
	Number present	Number survived	Number present	Number survived	Number present	Number survived	Number present	Number survived
GRASS								
Andropogon scoparius	1	0	0	0	0	0	1	
Bouteloua curtipendula	23	0	9	0	112	14	144	14
Bouteloua hirsuta	8	0	1	1	75	52	84	53
Sporobolus pilosus	4	0	0	0	3	2	7	2
Total	36	0	10	1	190	68	236	69
FORBS								
Asclepias pumila	0	0	10	6	1	0	11	6
Arenaria texana	0	0	0	0	1	1	1	1
Cheirinia aspera	12	2	469	93	2	0	483	95
Echinacea angustifolia	1	0	12	2	5	4	18	6
Gutierrezia sarothrae	0	0	0	0	3	3	3	3
Galpinsia lavandulaefolia	0	0	0	0	0	1	0	1
Hymenopappus corymbosus	0	0	2	1	0	0	2	1
Lithospermum linearifolium	1	0	4	3	39	2	44	5
Lesquerella ovalifolia	10	0	11	3	4	1	25	4
Liatris punctata	3	1	4	1	8	3	15	5
Meriolix serrulata	0	0	9	2	136	58	145	60
Psoralea tenuiflora	0	0	6	4	2	1	8	5
Thelesperma gracile	2	0	19	3	35	11	56	14
Tetraneuris stenophylla	1	0	1	0	3	0	5	0
Senecio plattensis	0	0	1	0	3	0	4	0
Scutellaria resinosa	0	0	0	0	2	0	2	0
Total	30	3	568	118	245	84	823	205

Cheirinia aspera. Other forbs, especially Lithospermum linearifolium, Mertiolix serrulata, and Thelesperma gracila, were present in greater numbers in 1941 than in 1940. The unusually wet spring of 1942 was conducive to the development of certain fungi and many seedlings were destroyed by this organism.

Total Seedlings on Middle Slope

Seedlings were less numerous in this location than on the upper slope. This was doubtless due to the greater basal cover of grasses on the mid-slope.

Grass Seedlings on Middle Slope

Only one Bouteloua curtipendula seedling was found in this area in 1939, and it failed to survive. In 1940, two Bouteloua hirsuta seedlings were charted and both lived. The following year one bunch was approximately one inch in diameter and the other about two inches in diameter. When charted in 1942 both bunches had increased to about three inches in diameter. In 1941, 29 seedlings were present. Three Bouteloua curtipendula and one B. hirsuta had survived when charted the following year. The bunches of Bouteloua curtipendula ranged from one to two inches in diameter and that of B. hirsuta nearly three inches in diameter. The bunches in the open spaces increased in size more rapidly, than did those in close proximity to mature grasses (Table 40).

Forb Seedlings of Middle Slope

Only three seedlings, two Cheirinia aspera and one Yucca glauca, were present in the area in 1939. The Yucca seedling was the only one to survive

TABLE XL. Number of seedlings present in 4 meter quadrats of the little bluestem type on the middle slope and the number surviving each year for 3 years. Hays, Kansas.

Species	1939		1940		1941		Total	
	Number present	Number survived	Number present	Number survived	Number present	Number survived	Number present	Number survived
GRASSES								
Bouteloua curtipendula	1	0	2	2	25	3	28	5
Bouteloua hirsuta	0	0	0	0	4	1	4	1
Total	1	0	2	2	29	4	32	6
FORBS								
Asclepias pumila	0	0	0	0	6	4	6	4
Amorpha canescens	0	0	0	0	1	0	1	
Cheirinia aspera	2	0	164	2	0	0	166	2
Echinacea angustifolia	0	0	5	2	4	3	9	5
Kuhnia glutinosa	0	0	0	0	1	0	1	0
Calceolaria verticillata	0	0	3	0	0	0	3	0
Liatris punctata	0	0	0	0	1	0	1	0
Tragia ramosa	0	0	0	0	1	1	1	1
Psoralea cuspidata	0	0	0	0	1	0	1	0
Morongia uncinata	0	0	0	0	3	2	3	2
Petalostemon purpureus	0	0	0	0	1	0	1	0
Psoralea tenuiflora	0	0	3	1	7	4	10	5
Psoralea tenuiflora	0	0	0	0	1	0	1	0
Senecio plattensis	0	0	0	0	5	0	5	0
Tetraneuris stenophylla	0	0	0	0	1	0	1	0
Thelesperma gracile	0	0	13	2	52	18	65	20
Yucca glauca	1	1	0	0	0	0	1	1
Total	3	1	188	7	85	32	276	40

(Table 40). In 1940, 188 seedlings were found but only seven survived until the following year. Of the 85 seedlings found in 1941, 32 were alive the next year.

