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Regeneration of Native Midwestern Pastures under Protection

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Nebraska Conservation Bulletin

Number 23 June 1941

REGENERATION OF NATIVE MIDWESTERN PASTURES UNDER PROTECTION

J. E. WEAVER
W. W. HANSEN

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UNIVERSITY OF NEBRASKA
CONSERVATION AND SURVEY DIVISION

NEBRASKA CONSERVATION BULLETIN

NUMBER 23 JUNE 1941

CONTRIBUTION 128 FROM THE DEPARTMENT OF BOTANY

REGENERATION OF NATIVE MIDWESTERN PASTURES UNDER PROTECTION

BY

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PUBLISHED BY THE UNIVERSITY OF NEBRASKA
CONSERVATION AND SURVEY DIVISION, LINCOLN

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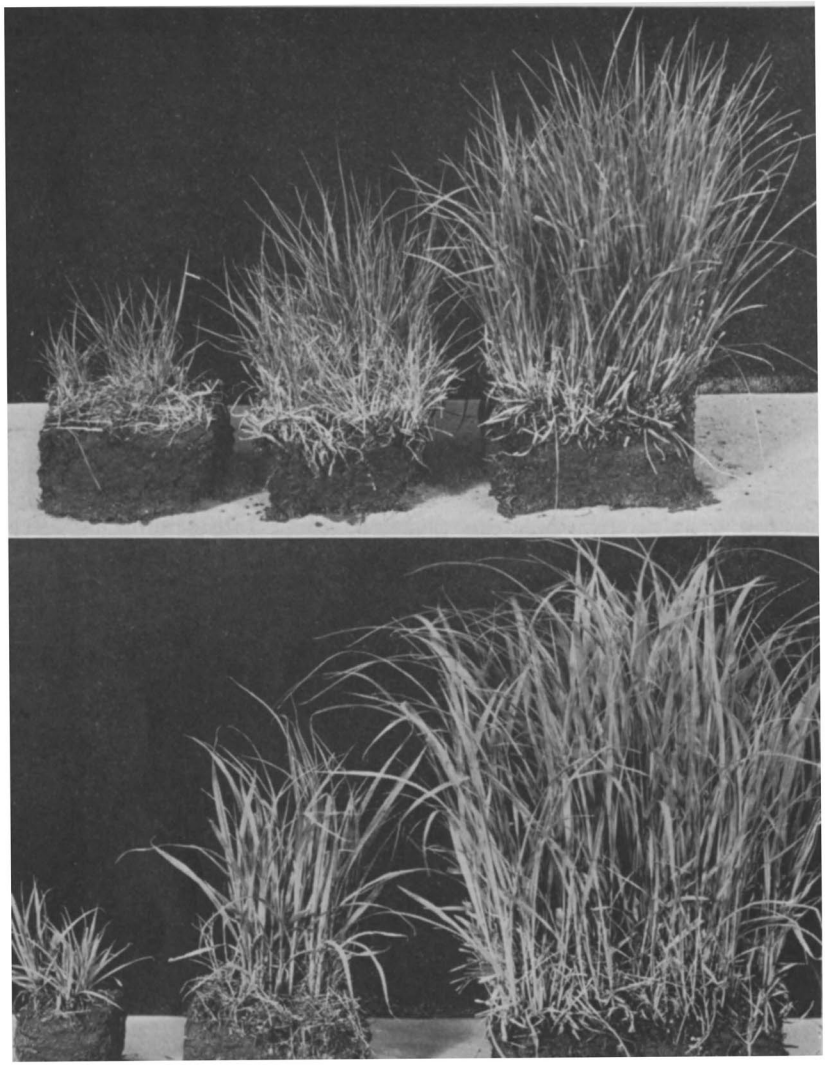
Introduction

THE ORIGIN of native midwestern pastures from virgin prairie and the degeneration of the prairie under long-continued grazing have been outlined in some detail in a previous bulletin (Weaver & Hansen 1941).* During the last four years much study has been given to the converse phenomenon of the regeneration of native midwestern pastures when grazing animals were excluded. This universal phenomenon of the return of vegetation to something of its former natural condition is summed up in the term plant succession (Clements 1928). In connection with pastures derived from true prairie, it is of great practical as well as scientific importance, since no pasture at any stage in the degeneration of true prairie produces continuously so great an amount of highly nutritious forage as do the native bluestem grasses. Recognition of this fact has led to such practices as deferring grazing in bluestem pastures until late spring or early summer, but few or no studies have been made in the true-prairie area to determine the rate of regeneration of the better grasses in pastures already dominated by species of lower forage value. Much work has been done in the more arid ranges in the western United States (Sampson 1919; Campbell 1931, 1940; Whyte 1939).

This study falls naturally into two phases or parts. The first, begun as materials for the junior author's doctoral thesis in 1937, deals with changes in the plant population. The original plans have been considerably extended and continued through a period of four years. The second part, executed in 1939 and 1940, has to do with relative production of forage in pastures protected from grazing during a first, second, and fourth year, and of native prairie. The results reveal not only the profound changes in the numbers and kinds of grasses and forbs, as well as their total yield under different lengths of periods of protection, but also the degree of their utilization.

J. E. W.
W. W. H.

* All references are to the bibliography, page 90.



FRONTISPIECE.—Upper: bunches of little bluestem selected on June 13, 1940, for average size under first, second, and fourth year of protection. Heights are 3, 5.5, and 9 inches respectively. Note that the first bunch has only a fringe of stems on one side; the second is only one-fourth filled with stems, but the last has a dense stand of stems throughout.

Lower: bunches of big bluestem selected as in upper figure. Respective heights are 3.5, 8, and 13 inches. Photo June 13, 1940.

Regeneration of Native Midwestern Pastures under Protection

PART I. CHANGES IN THE PLANT POPULATION

A FOUR-YEAR experimental study was begun in early spring of 1937 to determine the nature and rate of regeneration of an old native pasture under complete protection. All changes in the plant population were recorded. The area selected lies 3 miles north and 1 mile west of the University of Nebraska in Lincoln. It consists of a large tract of unbroken native prairie, a considerable portion of which was fenced and grazed continuously for 23 years. The prairie and pasture cover a tract of gently rolling to moderately hilly land. They are about one-half mile long, from north to south, and about one-quarter mile wide. The soil is Carrington clay loam, a type common and extensive in eastern Nebraska, as is also this type of topography.

Original Vegetation.—The prairie vegetation is of the upland mid-grass type. The chief dominant is little bluestem (*Andropogon scoparius*), which alone constitutes about 60 per cent of the cover, fig. 1. Needle grass (*Stipa spartea*), prairie dropseed

Fig. 1.—Detail of original bluestem prairie. Most of the grass is little bluestem (*Andropogon scoparius*). Photo June 28, 1933.

(*Sporobolus heterolepis*), June grass (*Koeleria cristata*), and side-oats grama (*Bouteloua curtipendula*) are all important species. All are commonly designated as bunch grasses, but side-oats grama extends its territory by means of rhizomes, usually .5 to 2 inches in length. The sod-forming big bluestem (*Andropogon furcatus*), with a very little Indian grass (*Sorghastrum*

Fig. 2.—Selected sods of little bluestem on June 19, 1935, showing various degrees of loss by drought from 0 per cent (upper left where the grass is 16 inches tall) to 100 per cent (lower right). Note the retarded development where most of the bunch died.

nutans), is dominant in the ravines, but has also spread throughout much of the uplands where, like Kentucky bluegrass (*Poa pratensis*), it forms a 3 to 10 per cent mixture almost throughout. Tall panic grass (*Panicum virgatum*) and nodding wild rye (*Elymus canadensis*) occur sparingly on lowlands and occasionally in local upland areas where water content is increased, as about gopher mounds or burrows. Scribner's panic grass (*Panicum scribnerianum*) and Wilcox's panic grass (*P. wilcoxianum*) are important low-growing, interstitial species of almost constant occurrence. *Carex pennsylvanica* and *C. meadii* are the chief

sedges, but neither is of much importance. In addition to the grasses and sedges there are numerous composites, legumes, and other forbs as described by Weaver & Fitzpatrick (1934).

The grasses normally reach a general level of 12 to 18 inches in July when the vegetative growth is nearly complete. The basal cover is about 13 per cent and the foliage cover varies between 75 and 100 per cent during a season of approximately normal precipitation. The new cover of vegetation each year, consisting almost entirely of long-lived perennials, effectively screens the soil from direct insolation. The soil is almost entirely concealed by debris, usually only a few millimeters thick, which protects it from beating rains. This prairie has not been grazed for at least 40 years, and probably only moderately since the disappearance of the bison. It is used for the production of hay and is mowed annually in late summer or fall, except in years of extreme drought.

This description is more nearly that of conditions before the severe drought years of 1934 and 1936. As a result of this greatest drought ever recorded in the prairie region (Weaver, Stoddart, & Noll 1935), marked changes in the normal composition have occurred (Weaver & Albertson 1936, 1939, 1940). Chief among these was the high mortality of little bluestem, many bunches being entirely killed and others represented by a mere fringe of dwarfed stems, fig. 2. June grass, needle grass, and bluegrass also suffered greatly. Losses were severe among plants of the understory, notably Scribner's and Wilcox's panic grass, prairie cat's-foot (*Antennaria campestris*), and prairie violet (*Viola pedatifida*). Big bluestem, side-oats grama, and deeply rooted forbs were not greatly affected. This applied also to prairie dropseed and the small patches of blue grama (*Bouteloua gracilis*).

The Pasture.—The pasture had apparently never been greatly overgrazed. In 1932–33 it was studied and described as belonging to the No. 3 type which is characterized by about half dominance of bluestems and other prairie grasses and half of bluegrass (Weaver & Hansen 1941). The cover was practically intact, annual weedy species were few, and only a modicum of the usual perennial pasture weeds occurred. Changes resulting from the drought, aside from the almost complete disappearance of bluegrass and great injury to little bluestem, were the great increase in sand dropseed (*Sporobolus cryptandrus*) (Weaver & Hansen 1939), increase in side-oats grama, occurrence in locally disturbed areas of western wheat grass (*Agropyron smithii*), and increase in annual weeds. Some details of conditions in the exclosed areas and the changes from 1937 to 1940, inclusive, are given in connection with the experiments.

Exclosures.—Two pasture areas adjoining the prairie were exclosed to stock, a smaller one of 24 square rods on a west hillside near the south end of the pasture and a larger one, 4.5 rods wide and 31 rods long, extending from the top of a low hill northward to and including its level base. The slope in the main area varied from 1 to 5 per cent, figs. 3 and 4.

Fig. 3.—South end of prairie (left of fence) and pasture in 1938. A small area of prairie (near the car) was left unmowed opposite a similar exclosure in the pasture.

The south exclosure was typical of the more hilly portion of the pasture. It included a west-facing, gentle slope and also a portion of a northeast one. These were separated by a small ravine. The chief characteristic of the vegetation in the spring of 1937 was the scarcity of nearly all prairie grasses; they were found only upon close observation. The bluestems, for example, sometimes occurred at the rate of only 1 to 4 stems or small tufts per square meter; often there was none. There occurred, as in the prairie, many areas of a few square inches to several square feet almost completely unoccupied by vegetation. Dense patches of the annual peppergrass (*Lepidium densiflorum*) occurred throughout much of the pasture. Spikes of Pursh's plantain (*Plantago purshii*) were so numerous locally as to give a distinctly gray

color, figs. 5 and 6. An abundance of the bright green-colored horseweed (*Leptilon canadense*) was confined to the ravine or to nearly bare ground. No other weeds were of unusual importance. A two-thirds stand of bluegrass intermixed with scattered stalks of thrifty big bluestem grew in a narrow strip in and bordering

Fig. 4.—Experimental pasture fenced against cattle. Adjacent, ungrazed prairie to the right (east) of the line. Photo in March 1938, after one year of protection. Sand dropseed (*Sporobolus cryptandrus*) gives the light-colored tone to the landscape.

the ravine. Scattered bunches of June grass and a few relict prairie forbs were found. In bare or half-bare soil, plants of sand dropseed grew sparingly.

The southern or upland half of the large north exclosure was characterized by the almost complete disappearance of all the prairie grasses except thinly scattered bunches of June grass and side-oats grama. An exception was the occurrence of less than a dozen small patches of blue grama which were well defined but in general depleted to only one-third to one-sixth the normal basal cover. Bluegrass occurred in patches ranging from a few square inches to a square yard in area. There was much nearly unoccupied ground in which sand dropseed was the only grass.

Fig. 5.—Dense stand of Pursh's plantain (*Plantago purshii*) in newly protected pasture. The spikes are mature and 3 to 5 inches long. Photo June 18, 1937.

Fig. 6.—Dense stand of peppergrass (*Lepidium densiflorum*), a weed which was extremely abundant following the early years of drought. Average height is 14 inches. Photo June 7, 1937.

Large patches of smooth goldenrod (*Solidago glaberrima*), smaller but more frequent ones of many-flowered aster (*Aster multiflorus*), and scattered plants or aggregations of Pursh's plantain were the chief weeds. Yarrow (*Achillea occidentalis*) and horseweed were scattered throughout, and in the lower part a bad infestation of peppergrass occurred.

The outstanding feature of the northern (lower) half of the exclosure was the almost continuous stand of peppergrass, the

Fig. 7.—Relict bunches and patches of bluegrass on the lower ground in the north pasture in early spring of 1936. Further heavy losses were sustained during the dry summer.

crowns overlapping almost everywhere. Before the drought this area was clothed with a nearly continuous sod of bluegrass, of which only a few scattered patches remained, fig. 7. Other prairie grasses were rarely found, and peppergrass thrived. Sand dropseed usually occurred under this weed, though some bared areas produced only weeds. In the thinner stands, the dropseed numbered only three or four plants per square meter but in the thickest ones this species covered one-fourth to one-third of the soil. Yarrow was common in small patches and the annual horseweed was scattered thickly.

The prairie adjoining this portion of the pasture had suffered only moderately from drought, except for the spread of aster. The drier upland portion, however, had sustained losses of 25 to 50 per cent. In three places, western wheat grass was invad-

ing bared spots but repeated search revealed no sand dropseed.

Quadrats.—Meter quadrats were established in the exclosures early in 1937 for the purpose of determining quantitatively the increase or decrease of various species during a period of four years. Because of the variety and nature of the vegetation, the list or census method was employed. Ten permanent quadrats were marked out at random in widely distributed areas where sand dropseed dominated. Another lot of 10 was located at random in local areas revealing remnants of the bluestems, since over many square meters none was found. Ten other quadrats were located on the lower ground where small relict patches of bluegrass persisted. Ten quadrats, each of which included patches of blue grama grass at least one-fourth square meter in area, were also established; some of these were old stands, others had grown from seedlings since the drought began. Three quadrats were selected as representative of bared areas occupied by peppergrass. Stem counts of all plants occurring in the quadrats were made annually in June and July. An exception was the dense patches of blue grama grass where the percentage of basal cover, an inch from the soil surface, was ascertained.

Environment of Prairie and Pasture in 1937.—A study was made not only of the method and rate of regeneration of the vegetation but also of the differences in environmental factors in pasture and prairie. The object was to ascertain especially differences in water relations in the two habitats and variations of the intensities of the chief factors affecting both water content of soil and its loss directly or through the plant to the atmosphere.

THE SOIL.—The soil has a mature profile. The A horizon is dark in color, fairly rich in humus, and extends to a depth of 18 inches. Mechanical analysis showed that it contained about 25 per cent very fine sand, 38 per cent silt, and 26 per cent clay,[1] the remain-

Table 1.—Hygroscopic coefficients of soil and subsoil and pH values to a depth of 6 feet in prairie and pasture.

DEPTH	HYGROSCOPIC COEFFICIENTS		pH	pH
	Prairie	Pasture	Prairie	Pasture
feet				
.0–.5	8.9	9.4	6.0	6.1
.5–1	8.4	10.1	6.0	6.1
1–2	10.5	11.3	6.2	6.2
2–3	11.1	11.5	6.9	7.0
3–4	9.7	11.4	7.8	7.9
4–5	10.8	10.5	7.8	7.8
5–6	11.2	10.7	7.5	7.5

[1] Clay includes all particles with diameters less than .005 mm.

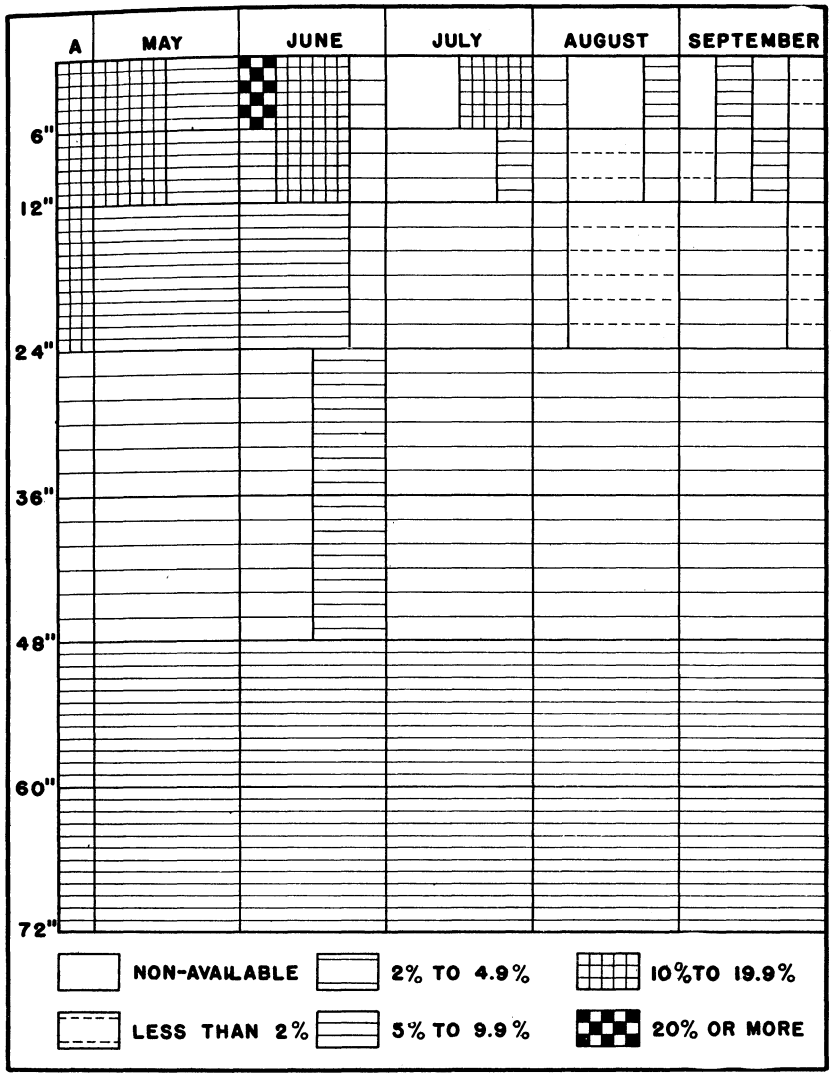


Fig. 8.—Available soil moisture in prairie by weeks to a depth of 6 feet in 1937. Rainfall as in figure 9.

der consisting of larger sand particles. At 12 inches depth the soil becomes lighter in color, and the clay loam of the surface foot grades into clay. The B horizon extends about 18 inches deeper. It consists of a yellowish clay which is plastic when wet but very hard when dry. The prismatic structure is well de-

veloped and during drought there is a great shrinkage among the vertical prisms. The C horizon begins at about 32 to 36 inches depth, depending upon slope. While there is an entire absence of coarse sand to this depth, the sand component consisting almost wholly of very fine sand, in the C horizon the clay gradually becomes intermixed with an increasing proportion of coarser sand. There is no lime layer at any depth; water percolates freely through the massive layer of parent material. At all levels, the soil is circumneutral in reaction. Hygroscopic coefficients and pH values are given in table 1.

PRECIPITATION AND WATER CONTENT OF SOIL.—The year 1937 was one of deficient precipitation. Rainfall during April (1.22 in.) was 1.31 inches below normal and that during May (1.89 in.) was 2.19 inches below normal. That of June (3.79 in.), July (3.10 in.), August (1.69 in.), and September (1.11 in.) were, in order, .53, .75, 1.88, and 1.87 inches below normal. Rainfall was measured by a standard rain gauge placed between the soil-sampling areas.

Samples of soil for water content determinations were taken weekly to 4 feet and on alternate weeks to 6 feet in depth, in both pasture and prairie. Brigg's geotomes were employed. Samples were obtained in foot sections, except that the first and second 6-inch soil cores were taken separately. The hygroscopic coefficient of the soil at each depth was subtracted from the total water content, thus giving the approximate amount of water available for plant growth. These data and also the amount of precipitation in inches between samplings are shown in figures 8 and 9. Since the areas for sampling were only about 50 feet apart on the same gentle (3.5°) slope, and the only visible difference was that of plant cover, comparison of water content at the two stations is of especial interest.

Total precipitation from January to May 1937, was almost normal, yet so severe had been the preceding drought that late in April only the surface 2 feet of soil had a good water content, figs. 8 and 9. Since water content below 2 feet remained constantly low (with one exception) in both pasture and prairie, differences in the surface 2 feet were of great importance.

In April the second foot of soil was drier in pasture than in prairie. In prairie this soil layer was continuously more moist than that in pasture, except for the last week in June, three weeks in August, and one in September when the pasture soil was of approximately the same water content as that of prairie. During these periods of nearly equal available soil moisture in August and September, the amounts at both stations were less than 2 per cent.

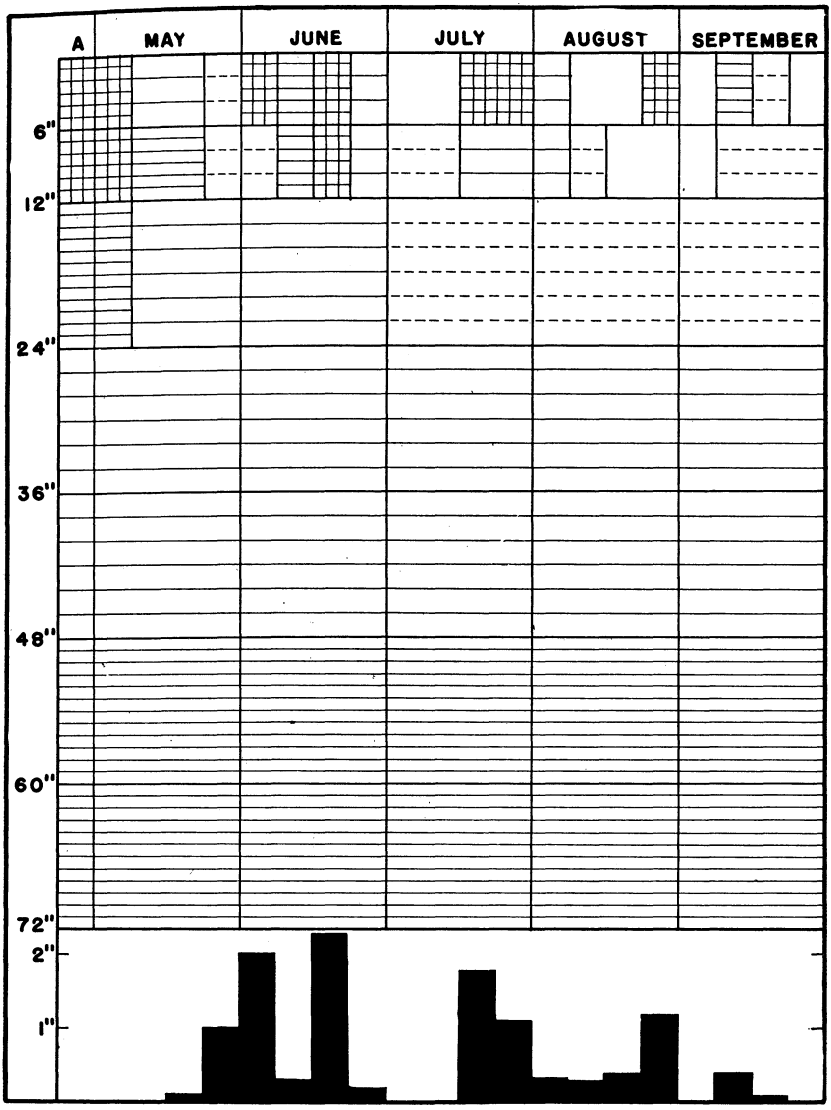


Fig. 9.—Available soil moisture by weeks to a depth of 6 feet in pasture in 1937, with rainfall in inches between the periods of sampling.

The first foot of pasture soil was drier than that in prairie during the last three weeks in May, available water content being less than 2 per cent during the last week. It was much drier throughout the first half of June. Water content was lower in

Table 2, Part I.—Total plant population, expressed in number of stems in each lot of quadrats in pasture in 1937.

SPECIES	SAND DROPSEED QUADRATS	BLUESTEM QUADRATS	BLUEGRASS QUADRATS	BLUE GRAMA QUADRATS	PEPPER-GRASS QUADRATS	TOTAL NO. STEMS
			Grasses and Sedges			
Sporobolus cryptandrus Sand dropseed	6,285	1,714	751	1,582	966	11,298
Bouteloua curtipendula Side-oats grama	448	748	268	404	29	1,897
Bouteloua hirsuta Hairy grama	365	97	0	263	0	725
Poa pratensis Kentucky bluegrass	315	713	23,085	288	225	24,626
Andropogon furcatus Big bluestem	181	741	450	392	6	1,770
Andropogon scoparius Little bluestem	112	2,048	369	169	0	2,698
Koeleria cristata June grass	58	273	8	71	0	410
Carex pennsylvanica Pennsylvania sedge	56	308	129	51	41	585
Festuca octoflora Six-weeks fescue	16	0	0	55	0	71
Sorghastrum nutans Indian grass	3	3	0	6	0	12
Panicum scribnerianum Scribner's panic grass	1	16	18	15	6	56
Sporobolus heterolepis Prairie dropseed	0	6	0	0	0	6
Sporobolus asper Tall dropseed	0	1	0	0	0	1
Total	7,840	6,668	25,078	3,296	1,273	44,155
Bouteloua gracilis * Blue grama	.02	0	0	5.9	0	5.9
			Native Forbs			
Hedeoma hispida Rough pennyroyal	586	443	195	486	462	2,172
Plantago purshii Pursh's plantain	796	656	127	6	14	1,599
Solidago glaberrima Smooth goldenrod	90	0	0	212	0	302
Erigeron ramosus Daisy fleabane	67	125	18	165	1	376
Aster multiflorus Many flowered aster	29	94	163	68	0	354
Oxalis stricta Yellow wood sorrel	25	4	12	5	0	46
Senecio plattensis Ragwort	15	0	1	0	0	16
Lithospermum linearifolium Puccoon	6	5	4	9	0	24

* Basal area in per cent.

pasture in the second 6 inches during the severe drought the first half of July. In August and again in early September water became entirely unavailable in the first foot in pasture but only in the surface 6 inches in prairie. There was less water in the second 6 inches in pasture throughout September, and also less in the first 6-inch layer during the last half of that month.

