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Gerald W. Tomanek

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by Gerald W. Tomanek

FORT HAYS KANSAS STATE COLLEGE STUDIES

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Introduction

Short grass pastures on the high plains of Western Kansas vary in their ability to produce forage for livestock consumption. One of the reasons for this difference is a variation in the degree of utilization in past years. Forage production of short grass ranges has been reduced to about one-half after only a few decades of improper grazing; therefore the problem of proper utilization is becoming more important every year (Forest Service, 1936). When the early settlers came to western Kansas they found an almost complete cover of native vegetation and for a number of years only a small portion of the range was put under cultivation. With the coming of the dry land farmer, however, a large percentage of the native prairie was broken. A recent survey shows that in the Great Plains Region there are about 17 million acres of range land as compared to approximately 11 million acres of crop land (Great Plains Committee, 1936). Many operators have been unable to adjust their livestock programs to the range lands that are diminishing in area and yield. Some have reduced their stocking rate so much that it has resulted in their pastures being undergrazed. Many operators, however, have retained too many animal units on their pastures, thereby producing some badly overgrazed grasslands.

The detrimental effects of improper management of the short grass ranges have never been fully understood. Farm operators have observed that some pastures are inferior to others, but they have been unable to correlate these conditions with past treatment. Many have been unable to recognize areas that have been either too lightly or too heavily utilized. This inability is probably due to the enormous changes that take place in the vegetative cover of the pastures during extreme variations in climatic conditions as well as those that result from light or heavy grazing. The effect of drought, dust, and different intensities of grazing upon the yield of short grass pastures was investigated by Albertson and Weaver (1944). Four classes of pastures were studied with reference to the amount of grazing and dusting to which each had been subjected in past years. The basal cover

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and composition of vegetation, the annual and monthly yields of dry forage, and the effect of different intensities of clipping on the yield of grasses were determined for the four classes of pastures during the two years immediately following the drought. Lacey (1942) found that moderate grazing maintained a constant forage yield and short grass cover, except under adverse climatic conditions, when a considerable decrease in short grass yield was noted. No data have been found, however, on the condition of various pasture types following a few years of normal or above-normal precipitation after the drought.

A number of other studies have been made which closely parallel the work described in this paper. They are concerned, however, with areas that would not be expected to produce the same results as the pastures of western Kansas.

Weaver and Hanson (1941) described five stages in the degeneration of native midwestern prairies and pastures of Iowa and Nebraska. According to their response to grazing, plants of the prairie were placed in six groups: (1) prairie grasses that decrease under grazing, (2) forbs* that decrease under grazing, (3) grasses that increase under grazing, (4) forbs that increase under grazing, (5) grasses that invade pastures and (6) weedy forbs that invade pastures.

The short grass ranges of the central Great Plains were classified into excellent, good, fair, and poor pastures by Costello and Turner (1944). These different classes of pastures were described thoroughly for the purpose of making the different conditions easier to recognize. The fluctuation in the annual forage production for the different classes was discussed but no comparison between the pastures was made. Different degrees of mountain meadow range conditions of eastern Washington and eastern Oregon in relation to grazing intensities were determined by Reid and Pickford (1946).

Jones (1934) studied the influence of grazing on the botanical composition and the productivity of pastures in England. The effect of different intensities of grazing upon native vegetation of the northern Great Plains has been studied by Sarvis (1923). This report stressed the effect of intense grazing upon the principal grasses and forbs of this region and the use of plants as indicators of range conditions.

The purpose of this study is to determine the characteristics of five pastures that have been subjected to different intensities of grazing in the past 15 years.

*Forbs—A collective ecological term referring to non-grassy, herbaceous plants.

Method of Study

Five pastures were selected for study. They were selected and classified with reference to the intensity of grazing to which they had been subjected during the past 15 years. General observations upon the amount of old growth present and the appearance of the vegetative cover were also used for distinguishing the types.

The history of the pastures with respect to the grazing program and general appearance for 15 years prior to the beginning of the study was obtained from the farm operator. A short description was also made of the general appearance of the pastures in the spring of 1946.

A detailed study of the differences found in these five pastures was made along the following lines: Basal cover and composition of the vegetation, monthly and seasonal yields, growth of the short grasses in height, growth and number of buffalo grass stolons, and amount of litter and debris present at each location. General correlations between cover, yield and growth of the short grasses were also made. In order to make the data more comprehensible environmental conditions affecting growth were measured during the period of study.

Representative areas in each of the pastures were selected for study and protected from grazing by exclosures for the entire growing season of 1946. Twenty clip quadrats, each a meter square, were laid out inside these experimental areas.

Since the basal cover of vegetation bears a direct relationship to the value of a pasture, all quadrats were charted with a pantograph at the beginning of the season. In charting, only places without cover of native perennial grasses larger than .8 of an inch in diameter were considered bare. The percentage of basal cover for each species in all quadrats was computed by the use of a planimeter. The average of the twenty quadrats at each location was used as the representative cover for the pasture.

The total number of forbs and the number for each species per 100 square feet were determined in all of the pastures. This was accomplished by using two stakes and a chain to draw 10 to 15 circles, each having an area of 100 square feet, at representative locations throughout the pasture. The native forbs were counted and identified in the circles and the average taken as representative of the forb population of the pasture.

Since the value of a pasture lies primarily in its ability to produce forage for livestock consumption, the monthly and seasonal yields of each pasture were determined. Ten quadrats in each of the

exclosures were clipped once a month from April to September, inclusive, and all vegetation was air dried and weighed. The amount of short grass in pounds per acre for each month of the growing season was determined in all pastures. The sum of the monthly yields was computed as the seasonal yield for the clipped series. The other ten quadrats in each pasture were set aside to be harvested only at the end of the growing season. They were clipped at the end of July, however, to avoid loss of dormant vegetation due to the midsummer drought. The final clipping was made the last of September and the average weight of the air dried forage was computed as the seasonal yield for the unclipped series in each of the pastures.

The growth in height of the two major constituents of the short grass prairie, buffalo (*Buchloe dactyloides*) *and blue grama* (*Bouteloua gracilis*), was measured every two weeks throughout the growing season. This was done by making at least five measurements of each species in each quadrat. Averages were thereby determined for the clipped and unclipped series. The differences in heights for each successive measurement was assumed to be the growth for a period of two weeks. The average total growth during one month for each species was determined by taking the sum of the two measurements made during that month.

Buffalo grass stolons have a definite effect upon the basal cover because of their ability to spread rapidly. The growth of stolons was measured every two weeks. In order to accomplish this, twenty vigorous stolons were selected for measurement within each exclosure and a 16-penny nail was placed at the growing tip of each stolon. The distance which the stolon extended past the nail at the end of two weeks was the growth made for that period. The average increase in length was assumed to be the growth made by living stolons in each pasture. On May 15, the number of living and dead stolons per square meter was determined by making 10 separate counts in representative areas throughout the pasture.

The amount of litter and debris was observed to vary appreciably in the different pastures. The amount of litter and debris in pounds per acre was determined in each of the pastures. This material was collected by hand from representative square meter areas and the average weight was taken as the amount found throughout the pasture. Litter was assumed to be that old vegetative material that forms a compact mulch on the surface of the soil, while debris was assumed to be the old vegetative growth, including old flower stalks, that lies loosely strewn about on top or intermixed with the new growth of grass.

The seasonal rainfall was obtained by placing two rain gauges at centrally located points. The average of the two gauges was assumed to be the rainfall for all of the pastures studied. Daily temperature records were obtained from G. W. Matthews of the U.S. Weather Bureau Station at Quinter, Kansas, about seven miles west of the areas under study. The mean temperature for each month was computed and compared with the normal mean for that period.