Seedlings of Lower Slope

The basal cover on this area was considerably less than on the middle slope. Hence the seedlings were more numerous.

Grass Seedlings of Lower Slope

In 1939, five grass seedlings were present in this area. Three were Bouteloua curtipendula and two were B. hirsuta. All failed to survive the fall drought of this year. In 1940, 44 seedlings were charted and 15 were present the following year. Of the 26 Bouteloua curtipendula only four lived. The bunches ranged from 1 to 2 inches in diameter. By August, 1942, they had increased to around 2 to 3 inches in diameter. Of the 18 Bouteloua hirsuta seedlings found in 1940, 11 were alive the following year. They had grown to a diameter ranging from 1 to 3 inches By 1942 they had increased to 2 to 4 inches in diameter (Figure 17).

In 1941, 185 seedlings were charted but only 19 survived until August, 1942. The high mortality rate was due to the great increase in the basal cover of Andropogon furcatus, which over-topped the grass seedlings. Of 83 Bouteloua curtipendula seedlings only seven survived. The bunches ranged from .5 to 1 inch in diameter. Of 12 B. gracilis seedlings, 2 survived and were approximately 2 inches in diameter. From 90 B. hirsuta seedlings, ten survived and the plants ranged from one to two inches in diameter (Table 41).

TABLE XLI. Number of seedlings present in 4 meter quadrats of the little bluestem type on the lower slope and the number surviving each year for 3 years. Hays, Kansas.

Species	1939		1940		1941		Total	
	Number present	Number survived	Number present	Number survived	Number present	Number survived	Number present	Number survived
GRASS								
Bouteloua curtipendula	3	0	26	4	83	7	112	11
Bouteloua gracilis	0	0	0	0	12	2	12	2
Bouteloua hirsuta	2	0	18	11	90	10	110	21
Total	5	0	44	15	185	19	234	34
FORBS								
Aster multiflorus	0	0	6	0	10	3	16	3
Cheirinia aspera	30	8	81	34	3	0	114	42
Cirsium undulatum	0	0	0	0	2	0	2	0
Echinacea angustifolia	1	0	7	3	28	8	36	11
Liatris punctata	1	0	0	0	5	1	6	1
Meriolix serrulata	0	0	0	0	11	4	11	4
Psoralea tenuiflora	1	1	4	1	7	3	12	5
Senecio plattensis	0	0	0	0	1	0	1	0
Scutellaria resinosa	0	0	0	0	4	3	4	3
Tragia ramosa	0	0	0	0	2	1	2	1
Thelesperma gracile	0	0	4	3	13	7	17	7
Ratibida columnifaris	0	0	0	0	4	4	4	4
Asclepias pumila	1	0	0	0	0	0	1	0
Asclepiodora decumbens	0	0	1	0	0	0	1	0
Total	34	9	103	41	90	34	227	81

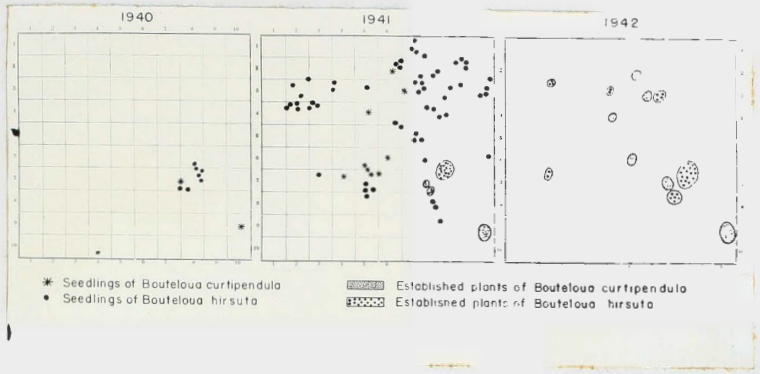


FIG. 17. A representative quadrat of each species of grass seedlings charted in little-bluestem type for 3 years. The number and basal cover of each seedling surviving the following year is also shown.