AERIAL ENVIRONMENT.—Temperatures were measured by means of hygrothermographs installed in prairie and pasture. Average

Table 2, Part II.—Total plant population, expressed in number of stems in each lot of quadrats in pasture in 1937.

SPECIES	SAND DROPSEED QUADRATS	BLUESTEM QUADRATS	BLUEGRASS QUADRATS	BLUE GRAMA QUADRATS	PEPPER-GRASS QUADRATS	TOTAL NO. STEMS
Native Forbs—Contd.						
Artemisia gnaphalodes Prairie sage	6	7	73	6	0	92
Antennaria campestris Prairie cat's-foot	5	0	0	6	0	11
Linum sulcatum Yellow flax	6	34	21	4	0	65
Amorpha canescens Lead plant	4	21	6	9	0	40
Silene antirrhina Sleepy catchfly	0	0	81	0	0	81
Achillea occidentalis Yarrow	0	0	70	62	0	132
Vernonia baldwini Ironweed	0	0	2	0	0	2
Kuhnia glutinosa False prairie boneset	0	0	1	0	0	1
Psoralea argophylla Silvery psoralea	0	0	0	2	0	2
Baptisia leucophaea False wild indigo	0	0	0	2	0	2
Petalostemon purpureus Purple prairie clover	0	0	0	6	0	6
Total	1,635	1,389	774	1,048	477	5,323
Ruderals						
Lepidium densiflorum Peppergrass	1,785	2,210	570	1,903	1,944	8,412
Leptilon canadense Horseweed	1,200	3,932	2,923	1,259	90	9,404
Hordeum pusillum Little barley	323	5	8	381	564	1,281
Grindelia squarrosa Gumweed	19	0	12	2	41	74
Bromus tectorum Downy chess	16	0	1	0	0	17
Schedonnardus paniculatus Tumblegrass	15	7	0	36	0	58
Verbena stricta Vervain	11	0	0	23	0	34
Euphorbia maculata Spotted spurge	1	0	0	2	0	3
Cirsium undulatum Wavy-leaved thistle	0	8	0	1	0	9
Tragopogon pratensis Goat's beard	0	1	0	0	0	1
Gaura parviflora Small flowered gaura	0	1	8	0	0	9
Ambrosia elatior Annual ragweed	0	0	9	0	0	9
Solanum rostratum Buffalo bur	0	0	0	2	0	2
Total	3,370	6,164	3,531	3,609	2,639	19,313

maximum day temperatures were between 92° and 105° F during a period of three months, and average day temperatures were rather uniformly high. The monthly temperatures exceeded the normal during the entire summer. Mean temperature in July was 4.3° F above normal, that in August 9.9°, and in September it was 3.9° above normal. Temperatures in protected pasture exceeded those in prairie at all times until the prairie was mowed on August 14. The early mowing was a direct result of the rapid

drying of the vegetation due to high temperature and other abnormal conditions unfavorable to growth.

Soil temperature at a depth of 4 inches was consistently 1° to 8° F higher in pasture than in prairie. The average day temperature in pasture from June 28 to September 4 ranged between 78° and 82° F and averaged 3.8° F higher than in prairie.

Wind movement was considerably above normal, but at a height of 10 inches no consistent differences were found in prairie and pasture, nor were there regular differences in the average day humidity, which was more than 10 per cent lower than in normal years. Evaporation from black spherical atmometers was high, the mean average daily loss at a height of 8 inches ranging from 38 to 85 cc per day. Until the prairie was mowed, losses were 5 to 10 cc higher in pasture than prairie. Thus, as regards available water content of soil, temperature, and drying power of the air, the growing season was dry, the pasture being a more xeric habitat than the prairie.

Vegetation in Quadrats in 1937.—A list of all the grasses and sedges, native forbs, and ruderals found in the several lots of quadrats is given in table 2. Species are arranged in the order of their abundance in the main (sand dropseed) type of vegetation. A total of 46 species was encountered in listing the 43 quadrats.[2] Among these (if the bared area occupied by peppergrass is omitted) eight species of grasses and sedges, nine of forbs, but only three of ruderals occurred in all four types.

Among the grasses, the small numbers of certain species make them somewhat incidental; these are June grass, six-weeks fescue, Indian grass, Scribner's panic grass, prairie dropseed, and tall dropseed. Of the eight important species, sand dropseed furnished 80 per cent of the stems where it was dominant. It constituted 26 per cent of the vegetation in the bluestem quadrats, but was represented by only 3 per cent in those of bluegrass. In quadrats dominated by blue grama grass, it had a 45 per cent representation, and formed 76 per cent of the grass population in the badly denuded quadrats of peppergrass.

Little bluestem constituted 31 per cent of the grasses in quadrats where bluestems were dominant. In the other types it occurred sparingly or not at all.

Kentucky bluegrass constituted 92 per cent of the grasses in quadrats where it was dominant, but was represented by only 11 per cent where most abundant in any of the other quadrats.

Although blue grama furnished 5.9 per cent of the basal area in its own type, it was insignificant in the quadrats of sand drop-

[2] The number increased to 57 by 1940.

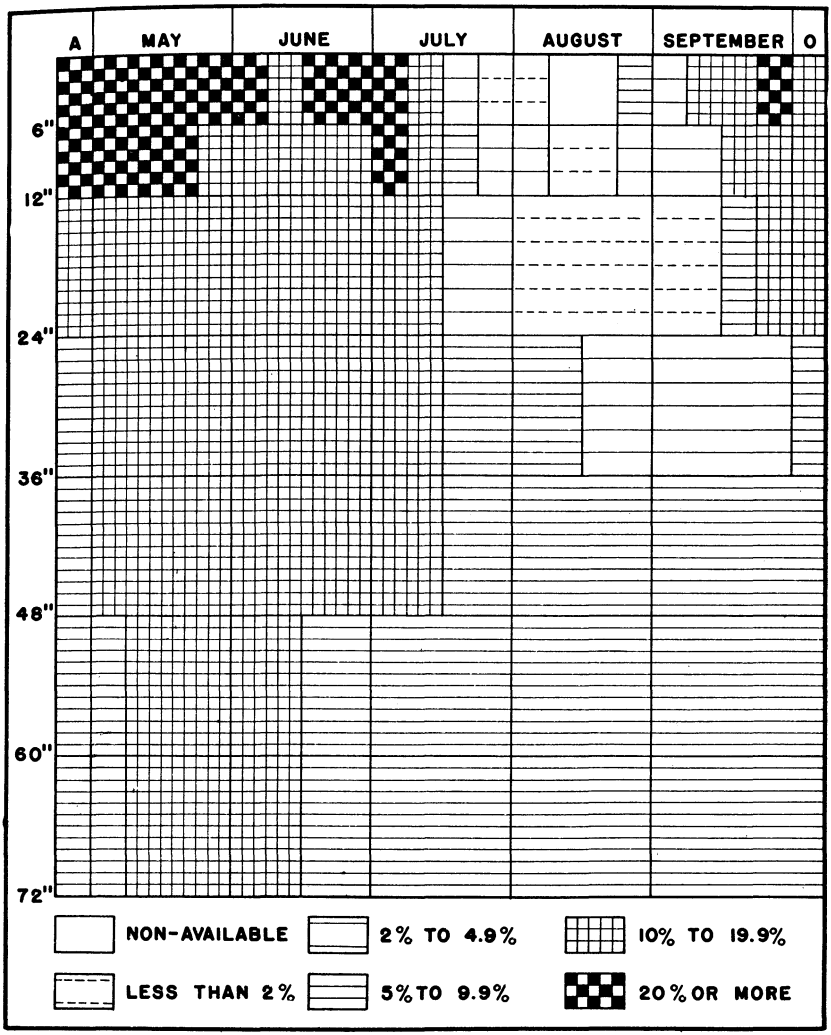


Fig. 10.—Available soil moisture by weeks to a depth of 6 feet in prairie in 1938. Rainfall as in figure 11.

seed and did not occur in any other type. It is significant that side-oats grama and big bluestem were fairly uniformly distributed in small amounts in all of the types of vegetation. Pennsylvania sedge, although occurring sparingly, was present in all of the quadrats and showed potential abilities to increase.

Kentucky bluegrass formed 56 per cent of all the grasses in the 43 square meters. Sand dropseed ranked second with 26 per cent.

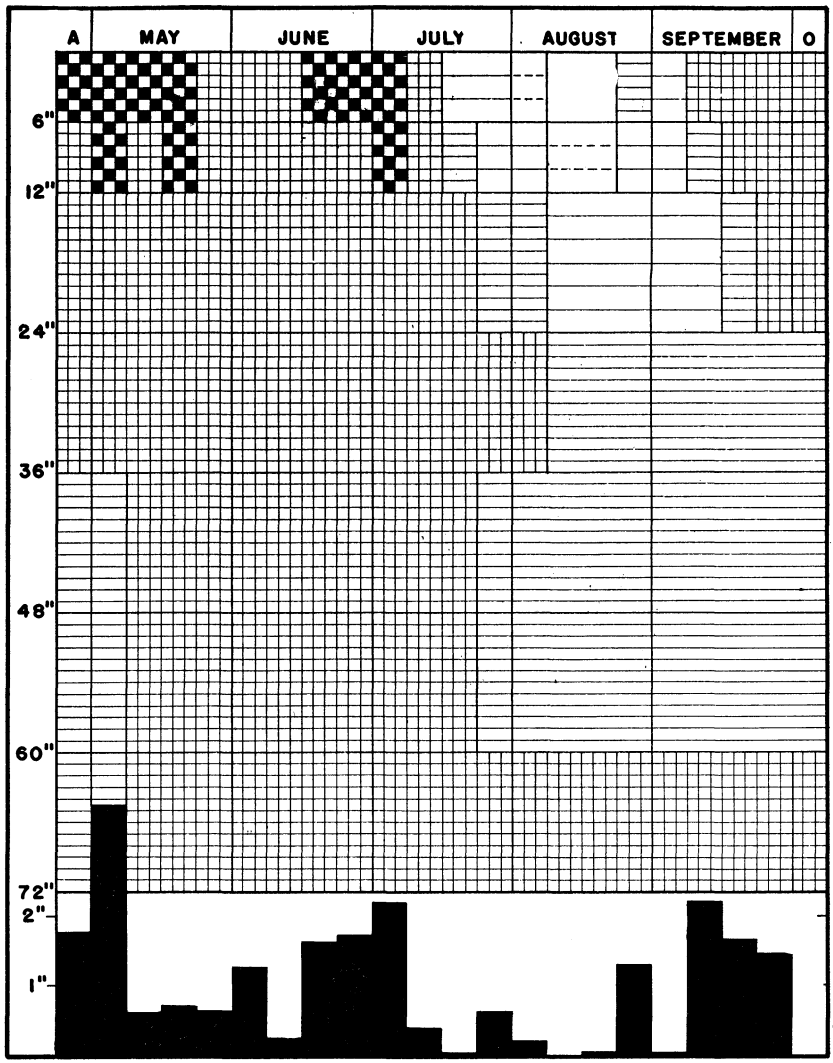


Fig. 11.—Available soil moisture by weeks to a depth of 6 feet in pasture in 1938, with rainfall in inches between the periods of sampling.

Little bluestem was third with 6 per cent. Next in order but of much less importance were side-oats grama and big bluestem.

The diminutive rough pennyroyal was the most abundant forb; Pursh's plantain ranked second. Smooth goldenrod, daisy fleabane, and aster were also common. Many of the 19 species found were of minor significance.

Among the ruderals, horseweed and peppergrass ranked very high, each with about 9000 plants. Little barley was third in rank and quite abundant. Gumweed was also somewhat uniformly distributed. None of the nine remaining species was of much importance.

This record in the sampling area furnished the background upon which changes in the following years were traced in detail and correlated with the general behavior of the vegetation of the entire exclosure and also with the conditions for growth.

Environment of Prairie and Pasture in 1938.—Environment in 1938 was much more favorable to plant development than during the preceding season. Vegetation responded by making good recovery towards former prairie conditions.

PRECIPITATION AND WATER CONTENT OF SOIL.—The light monthly precipitation from January to April was .23 to .43 inch in excess of the normal. April had 3.63 inches of rain, more than an inch above normal, and the 5.64 inches rainfall of May was 1.56 inches in excess of the normal precipitation. Vegetation flourished but growth was later retarded by deficiency of soil moisture both in June and in July, months which had 2.89 and 2.20 inches rainfall, respectively, or 1.43 and 1.65 inches deficiency. Precipitation in August (4.63 in.) was 1.06 inches above normal; rainfall in September (2.94 in.) was almost normal. Distribution of the precipitation between dates of soil sampling and its effect upon available soil moisture are shown in figures 10 and 11.

There was a good water content of soil in both prairie and pasture to a depth of 6 feet until July 15. Below the 3-foot level an available water content of 5 to 9.9 per cent prevailed in prairie throughout the season, and from 5 to 6 feet in pasture, where there appeared to be less absorption, there was 10 to 19.9 per cent available. There was usually a greater amount of water available in the third foot of pasture soil than in prairie after mid-July. In the second foot also, water content was depleted more thoroughly in prairie from July 15 to mid-September. Moisture was depleted somewhat more rapidly and restored a little later in the first foot of the prairie soil than in pasture. From these data, it would seem that two years' growth of grasses without trampling in the protected pasture and the winter's freezing and thawing had increased the rate of water infiltration. The thicker cover of vegetation in prairie, however, apparently depleted the supply somewhat more rapidly by transpiration than the more open, sand dropseed type in pasture.

AERIAL ENVIRONMENT.—Temperatures were considerably above normal every month during the summer of 1938, and about normal

in May. Deviations above normal were 1.8° F in June, 4.3° in July, 5.8° in August, and 4.9° in September. Average maximum day temperatures in the protected pasture were regularly 2° to 8° F higher than those in prairie.

Range in soil temperatures was smaller than in the preceding year, a difference undoubtedly due to more moist soil and the denser cover of vegetation. In 1938, the range was from 65° to 88°

Fig. 12.—Recovery of little and big bluestem in pasture after two years of protection. Photo July 25, 1938, in south exclosure.

F, in 1937 from 61° to 98°. In general, the pasture soil was uniformly warmer than that of the prairie.

Average wind movement in pasture (at a height of 10 inches) ranged from .75 to 2 miles per hour. It rarely exceeded 7 miles per hour. It was higher in pasture than in prairie until midsummer. Three days with hot winds in July, accompanied by temperatures of 105° to 112° F, practically ruined the crop of corn and were also very harmful to pasture and prairie. Evaporation was high, reaching an average daily rate (at a height of 8 inches) of 51 cc in mid-August; otherwise, the average daily range by weeks was 20 to 36 cc. In prairie it was 2 to 6 cc lower.

Vegetation in 1938.—Vegetation in the south exclosure showed a marked increase in grasses and a corresponding decrease in forbs, including noxious weeds. Big bluestem and little bluestem

shared equally in importance with sand dropseed. There were many bunches, mostly small and young, of June grass and side-oats grama which had also increased in abundance. The blue-stems and sand dropseed were not greatly intermixed but more or less dominated different local areas, fig. 12. Aster and golden-

Fig. 13.—Dense stand of sand dropseed in pasture protected two years. Photo July 25, 1938, in north exclosure.

rod were the most important weeds but, like all other perennial and annual forbs and weedy grasses, they were slowly giving way to the dominant grass-life form.

Vegetation in the north exclosure showed on repeated examination that the dominant grass everywhere was sand dropseed with side-oats grama second in importance but of much lower rank, and with the plants widely scattered, fig. 13. In many places sand dropseed covered the soil almost completely, the foliage cover being as high as 90 per cent late in July when the general grass level was about 12 inches and the flower stalks were 2.5 to 3 feet

tall. At a distance of a few rods, except for the tall daisy fleabane and gumweed, the pasture appeared to be completely dominated by sand dropseed and a sparse to moderate mixture of side-oats grama. A considerable part of the increase of sand dropseed resulted from the abundant seedlings of the previous summer. There was an abundance of daisy fleabane and often 300 to 400 flower stalks per square meter. This plant overtopped most of the weedy species.

All other grasses were far less abundant than the preceding, their order of importance being big bluestem, blue grama and hairy grama, little bluestem, June grass, and bluegrass. The considerable amount of big bluestem and somewhat less abundant little bluestem were impressive since in the preceding year they were scarcely to be found even when sought. Both species had regained former losses by vegetative propagation, and both produced seed, the former abundantly. Many small bunches of June grass were scattered throughout as were also many new plants of blue grama and tufts of hairy grama. Growth was vigorous in the bared soil. Scribner's panic grass and Wilcox's panic grass were found sparingly throughout and occurred in dense growths about the edges of bare places. Slender cyperus, found only rarely in 1937, was a common and even abundant species in the areas laid bare by the death of bluegrass; patches 5 to 10 square feet in area occurred. This plant has an excellent storage organ consisting of a small corm. Pennsylvania sedge, also profiting by the death of bluegrass, had increased considerably. Bluegrass was represented only by a few small patches and rarely by isolated tufts. Western wheat grass had made no progress in its invasion of either the pasture or adjoining prairie, although where plants occurred they fruited abundantly. Only three bunches of needle grass (*Stipa spartea*) were found.

Although the prairie grasses were not abundant, considering the area as a whole, yet they did dominate in many scattered square meters, a fact of much importance since it distinctly indicated the beginning of the return of prairie grasses.

The two chief weeds in sequence of importance were aster and goldenrod. Aster varied greatly in height and density of stand, depending largely upon competition. In pure stands, often 4 or more feet in length and breadth, it reached a height of 2.5 feet and the stems from the rhizomes were so densely aggregated that no other plants had returned to the drought-bared areas into which the aster had rapidly spread. Sometimes remnants of bluegrass were found in the deep shade. The goldenrod attained a height of 2 to 2.5 feet in dense patches where there was prac-

tically no grass, but where sand dropseed also occurred the stems were fewer and only 16 inches tall. The larger patches of this rhizomatous species were 12 feet wide and 18 feet long. The plants were often so densely aggregated that even grasses were all but excluded. However, fruiting stalks of sand dropseed and sideoats grama, or less frequently of big bluestem, appeared sparingly from plants enfeebled by the shade.

Little barley ranked third in importance among the weeds and was followed by Pursh's plantain and rough pennyroyal. These were most abundant in patches of dead bluegrass. They frequently occupied 2 to 8 square feet in pure or mixed stands. In general, the gray heads of the plantain, the species which dominated small areas the preceding year, were almost completely obscured by the thickening cover of grasses. Indeed, over the lower half of the pasture little barley and rough pennyroyal formed a distinct understory, at a height of 10 to 13 inches, beneath the perennial pasture and prairie grasses. During June, little barley appeared to suppress sand dropseed, but later the cover of this perennial was very thick and the weedy grass was subdued. In the smaller areas where little barley had complete control, the ripened stems, 20 inches long, became prostrate and formed dense mats, as occurred over many acres in old worn-out pastures. Except for little barley and plantain, annual weeds were of little significance despite the abundance of horseweed and the scourge of peppergrass in 1937. The perennials—yarrow, vervain, western ragweed, and puccoon—were present only in moderate numbers.

The control of the forbs (except aster and goldenrod) by the general thickening of the grasses was a marked feature in 1938. The abundant seedlings and the vigorous vegetative propagation by tillers and rhizomes indicated a decided upward trend in quality and quantity of forage. The quadrats showed steady gains in the numbers of the better grasses, except bluegrass.

General climatic conditions during 1939 and 1940 are given following with tables showing changes in vegetation during the four-year period.

Environment in 1939 and 1940.—The entire growing season of 1939, except for June, was one of deficient rainfall. A small moisture deficiency in April became acute in May when the rainfall was 2.47 inches below normal. The normal June precipitation (4.32 in.) allowed the vegetation to flourish. Subnormal rainfall in July, amounting to more than an inch below the mean, retarded growth. Precipitation during August was nearly an inch below normal, causing the vegetation to dry rapidly. The grow-

Table 3, Part I.—Species of grasses and sedges, native forbs, and ruderals in 10 meter quadrats dominated in 1937 by Sporobolus cryptandrus, and changes in plant populations during each of the four years of protection.

Species	Number of Stems				Per cent of Change			
	1937	1938	1939	1940	1937–38	1938–39	1939–40	1937–40
Grasses and Sedges								
Sporobolus cryptandrus	6,285	7,356	8,998	12,161	17.0	22.3	35.2	93.5
Bouteloua curtipendula	448	954	1,992	1,849	112.9	108.8	–7.2	312.7
Bouteloua hirsuta	365	717	895	774	96.4	24.8	–13.5	112.1
Poa pratensis	315	82	96	96	–74.0	17.1		–69.5
Andropogon furcatus	181	415	1,006	1,210	129.3	142.4	20.3	568.5
Andropogon scoparius	112	175	524	732	56.3	199.4	39.7	553.6
Koeleria cristata	58	268	465	740	362.1	73.5	59.1	1175.9
Carex pennsylvanica	56	75	105	221	33.9	40.0	110.5	294.6
Festuca octoflora	16	60	0	2	275.0	–100.0		87.0
Sorghastrum nutans	3	4	6	0	33.3	50.0	–100.0	–100.0
Panicum scribnerianum	1	1	0	0		–100.0		–100.0
Panicum wilcoxianum	0	6	0	0		–100.0		
Cyperus filiculmis	0	489	356	165		–27.2	–53.7	
Sporobolus heterolepis	0	0	0	35				
Total	7,840	10,602	14,443	17,985	35.2	36.2	24.5	129.4
Bouteloua gracilis *	.02	.06	.02	.0	200.0	–66.7	–100.0	–100.0
Native Forbs								
Plantago purshii	796	576	291	55	–27.6	–49.5	–81.1	–93.1
Hedeoma hispida	586	651	136	13	11.1	–79.1	–90.4	–97.8
Solidago glaberrima	90	170	426	215	88.9	150.6	–49.5	138.9
Erigeron ramosus	67	79	48	5	17.9	–39.2	–89.6	–92.5
Aster multiflorus	29	100	132	194	244.8	32.0	47.0	569.0

* Data for *Bouteloua gracilis* are expressed in average percentage of basal cover per square meter and not in number of stems.

Table 3, Part II.—Species of grasses and sedges, native forbs, and ruderals in 10 meter quadrats dominated in 1937 by Sporobolus cryptandrus, and changes in plant populations during each of the four years of protection.

Species	Number of Stems				Per cent of Change			
	1937	1938	1939	1940	1937–38	1938–39	1939–40	1937–40
Native Forbs—Contd.								
Oxalis stricta	25	43	25	26	72.0	–41.9	4.0	4.0
Senecio plattensis	15	2	0	0	–86.7	–100.0		–100.0
Lithospermum linearifolium	6	21	8	9	250.0	–61.9	12.5	50.0
Linum sulcatum	6	0	0	5	–100.0			–16.7
Artemisia gnaphalodes	6	0	55	8	–100.0		–85.5	33.3
Antennaria campestris	5	0	0	0	–100.0			–100.0
Amorpha canescens	4	3	2	4	25.0	–33.3	100.0	
Achillea occidentalis	0	0	0	13				
Total	1,635	1,645	1,123	547	0.6	–31.7	–51.3	–66.5
Ruderals								
Lepidium densiflorum	1,785	5	0	24	–99.7	–100.0		–98.7
Leptilon canadense	1,200	57	28	7	–95.3	–50.9	–75.0	–99.4
Hordeum pusillum	323	1,680	940	873	420.1	–44.0	–7.1	170.3
Grindelia squarrosa	19	16	2	6	–15.8	–87.5	200.0	–68.4
Bromus tectorum	16	0	0	0	–100.0			–100.0
Schedonnardus paniculatus	15	45	1	19	200.0	–97.8	1800.0	26.7
Verbena stricta	11	5	1	0	–54.5	–80.0	–100.0	–100.0
Euphorbia maculata	1	2	1	0	100.0	–50.0	–100.0	–100.0
Chenopodium album	0	13	0	0		–100.0		
Cirsium undulatum	0	4	12	7		200.0	–41.7	
Polygala verticillata	0	2	0	0		–100.0		
Gaura parviflora	0	1	8	0		700.0	–100.0	
Ambrosia elatior	0	0	4	0			–100.0	
Total	3,370	1,830	997	936	–45.7	–45.5	–6.1	–72.2

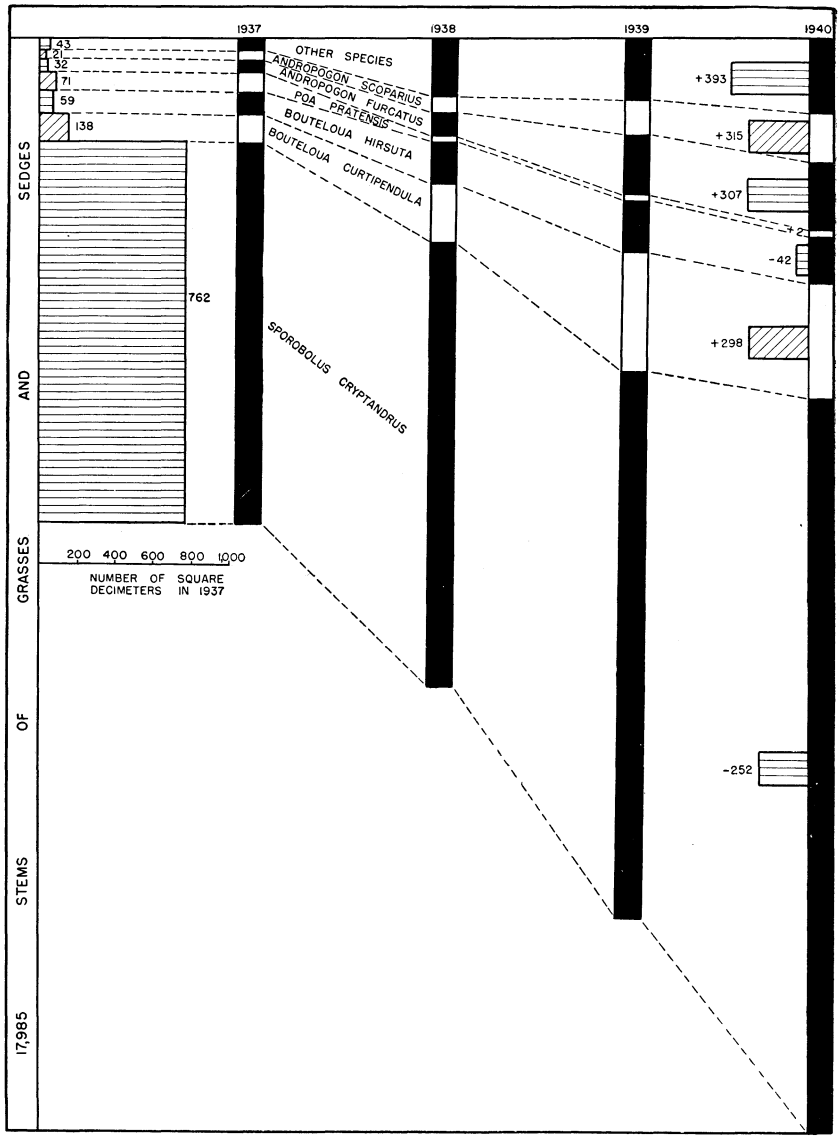


Fig. 14.—Quadrats of *Sporobolus cryptandrus*. Maximum number of stems of perennial grasses and sedges, number of square decimeters in which each of the most important species occurred in 1937 (horizontal bars), and relative abundance in the plots (vertical columns) in 1937, 1938, 1939, and 1940. Horizontal bars on the right indicate the increase or decrease in number of square decimeters occupied compared with 1937.

ing season was characterized by temperatures much above normal, 7.9° in May, 3.2° in June, and 5.4° in July. Soil moisture was reduced to the nonavailable point in the surface 6 inches several times, and available water content of soil to a depth of 2 feet was rather continuously less than 2 per cent after June 30.