The total amount of soil moisture was determined every two weeks to a depth of five feet by the use of a geotome. These determinations were made on all pastures. Monthly computations were made from an average of the two bi-weekly samplings.

The hygroscopic coefficients* for somewhat similar soils at Hays, Kansas, were used for determining the available moisture at the depths of 0-6 inches, 6-24 inches, and 24-60 inches. Hays is about 48 miles east of Collyer and the hygroscopic coeffieients are not exact the same but they are sufficiently similar for the purpose of this study. The total soil moisture minus the hygroscopic coefficient of the soil was assumed to approximate the amount of soil moisture that is available for plant use.

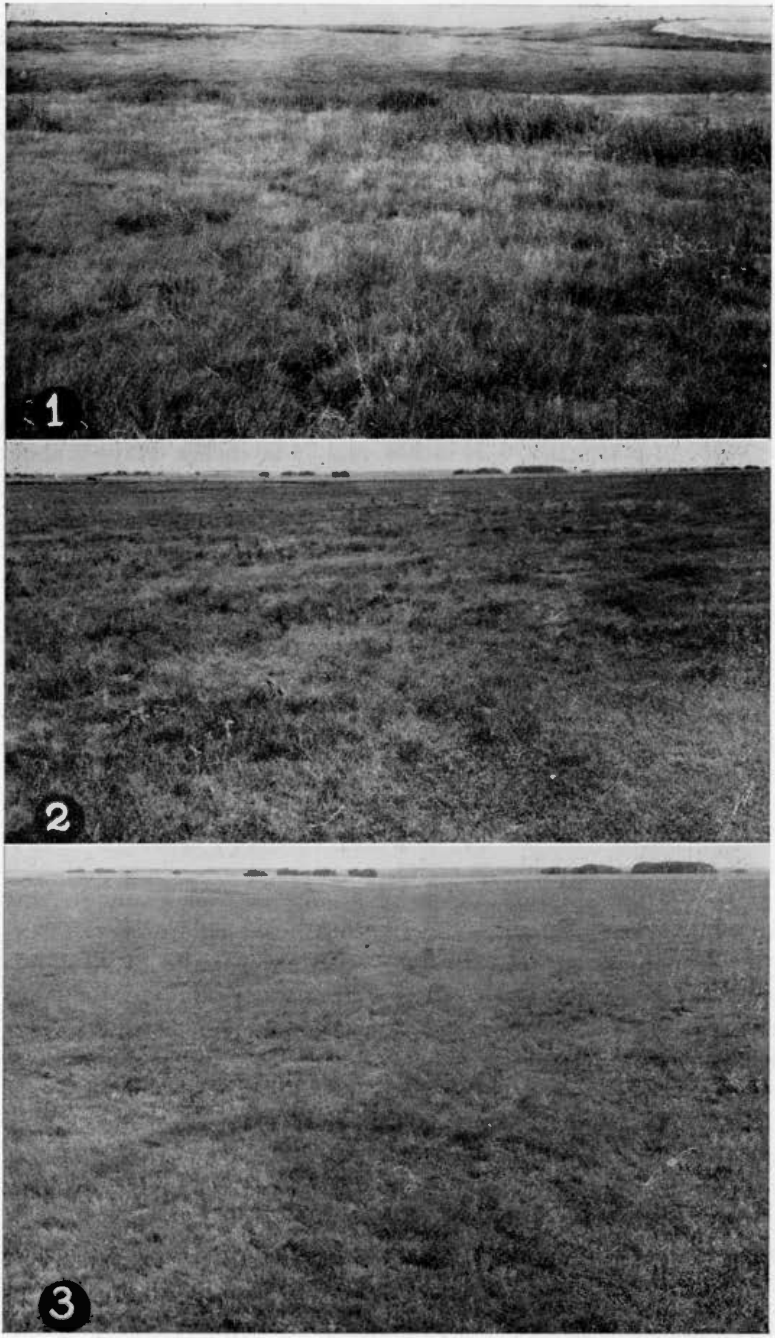
Results

History and Description of Pastures Studied

The pastures selected for study are located near Collyer, Kansas, which is about 100 miles east of the Colorado state line and 90 miles south of the Nebraska state line. The elevation is approximately 2580 feet above sea level. All five pastures lie within an area five miles in diameter and on typical gently rolling terrain with similar upland soils of the Holdrege series.

The pastures of this region have gone through many striking changes in response to extreme variations in the environment. During the drought period from 1933 to 1940, the vegetation of the native prairie was reduced to a few relicts with many new undesirable plants gaining possession (Weaver and Albertson, 1944). During the six normal or above-normal years that followed the drought the pastures recovered very rapidly. Those that were bare required much longer to recover than the ones with only scattered remnants of the original vegetation. Even the nearly bare pastures made a comparatively quick recovery because of the rapid spread of buffalo grass. This was especially true if these areas were subjected to moderate or heavy grazaing which removed the competition of weedy annuals.

*Hygroscopic coefficient—a term used to designate the amount of water the soil can take up from an approximately saturated atmosphere at a constant temperature when exposed in a layer about 1 millimeter in thickness. A soil which contains no more water than the hygroscopic coefficient is regarded as incapable of yielding water to plants. Any amount over the hygroscopic coefficient, therefore, is available for plant use.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Pasture number 1 contains 60 acres and was classified as ungrazed. During the drought years (1931 to 1940) it supported two saddle horses for approximately three months out of the year and from 1940 to 1946 the pasture was ungrazed. Before the drought a heavy stand of buffalo and blue grama grass grew on the uplands, with big bluestem (*Andropogon furcatus*) occupying the lowlands and buffalo wallows. During the dry years, however, all of the bluestem disappeared and the lowlands were invaded by the short grasses and western wheat grass (*Agropyron smithii*). Considerable dusting* also occurred on the uplands which laid bare large areas and killed much of the short grasses, giving the pasture a "patchy" appearance. Many kinds of undesirable weedy annuals, principally sunflowers (*Helianthus annuus*) and lamb's quarters (*Chenodopium album*), invaded these areas. The shading effect of these rank weeds added to the detrimental effect of dust which killed some of the grass and thereby made the bare areas even larger. Despite these conditions the grass retained enough cover to insure good pasturage during the years of drought. During the good years that followed the drought the pasture gradually improved, but there were still many bare areas. Pastures of this kind are at present fairly common in this community. At the beginning of the study the principal grasses found on the uplands were buffalo and blue grama grass, but scattered plants of sand dropseed grass (*Sporobolus cryptandrus*) and Texas crab grass (*Schedonnardus paniculatus*) occurred in the open areas. These grasses were very tall and formed a high foliage cover but close examination revealed that numerous open spaces occurred between the clumps of grass (Fig. 1). The common native forbs of these area were plentiful throughout the pasture.

Pasture number 2, the undergrazed location of 130 acres, had been subjected to a varied grazing program, but over the period of 15 years it was considered to be underutilized. From 1931 to 1940 it carried from 5 to 10 head of cattle on a six months basis. The pasture was moderately grazed during the growing seasons of 1940 through 1943 with about 25 head of cattle, but for the past three

*Dusting—A colloquial term used to describe the covering of vegetation by wind blown dust.

Fig. 1. General view of pasture number 1, the ungrazed location. Many large areas throughout the pasture were covered with weedy annuals. The irregular dark patches in the foreground are bare areas between the cover of short grasses.

Fig. 2. In the undergrazed pasture, spot grazing was evident as shown by the lighter colored areas. Many weedy annuals began to appear in areas not covered by the short grasses.

