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VEGETATION COVER, COMPOSITION, AND YIELD AS INFLUENCED BY SOIL, LITTER AND GRAZING INTENSITY

being

A thesis presented to the Graduate Faculty
of the Fort Hays Kansas State College in
partial fulfillment of the requirements for
the Degree of Master of Science

by

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Date 5-25-61 Approved F. Robertson
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THESIS ABSTRACT

Modha, V. V. 1960. Vegetation cover, composition, and yield as influenced by soil, litter, and grazing intensity.

Three pastures located 2.5 miles southwest of Hays were selected to determine the relationship of vegetation to depth of soil and different intensities of grazing. The pastures were classified as non-grazed, moderately-grazed, and heavily-grazed according to past use. Sites with deep and shallow soil were selected in each pasture to study in detail vegetational variations with respect to differences in soil and grazing intensity. When soil depth was less than 12 inches, soils were considered shallow and depths greater than 12 inches were considered deep. Ten quadrats, one square meter each, were selected on deep and shallow soil of each pasture.

A detailed study of vegetation and soil differences was made by studying the following factors: basal cover and composition, monthly yield of vegetation, growth of grasses in height, counting of forbs with three feet by one foot rectangle, textural classification of soil, amount of organic matter and soil pH, amount of mulch, and utilization of vegetation by livestock.

Basal cover increased with increased intensity of grazing. Deep and shallow soils of the heavily-grazed pasture had the highest basal cover when compared with the same type of soils of the non-grazed and moderately-grazed pastures. Composition of the species also varied according to the depth of soil and intensity of grazing. On deep soil of the non-grazed pasture, big bluestem was dominant while little bluestem dominated the shallow soil. On deep soil of both moderately-and heavily-grazed pastures,

buffalo grass, blue grama, and side-oats grama were the dominants. Blue grama, hairy grama, and side-oats grama were dominant on shallow soils.

Production of vegetation, mulch, and per cent organic matter was greater on deep and shallow soils of the non-grazed pasture as compared to the moderately-and heavily-grazed pastures. Deep soil of all three pastures produced higher vegetation, mulch, and organic matter than the shallow soil.

Percentage of organic matter was higher in the 0-to 6-inch layer than the lower 6-to 12-inch layer of soil in each type of soil and pasture. Organic matter content was greatest in deep soil than in shallow soil of each pasture.

Utilization of vegetation by livestock from the moderately-grazed pasture was 54.8 per cent while in the heavily-grazed pasture utilization was 77.8 per cent.

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INTRODUCTION

Grass is the natural cover on the soil in many places throughout the world. In many continents heavy grazing has deteriorated the grasslands and undesirable plants have replaced better forage species. Portions of North and South Africa, Greece, Spain, India, and Palestine are outstanding examples of the deteriorated grasslands due to overgrazing and periodic droughts (Renner, 1948).

In the United States, grasslands are extensive and cover parts of Wisconsin, Indiana, Missouri, Arkansas, and extend westward across the Dakotas, Nebraska, Kansas, to the Rocky Mountains. In the Southwest grasses spread across Texas into New Mexico and Arizona.

When the white man first settled the Great Plains, there was a complete cover of grass and a small portion of the range was under cultivation. Settlers rushed to this area from the East because of the fertile land and good cover of grass. As more land was cultivated, grazing pressure increased on the native prairie by increased livestock numbers. Overgrazing and improper management resulted in decreasing production of better vegetation. As a result undesirable low-yielding species which are resistant to grazing have increased in abundance. Bartlett (1883) states that the grasslands of Texas and nearby areas were highly productive and covered with good grasses. When the prairie land was given to the railroads in 1854, grazing use by livestock increased greatly and within a few years extensive grassland had deteriorated and became occupied by mesquite and prickly pear. Earlier Bidwell (1865) recognized that grasslands in California were deteriorated and high-yielding grasses were disappearing from the plains owing to improper management.

The grassland in Western Kansas is a part of the mixed prairie association with short grasses predominantly occuping uplands and tall grasses in the lowlands while a mixture of tall-and-short-grasses occupy the hillsides. Due to drought, dust, and intensity of grazing ground cover and production of tall grasses diminish while the cover of short grasses increases.

A thin cover of vegetation exposes the soil to serious erosion. Most of the exposed fertile soil is removed by rain and wind, leaving rock and gravel on the surface. Poor soil will support only poor cattle. Therefore, the livestock economy is seriously disturbed. Poor pastures, like poor crops, are expensive. In order to obtain maximum profits from a range it is necessary to graze an optimum number of livestock. The deteriorated grasslands and disturbed livestock economy raised the question of the proper investigation of grasslands. Much research work was then carried out to learn the effect of grazing upon the vegetation.

The purpose of this study is to investigate the difference in yields, basal cover, and composition in relation to depth of soil and different intensities of grazing on nongrazed, moderately-grazed, and heavily-grazed pastures during past years.

RELATED STUDY

Yield, or plant production, is the amount of forage a plant produces and is usually expressed as grams per square foot, pounds per acre, or tons per acre. Vinall (1934) states that there are two methods of estimating yields; one attempts to measure the herbage consumed by grazing animals, and the other measures the annual growth of herbage, or that available for grazing.