Forb Seedlings of Lower Slope

In 1939, 34 seedlings were present but only nine survived. Of 30 Cheirinia aspera seedlings, eight survived. The seedling each of Echinacea angustifolia, Liatris punctata and Asclepias pumila failed to live. However the lone seedling of Psoralea tenuiflora was still living the following year (Table 41). In 1940, 103 seedlings, comprising seven different species, were charted and 41 were present the following year.

Ninety seedlings were present in 1941, 34 of which became established and were living the following year.

During the period of study, the greatest number of grass seedlings was on the upper slope, next greatest on the lower slope and least on the middle slope. The mortality rate of seedlings for the upper, middle, and lower slope was 28, 19, and 15 per cent respectively.

The number of forb seedlings for the study period on the upper, middle, and lower slope was 843, 276, and 227 respectively. The average per cent that survived on the three slopes was upper slope, 24 per cent, middle

slope, 15 per cent, and the lower slope, 37 per cent.

Seedlings of Revegetation Type

The number of seedlings charted on the Buchloe dactyloides area, was limited to a few species of forbs. During the first year, seedlings were absent in this area. In 1940, five seedlings were charted but only one survived. All of the 3 Cheirinia aspera perished. Of the two Psoralea tenuiflora seedlings one was present the following year. In 1941, five seedlings were charted and all five were still living in August, 1942. Of this number, four were Psoralea tenuiflora and one was Astragalus shortianus (Table 42).

The number of seedlings of the Sporobolus cryptandrus area was confined to mostly grass seedlings. In 1939 seedlings were entirely absent in this area. In 1940, 37 Sporobolus cryptandrus seedlings were charted and only 2 survived. The following year these seedlings had grown to 1 to 2 inches in diameter (Figure 18). In 1942, they had made but slight increase, due to the enormous numbers of Ambrosia psilostachya that overtopped them. In 1941, two seedlings of Bouteloua gracilis and 13 of Sporobolus cryptandrus were charted. Of these only one Sporobolus cryptandrus seedling survived. When charted in 1942, it had increased to approximately 1 inch in diameter.

Seedlings of Dusted Type

The principal seedlings charted for this area during the period of

TABLE XLII. Number of seedlings in 3 meter quadrats of each area on the revegetation type and number surviving each year for 3 years. Hays, Kansas.

Area	Species	1939		1940		1941		Total	
		Number present	Number survived	Number present	Number survived	Number present	Number survived	Number present	Numbe survi
Buchloe doctyloides	Cheirinia aspera	0	0	3	0	0	0	3	
	Psoralea tenuiflora	0	0	2	1	4	4	6	
	Astragalus shortianus	0	0	0	0	1	1	1	
	Total	0	0	5	1	5	5	10	
Sporobdus cryptandrus	Bouteloua gracilis	0	0	0	0	2	0	2	
	Sporobolus cryptandrus	0	0	37	2	13	1	50	
	Verbena bipinnatifida	0	0	1	0	0	0	1	
	Total	0	0	38	2	15	1	53	

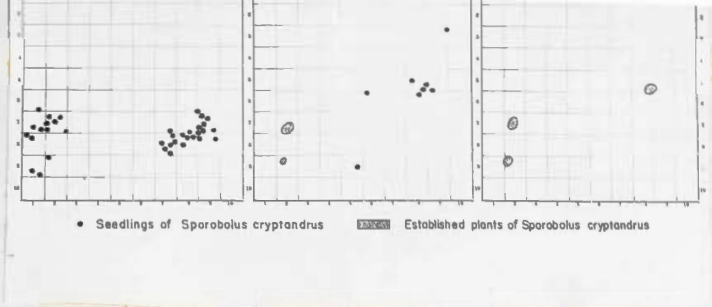


FIG. 18. A representative quadrat of each species of grass seedling charted in revegetation type for 3 years. Hays, Kansas. The number and basal cover of each surviving seedling the following year is also shown.

study were grass seedlings. Two Malvastrum coccineum seedlings were charted on the moderately dusted area in 1941 and both were present in 1942.

Grass Seedlings of Dusted Type

Badly Dusted

The badly dusted area produced three Bouteloua gracilis seedlings in 1939. All these plants were absent when charted the next year. In 1940, 18 Bouteloua gracilis and two Sporobolus cryptandrus seedlings were present. Both S. cryptandrus seedlings perished and only two Bouteloua gracilis seedlings survived. In 1941 they had increased to bunches approximately 1 inch each in diameter. By 1942, each bunch had increased to approximately 2 inches in diameter. In 1941, 67 Bouteloua gracilis seedlings were charted. The following year 15 of these had survived and they were present in little bunches approximately 1 inch in diameter (Table 43).