Fig. 3. Pasture number 3, the moderately grazed location, had an almost solid cover of grass.

years there have been only 5 head of milk cows grazing during the growing season. Before the drought a solid cover of buffalo and blue grama grass was found on the uplands throughout the pasture. During the following dry years the cover of grass steadily decreased and the bare spaces became larger and more numerous. When a little rain did fall a large number of weeds appeared which, due to the shade they cast, helped kill the nearby grasses. A small amount of

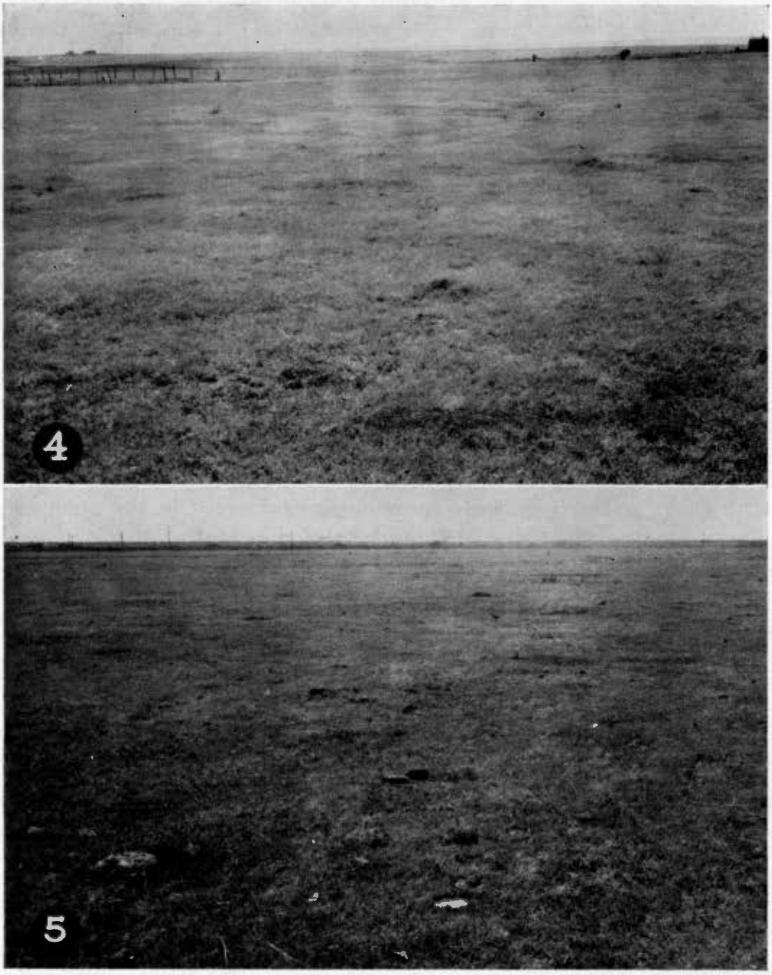

Fig. 4. General view of pasture number 4, the overgrazed location. The short grasses were closely grazed. Many bare areas, like those apparent in the foreground, were common throughout the pasture.

Fig. 5. The grass in pasture number 5, the heavily grazed location, seldom exceeded an inch in height and was generally less than .5 of an inch tall.

spot grazing was found where only favored areas were utilized, while the remainder of the pasture was undisturbed (Fig. 2). The intensity of grazing became lighter at greater distances from the farm buildings. The pasture contained numerous open spaces that were covered by mats of old grass and many little weedy annuals were beginning to appear in these open spaces.

Pasture Number 3, the moderately grazed location, contains 80 acres and had an average stocking rate of 15 animal units on a basis of 6 months. The stocking rate during the drought was much less than during good years that followed. It had a solid cover of grass until the dust storms of 1935. During these "black blizzards" and subsequent years much of the grass disappeared leaving only widely scattered clumps which furnished considerable forage. At no time, however, did the pasture have the appearance of a cultivated field as did those that were more heavily utilized. A few weeds appeared between the clumps of grass, especially in 1937 and 1938. Gains in the cover of grass were also made on nearby pastures in 1937 and 1938 but considerable losses occurred again in 1939 (Weaver and Albertson, 1944). After 1940, when soil moisture was plentiful, the original amount of cover was quickly restored. When the study was initiated, pasture number 3 appeared to be uniformly grazed with about 30 per cent of the area left undisturbed (Fig. 3). There was a good cover of vegetation composed of scattered, vigorous blue grama plants surrounded by a mat of buffalo grass. The few open spaces were well protected by a layer of old growth. Very few weeds appeared except in areas that were dusted heavily. The forbs native to this area were plentiful throughout the pasture.

Pasture number 4, the 77 acre overgrazed site, was stocked with 30 head of cattle from 1931 to 1940; 35 to 40 head from 1940 to 1945; and 20 head in 1945. The pasture was grazed every month of the year with some supplemental feed furnished during the winter. Although it was grazed fairly short before the drought it formed a solid cover with very few weeds but as the drought continued the cover was reduced so that by 1937 the pasture resembled a weedy cultivated field. When the years of normal rainfall returned, however, the cover of natural vegetation was gradually restored. Recovery was slow at first due to the sparseness of the vegetation but, the rate of spread became accelerated as the cover became more dense and by the end of the growing season of 1945, the buffalo grass stolons formed nearly a solid cover. At the beginning of the study the pasture had a cover of closely grazed grass with numerous small bare spaces between the areas occupied by buffalo grass (Fig. 4.)

The plants of buffalo grass varied in size but for the most part they were small and occurred at intervals along the stolons where roots anchored the runners to the ground. Upon close examination the cover was found to be a mass of intermingled stolons. There was evidence of some sheet erosion around these small clumps of vegetation.

Pasture number 5, classified as heavily grazed, contained 80 acres which carried 40 head of cattle on a year-round basis for the past 15 years. This area had a fair cover before the drought but was always kept very short. During the first two years of drought (1933 and 1934) most of the short grasses were killed and at the close of the dust storms in 1935 the cover was reduced nearly to nil. Often tufts of short grass .5 to 2 inches in diameter were spaced at distances of several yards. Many weeds filled the pasture until the last two or three years when the rapid growth of numerous buffalo grass stolons nearly covered the ground. At the beginning of the study the grass in this pasture was very short, sometimes less than .5 of an inch and nearly always less than 1 inch tall (Fig. 5). The cover was almost entirely buffalo grass stolons rooted down at intervals. There were very few native forbs. The unpalatable, drought resistant salmon-colored mallow (*Malvastrum coccineum*) made up the bulk of the forb population of the pasture. Many bare spaces were present with a considerable amount of sheet erosion.

Environmental Conditions During Period of Study

The total rainfall for the growing season of 1946 (April to September, inclusive) was 16.65 inches which is about 1.24 inches above normal. For the months of June and July, however, it was considerably below average being less than half normal during the latter month. Nearly half the rainfall in 1946 came during September which commonly is near the end of the growing season for the short grasses (Table I). Above normal temperatures occurred during June and July when rainfall was low (Table I).

Table I. The temperature and rainfall for the growing season of 1946 at Collyer, Kansas.