The spring of 1940 was cool and late; the April rainfall was slightly above normal, and there was sufficient water content to promote good growth. Precipitation in May was only .98 inch (3.10 in. below normal), and only about half the normal precipitation fell in June (2.11 in.). Despite these conditions, the grasses made a good growth, because of favorable distribution of rainfall until late in June. Because of no precipitation until almost the end of July, there was a period of four weeks during which growth ceased; water content on uplands was exhausted at all levels. The grasses dried. Some were bleached to nearly white, the bluestems took on the reddish-brown colors of autumn. Growth was renewed after July 26, and continued throughout August under a normal rainfall (3.59 in.).

Recovery of Pasture from 1937 to 1940. QUADRATS OF SPOROBOLUS CRYPTANDRUS.—Changes in plant population in 10 quadrats dominated in 1937 by *Sporobolus cryptandrus* are shown for each of the four years of protection in table 3. There was a steady increase of the dominant in each of the four years, viz., 17, 22, and 35 per cent over that of the preceding year. The total increase from 1937 to 1940 was 94 per cent. In 1937, sand dropseed alone constituted 80 per cent of the entire vegetation, exclusive of native forbs and ruderals; in 1940, 68 per cent. The increase of this species and its preponderance in the pasture is shown in figure 14. The figure also shows that sand dropseed occurred in 762 of the 1000 square decimeters in 1937 (an occurrence of 76 per cent) but in only 510 (762 minus 252) in 1940. This was a decrease of 33 per cent in distribution. Thus, the number of stems, or density of cover, increased but the species had lost its hold over much of the territory where it was formerly represented.

Bouteloua curtipendula was the second most important grass in 1937 but constituted only 6 per cent of the total grass cover. It increased 113 per cent in 1938 and 109 the next year. In 1940, however, there was a 7 per cent decrease from the preceding year. Total increase from 1937 to 1940 was 313 per cent, and this was reflected also in the unit areas of occurrence, which increased from 138 to 436 (138 plus 298). *B. hirsuta* behaved, in general, as did the preceding species, except that it lost considerably in unit areas occupied, fig. 14. *Poa pratensis* lost even the fourth place it held in 1937.

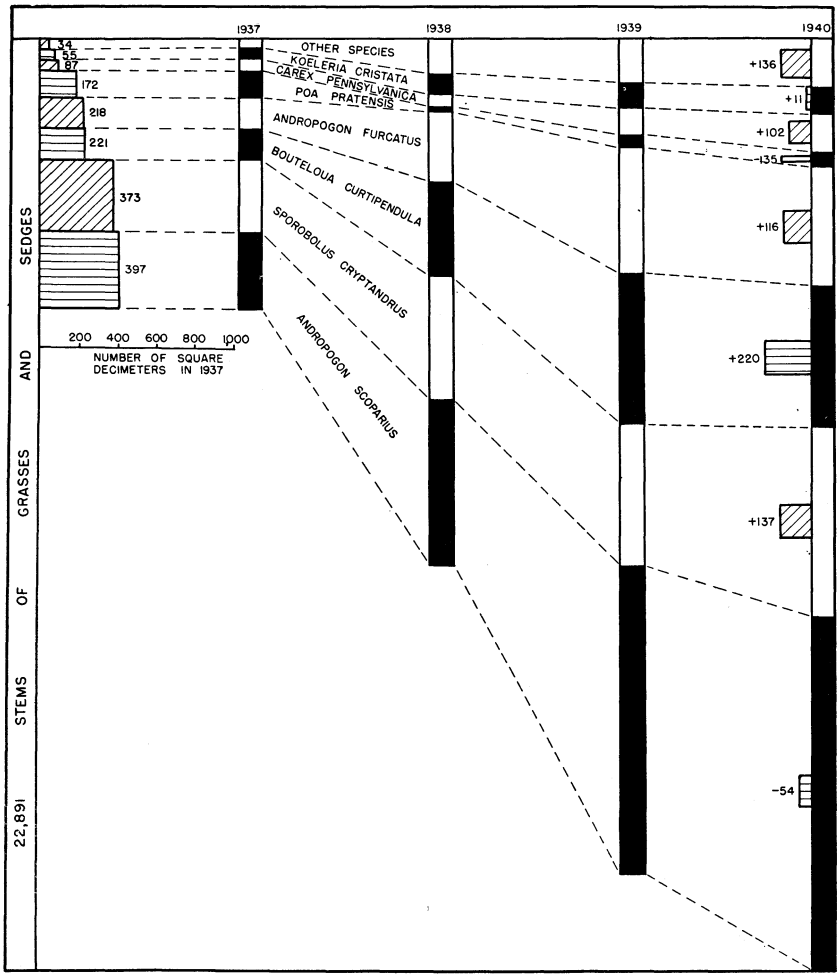


Fig. 15.—Quadrats of *Andropogon scoparius*. Maximum number of stems of perennial grasses and sedges, number of square decimeters in which each of the most important species occurred in 1937 (horizontal bars), and relative abundance in the plots (vertical columns) in 1937, 1938, 1939, and 1940. Horizontal bars on the right indicate the increase or decrease in number of square decimeters occupied compared with 1937.

Both species of *Andropogon* showed consistent gains. *A. furcatus* increased at the rate of 129, 142, and 20 per cent over the preceding year; the four-year increase was 569 per cent. In unit areas occupied, the gain was from 32 to 339 for this rhizomatous species. *A. scoparius* made a total gain of 554 per cent in number of stems and from 21 to 336 in number of units occupied. Other

grasses, collectively, gained rapidly in 1938, remained almost the same the next year, but increased again in 1940.

Only 13 native forbs were found. *Plantago purshii* was most abundant in 1937. This annual decreased yearly until in 1940 only 7 per cent of the original number was found. *Hedeoma hispida* showed no decrease until the third year of protection. It almost disappeared by 1940. Conversely, *Solidago glaberrima* and *Aster multiflorus* both increased under protection from grazing, but the goldenrod decreased during the fourth year. As a group, the native forbs decreased 67 per cent in competition with the grasses under protection.

Lepidium densiflorum and *Leptilon canadense,* both annuals, were extremely abundant in 1937. They almost disappeared over the entire pasture the next season and thereafter were never again abundant. Conversely, *Hordeum pusillum* occurred sparingly in 1937, was extremely abundant the next spring and plentiful thereafter. The group of 13 ruderals collectively decreased 72 per cent during the four years. In 1940 only six species were found.

QUADRATS OF ANDROPOGON SCOPARIUS.—Changes in plant population in 10 quadrats in which *Andropogon scoparius* was the most important species in 1937 are shown for each of the four years of protection in table 4. *Andropogon* formed 31 per cent of the total grass population in 1937. Number of stems increased 96, 90, and 16 per cent over the preceding year, respectively, and in 1940 this species constituted 39 per cent of the total grass cover, fig. 15. Since the number of unit areas occupied by the species actually decreased from 397 to 343, the gain was almost entirely due to recovery of bunches vegetatively; very few seedlings were found.

Andropogon furcatus increased in a manner similar to that of little bluestem although the initial numbers were smaller and the percentage gains of this rhizomatous species much larger. An exception was a small decrease in 1940. The total gain by 1940 was 287 per cent, which was less than that of *A. scoparius.* From an initial 11 per cent of the grass cover in 1937, it increased to 13 per cent by 1940. Moreover, it occupied 116 new unit areas, fig. 15.

Bouteloua curtipendula increased its numbers 218 per cent the first year and 60 per cent the second, but showed a slight decrease the third. The total increase (1937–1940) was 367 per cent and the unit area increase was 100 per cent.

Behavior of *Sporobolus cryptandrus* is of special interest under the competition afforded by the thickening vegetation. It increased 75 per cent in 1938, 19 more in 1939, and an additional 31 per cent by 1940 despite the dry fall preceding which resulted

Table 4, Part I.—Species of grasses and sedges, native forbs, and ruderals in 10 meter quadrats where Andropogon scoparius was the most important species in 1937, and changes in plant populations during each of the four years of protection.

Species	Number of Stems				Per cent of Change			
	1937	1938	1939	1940	1937–38	1938–39	1939–40	1937–40
Grasses and Sedges								
Andropogon scoparius	2,048	4,014	7,606	8,849	96.0	89.5	16.3	332.1
Sporobolus cryptandrus	1,714	3,006	3,565	4,660	75.4	18.6	30.7	171.9
Bouteloua curtipendula	748	2,378	3,813	3,492	217.9	60.3	–8.4	366.8
Andropogon furcatus	741	1,634	3,114	2,871	120.5	90.6	–7.8	287.4
Poa pratensis	713	131	343	331	–81.6	161.8	–3.5	–53.6
Carex pennsylvanica	308	399	645	880	29.5	61.7	36.4	185.7
Koeleria cristata	273	550	541	636	101.5	–1.6	17.6	133.0
Bouteloua hirsuta	97	210	383	417	116.5	82.4	8.9	329.9
Panicum scribnerianum	16	58	100	68	262.5	72.4	–32.0	325.0
Sporobolus heterolepis	6	16	52	112	166.7	225.0	115.4	1766.7
Sorghastrum nutans	3	24	6	51	700.0	–75.0	750.0	1600.0
Sporobolus asper	1	8	13	29	700.0	62.5	123.1	2800.0
Cyperus filiculmis	0	606	324	394		–46.5	21.6	
Panicum wilcoxianum	0	28	29	38		3.6	31.0	
Panicum virgatum	0	0	53	63			18.9	
Carex gravida	0	0	41	0			–100.0	
Total	6,668	13,062	20,628	22,891	95.9	57.9	11.0	243.3
Native Forbs								
Plantago purshii	656	715	371	30	9.0	–48.1	–91.9	–95.4
Hedeoma hispida	443	1,007	830	44	127.3	–17.6	–94.7	–90.1
Erigeron ramosus	125	145	31	6	16.0	–78.6	–80.6	–95.2
Aster multiflorus	94	179	451	483	90.4	152.0	7.1	413.8
Linum sulcatum	34	18	7	2	–47.1	–61.1	–71.4	–94.1

Table 4, Part II.—Species of grasses and sedges, native forbs, and ruderals in 10 meter quadrats where Andropogon scoparius was the most important species in 1937, and changes in plant populations during each of the four years of protection.

Species	Number of Stems				Per cent of Change			
	1937	1938	1939	1940	1937–38	1938–39	1939–40	1937–40
Native Forbs—Contd.								
Amorpha canescens	21	11	7	21	–47.6	–36.4	200.0	
Artemisia gnaphalodes	7	0	0	0	–100.0			–100.0
Lithospermum linearifolium	5	19	16	28	280.0	–15.8	75.0	460.0
Oxalis stricta	4	71	55	20	1675.0	–22.5	–63.6	400.0
Antennaria campestris	0	5	27	0		440.0	–100.0	
Vernonia baldwini	0	2	0	0		–100.0		
Vicia americana	0	2	0	0		–100.0		
Achillea occidentalis	0	0	3	8			166.7	
Total	1,389	2,174	1,798	642	56.5	–17.3	–64.3	–53.8
Ruderals								
Leptilon canadense	3,932	670	99	3	–83.0	–85.2	–97.0	–99.9
Lepidium densiflorum	2,210	52	4	62	–97.6	–92.3	1450.0	–97.2
Cirsium undulatum	8	6	1	2	–25.0	–83.3	100.0	–75.0
Schedonnardus paniculatus	7	52	0	0	642.9	–100.0		–100.0
Hordeum pusillum	5	6	0	5	20.0	–100.0		
Tragopogon pratensis	1	0	0	2	–100.0			100.0
Gaura parviflora	1	0	0	0	–100.0			–100.0
Verbena stricta	0	7	2	3		–71.4	50.0	
Polygala verticillata	0	3	0	0		–100.0		
Hieracium longipilum	0	2	0	0		–100.0		
Grindelia squarrosa	0	1	27	2		2600.0	–92.6	
Amaranthus retroflexus	0	4	0	2		–100.0		
Salsola pestifer	0	0	10	54			440.0	
Total	6,164	803	143	135	–87.0	–82.2	–5.6	–97.8

in decrease of big bluestem and side-oats grama. Its area was extended from 373 to 510 units.

Poa pratensis decreased in about the degree that *Carex pennsylvanica* gained. *Koeleria cristata* increased 133 per cent, while other grasses increased greatly in territory, but only slightly in numbers after 1939.

Among the forbs, *Plantago purshii, Hedeoma hispida,* and *Erigeron ramosus* alone were of much importance in 1937. These all decreased greatly by 1940, although *Aster multiflorus* made large gains. The forb population was reduced by 1940 to only 54 per cent of that in 1937.

Ruderals in 1937 ranked almost as abundantly in number of stems as the grasses. This was owing almost entirely to the abundance of *Leptilon canadense* and *Lepidium densiflorum* following the great drought. In 1938, numbers of forbs were greatly reduced, and the total reduction by 1940 was 98 per cent, table 4.

QUADRATS OF POA PRATENSIS.—*Poa pratensis* suffered great losses, often amounting to more than 95 per cent, following the great drought of 1934. It remained in small patches of a square meter or less in the experimental pasture when cattle were excluded in 1937. Of the 25,000 stems of grasses found in the 10 quadrats, 23,000 were bluegrass, table 5. All other species constituted but 8 per cent of the grass population, fig. 16. With a loss of 99 per cent of the bluegrass during the dry fall and winter of 1937–38, the total cover of grasses was reduced to 31 per cent in 1938, despite great gains of all the other grasses. Bluegrass, which occurred in 730 square decimeter units, was now found sparingly in only 196. Thus, much fertile soil was laid open to other occupants.

All other species had increased by 1938. Of the five best represented, *Sporobolus cryptandrus, Bouteloua curtipendula,* and *Carex pennsylvanica* had increased more than 300 per cent. The following year, every species at least doubled in number, except sand dropseed which increased only 3 per cent. The relict bluegrass increased more than 750 per cent during this season favorable to growth. *Sporobolus cryptandrus, Andropogon scoparius,* and *Carex pennsylvanica* alone, of the leading species, increased in 1940 in percentages of 26, 18, and 55, respectively. Conversely, *Bouteloua curtipendula, Andropogon furcatus,* and *Poa pratensis* all decreased, fig. 16. These decreases, however, were so slight that total population of each species, except *Poa,* was many times greater than that in 1937. For example, *Sporobolus* had increased 451 per cent, *Andropogon furcatus* 472, and *A. scoparius* 588. The total increase of the grasses (omitting *Poa*) was 240 per cent from

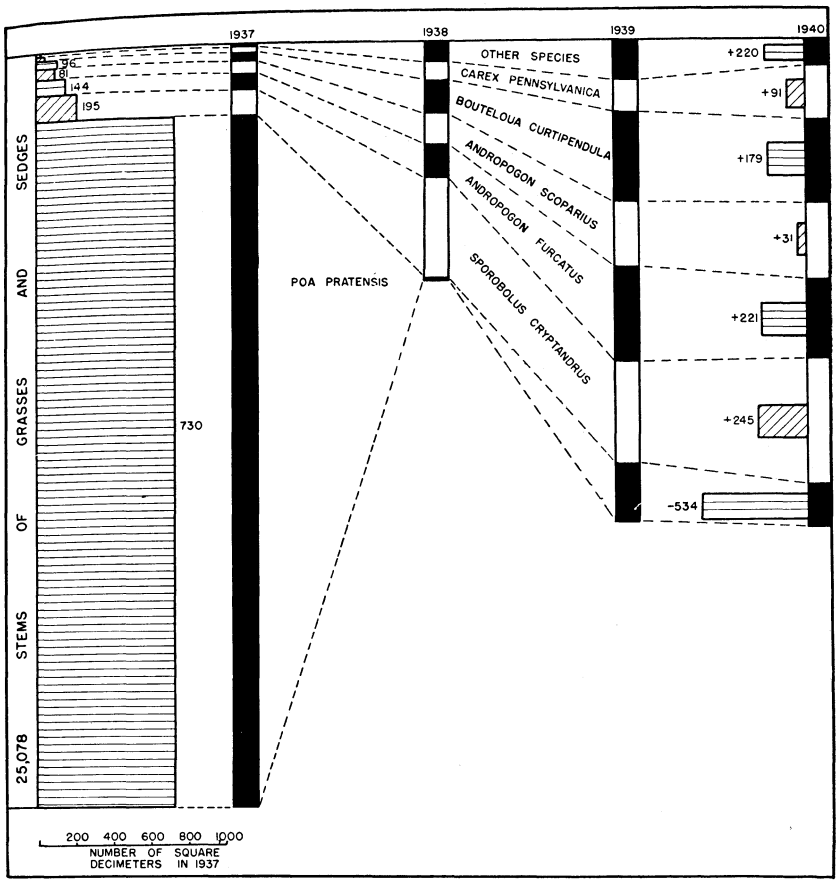


Fig. 16.—Quadrats of *Poa pratensis.* Maximum number of stems of perennial grasses and sedges (except *Bouteloua gracilis*), number of square decimeters in which each of the most important species occurred in 1937 (horizontal bars), and relative abundance in the plots (vertical columns) in 1937, 1938, 1939, and 1940. Horizontal bars on the right indicate the increase or decrease in number of square decimeters occupied compared with 1937.

1937 to 1940. Moreover, every species except *Poa* had extended its territory into unit areas where it was formerly unrepresented.

Native forbs were not abundant in the bluegrass sod, nor did they greatly increase with its death, except *Aster multiflorus* and *Oxalis stricta.* Only two ruderals, *Leptilon canadense* and *Lepidium densiflorum,* were of unusual importance, and these only in 1937, table 5, following.

Table 5, Part I.—Species of grasses and sedges, native forbs, and ruderals in 10 meter quadrats dominated in 1937 by Poa pratensis, and changes in plant populations during each of the four years of protection.

Species	Number of Stems				Per cent of Change			
	1937	1938	1939	1940	1937–38	1938–39	1939–40	1937–40
Grasses and Sedges								
Poa pratensis	23,085	205	1,755	1,371	–99.1	756.1	–21.9	–94.1
Sporobolus cryptandrus	751	3,194	3,279	4,140	325.3	2.7	26.3	451.3
Andropogon furcatus	450	1,112	3,092	2,576	147.1	178.1	–16.7	472.4
Andropogon scoparius	369	1,000	2,155	2,537	171.0	115.5	17.7	587.5
Bouteloua curtipendula	268	1,175	3,052	2,737	338.4	159.7	–10.3	921.3
Carex pennsylvanica	129	520	1,071	1,661	303.1	106.0	55.1	1187.5
Panicum scribnerianum	18	107	269	205	494.4	151.4	–23.8	1038.9
Koeleria cristata	8	139	98	111	1637.5	–29.5	13.3	1287.5
Cyperus filiculmis	0	393	842	591		114.2	–29.8	
Panicum wilcoxianum	0	20	136	41		580.0	–69.9	
Sorghastrum nutans	0	0	7	0			–100.0	
Total	25,078	7,865	15,756	15,970	–68.6	100.3	1.4	–36.3
Native Forbs								
Hedeoma hispida	195	140	28	37	–28.2	–80.0	32.1	–81.0
Silene antirrhina	81	1	0	0	–98.8	–100.0		–100.0
Artemisia gnaphalodes	73	22	114	0	–69.9	418.2	–100.0	–100.0
Plantago purshii	127	121	136	63	–4.7	12.4	–53.7	–50.4
Linum sulcatum	21	2	5	2	–90.5	150.0	–60.0	–90.5
Aster multiflorus	163	362	1,333	1,198	122.1	268.2	–10.1	635.0
Erigeron ramosus	18	39	0	12	116.7	–100.0		–33.3
Achillea occidentalis	70	41	9	8	–41.4	–78.0	–11.1	–88.6
Solidago glaberrima	0	2	33	0		1550.0	–100.0	
Amorpha canescens	6	4	0	0	33.3	–100.0		–100.0

Table 5, Part II.—Species of grasses and sedges, native forbs, and ruderals in 10 meter quadrats dominated in 1937 by Poa pratensis, and changes in plant populations during each of the four years of protection.

Species	Number of Stems				Per cent of Change			
	1937	1938	1939	1940	1937–38	1938–39	1939–40	1937–40
Native Forbs—Contd.								
Lithospermum linearifolium	4	13	37	19	225.0	184.6	–48.6	375.0
Oxalis stricta	12	147	263	179	1125.0	78.9	–31.9	1391.7
Vernonia baldwini	2	2	0	0		–100.0		–100.0
Senecio plattensis	1	2	0	20	100.0	–100.0		1900.0
Kuhnia glutinosa	1	0	0	0	–100.0			–100.0
Acerates angustifolia	0	0	1	1				
Total	774	898	1,959	1,539	16.0	118.2	–21.4	98.8
Ruderals								
Leptilon canadense	2,923	80	7	22	–97.3	–91.3	214.3	–99.2
Lepidium densiflorum	570	0	5	10	–100.0		100.0	–98.2
Grindelia squarrosa	12	6	17	25	–50.0	183.3	47.1	108.3
Ambrosia elatior	9	0	1	0	–100.0		–100.0	–100.0
Gaura parviflora	8	0	1	0	–100.0		–100.0	–100.0
Hordeum pusillum	8	93	89	40	1062.5	–4.3	–55.1	400.0
Bromus tectorum	1	0	0	0	–100.0			–100.0
Verbena stricta	0	48	56	14		16.7	–75.0	
Euphorbia maculata	0	13	8	4		–38.5	–50.0	
Amaranthus retroflexus	0	3	0	0		–100.0		
Cirsium undulatum	0	2	0	0		–100.0		
Solanum rostratum	0	1	0	0		–100.0		
Tragopogon pratensis	0	0	2	1			–50.0	
Total	3,531	246	186	116	–93.0	–24.4	–37.6	–96.7

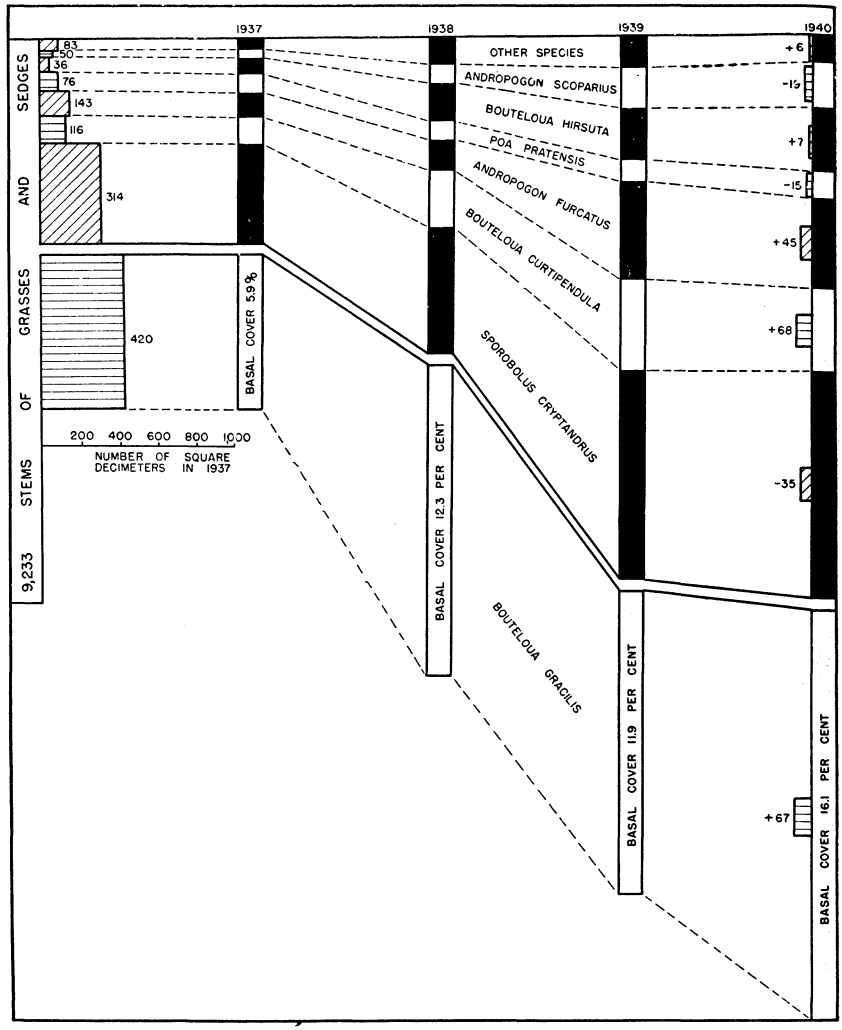


Fig. 17.—Quadrats of *Bouteloua gracilis*. Upper section: maximum number of stems of perennial grasses and sedges, number of square decimeters in which each of the most important species occurred in 1937 (horizontal bars), and relative abundance in the plots (vertical columns) in 1937, 1938, 1939, and 1940. Horizontal bars on the right indicate the increase or decrease in number of square decimeters occupied compared with 1937. Lower section: percentage of basal cover of *Bouteloua gracilis* each year, number of square decimeters in which it occurred, and increase in number occupied. Length of vertical columns cannot be compared directly with those in upper section.