Basal cover is the area of ground actually covered at the base of the plant and it is stated as percentage of the total area.

Composition means the percentage each species contributes to the basal cover and it is expressed as a percentage with the total composition always 100 per cent, regardless of the basal cover.

Production, basal cover, and composition are measures of vegetative structure. Schwan et al. (1949) at Colorado studied and compared total annual as well as summer and spring forage production on heavily grazed, moderately grazed, and non-grazed Kentucky blue grass pasture. The authors found that a pasture grazed moderately produces twice the production that a heavily-grazed pasture produced while a non-grazed pasture produces three times the production of the heavily grazed. They concluded that as the intensity of grazing decreased the forage yield increased.

Kipple and Costello (1960) found that grazing treatments influenced the herbage production of important species of short grass vegetation. Continued heavy grazing caused a reduction in the total yields of vegetation, especially the better forage plants. However, a majority of the desirable species were able to maintain good plant vigor and yield under continued moderate use. Light grazing of the short grasses for several years allows them to maintain or improve their yields.

Lacey (1942) in West Central Kansas, studied forage yields of short grass pastures when non-grazed, lightly grazed, and moderately grazed and found that the non-grazed pasture produced a high yield but less than that of the lightly grazed pasture. Forage yields and basal cover of short grass were greatest on lightly grazed pastures while moderate grazing maintained a constant forage yield. Careful grazing practices following heavy grazing caused an increase in forage yields but not in basal cover of short grass.

Weaver and Albertson (1944), soon after the great drought of the thirties, made a survey of the shortgrass pastures in Western Kansas. In almost every instance, a decrease in production of blue grama and buffalo grass on the Great Plains under periods of drought was found to be almost directly proportional to the intensity of grazing in past years.

Tomanek and Albertson (1953) at Hays, Kansas, studied the seasonal yield and variation in basal cover and vigor of plants under different intensities of grazing. Basal cover was greater in heavily grazed pastures and least on non-grazed pastures. Non-grazed pastures produced a forage yield of 2,296 pounds per acre as compared to 1,323 pounds per acre for heavily-grazed pastures. Height of heavily grazed plants was shorter and had only about one-half as many stems per unit area as did those of the ungrazed area.

Sampson and Malmstem (1926) studying the forage species in Utah, found that removal of herbage four or more times in a season resulted in sharp decline in yield and in a reduced life span for the vegetation.

Diller (1937), in Indiana, studied the seedling reproduction in grazed and ungrazed areas and found that the cover of vegetation was less in grazed areas than that in the ungrazed areas. The ground cover consisted mainly of weeds because the unpalatable plants which previously occupied the area in the ungrazed condition had been destroyed and were succeeded by less palatable species.

On Southwestern ranges Nelson (1934) studied the influence of precipitation and grazing upon black grama grass. He found that the average density of black grama grass over a thirteen-year period was practically the same when under conservative grazing. Over-grazing decreased the density of black grama rapidly in dry years and greatly handicapped recovery through natural revegetation in favorable growing periods.

Branson and Weaver (1953), in Nebraska, studied the degree of degeneration that resulted from long periods of grazing and found that ungrazed hilltops and upper slopes were covered mostly with short grasses. In lowlands cover of the tall grasses were decreasing under grazing while that of short grasses increased. Basal cover of short grasses increased while the yields decreased under grazing. On the hillside and hilltop grass yield decreased but basal cover increased.

Launchbaugh (1955) studied the effect of grazing on (1) the course of plant retrogression from climax on grazed native pastures and (2) trends of secondary succession on pastures retired from grazing. The author found that certain species decreased as the intensity of grazing increased, while other species increased in percentage under utilization. Certain plants invaded grazed pastures and were not found in ungrazed areas. Launchbaugh concluded that little bluestem was the important decreaser under grazing.

Hansan and Stoddart (1940) studied the effect of grazing on bunch wheatgrass and found that heavily grazed plants have 14.33 per cent total carbohydrates while protected plants had 17.77 per cent. Heavy grazing also reduced root systems, seed production, and size and number of plants.

Kelting (1954) working in tall grass prairie in Central Oklahoma, found that grazing decreased plant production. Basal cover of moderately-grazed pastures was higher than that of non-grazed areas.

Pasture types in relation to intensity of grazing were studied by Tomanek (1948) near Collyer, Kansas. Data revealed that heavy utilization reduced yield over 70 per cent and that grazing too lightly also decreased production compared to moderately-grazed pastures.

Aldous (1930) studied the effect of different clipping treatments on yield and vigor of prairie grass vegetation. By applying treatments at two-week intervals he found that density of the vegetation decreased about

60 per cent in three seasons. Clipping at three-week intervals resulted in a 13 per cent reduction of density.

Riegel (1947), in Western Kansas, found that the tall native grasses seemed to be more susceptible to clipping than were the short grasses. In every instance where the grasses were clipped for several months, total height increased but weight decreased.

Biswell and Weaver (1933) recorded the effects of the removal of tops on root growth and on regeneration and yield of aerial parts. Blocks of well established sod of seven important native pasture grasses were transplanted into large containers, grown under field conditions and clipped fortnightly. Each species had an unclipped control. It was found that the basal cover of unclipped grasses decreased, plants failed to produce new rhizomes, and the depth of root penetration was decreased.