		Temperature (Degrees F.)				
Month	April	May	June	July	Aug.	Sept.
Mean '46	58.4	56.8	73.2	79.2	75.0	66.3
Normal Mean	51.6	63.0	72.0	79.0	76.6	68.0
Deviation	+6.8	—5.2	+1.2	+0.2	—1.6	—1.7
		Rainfall (Inches)				
1946		2.93	2.54	1.25	2.58	7.00
Normal	2.05	2.81	3.29	2.80	2.38	2.08
Deviation		+0.12	—0.75	—1.55	+0.20	+4.92

All pastures had soil moisture available for plant growth to a depth of two feet during the first three months (Table II). The greatest amount was found in the first six inches. The moderately grazed pasture had a plentiful supply for that period, with 10 to 20 per cent available. The other pastures contained considerably less, with slightly more in the ungrazed and undergrazed locations than was found in the overgrazed and heavily grazed sites. The major portion of the drought occurred in July which resulted in a much decreased soil moisture content. No moisture was available in the overgrazed and heavily grazed pastures to a depth of 12 inches, while only slight amounts were present in the other three areas. In the second foot of soil only the moderately grazed pasture had any

TABLE II. Approximate percentages of available soil moisture to a depth of 5 feet for all pasture types during the six summer months, 1946.

Depth	Location	April	May	June	July	Aug.	Sept.
0- 6"	Ungrazed	8.5	12.4	8.2	.2	5.6	14.9
	Undergrazed	10.5	13.2	5.4	.5	5.0	18.0
	Mod. Grazed	14.6	19.8	12.3	2.7	7.7	19.0
	Overgrazed	3.1	14.1	7.3	—1.4	—0.1	14.1
	Heavily Grazed	4.6	14.1	6.0	—0.4	0.2	14.7
6-24"	Ungrazed	6.8	2.3	0.7	—1.5	0.3	5.1
	Undergrazed	8.2	6.5	4.6	0.1	0.4	4.6
	Mod. Grazed	12.6	11.2	9.9	2.3	2.7	5.0
	Overgrazed	1.6	4.1	4.3	—0.8	—0.9	1.8
	Heavily Grazed	5.0	5.4	1.8	—1.6	—0.7	4.4
24-60"	Ungrazed	—2.3	—2.3	—2.8	—2.8	—3.0	—3.2
	Undergrazed	—0.6	—1.6	—1.3	—1.4	—0.9	—2.6
	Mod. Grazed	2.6	0.9	0.2	—0.9	—1.7	—1.4
	Overgrazed	—3.1	—3.0	—3.1	—3.4	—3.4	—3.0
	Heavily Grazed	—2.0	—2.9	—3.8	—3.8	—2.8	—2.6

appreciable amount of moisture. Although the rainfall in August was above normal the soil moisture was practically unavailable to a depth of two feet in the overutilized pastures as compared to a percentage of 5 to 7 per cent available at the other three locations. The rainfall in September was nearly 5 inches above normal, which again restored available moisture to two feet in all pastures. The first six inches carried a very high percentage of the moisture. No water was available from a depth of 2 to 5 feet for any month in any of the pastures except for a slight amount during the first half of the season at the moderately grazed location.

With hardly an exception, available soil moisture was most plentiful at the moderately grazed location. The soils of the underutilized pastures consistently held more moisture than was found in the pastures that had been overutilized.

Basal Cover and Composition of the Vegetation

The average basal cover of the twenty quadrats pantographed in the ungrazed pasture was 52.9 per cent (Fig. 6). This included 31.1

per cent of buffalo grass and 21.6 per cent of blue grama, with only a trace of sand dropseed and Texas crab grass. The cover was composed of large clumps of blue grama and mats of buffalo grass with very few stolons. Numerous bare spaces were found in the center

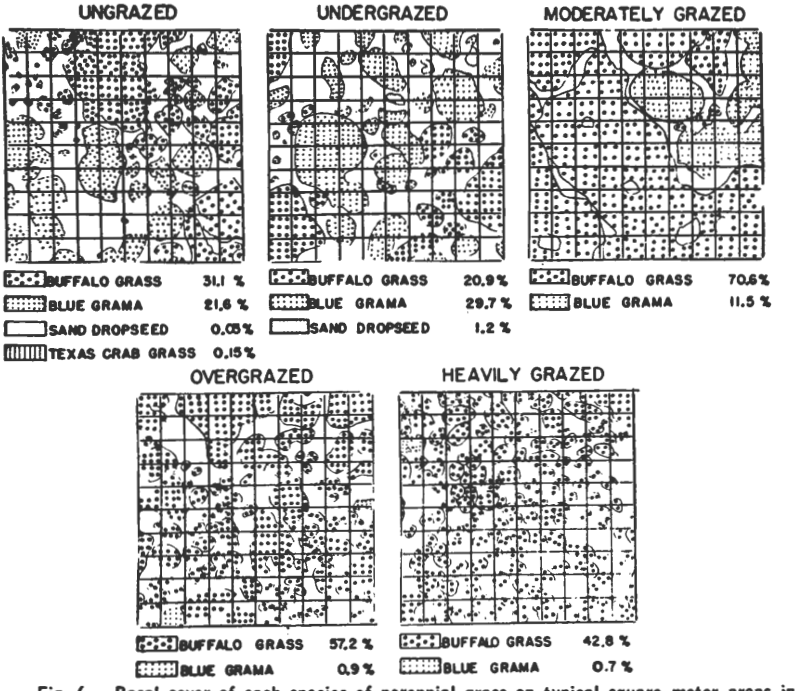

Fig. 6. Basal cover of each species of perennial grass on typical square meter areas in the different pasture types.

of the blue grama plants. Seventeen different spacies of native forbs were identified and an average of 29.8 plants were counted per 100 square feet (Table III). The principal forbs were the salmon-colored mallow, few flowered psoralea (*Psoralea tenuiflora*), wild onion (*Allium nuttallii*), and scarlet gaura (*Gaura coccinea*).

The total basal cover in the undergrazed pasture was 51.8 per cent. Blue grama was the principal grass having a cover of 29.7 per cent as compared with 20.9 per cent for buffalo grass. Sand dropseed grass was fairly common with an average cover of 1.2 per cent. This pasture supported more native forbs than any of the others, having an average of 39.5 plants per 100 square feet. There were, however, only 12 different species, most important of which were the few flowered psoralea, ragweed (*Ambrosia psilostachya*), wild onion, salmon-colored mallow and scarlet gaura.

The moderately grazed pasture had a heavy stand of grass with an average basal cover of 82.1 per cent. Although blue grama comprised only a small part of the total cover (11.5 per cent), the scattered plants were healthy and vigorous. Almost all of the area be-

TABLE III. Average number of each species of native forbs per square meter in each pasture type.

Exclosure Number	I	II	III	IV	V
Astragalus mollissimus				.4	.7
Malvastrum coccineum	12.1	4.9	12.1	1.5	4.1
Psoralea tenuiflora	6.5	10.8	3.9	.2	.5
Gaura coccinea	2.7	3.8		.1	
Allium nuttallii	3.3	6.2	1.5	.4	.2
Sideranthus spinulosus	.9	.2			
Gutierrezia sarothrae	.6				
Ratibida columnaris	1.8	.3	2.5		
Lygodesmia juncea	.3				
Aster multiflorus	.1		.2	3.2	
Astragalus shortianus	.2		.2		
Liatris punctata	.1			.2	
Callirrhoe involucrata	.6	.3		1.6	1.1
Vernonia baldwini	.2				
Opuntia macrorrhiza	.1		.4	.8	2.
Hymenopappus corymbosus	.1		.1		
Rumex altissimus	.1		.1	.1	
Polygonum ramosissimum	.1		.3	.2	
Ambrosia psilostachya		10.7	4.4	.2	1.4
Anemone caroliniana		2.0	4.5		
Cirsium undu atum		.1		.4	
Meriolix serrulata		.1			
Astragalus missouriensis		.1		.1	
Cogswellia macrocarpa			1.4	.7	
Solidago mollis				.2	
Artemisia kansana			.9		
Verbena bipinnatifida				.6	.1
Total No. of Forbs	29.8	39.5	32.5	10.9	8.3

tween these plants was covered with buffalo grass. Native forbs were numerous throughout the pasture, averaging 32.5 plants per 100 square feet, which included 14 species. The predominant forbs were salmon-colored mallow, wind flower (*Anemone caroliniana*), ragweed, few flowered psoralea, and prairie cone-flower (*Ratibida columnaris*).