Moderately Dusted

The moderately dusted area failed to yield seedlings in 1939. In

TABLE XLIII. Number of seedlings present in 4 meter quadrats of each area in the dusted type and the number surviving each year for 3 years. Hays, Kansas.

Species	1939		1940		1941		Total	
	Number present	Number survived	Number present	Number survived	Number present	Number survived	Number present	Number survived
BADLY DUSTED AREA								
Bouteloua gracilis	3	0	18	2	67	15	88	17
Sporobolus cryptandrus	0	0	2	0	0	0	2	0
Total	3	0	20	2	67	15	90	17
MODERATELY DUSTED AREA								
Bouteloua gracilis	0	0	46	12	3	0	49	12
Buchloe dactyloides	0	0	20	2	0	0	20	2
Malvastrum coccineum	0	0	0	0	2	2	2	2
Total	0	0	66	14	5	2	71	16
LIGHTLY DUSTED AREA								
Bouteloua gracilis	0	0	26	6	2	0	28	6
Buchloe dactyloides	0	0	12	6	0	0	18	6
Total	0	0	38	12	2	0	46	12

1940, however, 46 Bouteloua gracilis and 20 Buchloe dactyloides seedlings were charted (Table 43). Only 2 of the Buchloe seedlings were living the following year. One bunch was approximately four inches in diameter in 1941. The following year it had increased to approximately 22 inches in diameter (Figure 19). The other bunch was around two inches in diameter in 1941, and had increased to approximately 11 inches in diameter the following year. The 12 seedlings of Bouteloua gracilis that survived ranged in bunches from one to six inches in diameter. The large bunches were formed by the union of several seedlings through growth. By 1942 these large bunches were approximately 10 inches in diameter and the bunches formed from a single seedling were approximately 3 inches in diameter. The only grass seedlings charted in 1941 were three of Bouteloua gracilis which failed to survive. The low number of seedlings in this area in 1941, was due to the debris of Hordeum pusillum that covered the surface of the soil. The few seedlings that were produced were eaten by grasshoppers.

Lightly Dusted

The lightly dusted area failed to produce seedlings in 1939. In 1940, however, there were 26 Bouteloua gracilis and 12 Buchloe dactyloides seedlings present (Table 43). Six of each species were alive the following year. The Bouteloua gracilis seedlings had grown into bunches ranging from 1 to 2 inches in diameter (Figure 20). By 1942, they had increased to 2 to 3 inches in diameter. Two of the Buchloe dactyloides seedlings of 1940 had united to form an area approximately 4 inches in diameter. This

bunch had increased to nearly 12 inches in diameter by August, 1942. The

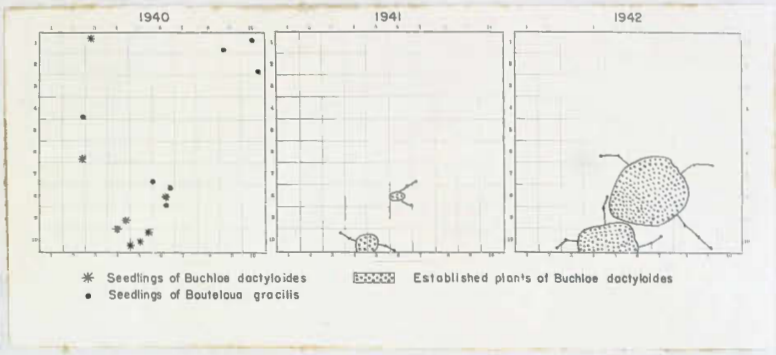


FIG. 19. A representative quadrat of each species of grass seedlings charted on moderately dusted area for 3 years. Hays, Kansas. The number and basal cover of each surviving seedling is shown.