QUADRATS OF BOUTELOUA GRACILIS.—Changes in plant population in 10 quadrats in which mats of *Bouteloua gracilis* occurred are shown in table 6. The outline of the grama grass mats in the several quadrats included approximately 8 to 64 per cent of the square meter, but the basal cover was much less since long-continued grazing resulted in very open short-grass vegetation. Since the increase in grama grass is shown as percentage of basal cover, it is separated from the other grasses in figure 17. In 1937 the total basal cover afforded by this species was only 5.9 per cent of the area of the 10 meter quadrats. This increased to 12.3 the next year but decreased slightly (to 11.9) in 1939. In 1940 a cover of 16.1 per cent was recorded; this was an increase of 173 per cent over the original basal cover. Since 420 unit areas contained this species originally but 487 finally, the increase of basal cover was due largely to a thickening of the mat. Some increase was due to tillering around the edges of the mats and a few seedlings became established outside. Very few forbs and almost no ruderals occurred in the mats of grama.

Sporobolus cryptandrus was the most important of other grass species. It increased each year and by 1940 was 136 per cent more abundant than in 1937. It had lost in distribution, however, since it had disappeared from 35 square decimeters, mostly in the grama sod.

Andropogon furcatus increased 276 per cent in number of stems and from 143 to 188 in number of unit areas in which it was found. *A. scoparius* increased in number of stems but decreased its area of occupation from 50 to 31 units. Both *Bouteloua curtipendula* and *B. hirsuta* made considerable gains. *Poa pratensis* maintained its slight hold in number of stems but not in units occupied. Other species were unimportant; *Koeleria cristata* and *Carex pennsylvanica* both made good gains, table 6, following.

Important species of native forbs and ruderals were nearly the same as in preceding quadrats. *Hedeoma hispida, Solidago glaberrima,* and *Erigeron ramosus* ranked high among the forbs. The most important ruderals were *Lepidium densiflorum, Leptilon canadense,* and *Hordeum pusillum.*

QUADRATS ON BARED SOIL.—Three quadrats where the soil was barest under the almost continuous growth of *Lepidium densiflorum* were selected for special study on revegetation. Death of the bluegrass especially, but also of many other plants, produced these nearly bare places. Here the annual peppergrass grew, but for one season only, at the rate of 600 to 700 plants per square meter. The scourge of this weed in both pasture and drought-stricken prairie was general from the Missouri River westward to and far beyond the Rocky Mountains (Weaver & Albertson

Table 6, Part I.—Species of grasses and sedges, native forbs, and ruderals in 10 meter quadrats containing mats of Bouteloua gracilis, and changes in plant populations during each of the four years of protection.

Species	Number of Stems				Per cent of Change			
	1937	1938	1939	1940	1937–38	1938–39	1939–40	1937–40
Grasses and Sedges								
Sporobolus cryptandrus	1,582	2,108	3,407	3,734	33.2	61.6	9.6	136.0
Bouteloua curtipendula	404	930	1,477	1,380	130.2	58.8	–6.6	241.6
Andropogon furcatus	392	469	1,615	1,473	19.6	244.3	–8.8	275.8
Poa pratensis	288	280	348	418	–2.8	24.3	20.1	45.1
Bouteloua hirsuta	263	623	844	1,051	136.9	35.5	24.5	299.6
Andropogon scoparius	169	338	648	696	100.0	91.7	7.4	311.8
Koeleria cristata	71	187	304	289	163.4	62.6	–4.9	307.0
Festuca octoflora	55	70	0	2	27.3	–100.0		–96.4
Carex pennsylvanica	51	65	85	95	27.5	30.8	11.8	86.3
Panicum scribnerianum	15	18	27	55	20.0	50.0	103.7	266.7
Sorghastrum nutans	6	0	0	0	–100.0			–100.0
Cyperus filiculmis	0	79	90	40		13.9	55.6	
Panicum wilcoxianum	0	8	4	0		–50.0	–100.0	
Total	3,296	5,175	8,849	9,233	57.0	71.0	4.3	180.1
Bouteloua gracilis *	5.9	12.3	11.9	16.1	108.5	–3.3	35.3	172.9
Native Forbs								
Hedeoma hispida	486	514	10	46	5.8	–98.1	360.0	–90.5
Erigeron ramosus	165	61	231	5	–63.0	278.7	–97.8	–97.0
Solidago glaberrima	212	301	696	422	42.0	131.2	–39.4	99.1
Aster multiflorus	68	119	296	160	75.0	148.7	–45.9	135.3
Achillea occidentalis	62	10	4	1	–83.9	–60.0	–75.0	–98.4

* Data for *Bouteloua gracilis* are expressed in average percentage of basal cover per square meter and not in number of stems.

Table 6, Part II.—Species of grasses and sedges, native forbs, and ruderals in 10 meter quadrats containing mats of Bouteloua gracilis, and changes in plant populations during each of the four years of protection.

Species	Number of Stems				Per cent of Change			
	1937	1938	1939	1940	1937–38	1938–39	1939–40	1937–40
Native Forbs—Contd.								
Amorpha canescens	9	3	2	1	–66.7	–33.3	–50.0	–88.9
Artemisia gnaphalodes	6	0	0	0	–100.0			–100.0
Antennaria campestris	6	4	10	0	–33.3	150.0	–100.0	–100.0
Plantago purshii	6	12	24	8	100.0	100.0	–66.7	33.3
Lithospermum linearifolium	9	7	16	1	–22.2	128.6	–93.8	–88.9
Oxalis stricta	5	33	40	11	560.0	21.2	–72.5	120.0
Baptisia leucophaea	2	0	2	0	–100.0		–100.0	–100.0
Petalostemon purpureus	6	1	2	0	–83.3	100.0	–100.0	–100.0
Psoralea argophylla	2	3	1	0	50.0	–66.7	–100.0	–100.0
Linum sulcatum	4	4	0	0		–100.0		–100.0
Vernonia baldwini	0	1	0	0		–100.0		
Astragalus crassicarpus	0	1	3	7		200.0	133.3	
Total	1,048	1,074	1,337	662	2.5	24.5	–50.5	–36.8
Ruderals								
Lepidium densiflorum	1,903	9	2	9	–99.5	–77.8	350.0	–99.5
Leptilon canadense	1,259	19	7	2	–98.5	–63.2	–71.4	–99.8
Hordeum pusillum	381	1,617	638	1,310	324.4	–60.5	105.3	243.8
Verbena stricta	23	18	8	12	–21.7	–55.6	50.0	–47.8
Schedonnardus paniculatus	36	51	24	23	41.7	–52.9	–4.2	–36.1
Grindelia squarrosa	2	6	1	2	200.0	–83.3	100.0	
Solanum rostratum	2	4	0	0	100.0	–100.0		–100.0
Cirsium undulatum	1	0	0	0	–100.0			–100.0
Euphorbia maculata	2	0	11	2	–100.0		–81.8	
Amaranthus retroflexus	0	2	0	0		–100.0		
Ambrosia trifida	0	1	1	1				
Total	3,609	1,727	692	1,361	–52.1	–59.9	96.7	–62.3

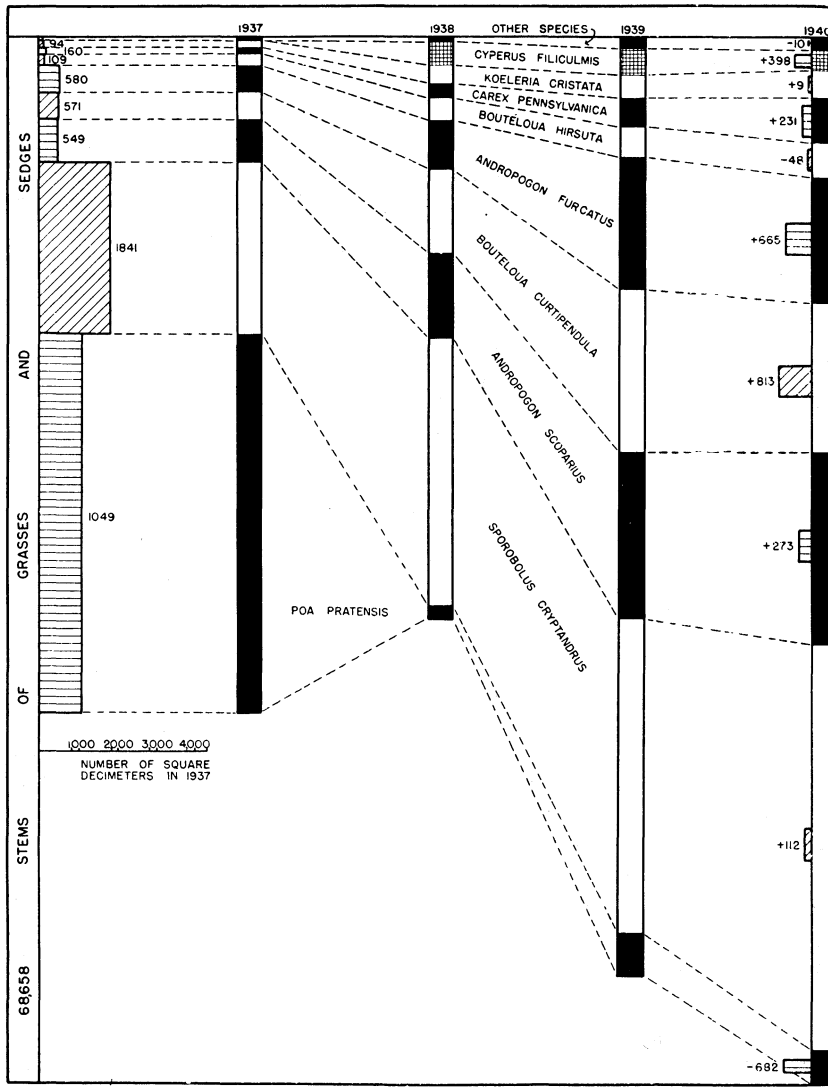


Fig. 18.—Summary of grasses in all quadrats. Maximum number of stems of perennial grasses and sedges, number of square decimeters in which each of the most important species occurred in 1937 (horizontal bars), and relative abundance in the plots (vertical columns) in 1937, 1938, 1939, and 1940. Horizontal bars on the right indicate the increase or decrease in number of square decimeters occupied compared with 1937. *Poa pratensis* constituted 56 per cent of the pasture grasses and sedges in 1937 but only 3 per cent in 1940.

1938). *Hordeum pusillum* occurred frequently, increased almost 900 per cent the second year, waned in 1939, but reached its greatest abundance (1900 stems per square meter) in 1940. Other weeds were only moderately abundant, especially *Leptilon canadense, Grindelia squarrosa,* and *Verbena stricta.* Native forbs were of little significance, although plantain was common.

Under this canopy, *Sporobolus cryptandrus* had 322 stems per square meter, doubled this number the next year, showed a slight decrease in 1938, but a total increase of 137 per cent for the four summers ending 1940. *Poa pratensis* entirely disappeared, *Carex pennsylvanica* increased 106 per cent, and *Bouteloua curtipendula* 280 per cent, although it decreased in 1939. *Andropogon furcatus* increased from 6 stems to 54. *Cyperus filiculmis* entered the plots in 1938, flourished in 1939, but lost half its numbers in 1940. The total loss over the four-year period was 51 per cent. Only 12 grass seedlings (all sand dropseed) were found in the plots during the four summers.

RESULTS FROM ALL QUADRATS. *Grasses and Sedges.*—Changes in plant populations in the 43 quadrats taken collectively are shown for each of four years of protection in table 7. *Poa pratensis* comprised 56 per cent and *Sporobolus cryptandrus* 26 per cent of the total grasses in 1937. The bluegrass had been greatly weakened by severe drought in 1934 and was reduced to only 3 per cent of its 1937 importance by 1938. Thereafter it made a gain of 257 per cent in 1939 but lost slightly the next year. Its distribution in 1049 units was reduced to 367, fig. 18.

Sporobolus cryptandrus gained consistently in numbers year by year, from 11,000 to 17,000, then to 21,000 and finally to 27,000. Yearly gains in percentages were 55, 19, and 29. Increase in number of stems from 1937 to 1940 was 137 per cent. Since its gain in square decimeters occupied was only 112 units, its chief development was that of plants already established, although seedlings occurred far more abundantly than those of any other grass. Moreover, its wide initial distribution in more than 37 per cent of the unit areas should be emphasized.

Bouteloua curtipendula increased even more rapidly than did sand dropseed. This was also true of both species of *Andropogon.* Gains of side-oats grama were 195 and 91 per cent, respectively, in the first two years, but these were followed in 1940 by a 9 per cent decrease. The four-year gain was 413 per cent. This species spread from an initial area of 571 units to 1384. *Andropogon furcatus* likewise gained rapidly, 105 and 144 per cent the first two years, and then decreased 8 per cent. Its total gain by 1940 was 362 per cent in number of stems and from 580 to 1245 units in area. Although the increase in *A. scoparius* was greatest the first

Table 7, Part I.—Summary of species of grasses and sedges (except Bouteloua gracilis), native forbs, and ruderals in the 43 meter quadrats, and changes in plant population during each of the four years of protection.

Species	Number of Stems				Per cent of Change				Occurrence in Square Decimeters			
	1937	1938	1939	1940	1937–38	1938–39	1939–40	1937–40	1937	1938	1939	1940
Grasses and Sedges												
Sporobolus cryptandrus	11,298	17,487	20,792	26,769	54.8	18.9	28.7	136.9	1,841	2,246	2,415	1,953
Poa pratensis	24,626	713	2,542	2,215	–97.1	256.5	–12.9	–91.0	1,049	213	218	367
Andropogon scoparius	2,698	5,527	10,933	12,814	104.9	97.8	17.2	374.9	549	496	528	822
Bouteloua curtipendula	1,897	5,596	10,709	9,738	195.0	91.4	–9.1	413.3	571	950	1,228	1,384
Andropogon furcatus	1,770	3,638	8,878	8,184	105.5	144.0	–7.8	362.4	580	733	1,022	1,245
Bouteloua hirsuta	725	1,550	2,122	2,242	113.8	36.9	5.7	209.2	109	107	142	61
Carex pennsylvanica	585	1,105	2,005	2,963	88.9	81.4	47.8	406.5	160	300	489	391
Koeleria cristata	410	1,144	1,408	1,776	179.0	23.1	26.1	333.2	94	135	197	103
Festuca octoflora	71	146	0	4	105.6	–100.0		–94.4	33	64	0	3
Panicum species	56	257	592	428	358.9	130.4	–27.7	664.3	33	50	78	38
Sorghastrum nutans	12	28	19	51	133.3	–32.1	168.4	325.0	7	7	11	9
Sporobolus asper	1	8	13	29	700.0	62.5	123.1	2,800.0	1	2	1	2
Cyperus filiculmis	0	1,659	1,721	1,235		3.7	–28.2		0	581	454	398
Panicum virgatum	0	0	53	63			18.9		0	0	6	8
Sporobolus heterolepis	6	16	52	147	166.7	225.0	182.7	2,350.0	0	0	6	4
Carex gravida	0	0	41	0			–100.0		0	0	8	0
Total	44,155	38,874	61,880	68,658	–12.0	59.2	11.0	55.5	5,027	5,884	6,803	6,788
Native Forbs												
Hedeoma hispida	2,172	2,381	1,004	148	9.6	–57.8	–85.3	–93.2	838	1,087	535	123
Plantago purshii	1,599	1,457	943	167	–8.9	–35.3	–82.3	–89.6	572	481	482	139
Erigeron ramosus	376	325	314	28	–13.6	–3.4	–91.9	–92.6	349	207	73	20
Aster multiflorus	354	808	2,237	2,053	128.2	176.9	–8.2	479.9	97	205	700	698
Solidago glaberrima	302	473	1,155	637	56.6	144.2	–44.8	110.9	41	115	331	249
Achillea occidentalis	132	51	23	61	–61.4	–54.9	165.2	–53.8	38	10	17	43
Artemisia gnaphalodes	92	22	169	8	–76.1	668.2	–95.3	–91.3	40	23	83	48
Silene antirrhina	81	1	0	0	–98.8	–100.0		–100.0	48	1	0	4
Lithospermum linearifolium	24	60	77	57	150.0	28.3	–26.0	137.5	17	32	59	46
Linum sulcatum	65	24	12	9	–63.1	–50.0	–25.0	–86.2	44	5	11	7

Table 7, Part II.—Summary of species of grasses and sedges (except Bouteloua gracilis), native forbs, and ruderals in the 43 meter quadrats, and changes in plant population during each of the four years of protection.

Species	Number of Stems				Per cent of Change				Occurrence in Square Decimeters			
	1937	1938	1939	1940	1937–38	1938–39	1939–40	1937–40	1937	1938	1939	1940
Native Forbs—Contd.												
Oxalis stricta	46	349	459	312	658.7	31.5	–32.0	578.3	19	255	316	186
Amorpha canescens	40	21	11	26	–47.5	–47.6	136.4	–35.0	27	13	11	14
Senecio plattensis	16	4	0	20	–75.0	–100.0		25.0	6	4	0	0
Antennaria campestris	11	9	37	0	–18.2	311.1	–100.0	–100.0	10	2	8	5
Petalostemon purpureus	6	1	2	0	–83.3	100.0	–100.0	–100.0	3	1	2	0
Vernonia baldwini	2	4	0	0	100.0	–100.0		–100.0	2	2	0	0
Baptisia leucophaea	2	0	2	0	–100.0		–100.0	–100.0	1	0	2	0
Psoralea argophylla	2	3	1	0	50.0	–66.7	–100.0	–100.0	2	3	1	0
Kuhnia glutinosa	1	0	0	0	–100.0			–100.0	1	0	0	0
Astragalus crassicarpus	0	1	3	7		200.0	133.3		0	1	1	1
Vicia americana	0	2	0	0		–100.0			0	2	0	0
Acerates angustifolia	0	0	1	1					0	0	1	0
Equisetum arvense	0	0	1	0			–100.0		0	0	1	0
Total	5,323	5,996	6,451	3,534	12.6	7.6	–45.2	–33.6	2,155	2,449	2,634	1,583
Ruderals												
Leptilon canadense	9,404	851	149	37	–91.0	–82.5	–75.2	–99.6	2,468	431	117	30
Lepidium densiflorum	8,412	66	11	112	–99.2	–83.3	918.2	–98.7	2,563	39	11	50
Hordeum pusillum	1,281	8,885	5,213	6,630	593.6	–41.3	27.2	417.6	283	700	401	433
Grindelia squarrosa	74	33	48	35	–55.4	45.5	–27.1	–52.7	57	32	22	27
Schedonnardus paniculatus	58	154	25	43	165.5	–83.8	72.0	–25.9	26	74	6	7
Verbena stricta	34	155	128	83	355.9	–17.4	–35.2	144.1	28	115	80	45
Bromus tectorum	17	0	0	0	–100.0			–100.0	5	0	0	0
Gaura parviflora	9	1	12	0	–88.9	1,100.0	–100.0	–100.0	9	1	12	0
Ambrosia elatior	9	2	12	160	–77.8	500.0	1,233.3	1,677.8	9	2	11	54
Cirsium undulatum	9	12	13	9	33.3	8.3	–30.8		8	12	10	9
Euphorbia maculata	3	15	21	7	400.0	40.0	–66.7	133.3	3	14	21	6
Solanum rostratum	2	5	0	0	150.0	–100.0		100.0	2	4	0	0
Tragopogon pratensis	1	0	2	3	–100.0		50.0	200.0	1	0	2	3
Chenopodium album	0	13	0	0		–100.0			0	2	0	9
Amaranthus retroflexus	0	11	0	2		–100.0			0	10	0	0
Polygala verticillata	0	5	0	0		–100.0			0	5	0	0
Salsola pestifer	0	0	11	54			390.9		0	0	4	0
Total	19,313	10,208	5,645	7,175	–47.1	–44.7	27.1	–62.8	5,462	1,441	697	673

year (105 per cent) its gains were continued a second (98 per cent) and third season (17 per cent). Thus, the total gain was 375 per cent but the increase in area of this bunch grass was only from 549 to 822 units. Very few seedling bluestems of either species were found.

Bouteloua hirsuta, Koeleria cristata, and *Carex pennsylvanica* all increased steadily in number of stems. Increase in area was more than doubled in *Carex pennsylvanica; Koeleria cristata* gained but slightly; and *Bouteloua hirsuta* lost area formerly occupied.

Table 8.—Percentage composition of pasture grasses and sedges in 1937 and 1940 based upon the number of stems.

Species	Per cent Composition 1937	1940	Species	Per cent Composition 1937	1940
Poa pratensis	56	3	Bouteloua hirsuta	1.7	3
Sporobolus cryptandrus	26	39	Carex pennsylvanica	1	4
Andropogon scoparius	6	18.5	Koeleria cristata	1	2.5
Bouteloua curtipendula	4	14	Cyperus filiculmis	0	3
Andropogon furcatus	4	12	Other species	0.3	1

As regards relative number of stems, if *Poa pratensis* is omitted, the major species ranked in importance in 1940 just as they did in 1937. Of the three least abundant, *Carex pennsylvanica* in 1940 outranked *Bouteloua hirsuta,* which was formerly ahead. *Koeleria cristata* and *Cyperus filiculmis* were at the foot of the list. In fact, *Cyperus filiculmis* did not appear until 1938; it increased slightly the next year, but decreased in 1940, fig. 18. Other species constituted only a small fraction of the grasses.

All of the species except *Poa pratensis* and *Festuca octoflora* increased in abundance during the four-year period, table 7. The composition of vegetation as regards grasses and sedges in 1937 and 1940 is shown in table 8.

Native Forbs.—Among the 23 native forbs growing in the quadrats, only 5 were of outstanding importance. Together they constituted 90 per cent of the total native forb population, table 7 and fig. 19. *Hedeoma hispida* and *Plantago purshii* were the chief forbs in 1937. *Hedeoma* increased somewhat in 1938 and then rapidly decreased in 1940 to 7 per cent of its abundance in 1937. *Plantago* likewise decreased, especially after 1938, to 10 per cent of its original number. Both species lost greatly in area of distribution. *Hedeoma* originally occurred in 838 units but disappeared from 715; *Plantago* formerly occurred in 572 units but disappeared from 433. *Erigeron ramosus,* of much less importance, behaved in a manner similar to *Hedeoma.* This species had made an enor-

mous increase everywhere in pasture and prairie following the drought year of 1934, and was just beginning to decline in 1937–38 (Weaver & Albertson 1936).

Solidago glaberrima and especially *Aster multiflorus* spread widely by rhizomes. Number of stems increased 57 and 128 per cent, respectively, the first year and 144 and 177 per cent the second, after which there was a considerable decrease in both species as the grass population became denser. The net increases

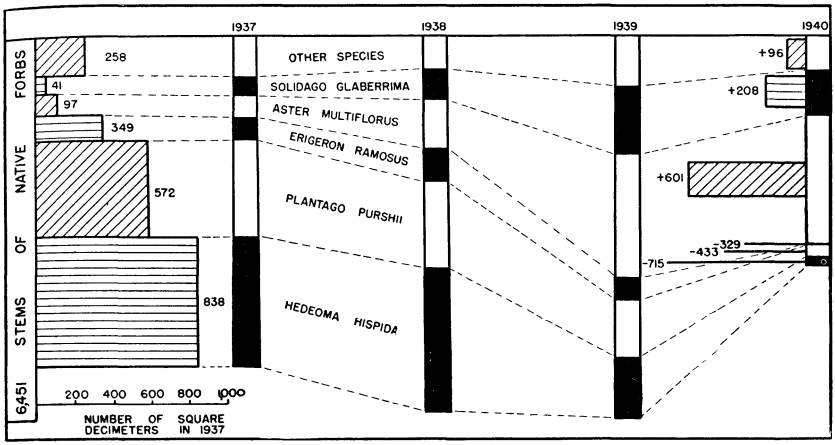


Fig. 19.—Summary of native forbs in all quadrats. Maximum number of stems of native forbs, number of square decimeters in which each of the more important species occurred in 1937 (horizontal bars), and relative abundance in the plots (vertical columns) in 1937, 1938, 1939, and 1940. Horizontal bars on the right indicate increase or decrease in number of square decimeters occupied compared with 1937.

from 1937 to 1940 were 111 per cent for goldenrod and 480 for aster. Much of the increase was an actual spreading into new territory.

The total forb population increased 13 per cent in 1938 and 8 per cent in 1939 over the preceding year. This was followed by a heavy loss of 45 per cent in 1940. Moreover, of the five leading species in 1937, the three ranking highest were far surpassed in importance in 1940 by *Aster multiflorus* and *Solidago glaberrima.* Number of species in the plots was reduced from nineteen in 1937 to fourteen in 1940; seven species disappeared and one new one appeared by 1940, table 7. Decrease in both species and numbers of forbs has been general in pastures and prairies following the great drought.

Ruderals.—Among the 17 species of weeds encountered in quadrating, only three were of outstanding importance. They

constituted 98 per cent of the ruderal fraction of the vegetation in 1937, *Leptilon canadense* forming 49 per cent, *Lepidium densiflorum* 44, and *Hordeum pusillum* 7 per cent. *Leptilon* decreased 91 per cent the first year and *Lepidium* 99. Thereafter neither was of much significance. Formerly occurring in a territory of about 2500 square decimeters, they were finally reduced to 50 or less. This remarkable change is to be attributed very largely to seasonal differences due to changes in physical environment and not to the cumulative competitive effect of a denser grass cover, since it occurred in drought-depleted prairie as well as pasture.