The basal cover of 58.1 per cent in the overgrazed pasture was made up of 57.2 per cent of buffalo grass and the remainder was composed of blue grama and a trace of sand dropseed. It is significant to note that the tufts of grass were very small, which allowed many bare spaces to exist between the clumps. The native forb population of the pasture was relatively small, with only 10.3 plants per 100 square feet, but comprised 17 different species. The principal forbs were the many flowered aster (*Aster multiflorus*), salmon-colored mallow, and the prickly pear cactus (*Opuntia macrorrhiza.*)

Of the total cover of 43.6 per cent found in the heavily grazed pasture, buffalo grass formed 42.8 per cent. The few relict blue grama plants formed a cover of only .7 per cent. The numerous small clumps shown in Figure 6 represent the rootings of stolons as they

spread out to cover the ground. Only about one-fourth as many native forbs (8.3 per 100 square feet) were found here as compared to the number found in the moderately grazed pasture. Of the eight different species of forbs the most common were salmon-colored mallow, ragweed, and purple poppy mallow (*Callirhoe involucrata*).

Yields of Dry Forage

Seasonal Yields

In the ungrazed pasture the total yield from the quadrats clipped each month was 2438 pounds per acre (Fig. 7). On the unclipped

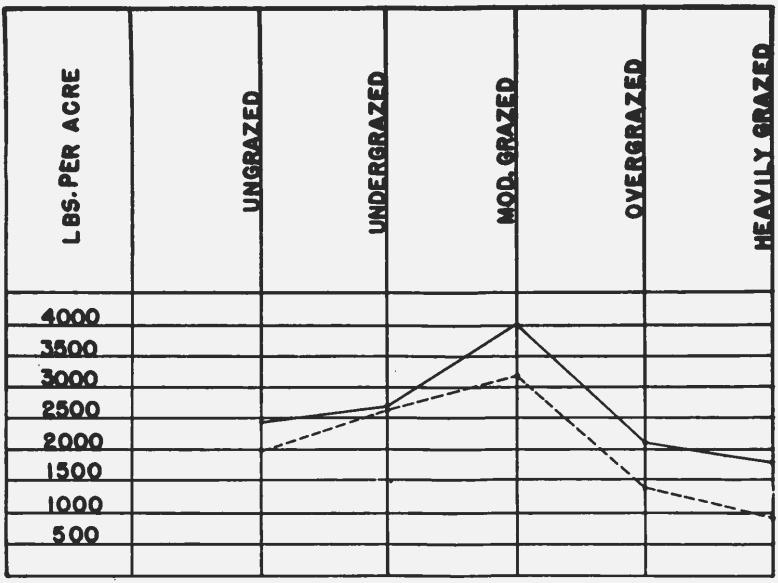

Fig. 7. Average seasonal yield of short grass in pounds per acre for the clipped and unclipped series of quadrats in each pasture.

series (clipped at end of season) it was only 1988 pounds per acre, or 81.6 per cent of the amount from the clipped quadrats.

The average amounts of forage produced from the two treatments on the undergrazed location were nearly the same, being 2686 pounds per acre on the clipped series and 2659 pounds for the other group.

The moderately grazed pasture had a forage production of approximately two tons (4001 pounds) per acre in the clipped series. Only 79.7 per cent as much (3192 pounds) was collected from the unclipped group.

On the overgrazed area an average of 2090 pounds of dry forage was produced in the quadrats that were clipped each month. About two-thirds of this yield or an average of 1388 pounds was collected in the unclipped series.

On the heavily grazed pasture the yield for the clipped series was 1774 pounds but only 941 pounds per acre on the unclipped group.

Monthly Yields

In the ungrazed pasture, the monthly productions were 723, 839, 460, 233, 143, and 38 pounds per acre, respectively, from April to September, inclusive (Fig. 8). Approximately 81.8 per cent of the total yield was produced during the first three months.

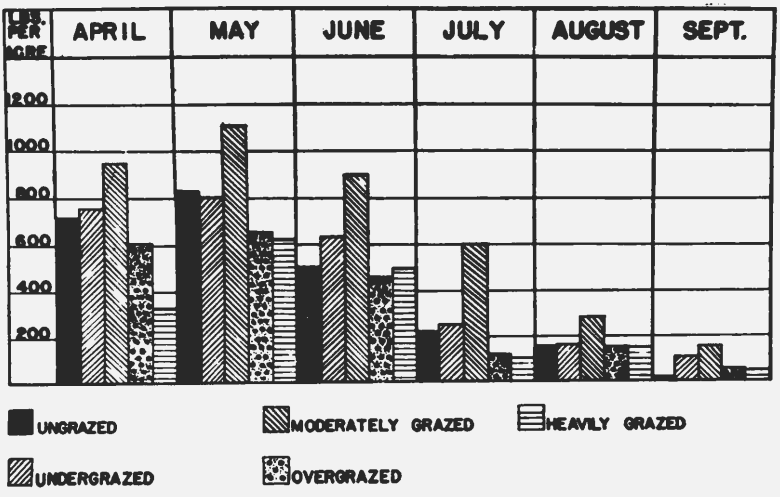

Fig. 8. Average yield of short grass in pounds per acre for each month of the growing season in all pastures.

May was the highest producing month (800 pounds) in the undergrazed pasture, followed by April (757 pounds) and June with 626 pounds, making a total for the three months of 2183 pounds or 81.7 per cent of the production for the entire season. The yield decreased each month after June, with only 241 pounds in July, 152 in August and 107 in September.

In the moderately grazed pasture, 1111 pounds per acre of forage were collected in May as compared to the low of 144 pounds in September. Over 900 pounds were produced during both months of April and June. July followed with 608 pounds while August yielded

only 271 pounds. Nearly three-fourths (74.4 per cent) of the total yield was produced during the first three months.

The overgrazed pasture yielded 612, 656, and 460 pounds per acre, respectively, for April, May, and June. The yield for these three months represented 86.0 per cent of the total for the season. The production dropped to 134 pounds in July followed by a slight rise in August (164 pounds) and then a decrease to only 53 pounds in September.

During the months of April, May and June 1340 pounds were produced in the heavily grazed pasture representing 75.5 per cent of the total yield. The monthly productions in the order of their occurrence were, respectively, 374, 616, 499, 121, 166, and 44 pounds per acre.

Correlation Between Basal Cover and Yield

Examination of the data presented in Table IV shows only a general correlation between basal cover and seasonal yield. The pounds of forage per 1 per cent cover ranged from 34 for the overgrazed to 52 for the undergrazed pasture. The more heavily utilized locations had less production in relation to cover than did any of the other three areas. This indicates that the growth of grass in height must also be considered as a factor in the production of forage. The larger amount of forage in relation to cover in the undergrazed pasture as compared to the moderately grazed location indicates that other factors besides cover and the height of grass play a part in production.

TABLE IV. A comparison of the basal cover and seasonal yield of the short grasses in the five pasture types.