Robertson (1933) studied the effect of frequent clipping on development of certain grass seedlings and observed that, in general, frequent clipping retarded root penetration from 35 to 63 per cent and reduced yields from 80 to 98 per cent.

Blaisdell and Pechance (1949), in Utah, studied the effects of herbage removal on vigor of bluebunch wheatgrass and arrowleaf balsamroot and found that complete herbage removal of bluebunch wheatgrass and arrowleaf balsamroot is most injurious after the date when substantial regrowth is impossible and before maturity. The effect of clipping wheatgrass and balsamroot apparently depends upon the amount of herbage present during the storage period following cessation of growth. Subsquently, flower stalk production is more seriously affected by ground level clipping than is herbage; however, vigor can best be judged by a combination of the two.

Stapledon and Milton (1930), at the Welsh Plant Breeding Station, Aberystwth, found that plants cut to six inches yielded more than the

plants cut to ground level. Indications were that heavy or continuous utilization had a detrimental effect on herbage production and root development.

On a semidesert range in Arizona, Canfield (1939) reported that persistant cropping of all herbage of black grama to a two-inch stubble height or less eventually resulted in destructive reduction of basal cover, regardless of frequency of harvesting. Forage yield was reduced one half in three or four years and to zero in eight or nine years. Repeating this experiment on tobosa grass, Canfield found that the basal area increased with clipping at four inches but decreased with two-inch clipping.

Albertson et al. (1953) made a five year study from 1942-47 on the effects of different intensities of grazing on short grass in West Central Kansas. The authors discovered that when nearly 50 per cent of the production of grass was left on an area each year the total production removed from these locations for five years equalled total production on the areas where all growth was harvested. Clipping stimulated top growth, especially during the early years of study. During the first season, total elongation of tops was nearly three times as much on closely clipped as on non-clipped, and two times as much on moderately clipped. There was no great effect of top removal on basal cover except on closely clipped areas where crowns died in the centers and marginal tillers were more slender and sparse than elsewhere. Decrease in growth on closely clipped locations resulted in greatly reduced yields later in the study. Roots and tops suffered a 50 per cent reduction in weight when plants were clipped.

Graber (1931) working with Kentucky bluegrass in Wisconsin, found that unclipped potted plants produced abundant rhizomes, while those that were clipped seven times produced none. He concluded that not only did the amount of underground growth and total weight of top growth ultimately tend to

vary inversely with the frequency of clipping, but that reduced growth sometimes occurred for several months following excessive defoliation.

Robecker and Miller (1955), in Wisconsin, found that cutting at pasture stage, or four times at monthly intervals during the growing season, beginning one year after seeding, caused decreased vigor and density of big bluestem, switchgrass, and virginia wildrye. There was little or no decrease in vigor or density of Indian grass. Little bluestem decreased in vigor and herbage production in each cutting for the duration of the experiment. Side-oats grama increased greatly when clipped at the pasture stage.

One of the most important aspects of range condition and productivity of rangeland is the maintenance of mulch on the surface soil. Mulch is one of the indicators of utilization intensity during past years.

On mountain ranges in the Northwest, Pickford and Reid (1950) reported that an average leaf length of not less than 3 inches should be left to maintain the mulch and thus, maintain the climax species of bluebunch wheatgrass, sandberg bluegrass, and green fescue.

In California, Hedrick (1948) studied the mulch layer of annual ranges. He stated the importance of leaving sufficient forage residue at the end of each grazing season for protection of soil and for range improvement. Hedrick found that humic mulch seldom forms a discrete layer on annual ranges and pointed out the fact that continued heavy grazing reduces the amount of humic mulch on annual ranges.

Schwan et al. (1949) studied and compared the seasonal yield of mulch on heavily, moderately, and non-grazed Kentucky bluegrass ranges in Colorado. The authors found that an ungrazed range produced the highest yield of mulch and concluded that as the intensity increased the mulch decreased.

Hopkins (1954) at Hays, Kansas, studied the effect of mulch on grasslands of the mixed prairie. He collected mulch from the upland, lowland,

and hillside of heavily, moderately, and ungrazed areas. He found that each habitat of the ungrazed area yielded more than moderately and heavily-grazed areas. Ungrazed and grazed areas of the lowland yielded 22,610 pounds per acre and 1,740 pounds, respectively. Hopkins also found that mulch reduces soil temperatures and retards evaporation. Its effectiveness in reducing evaporation was greatest when the surface soil was moist. Rates of water infiltration and soil moisture content were consistently greater on soils with mulch than without mulch.

Sampson (1952) describes the importance of mulch as follows:

> Mulch is an intermediate link between the volume of forage produced and the organic matter of the soil. If this link is weakened the quality and yield of forage will decline, and an undesirable condition of the soil will result. Mulch helps to keep the seed in place during rain storms, improves the habitat for seed germination, protects seedlings from the elements, promotes early spring growth, maintains high production capacity of the soil, and minimizes soil erosion.

METHODS OF STUDY

Early in June, 1960, three different grasslands were chosen for study to determine certain differences that occur when the pastures are continuously non-grazed, moderately-grazed, and heavily-grazed. The study areas were selected on the basis of observations of the general appearance of vegetation and slopes. Both deep and shallow soils were chosen within each of the three pasture sites to determine vegetation responses to soil depth. Soil depth was determined with a soil auger. When depth was 0-to 12-inches soils were considered shallow and at depths greater than 12 inches they were considered as deep soil.