Weed population was not reduced in proportion to these two species in 1937, since *Hordeum pusillum* increased sufficiently (594 per cent) to maintain the general decrease at 47 per cent. In 1938, this weed alone composed 87 per cent of the ruderals. *Hordeum* decreased 41 per cent in 1939 but again increased 27 per cent in 1940. Occurring in 283 unit areas in 1937, in 1940 it was found in 433. Since other species collectively remained fairly

Table 9.—Kind and number of seedlings of grasses, native forbs, and ruderals found in the 43 quadrats when listed in June or July of each year.

SPECIES	1937	1938	1939	1940
		Grasses		
Sporobolus cryptandrus		390	350	255
Andropogon scoparius			6	4
Bouteloua curtipendula			51	30
Andropogon furcatus			4	19
Bouteloua hirsuta			18	
Koeleria cristata		25	3	4
Panicum scribnerianum			3	18
TOTAL		415	435	330
		Native Forbs		
Erigeron ramosus	176	61	1,051	347
Aster multiflorus		9	25	33
Achillea occidentalis	1	53	71	13
Lithospermum linearifolium			17	123
Oxalis stricta				161
Senecio plattensis	4	12		
TOTAL	181	135	1,164	677
		Ruderals		
Leptilon canadense			4	18
Grindelia squarrosa	19		87	181
Verbena stricta	12	4	11	48
Cirsium undulatum	8	3	6	2
Euphorbia maculata	1	13	3	7
Solanum rostratum				1
Amaranthus retroflexus	2	3		7
Salsola pestifer		1	11	151
TOTAL	42	24	122	415

constant in number, the rise or decline of weeds after 1937 was determined almost entirely by *Hordeum.* By 1940 the total weed population had decreased 63 per cent from that of 1937 and the number of unit areas in which they occurred from approximately 5500 to 700.

Occurrence of Seedlings.—The number and kinds of seedlings found in each quadrat were recorded each season. Because of the intermittent periods of drought that occurred every year, seedling population was small considering the openness of the vegetation, especially during the earlier years of protection. Data for the four seasons are given in table 9.

Examination of table 9 shows that among the grasses there were no seedlings the first year of protection, and that *Sporobolus cryptandrus* was by far the most prolific seeder. It also shows that total seedling production was greatest in 1939 and 1940. Seedlings of only 7 species of grasses, 6 species of native forbs, and 8 species of ruderals were found. *Erigeron ramosus* produced the largest number of plants but *Achillea occidentalis, Verbena stricta, Cirsium undulatum,* and *Euphorbia maculata* produced at least a few seedlings each year. While some seedlings undoubtedly appeared after the times of quadratting, many that were counted died. Although the stems of living seedlings were included in the stem counts, relatively they were few. An exception was *Sporobolus cryptandrus;* its seedlings were very successful in establishing themselves. Consequently the consistent increase in all kinds of plants was due to tillering, production of shoots from rhizomes, or other means of vegetative propagation.

Further Studies in Protected Pastures in 1940. DENSITY AND COMPOSITION OF VEGETATION.—Additional data were obtained upon the density and composition of vegetation in pastures under different periods of protection from grazing. Long parallel strips of pasture in the north exclosure had been protected from grazing a first, second, and fourth year, respectively. This was accomplished by exclosing to cattle a new area in the spring of 1937, another in 1939, and still another in 1940. Five quadrats were selected at random, but approximately opposite each other, in the several long, narrow, protected areas on June 15, 1940. Foliage cover and basal cover were ascertained in each quadrat, stem counts were made, and the percentage composition of the vegetation in each was determined.

Foliage cover was estimated separately by each of three experienced investigators after each quadrat had been temporarily divided into five strips, each 2 decimeters wide. Experience has

shown that this is the best size of area for this purpose in this type of vegetation. The three estimates for each 2-decimeter strips were averaged (added and divided by five) to obtain the total foliage cover for each square meter. Foliage cover is equivalent to the percentage of soil surface that is concealed by the vegetation when the estimator views the plant cover directly from above. Basal cover was estimated for each square decimeter, i.e., 100 estimates were made and averaged for each quadrat.

Stems were listed in the usual manner except that the average count of 43 quadrats in the pasture protected a fourth year was

Table 10.—Foliage cover and basal area of pasture vegetation on June 15 during the first, second, and fourth year of protection.

QUADRAT	FOLIAGE COVER			BASAL AREA		
	First Year	Second Year	Fourth Year	First Year	Second Year	Fourth Year
1	46.4	58.0	72.2	12.24	21.01	18.20
2	24.0	56.2	60.4	11.25	18.97	16.52
3	36.2	76.4	49.0	14.84	22.81	20.78
4	25.4	60.0	64.0	7.15	28.12	22.01
5	16.4	32.0	61.0	6.85	15.31	20.68
Average	29.7	56.5	61.3	10.47	21.24	19.64

employed. The proper number for five quadrats was obtained by dividing the total number of stems for each species by 43 and multiplying the quotient by five. Percentage composition of vegetation was ascertained by dividing each quadrat into 10 decimeter strips and considering the total vegetation in each as 100 per cent. Two investigators, working together, then estimated what percentage of the entire vegetation was constituted by sand dropseed, little bluestem, etc. This was based solely on area occupied by the bases of bunches or stems of each species. Forbs were estimated collectively. All estimates, as in foliage cover and basal area, were made to the nearest per cent; decimals in the tables are the results of mathematical computations.

A study of the foliage cover shows some irregularities, as would be expected in random sampling. There is a marked increase in average cover during the second year of protection—a gain of 90 per cent, table 10. This increase in the amount of vegetation is also expressed in a somewhat comparable increase (102 per cent) in basal area. Increase in foliage cover from the second to the fourth year was only 8 per cent and the basal cover decreased slightly. This decrease is attributed largely to partial replacement of the wide-based sand dropseed by the more erect bluestems and side-oats grama, and in part to the more erect habit of sand dropseed under competition.

The number of stems of *Sporobolus cryptandrus* showed a marked increase (85 per cent) under the second year of protection as compared with the first. By the fourth year, however, the number had decreased until it was somewhat less than that in the first year, table 11. This behavior is in accord with the

Table 11.—First section (left): number of stems of grasses and sedges, native forbs, and ruderals, and number of seedlings in pasture vegetation during the first, second, and fourth year of protection. Second section (right): percentage of basal cover furnished by each grass and by forbs and ruderals under different periods of protection.

Species	Number of Stems				Percentage of Basal Cover		
	Protected First Year 1940	Protected First Year 1937	Protected Second Year 1940	Protected Fourth Year 1940	Protected First Year 1940	Protected Second Year 1940	Protected Fourth Year 1940
Grasses and Sedges							
Sporobolus cryptandrus	3,509	(1,314)	6,487	3,112	48.9	80.7	39.2
Poa pratensis	91	(2,860)	13	52	.7	.1	.3
Andropogon scoparius	74	(314)	143	1,490	.3	1.1	17.6
Bouteloua curtipendula	141	(221)	418	1,132	1.5	4.3	18.1
Andropogon furcatus	211	(206)	186	952	1.6	1.2	18.5
Bouteloua hirsuta	0	(84)	0	261			
Carex pennsylvanica	139	(68)	100	344	1.8	.8	1.6
Koeleria cristata	0	(49)	62	207	.0	.4	1.2
Festuca octoflora	0	(8)	0	0			
Panicum spp.*	28	(5)	74	52	.4	.6	.5
Sorghastrum nutans	0	(1)	0	6			
Sporobolus asper	0	(0)	0	2			
Cyperus filiculmis	405	(0)	446	144	2.1	2.3	.3
Panicum virgatum	0	(0)	0	7			
Sporobolus heterolepis	0	(0)	0	13			
Total grasses and sedges	4,598	(5,130)	7,929	7,774	57.3	91.5	97.3
Native Forbs							
Total native forbs	823	(624)	279	428	9.9	3.0	.7
Ruderals							
Total ruderals	10,115	(2,246)	2,743	822	32.8†	5.5	2.0
Grass Seedlings							
Total grass seedlings	16	(0)	22	36			

* *Panicum scribnerianum* and *P. wilcoxianum.*
† Mostly *Hordeum pusillum.*

percentage composition. In the first year of protection sand dropseed alone constituted 49 per cent of the grasses, in the second 81 per cent, but in the fourth year only 39 per cent. This resulted from the rapid increase in this species immediately following protection and its actual decrease after four years resulting from the competition of other grasses, especially *Andropogon scoparius* and *Bouteloua curtipendula.* Table 11 shows that the total number of stems of all grasses and sedges was not very different in pastures protected two and four years, respectively.

Number of stems of *Andropogon scoparius* about doubled after

one year of protection but increased nearly 20 times by the fourth year. Increases of *Bouteloua curtipendula* were similar. Percentage composition of both species increased from 1.5 per cent or less under the first season of protection to about 18 per cent in the pasture protected a fourth year. Percentage composition of *Andropogon furcatus* increased from 1.6 to 18.5, but the stem counts were not so high in this coarser plant. Changes in most other species were small or insignificant. *Cyperus filiculmis* made a slight gain under two years of protection and then suffered severe drought loss.

Table 12.—Variation in size (in inches) and number of stems in bunches of grasses in grazed pasture and in pasture during the first, second, and fourth year of protection, respectively.

CRITERIA	GRAZED PASTURE	PROTECTED FIRST YEAR	PROTECTED SECOND YEAR	PROTECTED FOURTH YEAR
	Sporobolus cryptandrus			
Diameter of bunch	1.7	2.8	2.4	2.2
Number of stems	6.7	12.5	15.4	19.9
Length of stems	2.2	4.0	7.1	7.6
	Andropogon scoparius			
Diameter of bunch	1.5	2.2	2.3	2.9
Number of stems	11.6	22.7	40.8	49.9
Length of stems	1.6	2.4	4.3	6.8

A very significant fact is the increase in vegetation from 57 per cent non-weedy and practically wholly perennial grasses in the pasture recently protected to 91.5 per cent in the area protected a second year, and to 97.3 per cent in the area protected a fourth year.

Decrease in percentage composition of forbs from 9.9 to .7 per cent is likewise significant. Ruderals showed a marked decrease from about 10,000 stems (mostly little barley) in the recently grazed pasture to about 3000 in the one protected 2 years. In the pasture protected a fourth year, the number had decreased to less than 1000.

Comparison of vegetation during the first year of protection in 1940 with that protected for the first year in 1937 (table 11, figures in parentheses) shows clearly that bluegrass in 1937 was more than twice as abundant as sand dropseed. Total number of stems of grasses and sedges was slightly greater in 1937, before the further loss of bluegrass; number of forbs was somewhat less; stems of ruderals were far fewer, since *Hordeum pusillum* was not yet abundant.

SIZE AND CHARACTER OF BUNCHES.—One hundred bunches of sand dropseed were selected at random in each of the three protected

areas and in the grazed pasture. The diameter of the bunch one-half inch above the soil surface was measured, and the number of stems per bunch was determined, as was also the length of stems. Bunches of little bluestem were similarly measured, 25 from each of the four habitats being used. The data were ob-

Fig. 20.—Bunches of sand dropseed on December 15, 1940. Plant on left is from pasture protected one summer and shows the spreading, open habit of stems; that on the right with erect stems has grown under close competition with other grasses protected four years. Height about 26 inches.

tained on July 15, before flower stalks had appeared. The averages of these measurements are shown in table 12.

Diameter of bunches of little bluestem gradually increased with protection, but bunches of sand dropseed first increased and then became smaller. The smallest average diameter of sand dropseed under protection was that of bunches having the largest number of stems. This resulted from the basal spreading habit of the grass under recent grazing and its more erect one under competition for light, fig. 20. Length of stems of both species increased rapidly and consistently under protection as did also their numbers.

Those of little bluestem practically doubled in number the first year of protection and almost repeated this increase the second growing season.

Increase in foliage with increasing periods of protection also resulted in greater production and greater accumulation of litter. Average square meter areas under 0, 1, 2, and 4 years of protection yielded respectively 31, 56, 88, and 93 grams of air-dried litter. This increase in soil mulch is very beneficial, especially in relation to conservation of precipitation.

PART II. RELATIVE PRODUCTION IN PASTURE AND PRAIRIE

The amount and kind of forage produced in pasture protected the first year and in pasture protected a third year were determined in 1939. During 1940, production was ascertained in pastures protected a first, second, and fourth year and in native prairie.

Methods.—The fence on the west side of the large exclosure set aside for study in 1937 was moved, in early spring of 1939, 20 feet farther west so as to exclude cattle from a new strip of pasture. Two lots of 25 meter quadrats each were located at random along two parallel north-south lines which were 20 feet apart, one lot in the center of the new exclosure and one in the pasture to be protected a third year. The quadrats along the two lines were approximately opposite each other, the distance between any two in a line being 15 feet, fig. 21. Five other meter quadrats were located in the pasture in the south exclosure, also to be protected a third year, and five were established in small exclosures in the adjacent grazed pasture, fig. 22.

Pasture protected a third year, and hereafter designated as pasture A, was burned slowly on a damp, quiet day in March to remove the debris of the preceding year. Coarse, ungrazed weeds were cut and removed from the new exclosure where the grasses had been closely grazed, hereafter designated as pasture B.

The quadrats were clipped first on May 30 at a height of 1.5 inches, since that was found to be the general level to which the grasses were grazed. The clip quadrat has been widely used in pasture investigation during two decades (Sarvis 1923, Taylor & Loftfield 1924, Aldous 1930, Hanson *et al.* 1931, West 1936, Canfield 1939, Weaver & Hougen 1939, and others). The time of subsequent clippings was determined by the rate of recovery and growth of the grasses. At each clipping the vegetation of each quadrat was separated by selective cutting into prairie grasses, pasture grasses, and forbs. Each partial yield was placed in a separate cloth sack, thoroughly air dried, and its dry weight

Fig. 21.—North exclosure on June 18, 1939, showing strip of pasture (right) protected the first year. It contains an abundance of little barley but less yarrow than the pasture protected a third year (left).

Fig. 22.—South end of experimental prairie and pasture on September 14, 1940. The small south pasture exclosure is shown to the right of the prairie. Each of the five wire frames protects one quadrat (in the center of an area of 30 square feet) from grazing.

determined. Dry weight is one of the best quantitative characteristics of vegetation (Hanson 1938), and increase in dry weight is the best measure of growth (West, Briggs, & Kidd 1920).

Prairie grasses, as listed below, included all plants of grasslike habit that were found more or less regularly in normal, undisturbed prairie. Pasture grasses included similar species not common to climax eastern Nebraska prairies, and bluegrass, which is a long-established invader. The approximate percentage of each species utilized by cattle in fully stocked pastures is also indicated in the list. Only very small amounts of grasses not listed were found.

Prairie Grasses

Andropogon scoparius 70	Panicum virgatum 60
Andropogon furcatus 80	Panicum scribnerianum 50
Bouteloua curtipendula 80	Sorghastrum nutans 70
Bouteloua gracilis 70	Sporobolus asper 40
Bouteloua hirsuta 70	Sporobolus heterolepis 70
Carex pennsylvanica 55	Stipa spartea 80
Koeleria cristata 75	

Pasture Grasses

Aristida oligantha 10	Hordeum pusillum 10
Cyperus filiculmis 60	Hordeum jubatum 10
Eragrostis cilianensis 30	Poa pratensis 80
Eragrostis pectinacea 15	Sporobolus cryptandrus 50

At each clipping were recorded the prairie and pasture grasses and forbs which afforded the major portion of the yield from each quadrat. All other species encountered were likewise recorded.

Environment in 1939.—Spring was somewhat late. Despite a deficiency of .87 inch precipitation in April, moisture in spring was sufficient to promote good growth. Drought threatened late in May, when many plants wilted, the rainfall being about 2.5 inches below normal. During June vegetation flourished, benefiting from more than 4 inches of precipitation. July rainfall was subnormal; after the fifth no rain fell which added perceptibly to soil moisture and plant growth was retarded. Rainfall during August was an inch below normal and the surface soil was scarcely moistened after August 15. Vegetation dried rapidly, bluestems and other late blooming grasses failing to produce flower stalks. September also was dry throughout.

Water content to a depth of 6 feet in grazed pasture at nine periods during the growing season is shown in figure 23. Available water content of soil below 2 feet never exceeded 2 to 5 per cent, and late in the growing season it was reduced to less than 2 per cent. In the upper 2 feet the favorably moist soil of spring lost nearly all of its available water in the first foot after the middle of May. This condition was repeated in July, and all available water was used in late August and September.

The season was characterized by temperatures somewhat above normal, especially those of May and July. By months they were:

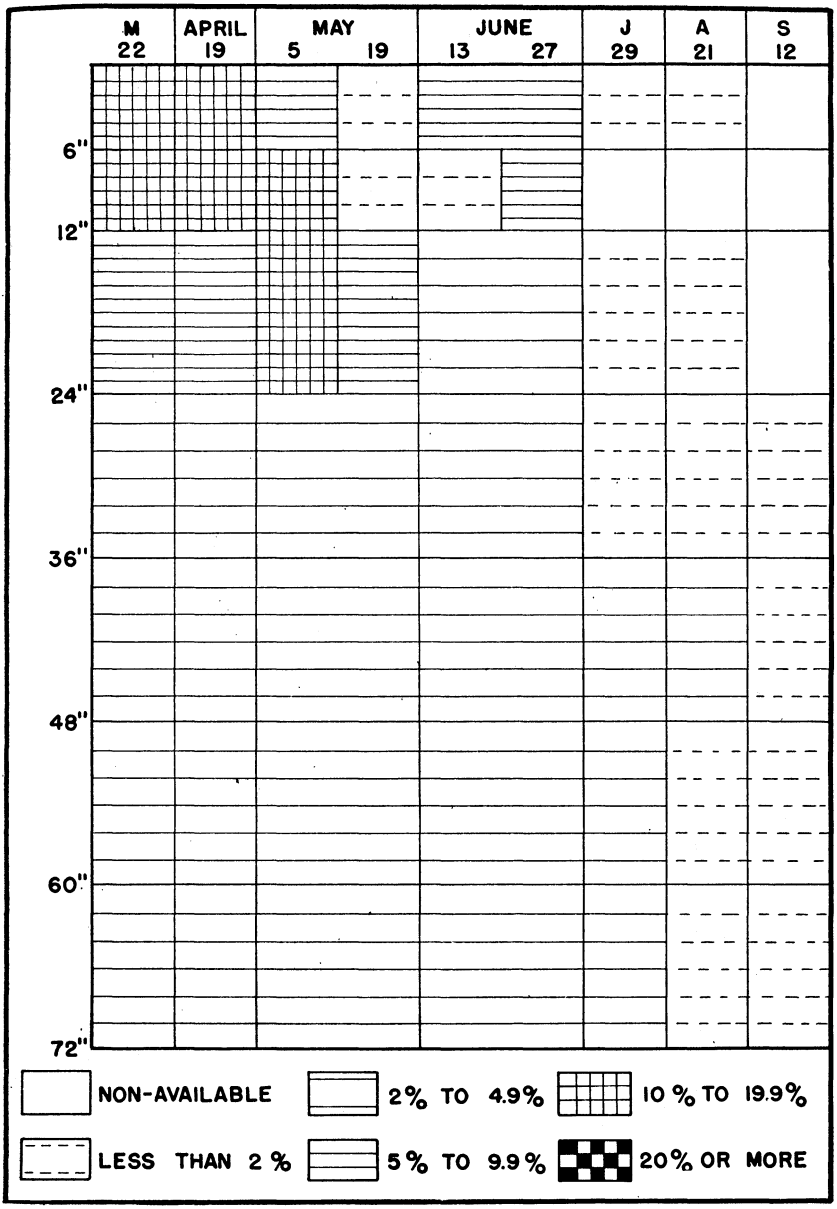


Fig. 23.—Available soil moisture at various intervals to a depth of 6 feet in grazed pasture in 1939. These data show clearly the moist spring and the severe drought in late summer.

May, 77.5° F; June, 77.8°; July, 87.3°; and August, 75.6°, which were 7.9°, 3.2°, 5.4°, and 0.6°, respectively, above the mean.

Wind in the grazed pasture was high, attaining (at a height of 10 inches) an average weekly movement of 3.5 to 4.5 miles per hour during five weeks. In pasture protected a third year, the maximum velocity occurred in May while the grasses were still of low stature. The outstanding fact was the constantly greater movement in grazed pasture where little resistance to wind was offered by the short vegetation.

The severity of the drought, especially in July and August, was shown by the high evaporation rates from pairs of black, porous cup atmometers operated in both grazed pasture and pasture A. Height of the evaporating surface was about 8 inches. From July 7 to 14, when temperatures as high as 110° F occurred and strong hot winds prevailed, average daily evaporation rates of 59 cc were recorded in pasture A and 94 cc in grazed pasture. Average weekly water losses of 60 to 70 cc per day were common in grazed pasture; those in pasture A were 10 to 20 cc lower.

GROWTH LATE IN MAY.—A study was made on May 30, at the time of the first clipping, of the relative abundance of various species of grasses and forbs in the two areas. Little and big bluestem and side-oats grama were making remarkable gains in pasture A, but only the merest remnants of these occurred in pasture B. In pasture A, the bunches of grasses were well filled with stems, which showed both by their abundance and height that they had regained their normal vigor, fig. 24. Conversely, the bunches that had been continuously grazed were often merely bordered by a rim of new growth of low stature, but sometimes loosely filled with scattered stems, or the sod had broken up into small tufts, none of which had more than a little short foliage.

June grass occurred much more frequently in the rejuvenated pasture A, and a few scattered bunches of prairie dropseed, tall dropseed, plains muhly (*Muhlenbergia cuspidata*), and needle grass (*Stipa spartea*) were found there only. The small young bunches of needle grass were seeding abundantly. These grasses had remained in the 25-year-old pasture sparingly or had spread into it much more slowly than had the bluestems and side-oats grama. In fact, portions of pasture A both in upland and lowland contained so much bluestem, now 12 to 14 inches tall, that it had the superficial appearance of climax prairie. In sharp contrast, other local areas were free of bluestems, and sand dropseed alone or with forbs only clothed a few square meters. Although bluegrass occurred only as remnants and very sparsely, yet it had set forth flower stalks and completed blossoming. Former small

bared places in both pastures had been claimed by Scribner's panic grass, which formed large clumps often a foot in diameter, the grass sometimes fruiting at a height of 12 inches. More often slender cyperus, now 4 inches high and heading, covered the bare ground unoccupied by other species. It was most abundant in pasture B. Other bare spaces in this pasture had been thickly

Fig. 24.—Photo June 7, 1939, showing excellent development of the bluestems on upland during the third year of protection from grazing.

filled with little barley. Neither this weed nor plantain occurred in pasture A, where many small spaces remained without vegetation. These early maturing, almost worthless annuals were fully headed and would soon ripen seed.

Aster was the worst weed in pasture A. It varied from clumps 3 feet in diameter, with stems so thickly spaced as to reveal upon their removal only bare ground, to small clumps or patches so open that a thin stand of sand dropseed thrived as an understory. Aster averaged a foot in height. It also occurred in pasture B but here it was much weakened by previous grazing and the growth was correspondingly more open and shorter.

Yarrow, in full bloom at a height of 2 feet, was about three times as abundant in pasture A as in pasture B, probably because

it was grazed with the grasses. Smooth goldenrod, abundant in both areas, had scarcely changed its status during the two years of protection.

Five annual weeds, which were equally abundant in both areas two years earlier, had practically disappeared from the one longest protected, a phenomenon which may have resulted in part from the spring burning. These were little barley, plantain,

Fig. 25.—Detail of little barley in pasture protected the first year (foreground) and excellent development of bluestems and other grasses during the third year of protection (background). Photo June 7, 1939.

horseweed, rough pennyroyal, and peppergrass. Peppergrass had also vanished from the unprotected pasture but the plantain formed extensive gray patches scattered throughout and reached a height of 6 inches or more. Little barley was by far the worst pasture weed, almost ruining wide areas for grazing, fig. 25. Horseweed was scattered rather openly; the bright green of this weed contrasted sharply with the yellow patches of little barley and the gray carpet of plantain.

Vervain, daisy fleabane, and gumweed were more or less equally distributed in both areas, as was also gaura.

FIRST CLIPPING.—At the first clipping on May 30, little bluestem varied in height, from upper to lower slope, from 6 to 11 inches in pasture A. Big bluestem was about 2 inches taller. Side-oats grama was 6 to 7 inches high, and June grass 11 to 15 inches. In

pasture B, side-oats grama was somewhat shorter, and sand dropseed averaged 2 inches shorter than in pasture A where it was 5 to 7 inches high. Other grasses and sedges common in pasture B, but all 5 inches or less in height, were slender cyperus, blue grama, Pennsylvania sedge, and Scribner's panic grass, fig. 26.

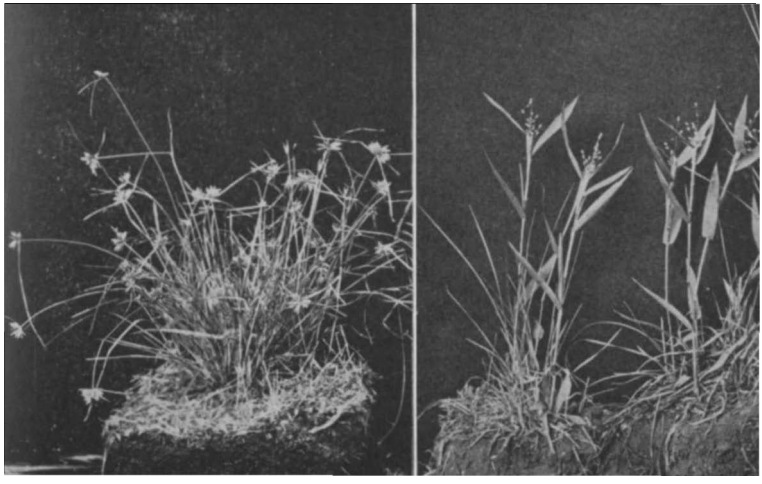
While pasture A contained no little barley and very little plantain or horseweed, these were all abundant and 6 to 8 inches tall in pasture B. The chief forbs in pasture A were smooth

Fig. 26.—*Cyperus filiculmis* (left) in fruit and *Panicum scribnerianum* (right). Both are low growing plants usually only about 6 inches tall.

goldenrod, 4 to 8 inches tall; aster, 10 to 16 in.; yarrow, 13 to 22 in.; and daisy fleabane, 11 to 22 in. These all occurred in pasture B as well, but here they were 3 to 9 inches shorter. Other important forbs in pasture B were vervain, peppergrass, gaura, gumweed, and rough pennyroyal.