Pasture Type	I	II	III	IV	V
Basal Cover	52.9	51.8	82.1	58.1	43.6
Seasonal Yield*	2438	2686	4001	2009	1774
Pounds of Forage per 1 per cent Cover	46	52	49	34	40

*Sum of the monthly yields.

Growth of Grass in Height

The results of this portion of the study are also presented in two groups, the clipped and the unclipped series. It should be remembered that the clipped series represents those areas which were harvested each month while the other group was clipped only twice, once in July and again in September.

Clipped Series

In the ungrazed pasture buffalo grass produced a seasonal increment of 8.1 inches as compared to 8.9 inches for blue grama (Fig. 9). The average total growth for both grasses was 8.5 inches, of

which 81.2 per cent occurred during the first three months. The monthly increment ranged from 3.4 inches in April to .15 of an inch in September (Fig. 10).

The total season's growth in the udergrazed pasture was 8.5 inches for buffalo grass and 10.3 inches for blue grama. The average

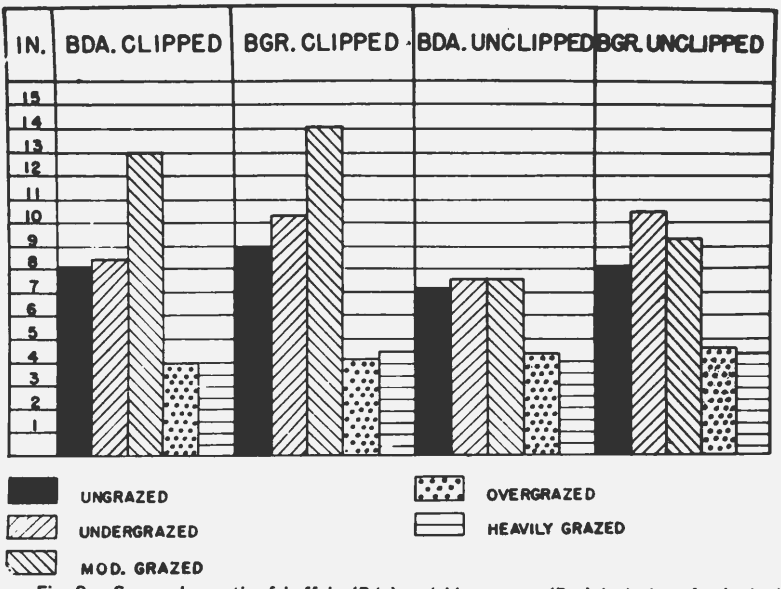

Fig. 9. Seasonal growth of buffalo (Bda) and blue grama (Bgr) in inches, for both the clipped and unclipped series of quadrats on all pastures.

of the two was 9.4 inches with 87.9 per cent of the increment produced during the first three months. Growth of both grasses was greater during April with 3.1 inches after which there was a gradual decrease until the low of .18 of an inch occurred in September.

The average total growth in the moderately grazed pasture was 13.6 inches comprising 13.0 inches for buffalo grass and 14.1 inches for blue grama. Slightly over two-thirds of the total increment (66.8 per cent) occurred during the first half of the growing season. The increment varied from the highest of 3.5 inches in May to the lowest of a little less than .4 of an inch in September.

The growth of grasses in the overutilized pastures was considerably less than the increment found at the other locations. The increment in the overgrazed pasture was 4.0 inches for buffalo grass and 4.2 inches for blue grama. Over three-fourths of this growth (79.3 per cent) was made during April, May, and June. The great-

est increment occurred during the first month, with 1.3 inches, but thereafter it gradually diminished each month to only .11 of an inch in September.

In the heavily grazed pasture, buffalo grass grew 3.6 inches as compared to 4.5 for blue grama, making an average total increment for the season of 4.1 inches. Of this total 74.7 per cent was pro-

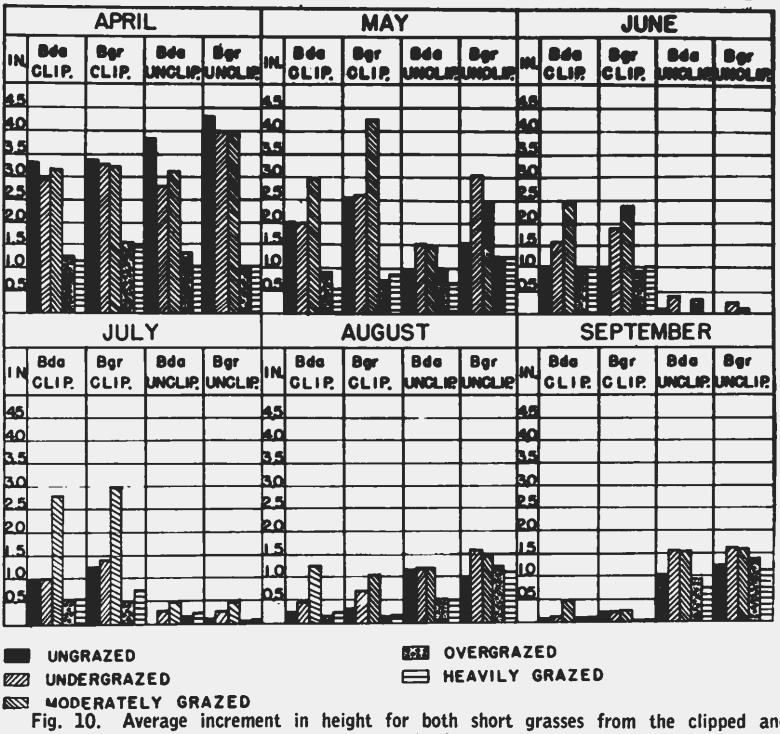

Fig. 10. Average increment in height for both short grasses from the clipped and unclipped areas of the five pastures for each month of the growing season.

duced during the first three months. The growth became successively less from April, with 1.32 inches, to .1 of an inch in September.

Unclipped Series

Since a clipping was made the last of July and thereby furnished some stimulus to the growth in this series only the comparison of seasonal increments is given.

In the ungrazed pasture the total increment for the short grasses was 7.7 inches. Blue grama made a growth of 8.2 inches as compared to 7.2 for buffalo grass (Fig. 9).

The average total increment of both grasses in the undergrazed pasture (9.0 inches) was greater than that found at any of the other

locations because of the exceptional growth of 10.5 inches for blue grama. For buffalo grass it was 7.5 inches.

The moderately grazed pasture produced an average increment of 8.4 inches for the season. Blue grama again made the greatest growth with 9.3 inches as compared to 7.5 inches for buffalo grass.

The total increment in the overgrazed pasture was 4.5 inches. Very little difference was found between the growth of blue grama (4.7 inches) and buffalo grass (4.3 inches).

The heavily grazed location produced an average total increment of only 3.9 inches. Blue grama made the greatest growth with 4.4 inches as compared to 3.3 for buffalo grass.