The detailed study of the differences of the vegetation and soils of the three pastures was made by studying the following factors: basal cover and composition, monthly yields of the forage, growth of the grasses in

height, counting of the forbs, textural classification of the soil, amount of soil organic matter, soil pH, amount of mulch, and utilization of the grasses by livestock.

Ten, square meter, quadrats were selected in each of the areas on deep and shallow soil in each of the three pastures. The non-grazed area was fenced and has been protected from grazing since 1902. In moderately and heavily-grazed areas, the selected quadrats were protected from grazing by use of "teepee" exclosures.

Basal cover and per cent composition of the species were determined by the point transect method. Nearly two hundred points on both deep and shallow soils of each pasture were recorded.

For the study of the structure of vegetation, typical quadrats two each on deep and shallow soils of each pasture were selected and pantographed June 28, 1960, before the first clipping. A planimeter was used to determine basal cover from the pantograph records.

Vegetation on each quadrat was clipped on the first day of each month from July to October to determine the monthly yield during the growing season. Height of the grasses was measured before each clipping. The clipped forage was put into a paper bag, properly labeled, air dried, and weighed. Plot weights were converted to pounds per acre of forage. Tall grasses, short grasses, and forbs were clipped and weighed separately. The grasses studied were classified as "short, mid and tall" as follows:

SHORT GRASSES

Buffalo grass	Buchloe dactyloides	(Nutt) Engelm.
Blue grama	Bouteloua gracilis	(H.B.K.) lag ex. Steud.
Hairy grama	Bouteloua hirsuta	Lag.

MID AND TALL GRASSES

Big bluestem	Andropogon gerardi	Vitman.
Little bluestem	Andropogon scoparius	Michex.
Side-oats grama	Bouteloua curtipendula	Michex.
Tall dropseed	Sporobolus asper	(Michex) Kunth.
Red three-awn	Aristida longisita	Steud.
Western wheatgrass	Agropyron smithii	Rydb.

The forbs growing on deep and shallow soils of each pasture were determined by a rectangle three feet by one foot. The number of forbs was counted on two rectangles adjacent to and located on opposite corners of each of ten quadrats.

For textural classification, soil samples were taken with a geotome from deep and shallow soil of each pasture. Each sample was then placed carefully in small tins and properly numbered. The percentage of soil seperates were determined by the hydrometer method.

To determine the amount of organic matter and soil pH, soil samples from 0-to 6-and 6-to 12-inches were taken with the geotome from deep and shallow soils of each pasture, in October, 1960. Each sample was then placed carefully in small tins, properly numbered and air dried. Total carbon was determined by the dichromate wet digestion method described by Bear (1955) and soil pH was determined by using an electrometer.

The mulch was collected from each quadrat on deep and shallow soils of the three pastures at the end of the growing season. The collected mulch was put into a paper sack, properly labelled, air dried and converted to pounds per acre.

To determine the utilization of forage from each pasture the vegetation that remained at the end of the growing period was clipped from five newly

selected quadrats from the unprotected grazed area irrespective of the depth of the soil. The grasses and forbs were clipped separately and placed in the separate paper sacks, properly numbered, air dried and weighed. The amount of vegetation utilized by cattle was determined from the difference in the yield between protected and grazed areas.

HISTORY AND DESCRIPTION OF THE STUDY AREA

The study was conducted on three pastures located approximately 2.5 miles southwest of Hays, Kansas. The topography of the study area is similar to that of the other areas found in the mixed prairie and is characterized by undulating rolling hills. Elevation ranges from 2,000 feet in the lowland to 2,200 feet on the highest hillside and table lands. Several tributaries, both large and small, drain into central ravines, thus creating a rough, broken topography (Albertson, 1937).

The history of grasslands with respect to past grazing was obtained from the owner of the grazed pastures and from the records kept by Fort Hays Kansas State College on the non-grazed and moderately-grazed pastures.

Non-grazed Pasture

This research area is a part of the Fort Hays State College Farm, comprising approximately 35 acres and generally referred to as the "Relict Area". The area has been protected from grazing and fire since 1902. Where soil is deep, big bluestem, a tall grass, is dominant while on the poor open and shallow soils little bluestem is dominant. The vegetation on this area is considered climax for the existing soils and climate.

Deep Soil. The study area was dominated by big bluestem and side-oats grama (Fig. 1). Western wheatgrass and tall dropseed were common and found scattered on the lowlands where the soil was deep and black. Little bluestem was found to a lesser extent on the slopes. Short grasses were

Figure 1. General view of deep soil of the non-grazed pasture showing dense growth of big bluestem. Sites having deep soil are clearly outlined by light-colored big bluestem.

not common but occurred sparsely intermixed with western wheatgrass. Many forbs were present throughout the growing season. The most common forbs were Amorpha canescense, Psoralea tenuiflora, and Solidago rigida (Table 1). The average soil depth was 21.8 inches varying from 18 to 30 inches (Table 2). The texture of the soil was silty clay loam having 24 per cent sand, 33 per cent silt, and 43 per cent clay (Table 3). Depth of mulch varied from 3 to 9 inches and averaged 5.5 inches.