Yields from the first clipping are shown in table 13, page 61.

Examination of table 13 reveals the facts that the yield of prairie grass was 38 times as great in pasture A as in pasture B, that pasture grasses yielded nearly 2.5 times as much in pasture B as in pasture A, and that production of forbs was somewhat greater in pasture A. Quadrats in pasture A, in every case but two, exceeded quadrats opposite them in pasture B in the production of prairie grasses. In these two pairs of quadrats total production of grasses was low. Quadrats in pasture A were exceeded in production of pasture grasses by each opposite pasture quadrat, except in three instances. Prairie grasses yielding the



most forage were big and little bluestem and side-oats grama; the high yielding pasture grasses were sand dropseed and little barley. Most important among the forbs were aster and goldenrod, but also plantain and horseweed in the pasture. Total yield of vegetation in pasture B was only 83 per cent of that in pasture A.

SECOND CLIPPING.—At the second clipping, June 20–21, after a three-week interval, the bluestems and side-oats grama, especially, had made considerable growth. They were 5 to 7 inches tall in the quadrats in pasture A but, like nearly all of the other grasses, averaged .5 to 2 inches shorter in pasture B. Sand dropseed alone was an exception, being about 4 inches tall in both areas. Side-oats grama had made the best recovery of all the prairie grasses in pasture B.

What little new growth had been made by the gumweed and smooth goldenrod had been eaten by grasshoppers, which were plentiful. Little barley, so abundant at the earlier cutting, had made no renewed growth. Growth of plantain was small. Horseweed produced new shoots from basal buds. The best recovery was made by aster which was rather uniformly 3 inches tall. Thus, the forbs contributed but little to dry weight production at this cutting.

Total yields were smaller than at the first clipping. Prairie grasses yielded 25.3 grams per quadrat in pasture A but only 5.3 in pasture B. The yield of pasture grasses in pasture A, 18.7 grams, slightly exceeded that in pasture B (17.5). The chief reasons for this change in production were that the entire crop of little barley was harvested with the first clipping while sand dropseed, the heaviest yielding pasture grass, was somewhat more abundant in pasture A. Slender cyperus, however, had replaced little barley as the second heaviest yielder among pasture grasses. Bluestems, side-oats grama, and Scribner's panic grass yielded the heaviest among prairie grasses. Yield of forbs averaged only 1.3 grams in pasture A and 1.1 in pasture B. No quadrat yielded more than 8 grams of forbs. Few forbs had made much growth since the initial clipping. Total yields in pasture B were only 53 per cent as great as in pasture A.

THIRD CLIPPING.—No effective rain had fallen since July 5, hence at the third cutting on July 19–20 the vegetation was suffering from drought. The bluestems had made a good growth but were now wilted and slender cyperus was rapidly drying. The bluestems averaged 7 inches tall in pasture A but only 4 in pasture B. Side-oats grama was 2 inches taller in pasture A (6 in.), but sand dropseed was nearly the same height in both lots of quadrats. None of the other grasses or sedges exceeded 4 inches in height,

except purple lovegrass (*Eragrostis spectabilis*) which was 10 inches.

The small amount of growth made by the forbs was very noticeable. Yarrow, goldenrod, plantain, and gaura had made no recovery. Aster, gumweed, and vervain had made some growth to heights of only 3 to 4 inches. Grasshoppers, although repeatedly depleted in numbers by poisoned bait, continued to do some damage.

Yields on July 19–20, although much greater than those in June, did not equal the yields of the first cutting. Pasture A for a third time outyielded pasture B in prairie grasses, but production of pasture grasses in pasture B exceeded that in pasture A. Yield of forbs, although showing a slight increase over that in June, was low. The steady increase of prairie grasses in pasture B is of interest, table 13, page 61. In nearly all the quadrats in pasture B this was due to the yield of side-oats grama (but sometimes big bluestem) which withstands grazing exceptionally well. The steady although slight decrease in yield of pasture grasses in pasture A is equally interesting and must be attributed to a lessened vigor of sand dropseed owing to competition with prairie grass or a similar effect on slender cyperus, the other chief contributor to yield. Increased yield of forbs resulted almost entirely from renewed growth of gumweed, goldenrod, aster, and vervain. Total yield in pasture B was 91 per cent of that in pasture A, table 13.

GROWTH IN AUGUST.—Vegetation in the quadrats in both pastures ceased growing after the third cutting until one-quarter inch of rain fell on August 4, and was followed by an inch of rain on August 8 and 9. A second survey early in August revealed marked differences between pastures A and B. Pasture B showed on August 4 an aspect of grasses with the goldenrod submerged a little below the general grass level of about 10 inches. Flower stalks of side-oats grama stood thinly to thickly throughout at an average height of about 2 feet. Those of sand dropseed at a similar height were no thicker than those of side-oats grama, with which they were usually intermixed.

These flower stalks gave the general tone in pasture A. Scattered throughout at a height of 10 to 12 inches on the hill and at 12 to 20 inches on lower ground were numerous bunches and patches of big and little bluestem, now tinged reddish as a response to drought. Scattered bunches of blue and hairy grama, with flower stalks about 10 inches tall, occurred frequently on the upper slope but sparsely on the lower one. Except for scattered plants of June grass and a few bunches of prairie dropseed and tall dropseed, no other grasses were important. Sand drop-

seed had lost its place as the most important dominant in certain locations; in others it appeared in almost pure stands. After prolonged study and measurement it was estimated that the total basal cover was divided among the grasses in the following percentages: sand dropseed 35, side-oats grama 20, big bluestem 20, and little bluestem 15 per cent. The remaining 10 per cent consisted of Pennsylvania sedge, slender cyperus, Scribner's panic grass, and Wilcox's panic grass, prairie dropseed, tall dropseed, June grass, and plains muhly.

As to the forbs in pasture A, the patches of smooth goldenrod, which were 6 to 8 inches high, were quite open and the territory was plainly being taken over by the grasses. The rhizomes of this goldenrod frequently threaded their way through the patches of blue grama. Aster, which was more conspicuous with its dark green bunches, often in groups, ranged from 8 to 18 inches in height. The stands were also less dense than in former years and the grasses were usually well on the way toward replacing the aster. The shade, with rare exceptions, did not exceed 50 per cent. Moreover, the territory occupied by aster had been reduced fully one-third. Other forbs of considerable importance were yarrow and vervain. Those of lesser significance included gumweed, thistle, horseweed, daisy fleabane, annual ragweed, gaura, snow-on-the-mountain (*Euphorbia marginata*), and ironweed.

The drought had caused the bluestems to brown considerably even on the lower ground, and all were damaged. Side-oats grama and sand dropseed immediately unfolded their tightly rolled leaves after the rains of August 5 to 9 and seemed entirely unharmed. All were again overtaken by drought in the middle of August and the yield of the fourth cutting, on August 25–26, was light.

FOURTH CLIPPING.—Sand dropseed had made the best recovery in the clipped quadrats, followed closely by side-oats grama. Recovery of the other species, especially the bluestems, was poor. Their recovery and growth, however, were somewhat better in pasture A than in pasture B, probably because better root systems had developed under protection. None of the grasses was over 3.5 inches tall in any of the quadrats, except that sand dropseed, side-oats grama, blue grama, and big bluestem had produced a few short flower stalks.

At the fourth clipping (August 25–26) all yields were small, owing to very unfavorable conditions for growth. The average per quadrat for prairie grasses was 6 grams and 2.1 grams in pasture A and pasture B, and that of pasture grasses 12.5 grams and 10.5 grams in the same order. Clipping, drought, and grasshoppers

Table 13.—Yields in grams of prairie grasses, pasture grasses, and forbs at each clipping, and total yields in pasture A and in pasture B during the first year of protection.

	MAY 30–31		JUNE 20–21		JULY 19–20		AUGUST 25–26		TOTAL	
	A	B	A	B	A	B	A	B	A	B
Prairie grasses	1,564	41	759	159	1,116	423	180	64	3,619	687
Pasture grasses	689	1,696	560	526	890	1,484	375	315	2,514	4,021
Forbs	1,628	1,478	38	34	144	42	37	2	1,847	1,556
TOTAL	3,881	3,215	1,357	719	2,150	1,949	592	381	7,980	6,264

combined had practically eliminated growth of forbs. Average production of forbs per quadrat was 1.2 and .07 grams, table 13.

After this last cutting, drought was pronounced. The grasses took on their autumnal coloration late in August when the reddish tinge of both bluestems was prominent. Sand dropseed bleached to a pale straw color and side-oats grama also lost all of its green. Both of these dominants produced seed, however, before they were overtaken by drought. The andropogons, tall dropseed, and prairie dropseed failed to seed or even to produce flower stalks. Showers on September 28 were followed by slight revival of needle grass, June grass, and a few others which normally make a good growth in fall, but once again the water supply was soon exhausted. No plants in the clipped quadrats produced any forage after the fourth clipping.

Composition of Vegetation in the Quadrats.—At each clipping, prairie and pasture grasses and forbs in each quadrat were recorded, table 14. The chief prairie grasses occurring in quadrats in pasture A were *Andropogon* in all but two, *Bouteloua curtipendula* in all, and *Carex pennsylvanica* and *Panicum scribner-*

Table 14.—Prairie and pasture grasses (and sedges) and forbs occurring in quadrats in pasture A and pasture B and the number of quadrats in which each was found. Species occurring in only one quadrat are omitted.

SPECIES	PASTURE A	PASTURE B	SPECIES	PASTURE A	PASTURE B
Prairie Grasses			*Forbs*		
Andropogon spp.	28	26	Aster multiflorus	26	15
Bouteloua curtipendula	30	30	Achillea occidentalis	12	4
Carex pennsylvanica	16	19	Verbena stricta	6	10
Panicum scribnerianum	15	16	Plantago purshii	1	12
Bouteloua hirsuta	5	4	Grindelia squarrosa	1	10
Panicum wilcoxianum	3	4	Erigeron ramosus	8	7
Bouteloua gracilis	2	3	Leptilon canadense		8
Sorghastrum nutans	3	1	Solidago glaberrima	6	4
Koeleria cristata	1	3	Gaura parviflora	2	5
Eragrostis spectabilis		2	Oxalis stricta	4	
Pasture Grasses			Cirsium undulatum	3	1
Sporobolus cryptandrus	30	30	Lithospermum linearifolium	2	1
Cyperus filiculmis	27	29	Euphorbia maculata	2	
Hordeum pusillum		25			
Panicum capillare	5				
Eragrostis cilianensis	1	6			
Aristida oligantha	2	1			
Poa pratensis	1	2			

ianum in 16 and 15, respectively. Other prairie grasses were important in only 5 of the quadrats or less. Those occurring in pasture quadrats were *Andropogon* in 26, *Bouteloua curtipendula* in all, and *Carex pennsylvanica* and *scribnerianum* in 19 and 16, respectively. No others were important in more than 3 or 4 quadrats.

The chief pasture grasses found in the quadrats of pasture B were *Sporobolus cryptandrus* in all, *Cyperus filiculmis* in 29, and *Hordeum pusillum* in 25. No others were consistently important in more than 6 quadrats. Those occurring in pasture A were *Sporobolus cryptandrus* in all, and *Cyperus filiculmis* in 27. Others were important in only 5 quadrats or less.

Table 15.—Percentage composition of yields at each cutting in pastures A and B.

	MAY 30–31		JUNE 20–21		JULY 19–20		AUG. 25–26		TOTAL YIELD	
	A	B	A	B	A	B	A	B	A	B
Prairie grasses	40.3	1.2	55.9	22.1	51.9	21.7	30.4	16.8	45.4	11.0
Pasture grasses	17.8	52.8	41.3	73.2	41.4	76.1	63.3	82.7	31.5	64.2
Forbs	41.9	46.0	2.8	4.7	6.7	2.2	6.3	.5	23.1	24.8

The chief forb in pasture A was *Aster multiflorus*, occurring in 26 quadrats, *Achillea occidentalis* in 12, *Erigeron ramosus* in 8, and *Verbena stricta* and *Solidago glaberrima* in 6 each. Other forbs were important in only 4 quadrats or less. The most important forbs in pasture B were *Aster multiflorus* in 15 quadrats, *Plantago purshii* in 12, *Grindelia squarrosa* and *Verbena stricta* in 10 each. *Leptilon canadense* and *Erigeron ramosus* were found in 8 and 7, respectively. No others occurred in considerable numbers except in 5 quadrats or less.

Seasonal Yields.—The annual yield of prairie grasses in pasture B was only 19 per cent of that in pasture A. The yield of pasture grasses in pasture B was 160 per cent of that in pasture A. Pasture B yielded 84 per cent as much dry weight of forbs as pasture A, table 13. Total yield in pasture B was only 78 per cent of that in pasture A. Yields in tons per acre were .93 and 1.19 in pastures B and A, respectively.

Percentage yields of each increment at each cutting are shown in table 15. Forbs bulked large only at the first clipping. Prairie grasses ranged from 30.4 to 55.9 per cent of the total yield in pasture A but only 1.2 to 22.1 per cent of that in pasture B. Pasture grasses furnished 52.8 to 82.7 per cent of the yield in pasture B and 63.3 per cent of that in pasture A at the last clipping. This reflects the great ability of sand dropseed (and slender cyperus)

to produce forage during drought. Of the total yield in pasture A, 45.4 per cent was prairie grasses, and 31.5 per cent pasture grasses. Yield in pasture B consisted of 11 per cent prairie grasses and 64.2 per cent pasture grasses.

Percentages of the total yields afforded by each increment at each cutting are shown in table 16. Omitting the August clipping, which was abnormally low because of drought, percentage production of prairie grasses in prairie tended to decrease at the subsequent cuttings, i.e., they were 43, 21, and 31 per cent, while that in pasture steadily increased, i.e., 6, 23 and 62 per cent. This probably resulted from the late revival of growth of the much weakened remnants of prairie grasses in pasture, since the yield of the competing little barley showed that early competition was

Table 16.—Percentage yields of prairie grasses, pasture grasses, and forbs at each clipping in pastures A and B, based upon the seasonal yield (as 100 per cent) of each type of vegetation.

	MAY 30–31		JUNE 20–21		JULY 19–20		AUGUST 25–26	
	A	B	A	B	A	B	A	B
Prairie grasses	43.2	6.0	21.0	23.1	30.8	61.6	5.0	9.3
Pasture grasses	27.4	42.2	22.3	13.1	35.4	36.9	14.9	7.8
Forbs	88.2	95.0	2.0	2.2	7.8	2.7	2.0	0.1

severe. Little barley did not revive and there was less competition later.

Plan in 1940.—Early in the spring of 1940 the fence on the west side of the exclosure was again moved 20 feet farther west so as to exclude cattle from a new strip of pasture. Twenty-five meter quadrats were located at random 20 feet apart along a north-south line in the middle of the enclosed strip. The five remaining quadrats in this group were likewise protected near the smaller, south exclosure, fig. 22. In the adjacent long, narrow strip of pasture, now undergoing a second year of protection, quadrats were located between those clipped in 1939. A new lot of quadrats was also located between the old ones in the area beginning its fourth year of protection. To these was added a new lot of 30, likewise placed at random, in the prairie on a north-south line paralleling the preceding. Clippings from these four groups of 30 quadrats were to furnish data on the amount of prairie grasses, pasture grasses, and forbs produced each month during summer. They represented pastures protected the first, second, and fourth year as well as native prairie (somewhat damaged by drought) from which these pastures were derived.

Both prairie and pasture were mowed about 1.5 inches high before growth was resumed. The grass was collected with a hayrake and removed from the field.

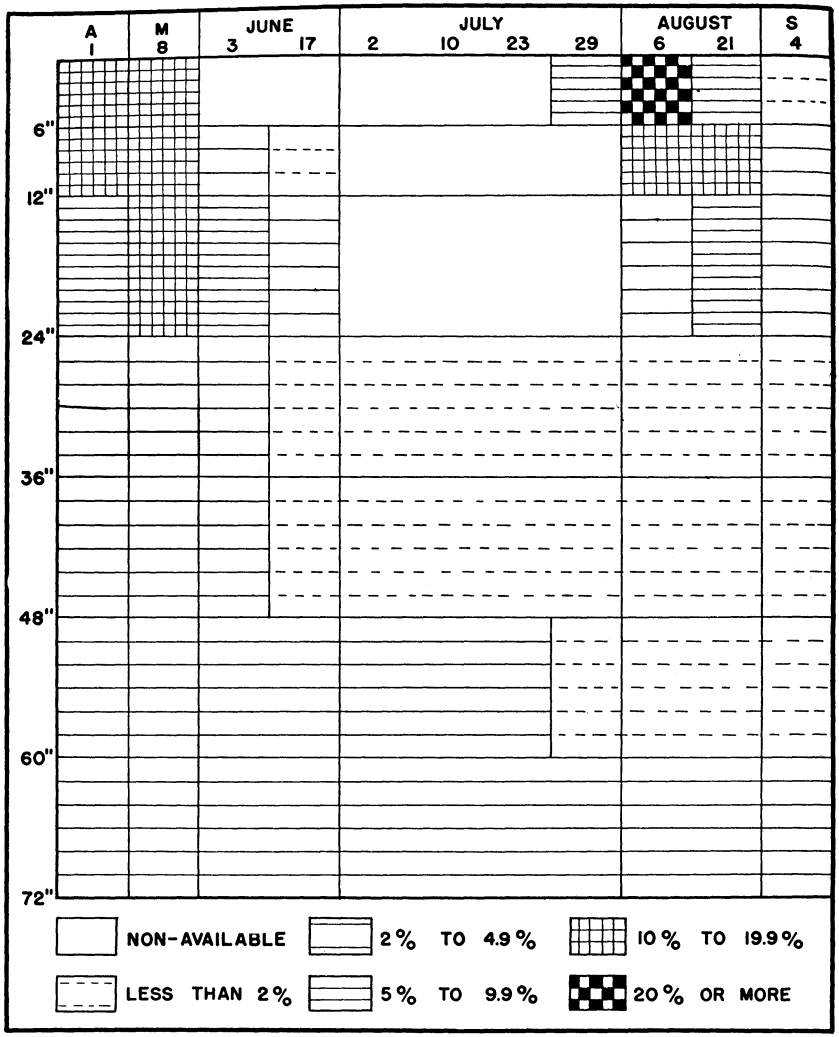


Fig. 27.—Available soil moisture at various intervals in prairie to a depth of 6 feet in 1940.

ENVIRONMENTAL CONDITIONS.—The early growing season was cool and late. Precipitation for both March and April was slightly above normal and there was sufficient soil moisture to promote a good growth of the grasses. Drought threatened after the middle of May, which had only .98 inch of the normal 4.08 inches rainfall. Precipitation in June was light (2.11 inches), being 2.21 inches below normal, but the showers were so distributed that the vegeta-

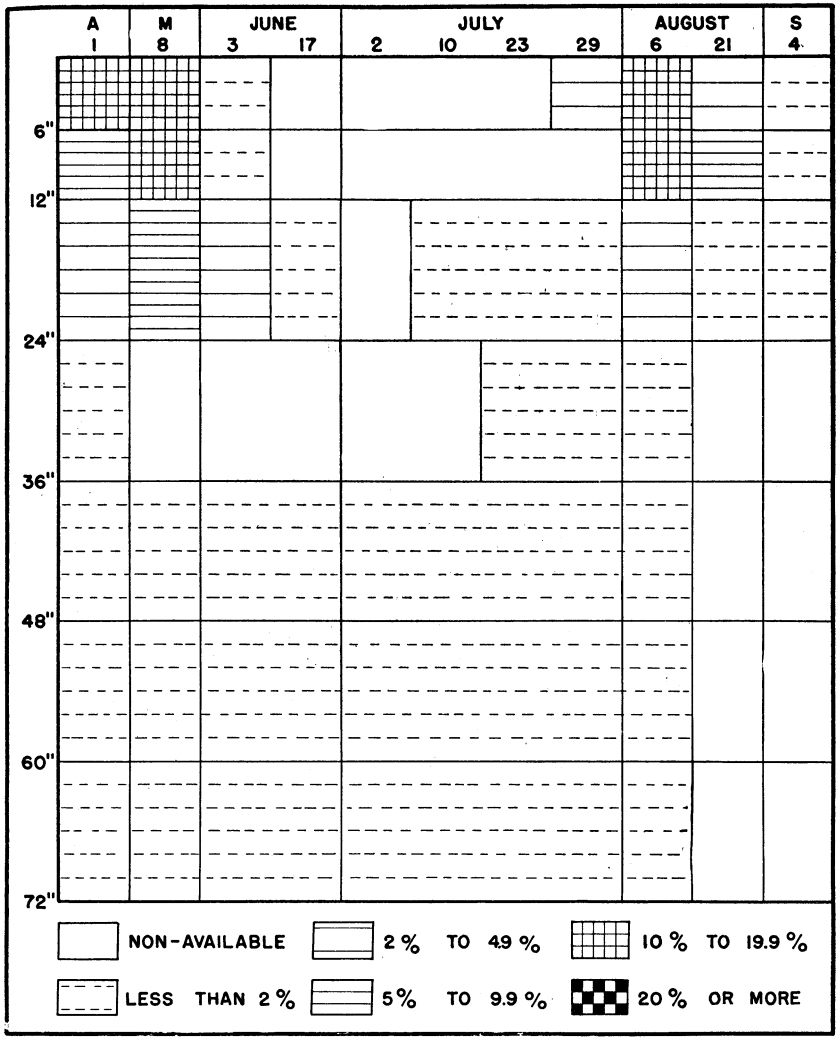


Fig. 28.—Available soil moisture at various intervals in pasture to a depth of 6 feet in 1940.

tion made a good growth until late in the month. No rain fell in July until the 26th. Thus, there was a midsummer period of four weeks duration during which there was no growth. Vegetation not only wilted but also was greatly damaged by the severe drought. The normal green color of the grasses practically disappeared and the bluestems turned reddish brown as they normally do in October. More than 4.25 inches of rain fell be-

tween July 26 and August 4. Growth was renewed, except in a few plants which had died, and much foliage was produced by all of the grasses. Good rains occurred again during the latter half of August. Sand dropseed, side-oats grama, and blue grama produced flower stalks abundantly and there was a good crop of seed. The bluestems never recovered sufficiently to send forth flower stalks, except rarely. Early September was dry.

Fig. 29.—Pasture on June 25, 1940. The old fence line between the fourth year exclosure (left) and later ones (right) is very distinct because of the abundance of little barley in the second and first year exclosures. This weedy grass, which is already drying, is about 10 inches tall. Note the flower stalks of bluegrass in left foreground.

Water content in prairie and grazed pasture was determined at eleven periods to a depth of 6 feet. A study of figures 27 and 28 shows that the prairie soil was frequently more moist than that of pasture. Available water content was continuously less than 2 per cent and often nil below 2 feet depth in pasture. Available moisture below 2 feet in prairie gradually decreased, except at the deepest level, from less than 5 per cent to less than 2 per cent. The first and second foot of soil were without available water, or nearly so, during most of July.

The early portion of the season had subnormal temperatures; during the middle part they were far above normal and continued so during August. By months they were: April, 50.2° F; May, 61.2°; June, 73.7°; July, 81.9°; and August, 73.7°, which were –1.3°,

–.5°, +2.3°, +5.4° and –.7°, respectively below or above the mean. These high temperatures with great intensity of sunshine promoted great water loss and resulted in severe midsummer drought. This was especially detrimental to the less xeric grasses, such as the bluestems, and undoubtedly greatly reduced their yield.

GROWTH IN PASTURES EARLY IN JUNE.—The most conspicuous feature of the first-year exclosure at the time of the first cutting, about June 1, was the dense growth of little barley. It ranged in height from 4 to 14 inches, depending upon the degree of denudation and slope with consequent change in water content. This early maturing grass was the most abundant and important annual, fig. 29. In places, little barley alone was found, often at an average rate of 75 stems with spikes per square decimeter. Most of the plants had headed and were half dried. The stand thinned almost proportionately to the increase in sand dropseed, which was the most important perennial. It formed fully 90 per cent of the more stable grassy cover. Although only a half dozen green plants showed plainly beneath the little barley in some square meters, the range was to a maximum of about one-half of a complete cover. Other perennial grasses consisted of side-oats grama, June grass, and blue grama, with similar small bunches of Pennsylvania sedge. All appeared dwarfed and starved. The bluestems were so rare that one found them only after considerable searching. Dense patches of smooth goldenrod occurred, and open, fragmentary ones of Pursh's plantain, and aster. Vervain, gumweed, ironweed, horseweed, and Russian thistle (*Salsola pestifer*) were common weeds scattered more or less throughout. Others were of little importance.

Under the second year of protection, little barley was somewhat less abundant but of greater stature and greener, varying mostly from 8 to 14 inches in height. Sand dropseed was also more abundant, more vigorous, and taller. Blue grama was noticeably better than the preceding, the height increasing from 1.5 to 4 inches. Bunches of little bluestem were common and less fragmentary. Some flower stalks of relict bluegrass attained a height of 2 feet and bore seed. Those of June grass were 5 to 8 inches taller than the dwarfed ones only recently protected. Side-oats grama had increased in average height from 3 to 6 inches. The improvement of all grasses in both size and abundance was striking. Aster, now recovering from grazing, was much more vigorous than before, and the plants were 6 to 10 inches taller. Peppergrass, as in the preceding area, was rare. The patches of plantain were being broken up by a striking increase in grasses.

Fig. 30.—Dense growth of smooth goldenrod under second year of protection. Photo June 25, 1940.

Fig. 31.—Open growth of smooth goldenrod under fourth year of protection. It was formerly similar to that in figure 30 but is giving way to competing grasses.

The individual plantains were more widely spaced but taller. Russian thistles, horseweed, and other annuals were fewer, partly because of less unoccupied soil and increased competition. The transition to pasture undergoing a fourth year of protection was sharp.