Correlation Between Yield and Increment

As indicated in Figure 11 a general correlation exists between

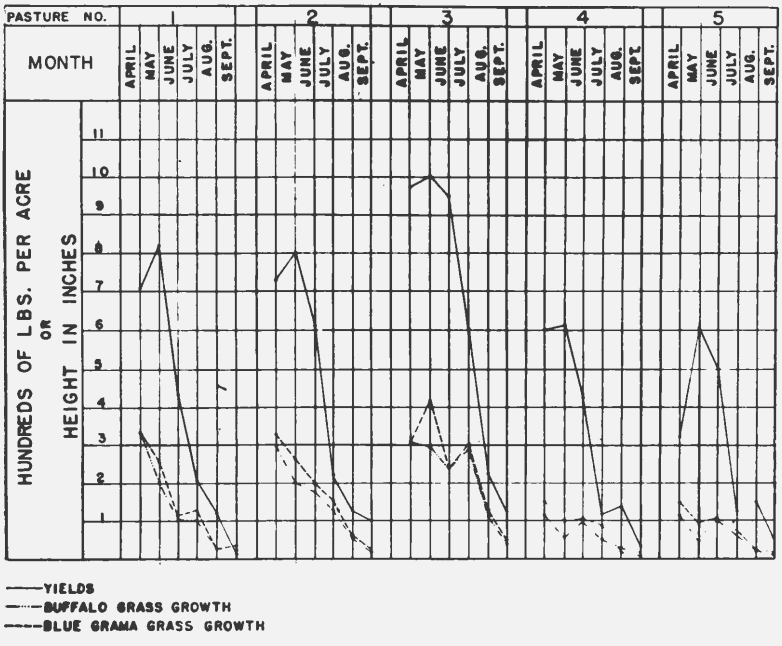

Fig. 11. Correlation between the growth of the short grasses in height and the production of forage for the six summer months at the different areas.

the inches of growth and the amount of forage produced by the short grasses.

The amounts of forage and increment produced during the first three months were similar in all pastures. The percentages of total increment for the first three months in pastures 1 to 5 were, respectively, 81.2, 87.9, 66.8, 79.3 and 74.7. The percentages of yield for

the same period, in the same order of pastures, were 81.8, 81.7, 74.4, 86.6 and 75.5.

At all locations an increase in yield from April to May was accompanied by a decrease in increment, but both yield and increment decreased with slight exceptions from May to September. For example, an increase in increment for the grasses in the ungrazed and moderately grazed locations occurred from June to July and the yield continued to decrease. In the overutilized pastures an increase in increment was accompanied by a decrease in yield from May to June while the reverse was true in both pastures from July to August. These exceptions from the general correlation suggest that factors other than growth in height enter into the production of forage.

Growth of Buffalo Grass Stolons

The rapid spread of buffalo grass stolons played an important role in the recovery and maintenance of the vegetative cover in the short grass prairies.

An average of 73 stolons per square meter was counted in the ungrazed pasture and of these 19 per cent were dead (Table V). The average total growth made by the stolons during the period of study

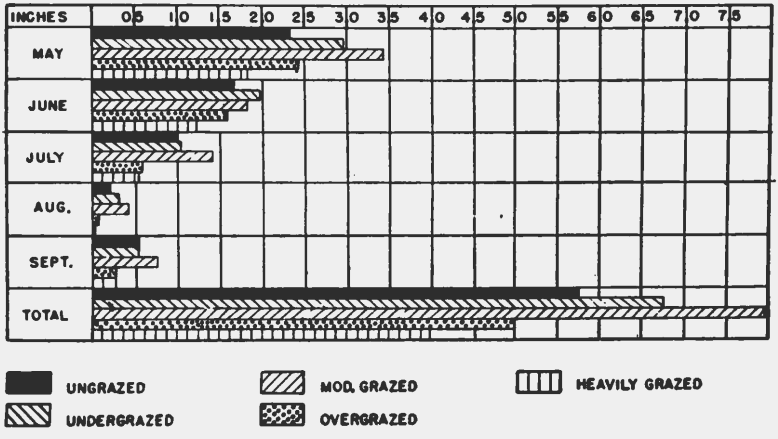

Fig. 12. Average growth of buffalo grass stolons in inches on each pasture.

was 5.75 inches (Fig. 12). The greatest and least increments occurred in May and August, respectively.

The undergrazed pasture contained a total of 78 stolons per square meter, of which 13.6 per cent were dead. The stolons made a total growth of 6.75 inches for the season which included increments

TABLE V. The number of live and dead buffalo grass stolons found per square meter in each pasture.

Pasture Type	No. of Lives Stolons	No. of Dead Stolons	Total No. of Stolons	% of Live Stolons	% of Dead Stolons
Ungrazed	59	14	73	80.8	19.2
Under-Grazed	66	12	78	86.4	13.6
Moderately Grazed	171	27	198	86.4	13.6
Over-Grazed	558	81	639	87.4	12.6
Heavily Grazed	378	63	441	85.7	14.3

of 2.95, 1.95, 1.05, .3 and .55 inches, respectively, for May, June, July, August and September.

Of the average of 198 stolons per square meter in the moderately grazed pasture, 13.6 per cent were dead. The greatest growth of stolons in any of the pastures was made at this location, averaging 7.95 inches for the season. The monthly growth became progressively less from the high in May (3.4 inches) to the low in August (.4 of an inch). The heavy rains in September brought the increment up to .75 of an inch.

The overgrazed pasture had the greatest number of stolons per square meter (639) and only 12.6 per cent of them were dead. Monthly increments were 2.4, 1.6, .6, .1 and .3 inches, respectively, for May. June, July, August and September, making a total increment of 5 inches.

In the heavily grazed pasture, 14.3 per cent of the 441 stolons found per square meter were dead. Only 4 inches of growth were produced by the stolons from May to September, inclusive. An increment of 1.8 inches was produced in May as compared to only .05 of an inch in August.

Litter and Debris

The ungrazed pasture had a surface layer of partially decomposed litter approximately 3.7 inches in depth which averaged 2004 pounds per acre (Fig. 13). The undergrazed pasture produced slightly less than this with 1789 pounds to an average depth of 2.9 inches, while on the moderately grazed location the amount was only 930 pounds to a depth of 1 inch.

The amount of litter found in the overutilized pastures was insignificant, with only 49 and 30 pounds per acre, respectively, on the overgrazed and heavily grazed locations. Small areas scattered throughout the pastures were covered to a depth of approximately .5 of an inch while the major portion of the soil was bare.

The amount of debris was much greater on the ungrazed pasture

than in the other areas (Fig. 13). An average of 1928, 952 and 524 pounds per acre, respectively, was collected from the ungrazed, undergrazed and moderately grazed locations. Because of the extreme-

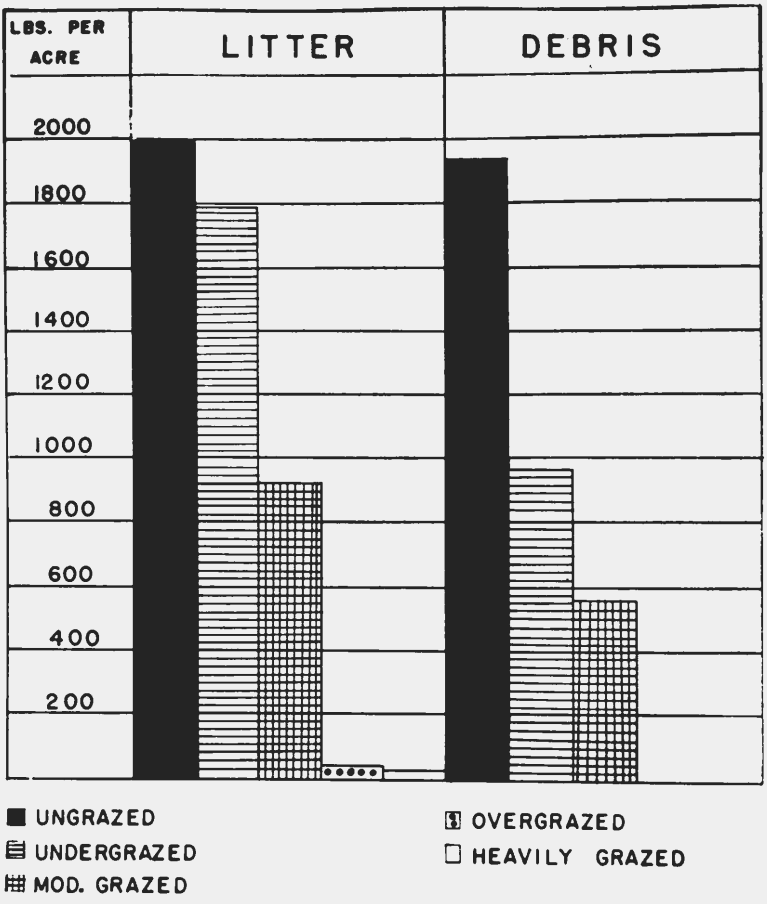

Fig. 13 Amount of litter and debris in pounds per acre for each pasture type.

ly close cropping of the grass no debris was present on either the overgrazed or heavily grazed pastures.