Shallow Soil. The study site was located on the brow of the hill where the soil was thin and open with a limestone pavement. Little bluestem was dominant while side-oats grama was found scattered in the area (Fig. 2). The vegetation was not as thick as on the deep soil area. In the open spaces the forbs were numerous. The prominent forbs present were Solidago rigida, Psoralea tenuiflora, and Tragia ramosa (Table 1). Average depth of soil was 8.7 inches which varied from 6 to 12 inches (Table 2). The texture of the soil was clay loam to silty clay loam with sand, silt, and clay in the proportions of 24.8, 30.8, and 44.4 per cent, respectively (Table 3). Depth of mulch varied from 1 to 5 inches and averaged 2.25 inches.

Moderately-Grazed Pasture

The moderately-grazed site comprises approximately 800 acres. The area was fenced and has been moderately grazed by cattle during a major portion of the time since its acquistion in 1900. Short grasses were dominant on the top of the hill while mid grasses were found on the slopes and tall grasses were found on lowlands.

Deep Soil. The study area was dominated by buffalo grass, blue grama, and side-oats grama (Fig. 3). Big bluestem was common and contributed considerably to the total composition. Three-awn grass was scattered and forbs thickly populated the area. The dominant forbs were Aster ericoides, Solidago rigida, and Thelesperma gracile. The average depth of soil was

Table 1. Average occurence of forbs in 3' by 1' rectangle of non-grazed, moderately-grazed, and heavily-grazed pasture on deep and shallow soil

Name of Species	Deep Soil			Shallow Soil		
	N.G.	M.G.	H.G.	N.G.	M.G.	H.G.
1. Arenaria texana Britt.	-	-	-	-	-	2
2. Ambrosia psilostachya Gray.	1.5	1.5	12.5	2.5	9.5	13.5
3. Amorpha canescens Pursh.	4	2	2	2	-	-
4. Asclepiodora decumbens (Nutt.) A. Gray.	-	-	-	-	1	-
5. Aster ericoides L.	-	6.5	4	-	9.5	5
6. Aster multiflorus Ait.	3	2	2	-	-	-
7. Aster oblongifolius Nutt.	2	1.5	1	1.5	1	2
8. Callirrhoe involucrata (T.G.)A. Gray.	-	-	-	-	1	-
9. Castilleja sessiliflora Pursh.	1	1	1.5	-	-	-
10. Cirsium undulatum (Nutt.) Spreng.	-	1	1	2	2	1
11. Dalea enneandra Nutt.	-	-	-	-	1	-
12. Echinacea angustifolia DC.	2	2	1.5	1.5	3	2

Table 1 (Continued)

13.	Erigeron racemosus Nutt.	6	-	9	-	-	6
14.	Evolvulus pilosus Nutt.	-	1.5	2	-	1	2
15.	Gutierrezia sarothrae (Pursh) Britton and Rusby	-	2	3.5	-	2.5	14
16.	Helianthus annuus L.	-	-	1	-	-	1
17.	Houstonia angustifolia Michx.	2	2.5	1	1.5	5	1
18.	Hymenopappus corymbosus T.&G.	-	1	5	-	1	7.5
19.	Kuhnia glutinosa W. auth.	2	-	-	-	-	-
20.	Lesquerella ovalifolia Rydb.	-	-	1.5	-	-	5
21.	Lepidium densiflorum Sehrad.	-	-	1	-	-	1
22.	Liatris punctata Hook.	-	2	1	1.25	1.5	1.5
23.	Linum sulcatum Riddell.	-	1	1.5	-	1	1.5
24.	Malvastrum coccineum (Nutt.) A. Gray.	2	-	-	-	-	-
25.	Melilotus alba Desv.	-	-	2	2	1	2
26.	Morongia uncinata Britton.	1	1.5	1	2	2.5	1.5
27.	Oenothera serrulata Nutt.	2.5	2	1	3.5	1.5	2
28.	Paronychia jamesii T. & G.	*	1.5	1	2	2.5	1.5
29.	Pentstemon albidus Nutt.	1	1	-	-	1	-

Table 1 (continued)

30.	Petalostemon candidus (Willd.) Michx.	3	1	-	2.5	1	-
31.	Petalostemon purpureus (Vent.) Rydb.	-	2.5	13	-	4	8
32.	Polygala alba Nutt.	-	-	1	-	-	1
33.	Plantago spinulosa Deene.	-	-	1	-	-	6.5
34.	Prunus besseyi Bailey	-	-	3.5	-	-	-
35.	Psoralea tenuiflora Pursh.	6	1.5	2	3	1	2
36.	Psoralea cuspidata Pursh.	-	-	-	-	2	-
37.	Ratibida columnifera Woot. & Standl.	-	1.5	2	-	1	1.5
38.	Salvia pitcherii Torr.	1	-	-	-	-	-
39.	Scutellaria resinosa Torr.	-	2	2	5.4	2	2
40.	Solidago rigida L.	12	4.5	-	8.5	5	-
41.	Solidago glaberrima martens.	-	3.5	-	-	1	-
42.	Tetraneuris stenophylla Rydb.	1	1.5	3	3	4	4
43.	Thelesperma gracile (Torr.) A.Gray.	1	4	2	1	1.5	1.5
44.	Tragia ramosa Torr.	-	-	1	11	2.8	1.5
45.	Yucca glauca Nutt.	1	-	-	-	-	-