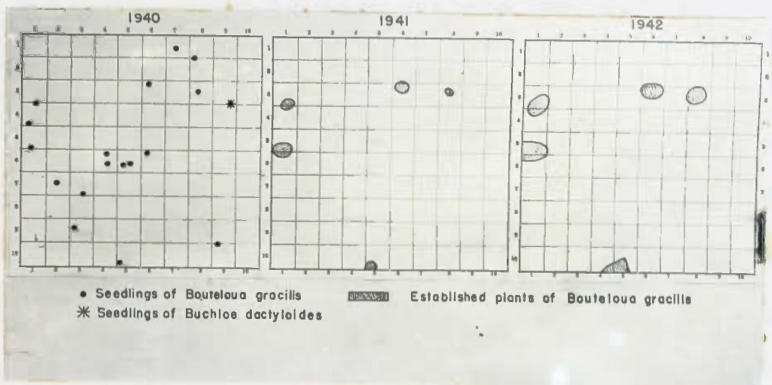


FIG. 20. A representative quadrat of each species of grass seedlings charted on lightly dusted area for 3 years. Hays, Kansas. The number and basal cover of each surviving seedling is shown.

other seedlings of Buchloe dactyloides produced in 1940, had increased to a bunch approximately 2 inches in diameter the following year. By 1942 it was nearly 4 inches in diameter.

Two Bouteloua gracilis seedlings were charted in 1941 but both failed to survive. The thick growth of Hordeum pusillum in 1941 offered too much competition for light.

SUMMARY

The purpose of this study was to determine variations in growth, seed yield, and seedling production of native prairie plants in various habitats of the mixed prairie, during the seasons of 1939, 1940, and 1941.

The study was made during three years that were extremely variable in climatic conditions. Precipitation during 1939 was 7.84 inches below normal. In 1940 it was approximately normal, and in 1941 it was 4.44 inches above normal.

The mean annual temperature for 1939 was 3.1 degrees F. above normal; in 1940, approximately normal, and in 1941, only 1.2° F. above normal.

Water content of soil correlated closely with precipitation. During the summer and fall of 1939 no soil moisture was available for plant growth in the upper 3 feet of soil. In 1941 soil moisture was available in only the upper 2 feet of soil, except July and August when it was more available to plant growth in the upper 6 inches. In 1941 it was available to plant growth in the upper 3 feet of soil every month, except July, when it was now available to plant growth in the upper 12 inches of soil.

All types of vegetation suffered greatly during the fall drought of 1939. The more xeric species, however, suffered least. During the wet season of 1941 most species more than regained their loss of the previous two years.

On the short-grass type Buchloe dactyloides suffered more reduction

in basal cover from the 1939 drought than did Bouteloua gracilis. When moisture was present in 1941, however, Buchloe dactyloides increased far more rapidly than did Bouteloua gracilis.

Of the forbs on the short-grass type, Malvastrum coccineum increased in number during the 1939 drought. Psoralea tenuiflora held its own fairly well.

Bouteloua curtipendula suffered less from drought than any species of grass on the little-bluestem type. Andropogon furcatus suffered the greatest loss.

During the wet season of 1941, Andropogon furcatus made a greater increase in cover than did the other species on the little-bluestem type.

In the big-bluestem type, Sporobolus hookeri increased in number of stems per unit area each season during the period of study. All other species suffered a loss during the dry season of 1939.

Buchloe dactyloides suffered a greater loss of basal cover than did Bouteloua gracilis on the dusted type. Buchloe dactyloides increased more rapidly during the wet spring of 1941.

Sporobolus cryptandrus showed an average caryopses count of 94 per hundred florets during the period of study. This was the highest of all species.

Bouteloua hirsuta produced an average of 30 caryopses per hundred florets, the highest average for the more important short grasses.

Sporobolus cryptandrus was the only species of grass that gave a high seed yield during the dry summer of 1939. Most of the other species yielded a small amount and many none at all.

The only forbs that produced any amount of seed in 1939 were Cheirinia aspera, Echinacea angustifolia and Meriolix serrulata. During the wet season of 1941, most all species produced a considerable amount of seed.

Hordeum pusillum yielded the most seed of all ruderals. In 1941 it produced 771 pounds of seed per acre. In one case a meter quadrat produced 9000 stems.

The mortality of seedlings was enormous during the extreme drought of 1939. The only seedlings able to survive were a few Psoralea tenuiflora and Cheirinia aspera.

The grass seedling with the lowest mortality rate during the season of 1940 and 1941 was Bouteloua hirsuta.

Forb seedlings with low mortality were Thelesperma gracile, Echinacea angustifolia, Meriolix serrulata and Ratibida columnaris.

Even in normal seasons the mortality of most seedlings is fairly high. Drought, insects, and competition from mature plants reduce the chances of surviving.

This study indicates that growth, seed yield and seedling production correlated very closely with the amount of available soil moisture during the season of growth.

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