Pasture protected the fourth year differed from the preceding in several ways. Most conspicuous was the general absence of little barley, except in a few places; where present, it was in small numbers. Plantain was likewise inconspicuous. The smooth goldenrod appeared much less important, owing largely to the greater height and density of the grasses but also to great thinning of the stands and a decrease in height of 2 to 3 inches, figs. 30 and 31. Conversely, the patches of aster were taller and more

Table 17.—Average heights in inches of foliage of representative components of the vegetation in the several areas on May 29–June 2, 1940.

SPECIES	FIRST YEAR PROTECTION	SECOND YEAR PROTECTION	FOURTH YEAR PROTECTION	PRAIRIE
		Prairie Grasses		
Andropogon scoparius	2.6	4.2	5.9	5.6
Andropogon furcatus	2.8	3.8	6.6	6.8
Bouteloua curtipendula	3.1	4.6	5.3	5.8
Carex pennsylvanica	4.3	4.9	4.7	6.2
Koeleria cristata	3.0	3.3	8.0	8.0
Panicum scribnerianum	3.1	4.1	5.6	6.7
		Pasture Grasses		
Cyperus filiculmis	2.3	2.6	2.3	
Hordeum pusillum	8.0	8.6	6.8	
Poa pratensis	2.8	4.5	4.5	4.5
Sporobolus cryptandrus	2.8	3.6	4.1	
		Forbs		
Aster multiflorus	6.8	8.7	8.6	10.2
Grindelia squarrosa	6.6	6.2	3.0	
Plantago purshii	4.6	5.0	4.2	
Solidago glaberrima	4.6	6.8	5.4	8.3
Verbena stricta	6.5	8.8	8.0	
Vernonia baldwini	6.7	10.0	7.0	11.0

distinct, and yarrow was much more abundant. Except for these forbs and vervain, other weeds were of minor importance and the impress was distinctly one of grasses. Sand dropseed had attained an average height of 9 inches, as had also big bluestem and Pennsylvania sedge. Little blue stem and side-oats grama averaged 6 inches in height. While sand dropseed prevailed in some places, and in mixture with side-oats in others in much of the area it was well intermixed with the bluestems, and frequently the latter were dominant and sand dropseed almost absent over considerable areas.

Average heights of the several species of prairie and pasture grasses (including sedges) and forbs in the different lots of quadrats are shown in table 17.

Table 17 reveals that prairie grasses were shortest in the plots only recently ungrazed, intermediate in the second group, and tallest in plots in the pasture longest protected and in prairie, see

frontispiece. Among pasture grasses the same sequence in height was shown by sand dropseed, fig. 32. The other grasses were either about the same height under the second and fourth year of protection or showed a decreased height under the fourth year without grazing. Forbs, with one exception, were at first shorter. They increased in height after a second year of protection but decreased again under the competition with the grasses protected the fourth year. Important grasses found in the prairie only were prairie dropseed, needle grass, and tall panic grass. They were 8.5,

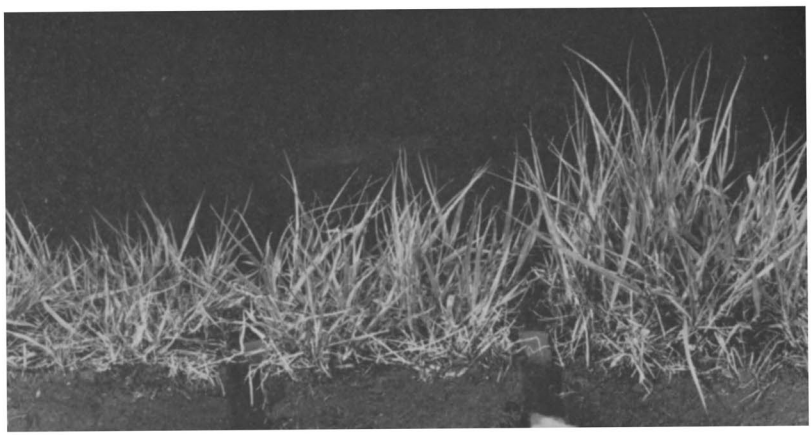


Fig. 32.—Sods of sand dropseed selected on June 13, 1940, to show average development under first, second, and fourth year of protection. The average height of foliage is 3, 4.5, and 7 inches, respectively. Both length and width of leaves increase under increasing periods of protection.

14.2, and 8.2 inches tall, respectively, when first clipped. Development in the prairie was good, but the former close cover, which had been greatly depleted by the drought, had been only partially restored.

FIRST CLIPPING.—Yield of prairie grasses was nearly 3 times as great under the second year of protection as the first, and more than 17 times as great under the fourth year of protection. The prairie yielded 1.5 times as much prairie grass as the best pasture. Pasture grasses during the second year without grazing yielded nearly 1.5 times as much as during the first year. The yield under a fourth year of protection decreased to 25 per cent of that under a second year of protection; in prairie it was only 3 per cent as great.

Prairie grasses protected for the first year yielded, with a single exception, from 1 to 0 grams (13 quadrats) to 6.6 grams. Under a second year of protection, the yield, except for one quadrat, varied

from 1 to 0 grams (7 quadrats) to 23.5 grams. Yield under the fourth year of protection ranged from 3.7 to 112.7 grams, half of the quadrats yielding more than 40 grams each. In prairie, the unit yield ranged from 29 to 138 grams. Average yields under the four conditions were 2.6, 7.3, 44.4, and 66 grams, respectively.

Yield of pasture grasses was less than 20 grams in six quadrats in the pasture under shortest protection but in only one under the second year of protection. But under four years of protection the number of such quadrats increased to 12, and no quadrat in the prairie had more than 12.7 grams of pasture grasses. Average yields under the four conditions were 87.5, 128, 31.5, and 3.7 grams, respectively.

Yield of forbs was variable. There were more annuals in the plots with the shortest period of protection, but the native forbs were larger and more vigorous under longer periods without grazing. Forbs were absent in only one or two quadrats in each group, but the yield per quadrat was highly variable in all. Average yield per quadrat from one-year protected pasture to prairie was 17.9, 28.2, 35.9, and 36.9 grams, respectively. Thus, the best pasture, greatly replenished by sand dropseed, yielded approximately as much as the somewhat drought-depleted prairie where the cover was more open.

SECOND CLIPPING.—The chief features of the vegetation were again recorded from June 27 to July 1, at the time of the second clipping. Under the first year of protection, little barley had ripened and the yellow straw with much shattered spikes still stood in place, as did also the gray, dried plantain. Sand dropseed had begun to roll and lose its green color. The general tone of the landscape was a dull gray except where brightened by the little barley. Clumps of Pennsylvania sedge were brown at the tips but otherwise quite green. Goldenrod was still conspicuous and the very open patches of aster nowhere had plants exceeding 12 inches in height. Numerous Russian thistles were present but all were dwarfed. Next to little barley, the deeply rooted, green and flowering vervain was the most conspicuous weed. It had attained a height of nearly 2 feet.

Under the second year of protection, the grasses were somewhat greener and less affected by drought, probably owing to better root systems. The greater heights of little barley (2 to 4 inches), goldenrod (about 3 inches), and aster (8 inches) were very noticeable. Scribner's panic grass was more abundant here and also taller. The drying bluestems and other vegetation revealed a better soil mulch of dead debris than there was in the preceding exclosure.

In pasture protected the fourth year, sand dropseed was taller (height about 12 inches) and not so dry. Here the root systems were firmly intrenched. June grass and Pennsylvania sedge were far more common and an occasional bunch of prairie dropseed was encountered. Little bluestem stood out conspicuously at a height of 10 inches in reddish bunches and patches. The tops of big bluestem were scorched and the leaves of side-oats grama were rolling. On the lower ground, the dried flower stalks of bluegrass were scattered thinly. The goldenrods were fewer and much dwarfed; often only the outlines of former dense patches remained. The patches of aster were likewise mostly very open. The vervains, common in other exclosures, had nearly disappeared. The bunches of grasses were much thicker, of greater height, and the basal area produced many more stems than elsewhere.

The grasses in the quadrats were about the same height at the second cutting as at the first, a month earlier. Little bluestem, for example, ranged from 2.7 inches through 4 and 6.6 to 7.2 inches in height from first year's protection to prairie, respectively. Prairie dropseed varied, in the same sequence, from 3.4 and 3.9 to 4.2 in the three grades of pastures. The dwarfing effect from too close grazing was shown in all grasses and sedges, and in general the increase in height and vigor was proportional to the degree of protection. In the prairie, the new growth of needle grass, prairie dropseed, and tall panic grass had attained an approximate height of 9 inches. Aster had regained heights of 2, 2.5, and 3.8 inches, respectively. Gumweed and goldenrod recovered poorly, while the new growth of vervain and ironweed had reached heights of about 4, 4.5, and 3.5 inches, respectively. Most native and ruderal forbs had little or no part in the composition of this cutting.

Yields of prairie grasses were in the same sequence as in the first cutting but they were much smaller, decrease in prairie being especially great. Total yields were 67, 173, 902, and 1140 grams, respectively. Yields of pasture grasses were also much less, but the sequence of yield was as on June 1. They were, in order, 773, 1062, 902, and 74 grams. Decrease in yield of these grasses under the first and second year of protection, especially, resulted in part from the fact that the entire crop of little barley was harvested with the first clipping. Yields of forbs were much less than before, being 186, 80, 124, and 120 grams, respectively.

MIDSUMMER DROUGHT.—On July 17, the whole aspect of the prairie was one of severe drought. The upper one-third of the bluestems were brown as if scorched by fire; the lower portions were bleached to a yellowish green. Side-oats grama and needle

grass had lost practically all of their green color. Nearly all of the plants, including the very drought-resistant Pennsylvania sedge, were wilted. The drought had resulted in so much shriveling of the grass that the height was only 7 to 8 inches. No forbs were in bloom; except for aster they were few, and most of them were wilted. In fact, the tops of many plants of goldenrod, aster, and lead plant were dead.

In the pasture exclosures, the abundance of sand dropseed gave a leaden gray color. The plants were shriveled, even the bases of the stems were bleached, and much bare ground was exposed. The reddish colored bluestems showed prominently as did also patches of the sedge with its dried tops and greenish yellow bases. No new fruiting stalks had developed, although those formed by some species before the drought remained. Blue grama grass, with its abundant inflorescences, was dormant. Even on the lowest ground all grasses were seriously harmed; the upper leaves had been killed. Only the more deeply rooted plants of false prairie boneset, aster, and goldenrod remained green. This was the condition also of the deeply rooted vervain and ironweed.

At this time, high southwest winds were prevalent; the air contained considerable dust, and the temperatures were so high that it seemed the wind was blowing from a desert. Drought conditions maintained for another ten days, until July 26.

THIRD CLIPPING.—That the long-protected grasses recuperated from clipping more readily than those more recently grazed was again shown at the third cutting. The heights of little bluestem from the first year of protection to prairie were 3, 3.5, 5, and 5.7 inches, respectively. Those of big bluestem increased gradually from 4.6 to 7 inches. Flower stalks of side-oats grama were 8.6, 9.5, 13, and 11.2 inches in the same order. The foliage of sand dropseed was 5.1, 5.5, and 6 inches tall, respectively, in the several groups of pasture quadrats. Its flower stalks increased from 11.5 to 13.6 inches in average height. In prairie, the third crop of needle grass was about 9 inches high. The new growth of aster scarcely exceeded 2.5 inches anywhere. Vervain ranged in height from 4 to 12 inches. The recovery of forbs was not general and their part of the total yield was small.

Yields were intermediate between those of the first and second clippings, except in prairie. Pasture grasses for the first time exceeded in yield the prairie grasses under the fourth year of protection. This increase was due partly to the effect of drought and partly to the excellent recovery of the xeric sand dropseed. Total yields, with the development of flower stalks of sand dropseed and side-oats grama, became proportionately greater in the pastures, table 20, page 79.

FOURTH CLIPPING.—At the last cutting on September 11, the line of demarcation between prairie and pasture protected the fourth year was very sharp, fig. 33. An enormous crop of flower stalks of sand dropseed was in the boot stage; about 10 per cent had expanded their panicles. The drying sheaths gave a light brown-

Fig. 33.—Photo in September, 1940, showing sharp line of demarcation between prairie (right) and pasture (left). The pasture contains millions of flower stalks of sand dropseed which have bleached white in the late summer drought. A little sand dropseed has invaded prairie but here the chief plant of light color is side-oats grama, which is also abundant in the pasture.

ish color to the entire landscape. A very large crop of seed had been produced. Often thickly intermixed were the flower stalks and inflorescences of side-oats grama. They were approximately the same height (28 to 30 inches) as sand dropseed and had dried to about the same color. Viewed at a distance, these flower stalks were all that was visible, since the lower vegetation was obscured.

In a single pace into the prairie the whole aspect changed. Here the grass was green; there were only a few scattered bunches of sand dropseed, but the fruiting stalks of prairie dropseed and side-oats grama occurred everywhere. The layer of flower stalks was

much more open; perhaps there were only one-tenth as many such stems. The foliage of these grasses and those of the bluestems, needle grass, and others showed prominently as did also the purple blossoms of blazing stars, the yellow inflorescences of goldenrod, and the white tops of false prairie boneset.

Within the pasture protected a fourth year, patches of blue grama with foliage 6 inches high were common. The deeper green of the new growth of bluestems was conspicuous. Occasional bunches of hairy grama, tall dropseed, prairie dropseed, and plains muhly were found as well as the dried flower stalks of June grass. The July drought had been especially harmful to the bluestems and flower stalks were scarce and dwarfed. The foliage of little bluestem was only 6 to 8 inches high and that of big bluestem about 13 inches. Where large bunches or patches of the bluestems or of blue grama were present, there was a distinct opening in the canopy of flower stalks afforded by sand dropseed and side-oats grama.

Certain species occurred in noticeably very small amounts, especially bluegrass, Scribner's panic grass, and slender cyperus. Pennsylvania sedge was occasionally found in patches 1 to 3 square feet in area. In order of their importance, the grasses were ranked as follows:

1. Sporobolus cryptandrus
2. Bouteloua curtipendula
3. Andropogon furcatus
4. Andropogon scoparius
5. Bouteloua gracilis
6. Koeleria cristata
7. Bouteloua hirsuta
8. Carex pennsylvanica

The patches of goldenrod and aster had thinned very greatly as the grasses increased. Many of the plants were less than a foot in height although some extended upward to 21 inches. The chief forbs (including also ruderals and little barley) were, in order: aster, goldenrod, little barley, vervain, yarrow, plantain, false prairie boneset, and ironweed.

Pastures protected only the first or second year were for a long time clearly delimited from that protected a fourth year because of the earlier opening of the panicles of sand dropseed. In the second year pasture, the goldenrods were decidedly more vigorous than in the one protected a fourth year. The height was about 3 inches greater and blossoming far more profuse. Here, too, flower stalks of sand dropseed were considerably fewer and of shorter stature (about 16 inches), and did not form so complete an upper story. Side-oats grama also was far less abundant as were all of the other prairie grasses. Thus, the basal cover was also less, a fact which accounted for the frequency of Russian thistles. This weed, vervain, and aster were far more abundant than in the pasture protected a fourth year.

In the thinner stand of grass in the pasture protected the first year, the panicles of side-oats grama were opened most widely, and the foliage was much greener. Height ranged from 16 inches to somewhat less than that under a second year of protection. The more open ground cover was very noticeable. Little difference in the stature of aster and goldenrod could be noticed between the plants in pasture protected the first year and the second year, but the aster was blooming more profusely. Certain weeds, especially Russian thistle and blue vervain, were far more abundant under the shorter time of protection against grazing.

Vegetation in the quadrats had again reached a height similar to that attained on August 15. The increasing vigor resulting

Table 18.—Selected species of grasses showing relation between time of protection and recovery from clipping. Average height is shown in inches.

SPECIES	FIRST YEAR PROTECTION	SECOND YEAR PROTECTION	FOURTH YEAR PROTECTION	PRAIRIE
Andropogon scoparius	3.0	3.2	4.5	4.8
Andropogon furcatus	4.0	4.4	5.7	6.0
Bouteloua curtipendula	3.0	3.5	4.2	5.0
Sporobolus cryptandrus	2.1	2.4	3.0	3.3
Koeleria cristata	2.1	2.3	2.2	3.5
Eragrostis spectabilis		3.2	5.0	10.0

from greater food reserves under long protection was again clearly revealed, table 18.

Needle grass in the prairie was again 9 inches tall but prairie dropseed only 5.5. The former regularly makes an excellent growth in autumn. Most of the ruderals had succumbed to the several cuttings and drought; other forbs were too short to contribute much to the yield; in fact they weighed less than at any other period.

Total yields were relatively small at the September clipping, table 20.

Composition of Vegetation in the Quadrats.—There was a gradual increase in the number of quadrats containing *Andropogon furcatus* from 22 in first-year protection to 30 in prairie. A similar increase for the number containing *A. scoparius* was from 8 to 27, table 19. *Bouteloua curtipendula* and *Carex pennsylvanica,* which do well under grazing, were much more evenly distributed. *Koeleria cristata* and *Panicum scribnerianum* were the only other grasses found regularly and they occurred in seven or more quadrats.

Among pasture grasses, *Sporobolus cryptandrus* alone occurred in every pasture quadrat, as well as in 12 in prairie. *Cyperus filiculmis* was found in at least 26 of all pasture quadrats, but in

Table 19.—Prairie and pasture grasses (and sedges) and forbs occurring in quadrats in pastures under the first, second, and fourth year of protection, and in prairie, and the number of quadrats in which each was found. Species occurring in only one quadrat are omitted.

SPECIES	PASTURES PROTECTED FIRST YEAR	SECOND YEAR	FOURTH YEAR	PRAIRIE
	Prairie Grasses			
Andropogon furcatus	22	23	27	30
Andropogon scoparius	8	17	24	27
Bouteloua curtipendula	26	27	26	25
Carex pennsylvanica	22	16	22	20
Koeleria cristata	12	8	4	7
Panicum scribnerianum	8	7	10	6
Sporobolus heterolepis		2		11
Stipa spartea		1		12
Sporobolus asper		1	2	7
Panicum virgatum	1		1	1
	Pasture Grasses			
Sporobolus cryptandrus	30	30	30	12
Hordeum pusillum	28	28	13	
Cyperus filiculmis	28	27	26	4
Eragrostis cilianensis	17	4		
Poa pratensis	4	5	17	27
Eragrostis pectinacea	4	2	2	
Agropyron smithii				4
Schedonnardus paniculatus		2		1
Panicum capillare				2
	Forbs			
Plantago purshii	21	17	15	
Aster multiflorus	11	16	19	21
Salsola pestifer	17	11	6	10
Solidago glaberrima	4	3	6	21
Amorpha canescens			1	27
Achillea occidentalis	4	11	15	
Lithospermum linearifolium	6	8	5	3
Verbena stricta	7	6	8	1
Grindelia squarrosa	6	9	2	
Lepidium densiflorum	8	2	5	2
Amaranthus retroflexus	8	1		
Vernonia baldwini	4	4	1	
Hedeoma hispida	4	4	4	1
Gaura parviflora	3	4		
Cirsium undulatum	3	3	1	
Oxalis stricta	2	1	5	
Acerates angustifolia	2	2		1
Leptilon canadense	2	1	2	
Helianthus rigidus				7
Baptisia leucophaea				4
Artemisia gnaphalodes	2		1	
Rosa arkansana				3
Psoralea argophylla				3
Kuhnia glutinosa				3
Equisetum laevigatum	1	1	1	
Erigeron ramosus			1	1

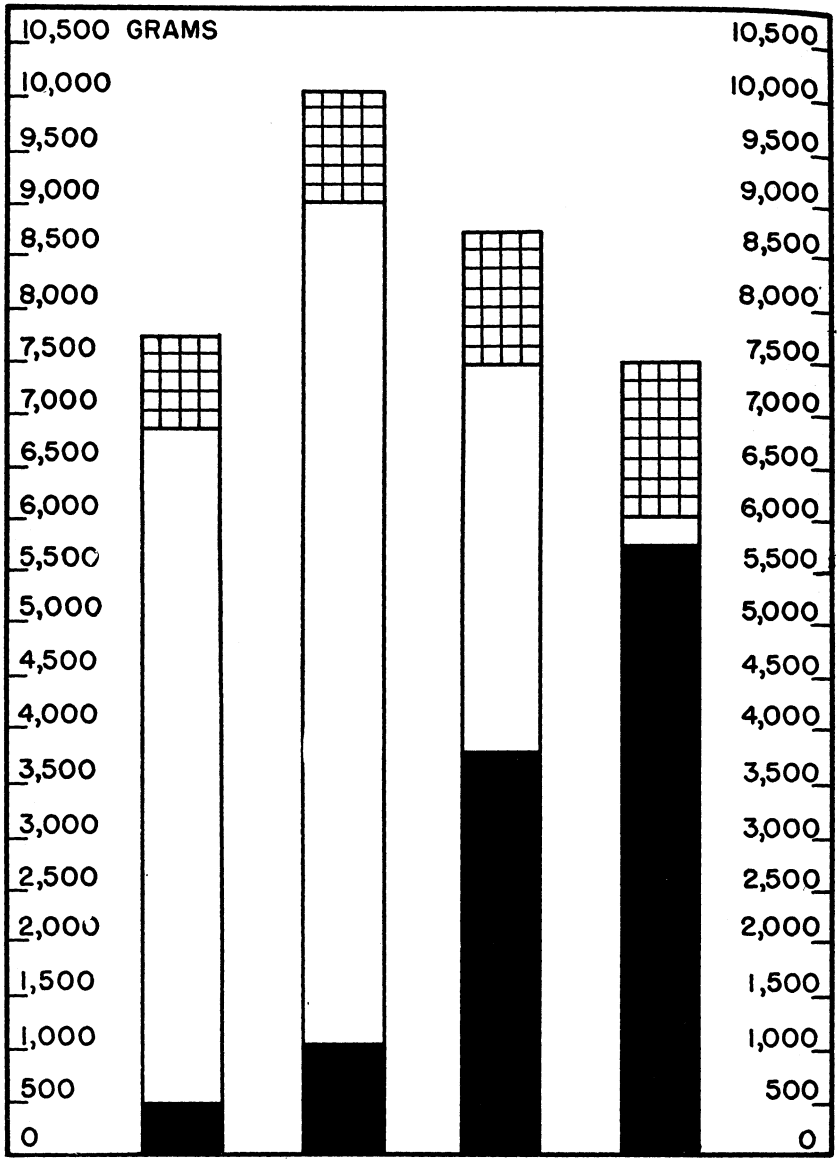


Fig. 34.—Yields of prairie grasses (black), pasture grasses (white), and forbs (crosshatch) in pasture protected the first year (left), second, and fourth years, and in prairie (right). Total yields in tons per acre are 1.15, 1.51, 1.31, and 1.12, respectively. Note the steady increase in amount of prairie grasses with increase in years of protection.

only 4 quadrats in prairie. *Hordeum pusillum* occurred in 28 quadrats in pastures protected for the first and second year, but in only 13 in the other pasture. The prairie quadrats had none. Number of quadrats with *Poa pratensis* increased from 4 or 5 to 17 and then to 27 in prairie, table 19.

Table 20.—Yields in grams of prairie grasses, pasture grasses, and forbs at each clipping and total yields in pastures protected the first, second, and fourth years and in prairie.

VEGETATION	PASTURES PROTECTED			PRAIRIE	TOTAL
	First Year	Second Year	Fourth Year		
		May 29 to June 3			
Prairie grasses	77	220	1,333	1,980	3,610
Pasture grasses	2,627	3,839	945	110	7,521
Forbs	539	846	1,078	1,106	3,569
Total	3,243	4,905	3,356	3,196	14,700
		June 27 to July 1			
Prairie grasses	67	173	902	1,140	2,282
Pasture grasses	773	1,062	902	74	2,811
Forbs	186	80	124	120	510
Total	1,026	1,315	1,928	1,334	5,603
		August 15–17			
Prairie grasses	157	343	822	1,030	2,352
Pasture grasses	1,921	2,151	1,108	64	5,244
Forbs	124	94	53	93	364
Total	2,202	2,588	1,983	1,187	7,960
		September 11–12			
Prairie grasses	173	309	774	1,594	2,850
Pasture grasses	1,061	948	663	84	2,756
Forbs	18	13	30	86	147
Total	1,252	1,270	1,467	1,764	5,753
		Seasonal Yield			
Prairie grasses	474	1,045	3,831	5,744	11,094
Pasture grasses	6,382	8,000	3,618	332	18,332
Forbs	867	1,033	1,285	1,405	4,590
Total	7,723	10,078	8,734	7,481	34,016

Distribution of forbs was much less uniform. *Amorpha canescens* was found in 27 prairie quadrats but only in one in pastures. Number of quadrats with *Aster multiflorus* increased gradually from 11 under the first year of protection to 21 in prairie. Conversely, *Plantago purshii* decreased in occurrence from 21 quadrats to 15 and was absent in prairie. *Salsola pestifer* occurred under all conditions of the experiment but grew in more quadrats in pasture under the first year of protection. Distribution of *Solidago glaberrima* was much wider in prairie (21 quadrats) than in any pasture (3 to 6 quadrats). *Verbena stricta, Lepidium densiflorum, Lithospermum linearifolium,* and *Hedeoma hispida* were found in a few quadrats under all pasture

conditions but occurred much less often in prairie. A total of 26 species of forbs was found in at least two of the 120 quadrats.

Seasonal Yields.—The annual yields of prairie grasses in percentages, based on the prairie as 100 per cent and beginning with the first-year protection, were 8.3, 18.2, 66.7, and 100. Annual yields of pasture grasses, based upon the first year protection as 100 per cent, were 100, 125.4, 56.7, and 5.2 per cent, respectively. Stating the yield of forbs in prairie as 100 per cent, production in the pastures, from first to fourth years of protection, was 61.7, 73.5, and 91.5 per cent, respectively. Total seasonal yields were heaviest in pasture protected a second year, next in that protected a fourth year, less in pasture protected the first year, and least in prairie, table 20 and fig. 34. Yields per acre, in the above sequence, were 1.51, 1.31, 1.15, and 1.12 tons, respectively.

Table 21.—Percentage composition of yields at each clipping in pastures under the first, second, and fourth years of protection and in prairie.