Table 2. Depth of deep and shallow soil from each quadrat of non-grazed (N.G.), moderately-grazed (M.G.), and heavily-grazed (H.G.) areas

Quadrat No.	Depth in Inches					
	Deep Soil			Shallow Soil		
	N.G.	M.G.	H.G.	N.G.	M.G.	H.G.
1	30.0	18.0	18.0	9.0	11.0	10.5
2	28.0	20.0	18.0	12.0	9.0	6.0
3	26.0	20.0	17.0	11.0	6.0	8.0
4	20.0	22.0	15.0	10.0	7.5	6.0
5	18.0	20.0	14.0	7.0	6.5	6.0
6	18.0	19.0	16.0	9.0	9.0	7.5
7	18.0	16.0	18.0	6.0	8.5	9.0
8	24.0	18.0	16.0	6.0	8.0	8.0
9	18.0	17.0	18.0	8.0	8.5	9.0
10	18.0	16.0	18.0	9.0	8.0	6.0
Average	21.8	18.6	16.8	8.7	8.0	7.4

Table 3. Percentage of sand, silt, clay, and texture of deep and shallow soils of non-grazed (N.G.), moderately-grazed (M.G.), and heavily-grazed areas (H.G.)

Soil Separates	Deep Soil			Shallow Soil		
	N.G.	M.G.	H.G.	N.G.	M.G.	H.G.
Sand	24.0	33.0	43.0	24.8	30.8	44.4
Silt	23.7	25.8	50.5	24.2	32.1	43.7
Clay	29.8	25.8	44.4	35.2	24.5	40.3
Texture	Silty Clay Loam	Silty Loam	Loam to Clay Loam	Clay Loam to Silty Clay Loam	Clay Loam to Silty Clay Loam	Loam

Figure 2. General view of shallow soil of the non-grazed pasture showing characteristic bunches of little bluestem.

Figure 3. General view of deep soil of the moderately-grazed pasture dominated by blue grama and buffalo grass. Plots are protected by "teepee" cages.

18.6 inches varying from 16 to 24 inches (Table 2). The soil texture was silty loam having 23.7, 25.8, 50.5 per cent of sand, silt, and clay, respectively (Table 3). Little mulch was present ranging only from 0.25 to 1.5 inches deep.

Shallow Soil. The dominant grasses on shallow soils of the moderately grazed sites were side-oats grama, blue grama, and hairy grama (Fig. 4). Big and little bluestem and three-awn grasses were scattered in the area. Numerous forbs were found, but not as abundant as on the deep soil. The prominent forbs were Ambrosia psilostachya, Aster ericoides, and Solidago rigida (Table 1). Average depth of soil was 8.0 inches and varied from 6 to 11 inches (Table 2).

The soil varied in texture from clay loam to silty clay loam. The percentages of sand, silt, and clay were 24.2, 32.1, and 43.7 respectively (Table 3). Mulch varied from 0 to 0.5 inch deep.

Heavily-grazed Pasture

The heavily-grazed study area was located adjacent to the south side of the non-grazed area and is approximately 120 acres in size. This area has been heavily grazed for several years and the grasses were reduced in stature and vigor as a result of heavy utilization.

Deep Soil. The vegetation of the deep soil of the study area was dominated by buffalo grass, blue grama, and side-oats grama. Big bluestem was found scattered in the favored locations. Three-awn grass was common in the area (Fig. 5). The average depth of soil was 16.8 inches varying from 15 to 18 inches (Table 2). The most common forbs were Ambrosia psilostachya, Gutierrezia sarothrae, and Petalostemon purpureus (Table 1). The texture of the soil was loam to clay loam having 29.8, 25.8, and 44.4 per cent of sand, silt, and clay, respectively (Table 3).

Figure 4. General view of shallow soil of the moderately-grazed pasture dominated by hairy grama, blue grama, and side-oats grama with three-awn scattered throughout the area.

Figure 5. General view of deep soil of the heavily-grazed pasture dominated by buffalo grass, blue grama, and side-oats grama.

Shallow Soil. The vegetation was dominated by hairy grama, blue grama, and side-oats grama (Fig. 6). Buffalo grass was found among the short grasses and big bluestem was scattered in the area. The drought-resistant and unpalatable Gutierrezia sarothrae and Ambrosia psilostachya were the most abundant forbs in this location (Table 1). Average depth of soil was 7.4 inches and varied from 6 to 10 inches (Table 2).

Bare areas and erosion was prominent on slopes of the heavily-grazed area. Cattle trails leading to the pond of water in the lowland had eroded until little or no soil remained (Fig. 7). Limestone out-cropping was common and due to the denuded condition, was quite obvious. The texture of the soil was loamy, having 35.2, 40.3, 24.5 per cent of sand, silt, and clay, respectively (Table 3).