Discussion and Summary

Pastures which have been subjected to different intensities of grazing exhibit definite characteristics which reflect their past treatment. Five pastures were selected for study with reference to their history of grazing for the past 15 years and were classified as ungrazed, undergrazed, moderately grazed, overgrazed and heavily grazed. Some of the characteristics of these areas were studied dur-

ing the growing season of 1946 and a short discussion of the results will help to evaluate them. A comparison of the pastures was made along the following lines: (1) basal cover and composition of the vegetation; (2) monthly and seasonal yields of air-dried forage; (3) growth and number of buffalo grass stolons; (4) growth of the grasses in height; and (5) amount of litter and debris present at each location.

The principal limiting factor in the growth of vegetation in the Great Plains area is the amount of soil moisture available to the plants. Consistently more moisture was available for plant growth in the pasture which had been moderately grazed than was found on the underutilized and overutilized pastures. The variation in the amount of soil water in the pasture types might be accounted for through some of the effects of past treatment. More moisture enters the soil on which it falls if the ground has a good basal cover and sufficient litter and debris to absorb the water and retard runoff. Water is lost from the soil primarily by transpiration from the leaves of plants and by evaporation from the surface of the soil. In overutilized pastures the soil between the living plants was unprotected which allows a high rate of evaporation, but on underutilized pastures it was protected by a dense layer of old vegetation which reduced evaporation to a minimum. On the latter types of pastures, however, the larger amount of leaf surface left exposed throughout the season probably resulted in a greater rate of transpiration. The moderately grazed area has enough litter and debris to cover the few bare spaces and it was utilized sufficiently to retard excessive transpiration. This ability of the moderately grazed location to retain more of its soil moisture partially explains the results of this study.

The cover of perennial grasses on the moderately grazed pasture was nearly twice that found at the other locations. The total cover of short grasses was nearly the same for the underutilized and overutilized pastures, but the composition was very different. On the former location about equal amounts of buffalo and blue grama grass were found, while on the latter the cover was practically all buffalo grass. The composition of the vegetation on the moderately grazed pasture was found to be intermediate with 70.6 per cent cover for buffalo grass and 11.5 per cent for blue grama.

Several reasons might be advanced for these conditions. Although blue grama is the most drought-resistant, buffalo grass endures closer grazing than does blue grama because of the greater amount of leaf surface close to the ground in the former species.

The fact that buffalo grass had the ability to spread rapidly by means of stolon growth might also account for the large amounts of that grass in the overutilized locations. The abundance of old growth in the underutilized pastures hinders the growth of these stolons. They tend to grow either on top of the litter and debris where they cannot establish roots or under the old growth where the lack of sunshine kills them. This accounts for the relatively few stolons found in the areas with heavy debris.

No appreciable difference was found in the native forb population in the ungrazed, undergrazed, and moderately grazed pastures. A considerable reduction in numbers, however, was noted on the overgrazed and heavily grazed locations. The more palatable forbs such as the wild onion and few flowered psoralea became fewer as the degree of utilization increased. Heavier grazing practices seemed to decrease the forb population about one-third. The salmon-colored mallow, being unpalatable and very drought-resistant, was the most prevalent forb in all pastures.

The highest seasonal yield of short grass in pounds per acre was produced in the moderately grazed pasture, followed in the order of their yields by the undergrazed, ungrazed, overgrazed, and heavily grazed locations. Nearly twice as much forage was produced in the moderately grazed pasture as there was in either of the two overutilized locations. Although the yield was much reduced in the underutilized pastures it was greater than that produced on the heavily stocked areas. Production was greatest in May in all pastures with over three-fourths of the yield being produced in the first three months. The production of forage in the areas that were clipped each month was greater than those quadrats of the unclipped series, which were harvested only twice during the season, indicating that clipping does initially stimulate grass yields. Generally speaking, those pastures with a denser cover of vegetation produced a greater yield, but other factors such as the growth of grass in height, production of tillers and so forth caused some variation from close correlation.

The greatest growth of the short grasses in height was made in the moderately grazed pasture for the clipped series. The greatest increment occurred in April and the least in August and September for all pastures studied. The reduction of the increment in July, due to the drought, was not as noticeable in the moderately grazed area as it was at the other locations. In general, blue grama grass produced more growth than did buffalo grass. The stimulating effect of clipping upon the short grasses of the moderately grazed pasture

was shown by a difference of 5 inches in height between those quadrats harvested each month and those clipped only twice during the season. A difference of less than an inch was found in the underutilized pastures and hardly any difference at all occurred in the overutilized areas. In Figure 10, the differences in the monthly increments of clipped and unclipped series also illustrate this stimulating effect. After the first harvest in April, the growth in the clipped series for May, June, and July was over twice that of the unclipped series. After the unclipped group was harvested in July, the growth was much greater in that series than it was in the quadrats that were clipped each month, which indicated that the greatest stimulation occurs during the first two or three months after the initial clipping.

A very close correlation was found between the seasonal yield and the seasonal growth of grasses in height. When the monthly yields and increments were compared, however, a number of exceptions to close correlation between the two were noted. In some cases it was found that yield increased while increment decreased. During the first part of the season many new tillers developed, which would increase the yield but might even decrease the average height of the grasses. In periods of drought such as occurred during this growing season, the number of tillers decreased, which would cause an opposite effect on the relations of the two factors. During the period of seed production many buffalo grass seed burs are collected while clipping, which would raise the yield in relation to the increment in height.

The greatest number of stolons was found in the overgrazed and the least in the ungrazed pasture. There were many times more buffalo grass stolons in the overutilized pastures than were found in the other three locations. The large number of stolons was not entirely due to differences in the composition of the vegetation but to the amount of old vegetation. The growth of stolons in each of the areas studied followed the same general pattern as did the growth of tillers and total yield of grass. The total growth was greatest in the moderately grazed, followed in the order of production by the undergrazed, ungrazed, overgrazed and heavily grazed pastures. Over three-fourths of this growth was made during the first three months.

The ungrazed location contained slightly over a ton of litter, followed by nearly 1800 pounds in the undergrazed and 730 pounds for the moderately grazed area. Only 49 and 30 pounds were found, respectively, on the overgrazed and heavily grazed pastures. The

less intense the utilization of a pasture the more litter it will contain because more vegetation is left each year to decompose. Therefore an accumulation of large amounts of litter seem to indicate an underutilized condition. Debris also may be used as an indicator but it only tells the story for one or two years because it soon begins to decompose and form litter. Nearly twice as much debris was present on the ungrazed area as on the undergrazed location and four times as much as on the moderately grazed pasture. No debris was found on the two closely grazed pastures. In an earlier discussion it was shown that a certain amount of litter and debris, as defined in this paper, is beneficial to a well managed pasture, but too large an amount can be detrimental to growth of native vegetation.

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