VEGETATION	MAY 29 TO JUNE 3	JUNE 27 TO JULY 1	AUGUST 15–17	SEPTEMBER 11–12	TOTAL
		Prairie Grasses			
1st year protection	2.4	6.5	7.1	13.8	6.2
2nd year protection	4.5	13.1	13.3	24.3	10.4
4th year protection	39.7	46.8	41.4	52.8	43.9
Prairie	62.0	85.5	86.8	90.4	76.8
		Pasture Grasses			
1st year protection	81.0	75.4	87.3	84.8	82.6
2nd year protection	78.3	80.8	83.1	74.7	79.4
4th year protection	78.3	80.8	83.1	74.7	79.4
Prairie	3.4	5.5	5.4	4.7	4.4
		Forbs			
1st year protection	16.6	18.1	5.6	1.4	11.2
2nd year protection	17.2	6.1	3.6	1.0	10.2
4th year protection	32.1	6.4	2.7	2.0	14.7
Prairie	34.6	9.0	7.8	4.9	18.8

Percentage yields of prairie grasses, pasture grasses, and forbs at each clipping are shown in table 21. At each clipping prairie grasses increased consistently from first-year protected pasture to prairie. Percentage total yields of prairie grasses in pastures protected for the first, second, and fourth year and in prairie were 6.2, 10.4, 43.9, and 76.8, respectively, table 21. Pasture grasses at the first and last two cuttings gave the highest percentage yield under first year of protection, and decreased gradually to prairie. This change was due in the first cutting to a heavy growth of little barley and in the later ones to late-growing, annual, weedy grasses such as stink grass. The percentage total yields of pasture grasses, however, were 82.6, 79.4, 41.4, and 4.4 from first-year protection to prairie, respectively. Forbs bulked large only at the

first clipping where they composed one-third of the yield in pasture protected a fourth year and in prairie. Per cent of seasonal yield increased slightly from recently protected pastures to climax prairie. The percentages were 11.2, 10.2, 14.7, and 18.8, respectively.

Percentages of the total yields in each pasture or in prairie afforded by each increment at each cutting are shown in table 22. The trend in pastures protected the first year or first and second years only was toward an increased percentage yield of prairie

Table 22.—Percentage yields of prairie grasses, pasture grasses, and forbs at each clipping based upon the seasonal yield (as 100 per cent) of each type of vegetation.

VEGETATION	MAY 29 TO JUNE 3	JUNE 27 TO JULY 1	AUGUST 15–17	SEPTEMBER 11–12
		Prairie Grasses		
1st year pasture	16.3	14.1	33.1	36.5
2nd year pasture	21.1	16.5	32.8	29.6
4th year pasture	34.9	23.5	21.4	20.2
Prairie	34.5	19.8	17.9	27.8
		Pasture Grasses		
1st year pasture	41.2	12.1	30.1	16.6
2nd year pasture	48.0	13.3	26.9	11.8
4th year pasture	26.1	24.9	30.6	18.3
Prairie	33.1	22.3	19.3	25.3
		Forbs		
1st year pasture	62.2	21.4	14.3	2.1
2nd year pasture	81.9	7.7	9.1	1.3
4th year pasture	83.9	9.7	4.1	2.3
Prairie	78.7	8.6	6.6	6.1

grasses in August and September; elsewhere the highest percentage yields (with one exception) were from the earlier clippings. Yields of pasture grasses in the prairie were too small (4.4 per cent, as shown in table 21) to have much significance. Largest partial yield of these grasses in pasture protected the first and second years was on June 1 and the next largest on August 15. Other yields were much smaller. The sequence was the same in the pasture protected the fourth year; the greatest yield was in August. These differences undoubtedly merely reflect the extreme variations in the environmental conditions during this dry summer.

Quality of Yield and Utilization.—Yields alone, however, do not give a proper basis for estimating forage values. The prairie grasses, except for tall dropseed, are all readily grazed and only relatively small percentages are left on the ground at the end of the grazing season in pastures that are properly managed. Among 9 of the 13 prairie grasses, the utilization factor is 70 to 80 per cent.

Pasture grasses, except bluegrass, rank much lower, three species having only 10 per cent utilization (see p. 52). It is fully realized that the utilization factor varies widely according to climatic conditions, method and time of pasturing, type of stock, previous habits of animals, amount and kind of forage available, etc.

Table 23.—Species of prairie and pasture grasses, their utilization factor, and percentage of yield afforded by each species or group in pastures protected for the 1st, 2nd, and 4th years and in prairie.

Utilization Factor	Pastures Protected	First Year	Second Year	Fourth Year	Prairie
	Prairie Grasses				
.77 (.80 / .70 / .80)	Andropogon furcatus Andropogon scoparius Bouteloua curtipendula	85	85	85	60
.60 (.55 / .75 / .50)	Carex pennsylvanica Koeleria cristata Panicum scribnerianum	13	13	13	5
.64	Other species (See table 19)	2	2	2	35
	Pasture Grasses				
.50	Sporobolus cryptandrus	77	90	94	26
.10	Hordeum pusillum	17	6	1	
.80	Poa pratensis	1	1	4	73*
.60	Cyperus filiculmis	2	2	1	1
.30	Eragrostis cilianensis	3	1		

* Small amounts of four other species are included in this increment: *Agropyron smithii, Panicum capillare, Schedonnardus paniculatus,* and *Eragrostis pectinacea.*

These percentages were selected only after a long period of observation and careful study during several seasons. They apply closely to pastures in eastern Nebraska during the past decade.

The utilization factor of each species or closely similar group of species of prairie and pasture grasses is given in table 23. The table also includes the estimated percentage of total yield furnished by each species or group in each pasture and in prairie. This furnishes a basis for calculating the amount of forage that would have been utilized by the stock under actual grazing. For example, little barley furnished 17 per cent (or 1085 grams) of the 6382 grams of pasture grasses yielded under the first year of protection. Under pasturing, however, only 10 per cent of this 1085 grams (i.e. 108 grams) would have been eaten by stock.

By use of the utilization factor, the utilization of the seasonal yield of prairie and pasture grasses has been calculated. It is assumed that the forbs as a group were utilized equally in the

three pastures. A factor of 20 per cent has been assigned to them. Since prairie forbs consisted largely of the very palatable legume, lead plant, a utilization factor of 50 per cent has been used for these forbs.

Examination of figure 35 shows that utilization of total forage was at least 32 per cent less in pasture protected the first year

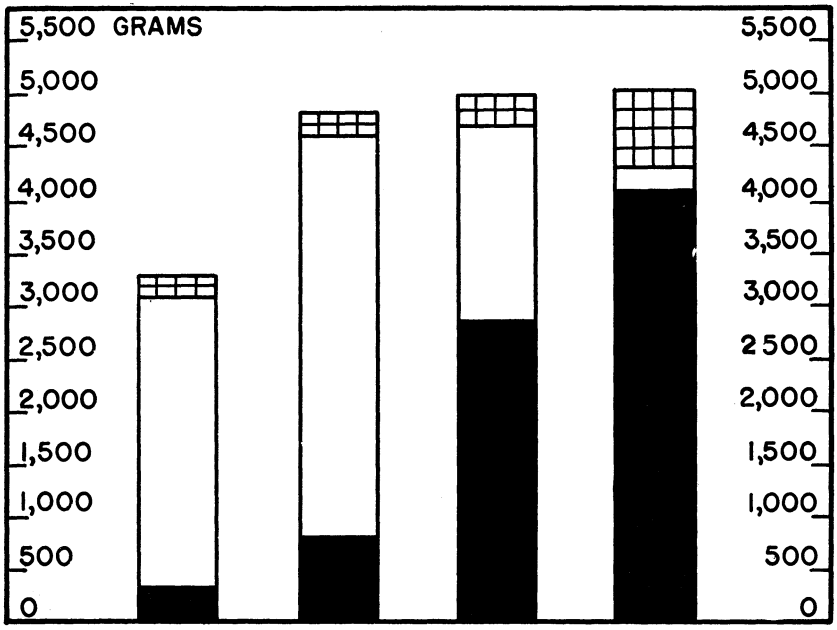


Fig. 35.—Utilization of prairie grasses (black), pasture grasses (white), and forbs (crosshatch) in pasture protected the first year (left), second, and fourth years, and in prairie (right). Utilization in tons per acre is .49, .72, .74, and .76, respectively.

than in either of the other pastures or in prairie. Utilization was slightly less in the pasture protected a second year than in the one protected a fourth year or than in prairie. It should be emphasized that the climax vegetation in the prairie had previously been much thinned by drought, that few invading species had entered, and that the original thick cover had not been reestablished. In tons per acre, the amounts of forage that would probably have been utilized by stock in the several areas from first year protection to prairie were .49, .72, .74, and .76 tons, respectively.

The results are representative, it is believed, of what has occurred in thousands of drought-stricken pastures of the sand

dropseed type. They show the amount of utilization of the forage produced, largely by the drought resistant sand dropseed, in pastures protected a second year. The steady replacement of this forage increment by prairie grasses is also shown. Under conditions of prolonged drought, a single year of protection increased the utilized forage to as great an amount as that produced after three full years without grazing. Reentry of prairie grasses would undoubtedly have been more rapid under normal weather conditions, but knowledge of productivity and utilization of forage under conditions of drought when feed is scarce is of especial value.

Aldous (1938), working in Kansas, found that in good bluestem pastures deferred grazing until about June 15 every two or three years was sufficient to maintain the normal stand and vigor of the vegetation. Hence, a plan has been developed whereby the pasture is divided into three units of approximately equal carrying capacity. On each part in turn, grazing is deferred for a single season until late in June. This plan thus allows of spring protection, once in three years, but permits of grazing during the remainder of the growing season (Anderson 1940).

In native pastures that have deteriorated as a result of poor grazing management, restoration of the better grasses is a long and costly process. It may involve several years of protection and in addition more or less control of weeds. Succession takes place slowly under protection, especially during years with a deficient water supply. Vegetation proceeds in its development toward the climax, especially as regards the disappearance of ruderals and the reestablishment of bluestem grasses. With decrease in the intensity of drought and the occurrence of a series of even moderately moist years, it is believed that the sand dropseed will be replaced by more mesic grasses whose forage will have a higher degree of utilization. Just how rapidly this will occur under different degrees of protection from grazing remains to be determined by experiment.

SUMMARY

The nature and rate of regeneration of a 23-year-old native pasture under complete protection from grazing was studied near Lincoln, Nebraska, during four summers, beginning in 1937.

The pasture was of the little bluestem (*Andropogon scoparius*) —Kentucky bluegrass (*Poa pratensis*) type preceding the great drought of 1934–36, but was dominated by sand dropseed (*Sporobolus cryptandrus*) and side-oats grama (*Bouteloua curtipendula*) following the high mortality of the less xeric grasses.

In 1937, both little bluestem and big bluestem (*Andropogon furcatus*) occurred very sparingly. Bluegrass remained only in scattered patches ranging from a few square decimeters to a square meter in area. Sand dropseed varied in occurrence from sparse to abundant as did also side-oats grama. Small amounts of blue grama (*Bouteloua gracilis*), June grass (*Koeleria cristata*) and a few other native grasses were found. Dense patches of peppergrass (*Lepidium densiflorum*) occurred throughout much of the pasture and Pursh's plantain (*Plantago purshii*) was very abundant in widely distributed patches. These, with smooth goldenrod (*Solidago glaberrima*), many flowered aster (*Aster multiflorus*), and horseweed (*Leptilon canadense*), were the major constituents of the weedy flora.

Five different lots of permanent, meter quadrats were established in 1937 in which the increase or decrease of each species was determined quantitatively by the stem-count method. Ten of these were marked out at random in widely distributed areas where sand dropseed dominated; 10 were similarly located in local areas revealing remnants of little bluestem; and 10 others were placed where relict patches of bluegrass persisted. A fourth lot of 10 was scattered widely to include small patches of blue grama, and three quadrats were established in representative bared areas occupied by peppergrass.

A total of 13 species of grasses and sedges, 19 of native forbs, and 13 of ruderals constituted the total vegetation in the 43 quadrats in 1937; the number increased to 57 in 1940.

The topography is rolling; the soil is a fertile clay loam about 3 feet in depth and underlaid with a deep porous subsoil, somewhat sandy in texture.

Drought occurred at certain periods each growing season, but 1937, 1939, and 1940 were especially dry. Conditions for growth were very favorable in spring and early summer of 1938. Precipitation from April to September inclusive was 8.53 inches below the normal 21.33 inches in 1937, .60 inch above in 1938, 8.22 inches below in 1939, and 8.08 inches less than normal in 1940.

Soil samples were taken at frequent intervals to depths of 4 to 6 feet in both pasture and adjacent prairie. They showed that the vegetation depended chiefly upon the current rainfall for its water for growth, since only small amounts of water occurred in the deeper soil layers at the beginning of the study. Water available for growth was frequently exhausted in the first and second foot. This condition, often combined with long periods of unusually high temperatures and extremely high rates of evaporation, retarded normal development of vegetation.

In addition to exact changes occurring in the quadrats, the more apparent variations in the entire protected pasture were followed from year to year.

The most marked change in the quadrats dominated by sand dropseed was the steady increase in the number of stems of this dominant from year to year—17, 22, and 35 per cent—and a total increase of 94 per cent during the four years. Despite this increase, it disappeared from 252 square decimeter units in which it originally occurred.

Side-oats grama, second in importance, made a total gain of 313 per cent in number of stems and spread into 298 new unit (square decimeter) areas.

Both big and little bluestem showed consistent gains both in number of stems and in area occupied. Hairy grama (*Bouteloua hirsuta*) gained in number of stems; the amount of bluegrass decreased. Other grasses, collectively, gained rapidly in 1938, remained almost the same the next year, but increased again in 1940.

There was a marked decrease in most native forbs, but smooth goldenrod and many-flowered aster increased. Almost all ruderals, except little barley (*Hordeum pusillum*), showed a marked decrease.

In quadrats where little bluestem was the most important dominant, this species steadily increased. It gained 332 per cent in number of stems but disappeared from 54 of the 397 square decimeters it originally occupied. Sand dropseed, side-oats grama, and big bluestem all increased greatly both in number of stems and in area occupied.

Bluegrass constituted 92 per cent of the grass population in relict areas which were first quadratted in 1937. With a loss of 99 per cent of bluegrass during the dry fall and winter following, the total cover of grasses was reduced to 31 per cent in 1938, despite great gains of all the other grasses. By 1940 it had increased slightly, but had disappeared from 534 of the 730 units in which it was originally found.

Blue grama formed only 5.9 per cent of the basal cover in the lot of 10 quadrats in 1937. This increased to 12.3 the next year and to 16.1 per cent in 1940, a gain due largely to the thickening of the mat in territory already occupied. Sand dropseed increased 136 per cent in number of leaves, side-oats grama 242, and big bluestem 276 per cent.

Changes in plant populations in the 43 quadrats taken collectively are shown for each of four years of protection. Bluegrass comprised 56 per cent of the total grasses in 1937, but was

so greatly weakened by drought that only 3 per cent of the 1937 stand remained in 1938. It gained greatly the following summer but lost slightly in 1940, and the total loss from 1937 was 91 per cent. Its distribution in 1049 square decimeters was reduced to 367.

Sand dropseed in 1937 comprised 26 per cent of the total grasses. It increased in number of stems 55 per cent in 1938, 19 the next year, and 29 per cent in 1940. The total increase (1937–40) was 137 per cent. It was more widely distributed than any other grass, occupying 1841 square decimeters in 1937. This area was increased only 112 units by 1940, hence, the chief development was that of plants already established.

Side-oats grama increased even more rapidly than did sand dropseed. Its gains were 195 per cent in 1938 and 91 the following summer, but it suffered a decrease of 9 per cent in 1940. The four-year gain was 413 per cent. Its initial area of 571 square decimeters was increased to 1384.

Little bluestem gained most the first year (105 per cent) but its increase continued a second (98 per cent) and third season (17 per cent). Thus, the total gain was 375 per cent, but it spread only from 549 to 822 units.

Big bluestem gained rapidly, 105 and 144 per cent the first two years, and then decreased 8 per cent. Its total gain in number of stems was 362 per cent and in unit areas occupied from 580 to 1245.

Hairy grama, June grass, and Pennsylvania sedge (*Carex pennsylvanica*) all increased steadily in number of stems, the total gains being 209, 333, and 406 per cent, respectively. The last-named species more than doubled its area, June grass gained but slightly, and hairy grama lost area formerly occupied.

Based on number of stems in 1937 and 1940, sand dropseed composed 26 and 39 per cent of the vegetation, respectively; little bluestem 6 and 18.5; side-oats grama 4 and 14; and big bluestem 4 and 12 per cent. Bluegrass originally composed 56 per cent, but finally only 3 per cent.

Only 5 of the 23 native forbs growing in the quadrats were of major importance. Together they constituted 90 per cent of the total native forb population. Rough pennyroyal (*Hedeoma hispida*), Pursh's plantain (*Plantago purshii*), and daisy fleabane (*Erigeron ramosus*) were the chief forbs in 1937, but all decreased 90 per cent or more by 1940 and lost heavily in unit areas occupied. Conversely, many-flowered aster and smooth goldenrod increased 480 and 111 per cent, respectively, by 1940; they also showed great increase in area. Between 1939 and 1940 they lost considerably in both number of stems and area occupied.

Only 3 of the 17 species of weeds growing in the quadrats were

of outstanding importance. Horseweed formed 49 per cent, peppergrass 44, and little barley 7 per cent of the ruderal fraction of the vegetation in 1937. The first decreased 91 per cent and the second 99 per cent the first year, and both were insignificant thereafter. Little barley increased nearly 600 per cent in 1938, composing 87 per cent of the ruderals, and was the chief weed thereafter.

No seedling grasses were found in 1937, but seedlings of grasses, especially sand dropseed, and forbs were abundant in 1939 and 1940.

Studies in 1940 on the density and composition of vegetation in plots under the first, second, and fourth year of protection showed marked differences. Foliage cover averaged 30, 57, and 61 per cent under the three conditions, respectively. Basal cover was 10.4, 21.2, and 19.6 per cent in the same sequence, decrease under longest protection resulting from an increase in grasses of more erect growth than sand dropseed.

Grasses and sedges furnished 57, 91, and 97 per cent, respectively, of the total vegetation in the several plots. Sand dropseed increased from 49 to 81 per cent and then decreased to 39 per cent of the total vegetation. Conversely, little bluestem, big bluestem, and side-oats grama increased from about 1 per cent each in the plot protected the first year to 18 per cent in that protected a fourth year. Native forbs composed 10, 3, and 1 per cent of the vegetation, and ruderals 33, 6, and 2 per cent, respectively.

Diameter of bunches, number of stems per bunch, and length of stems of little bluestem steadily increased from grazed pasture through pastures protected a first, second, and fourth year. Bunches of sand dropseed first increased in size and then under greater competition became smaller in diameter, the stems growing more erect. Otherwise they behaved as did little bluestem.

Relative production in pastures protected the first year (B) and third year (A) was determined in 1939. This was done by clipping 30 quadrats under each condition at a height of 1.5 inches four times to simulate grazing. At each clipping yields of prairie grasses, pasture grasses, and forbs were determined separately.

Vegetation grew well during the late cool spring; many plants wilted when drought threatened in May; they flourished during June, but growth was greatly retarded during the remainder of the season.

Annual yield of prairie grasses in pasture B was only 19 per cent of that in pasture A. Yield of forbs was 84 per cent as great in pasture B as in A. Yield of pasture grasses in pasture B was

160 per cent of that in pasture A. Total yields in pastures B and A were .93 and 1.19 tons per acre, respectively.

Yields in 1940 were obtained from adjacent areas of old pasture 20 feet wide and 31 rods long, that had been protected from grazing the first, second, and fourth year, and from virgin prairie. Thirty quadrats located at random under each condition were clipped at four different intervals.

Chief prairie grasses and sedges were little bluestem, big bluestem, side-oats grama, Pennsylvania sedge, June grass, and Scribner's panic grass. Little bluestem increased in occurrence from 8 quadrats under the first year of protection to 27 in prairie; side-oats grama was much more evenly distributed.

Chief pasture grasses were sand dropseed, little barley, slender cyperus (*Cyperus filiculmis*), and bluegrass. Sand dropseed was represented in all pasture quadrats and in 12 in prairie. Little barley and slender cyperus decreased in occurrence under increased protection from grazing, but bluegrass increased.

A cool moist spring was followed by a minor drought period in May but in June by conditions moderately favorable to growth. Then followed a midsummer period of four weeks during which there was no growth, but much foliage was produced during August.

Growth in height of prairie grasses after each clipping increased directly in proportion to the length of time of protection. It was about twice as great in the pasture protected a fourth year as in the one protected the first year. Outside the quadrats average height of little bluestem was 3, 5.5, and 9 inches, respectively, under the three conditions of protection on June 13; big bluestem had attained heights of 3.5, 8, and 13 inches. Sand dropseed recovered in a similar manner, but other pasture grasses were either about the same height under the second and fourth year of protection or showed a decreased height under the fourth year without grazing.

Total yields of prairie grasses in per cent, based on the prairie as 100 per cent and beginning with the first year of protection, were 8.3, 18.2, 66.7, and 100. Total yields of pasture grasses, based upon the first year protection as 100 per cent, were 100, 125.4, 56.7, and 5.2, respectively. Stating the yields of forbs in prairie as 100 per cent, production in the pastures in order of increasing time of protection was 61.7, 73.5, and 91.5 per cent.

At each clipping prairie grasses increased consistently from first year protected pasture to prairie. Percentage total yields were 6.2, 10.4, 43.9, and 76.8, respectively.

The percentage total yields of pasture grasses were 82.6, 79.4, 41.4 and 4.4 from first year protection to prairie, respectively.

Forbs bulked large only at the first clipping. Per cent of seasonal yield increased slightly from recently protected pastures (10.2) to prairie (18.8).

Total yields were heaviest in pasture protected a second year, next in that protected a fourth year, less in pasture protected the first year, and least in prairie. In tons per acre they were 1.51, 1.31, 1.15, and 1.12, respectively.

Yields alone do not furnish a proper basis for estimating forage values. Hence, a utilization factor was determined for each important species. This factor indicated the percentage of the particular species ordinarily removed by the livestock in grazing. It averaged .77 for the three chief prairie grasses found in pastures; it was .50 for sand dropseed, but only .10 for little barley. The percentage of total yield furnished by each species or group in each pasture was closely estimated.

Utilization of the seasonal yield of prairie and pasture grasses and forbs has been calculated from these data. In tons per acre, the amount of forage that would probably have been utilized by stock in the several areas from pasture protected a first year to prairie was .49, .72, .74, and .76 of a ton, respectively.

A single year of complete protection increased the quantity of vegetation utilized almost as greatly as three full years of protection. One year of protection more than doubled the amount of the better forage grasses utilized and three years of protection increased the amount eightfold.

BIBLIOGRAPHY

ALDOUS, A. E. 1930. Effect of different clipping treatments on the yield and vigor of prairie grass vegetation. Ecol. **11**:752–9.

ALDOUS, A. E. 1938. Management of Kansas bluestem pastures. Jour. Amer. Soc. Agron. **30**:244–53.

ANDERSON, K. L. 1940. Deferred grazing of bluestem pastures. Kans. Ag. Exp. Sta. Bul. **291**.

CAMPBELL, R. S. 1931. Plant succession and grazing capacity on clay soils in southern New Mexico. Jour. Ag. Res. **43**:1027–51.

CAMPBELL, R. S. 1940. Range management research methods in the western United States. Herbage Reviews **8**:121–38.

CANFIELD, R. H. 1939. The effect of intensity and frequency of clipping on density and yield of black grama and tobosa grass. Tech. Bul. **681**.

CLEMENTS, F. E. 1928. Plant Succession and Indicators. H. W. Wilson, New York.

CLEMENTS, F. E., and V. E. SHELFORD. 1939. Bio-ecology. John Wiley and Sons, New York.

HANSON, H. C. 1938. Ecology of the grassland. Bot. Rev. **4**:51–82.

HANSON, H. C., *et al.* 1931. Effects of different systems of grazing by cattle upon a western wheat-grass type of range. Colo. Ag. Exp. Sta. Bul. **377**.

SAMPSON, A. W. 1919. Plant succession in relation to range management. U.S.D.A. Bul. **791**.

SARVIS, J. T. 1923. Effects of different systems and intensities of grazing upon the native vegetation at the northern great plains field station. U.S.D.A. Dept. Bul. **1170**.

TAYLOR, W. P., and J. V. G. LOFTFIELD. 1924. Damage to grasses by the Zuni prairie dog. U.S.D.A. Dept. Bul. **1227**.

WEAVER, J. E., and F. W. ALBERTSON. 1936. Effects of the great drought on the prairies of Iowa, Nebraska, and Kansas. Ecol. **17**:567–639.

WEAVER, J. E., and F. W. ALBERTSON. 1939. Major changes in grassland as a result of continued drought. Bot. Gaz. **100**:576–91.

WEAVER, J. E., and F. W. ALBERTSON. 1940. Deterioration of grassland from stability to denudation with decrease in soil moisture. Bot. Gaz. **101**:598–624.

WEAVER, J. E., and T. J. FITZPATRICK. 1934. The prairie. Ecol. Mono. **4**:110–295.

WEAVER, J. E., and W. W. HANSEN. 1939. Increase of Sporobolus cryptandrus in pastures of eastern Nebraska. Ecol. **20**:374–81.

WEAVER, J. E., and W. W. HANSEN. 1941. Native midwestern pastures: their origin, composition, and degeneration. Univ. Neb. Cons. and Surv. Div. Bul. **22**.

WEAVER, J. E., and V. H. HOUGEN. 1939. Effect of frequent clipping on plant production in prairie and pasture. Amer. Midl. Nat. **21**:396–414.

WEAVER, J. E., L. A. STODDART, and W. NOLL. 1935. Response of the prairie to the great drought of 1934. Ecol. **16**:612–29.

WEST, C., G. E. BRIGGS, and F. KIDD. 1920. Methods and significant relations in the quantitative analysis of plant growth. New Phytol. **19**:200–7.

WEST, O. 1936. An investigation of the methods of botanical analysis of pasture. South African Jour. Sci. **33**:501–59.

WHYTE, R. O. 1939. Research on grassland, forage crops and the conservation of vegetation in the United States of America. Herbage Publ. Series. Bul. **26**.