CLIMATIC CONDITIONS

Climatic conditions in the study area during the 1960 growing season were rather adverse. The highest temperature recorded for June was 106° F. and the average maximum temperature was 81.6°. The season was warm in July and August having an average maximum temperature of 90.6° and 91.8° with high temperatures of 106° and 105°, respectively (Table 4). In July and August temperatures exceeding 90° were recorded for 15 and 21 days and the average minimum temperatures were 62.5° and 63.4°, respectively. September was warm in the beginning and the highest temperature recorded was 97° with 11 days exceeding 90° while the lowest temperature was 37°.

Total precipitation at Hays during the 1960 growing season was 14.05 inches which was 4.09 inches below normal (Table 4). Precipitation for June, July, and September was 1.07, 2.46 and 0.42 inches below normal, respectively. In April and August the total rainfall was 2.34 and 3.76 inches which was 0.21 and 0.84 inches above normal. During the last week

Figure 6. General view of shallow soil of the heavily-grazed pasture. Blue grama, hairy grama, and side-oats grama are dominant.

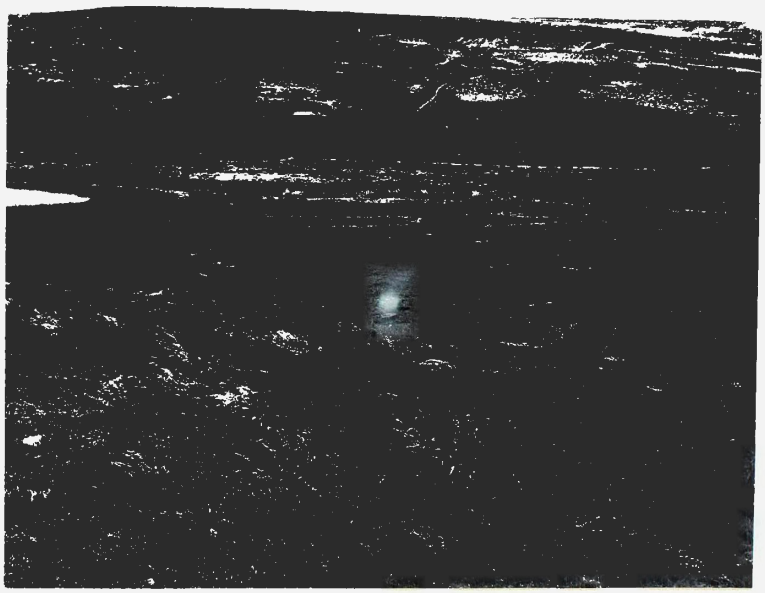

Figure 7. General view of the deep and shallow soil of the heavily-grazed pasture. Shallow soils are seen in the light-colored areas in the background.

Table 4. Precipitation and temperature for growing season of 1960 at Hays, Kansas[1]

Month	Precipitation		Temperature in °F				
	inches	departure from long term means	av. max.	av. min.	max.	min.	no. of days greater than 90°
April	2.34	0.21	69.2	42.3	87	26	0
May	2.87	-0.91	73.3	48.0	91	31	1
June	3.20	-1.07	81.6	59.7	106	50	6
July	0.09	-2.46	90.6	62.5	105	50	15
August	3.76	0.84	91.8	63.4	107	51	21
September	1.79	-0.42	84.3	55.9	97	39	11
Total	14.05						

[1]From Kansas Climatological Data

of April 1.69 inches of rain was recorded while the remaining 0.65 inch of rain occurred in traces during the rest of the month. In August light rains occurred throughout the month except on one day more than one inch of rain was recorded. Total rainfall for June was 3.20 inches which was well distributed from June 4 to June 20. July was dry having a total rainfall of 0.09 inch. During this month deficient moisture and high temperature had considerable effect on growth of vegetation. Early September was also dry but 1.79 inches of rain occurred during the last week.

RESULTS

Basal Cover and Composition of Vegetation by the Point Quadrat Method

Deep Soil. Basal cover of vegetation on deep soil of the non-grazed area was 16.41 per cent (Table 5). Big bluestem was the most abundant grass, having 54.69 per cent of the vegetative composition. Side-oats grama, western wheatgrass, and tall dropseed comprised, respectively, 12.83, 10.52 and 8.24 per cent of the composition. Buffalo grass and blue grama were present on the lowlands and comprised, respectively, 2.28 and 1.06 per cent of the composition. On the brow of the hills, the clumps of little bluestem averaged 4.91 per cent and the remaining 5.47 per cent of the vegetation was furnished by other grasses such as Canada wild-rye (Elymus canadenses) and switch grass (Panicum virgatum). Thus, the dominant species of the non-grazed area on deep soil was big bluestem (Fig. 1). Bare soil was mostly covered by a layer of mulch and very few open areas occurred. Foliage cover in this location was estimated to be nearly 95 to 100 per cent.

The total basal cover of the moderately-grazed vegetation on deep soil was 41.32 per cent (Table 5). Buffalo grass, blue grama and side-oats grama were the dominant grasses. They respectively contributed 46.39, 27.39, and 10.63 per cent to the composition. Big bluestem was also found in bunches, comprising 8.06 per cent of the composition. Little bluestem and

Table 5. Average basal cover and per cent composition of different grasses on deep and shallow soil of non-grazed, moderately-and heavily-grazed pastures, by the point transect method

SPECIES	Per Cent Composition					
	Deep Soil			Shallow Soil		
	N.G.	M.G.	H.G.	N.G.	M.G.	H.G.
Big bluestem	54.69	8.06	4.28	19.31	8.82	3.17
Little bluestem	4.91	1.02	--	68.52	2.31	--
Side-oats grama	12.83	10.63	15.22	9.45	12.62	17.43
Blue grama	1.06	27.39	21.56	0.63	28.03	26.15
Buffalo grass	2.28	46.39	52.99	0.87	9.13	10.24
Hairy grama	--	4.01	2.50	--	36.01	42.51
Western wheatgrass	10.52	--	--	--	--	--
Tall dropseed	8.24	--	--	--	--	--
Others	5.47	1.25	3.45	1.82	3.08	1.50
Total	100.0	100.0	100.0	100.0	100.0	100.0
Basal Cover	16.41	41.32	44.63	19.68	38.81	43.92

hairy grama were present on the brow of the hill, averaging 1.02 per cent and 4.01 per cent. Blue grama and buffalo grass formed a relatively dense sod over the deep soil of the moderately-grazed area (Fig. 3). Side-oats grama and big bluestem occurred in large clumps dispersed among the short grasses.

The vegetation of the deep soil on the heavily-grazed area had a basal cover of 44.63 per cent (Table 5). The principle grasses were buffalo grass, blue grama and side-oats grama composing 52.99, 21.56, and 15.22 per cent of the vegetative composition, respectively. Big bluestem was found in clumps throughout the area, having 4.28 per cent of the composition. Hairy grama was found on the brow of the hill and averaged 2.50 per cent. The short grass formed a dense mat over most of the area with interspersed clumps of mid-and-tall-grasses.

Shallow Soil. Non-grazed pasture had an average basal cover of 19.68 per cent (Table 5). The most abundant species was little bluestem, making up 68.52 per cent of the composition. Big bluestem and side-oats grama averaged 19.31 and 9.45 per cent of the total composition, respectively. Buffalo grass and blue grama were found in lesser amounts, the former contributed 0.63 per cent and the latter 0.87 per cent of the composition.

Average basal cover of the moderately-grazed pasture was 38.81 per cent (Table 5). Hairy grama, side-oats grama, and blue grama were the most abundant grasses and composed 36.01, 12.62, and 28.03 per cent of the vegetation, respectively. Big bluestem was found scattered throughout, making 8.82 per cent of the composition. Little bluestem was found on the open and very thin soil, comprising 2.31 per cent while buffalo grass, found in localized islands, contributed 9.13 per cent to the composition.

Hairy grama, blue grama, and side-oats grama were the most common species on the shallow soil of the heavily-grazed area and comprised 42.51,

26.15, and 17.43 per cent of the vegetative composition. The total basal cover was 43.92 per cent (Table 5). Buffalo grass was common on the area, and made up 10.24 per cent of the composition. Big bluestem was widely scattered over the area, contributing only 3.17 per cent. The remaining 1.50 per cent of the composition was made up by the other grasses such as tumble grass and three-awn.

Basal Cover by the Pantograph Method

Deep Soil. The average total basal cover on deep soil of the non-grazed pasture was 18.26 per cent (Table 6). Big bluestem was the most abundant grass in the quadrats having an average basal cover of 10.03 per cent of the total (Fig. 8). Average basal cover of side-oats grama and little bluestem was 4.71 and 1.92 per cent, respectively. Blue grama furnished only 0.55 per cent. Other grasses, such as Canada wildrye and tall dropseed contributed 1.05 per cent of the basal cover.

Total basal cover of the moderately-grazed vegetation on deep soil was 38.07 per cent (Table 6). The most common grasses were buffalo grass, blue grama, and side-oats grama, and the cover of each was 16.50, 9.50, and 7.20 per cent (Fig. 8). Big bluestem was found scattered in the quadrats and contributed 3.69 per cent of the basal cover. Little bluestem and hairy grama were also found in the quadrats and contributed 0.25 and 1.93 per cent to the total basal cover.

Average total basal cover of vegetation on deep soil of the heavily-grazed pasture was 40.7 per cent (Table 6). The principle grasses were buffalo grass, blue grama, and side-oats grama which contributed 24.01, 7.09 and 6.08 per cent of the basal cover, respectively (Fig. 8). Big bluestem was found scattered in the quadrats and contributed 3.69 per cent of the basal cover. The remaining 0.81 per cent of the basal cover was hairy grama.

Table 6. Average basal cover of different grasses on deep and shallow soil of the non-grazed, moderately- and heavily-grazed pastures by the pantograph method

Species	Per Cent Basal Cover					
	Deep Soil			Shallow Soil		
	N.G.	M.G.	H.G.	N.G.	M.G.	H.G.
Big bluestem	10.03	3.69	1.48	4.10	2.41	1.74
Little bluestem	1.92	0.25	--	13.21	1.07	--
Side-oats grama	4.71	7.20	6.08	2.12	3.50	5.39
Buffalo grass	--	16.50	24.01	0.50	3.35	5.08
Blue grama	0.55	9.50	7.09	--	10.00	7.52
Hairy grama	--	1.93	0.81	--	12.83	18.03
Other grasses	1.05	--	--	0.37	0.93	---
Total Basal Cover	18.26	38.07	40.70	20.30	34.78	37.74

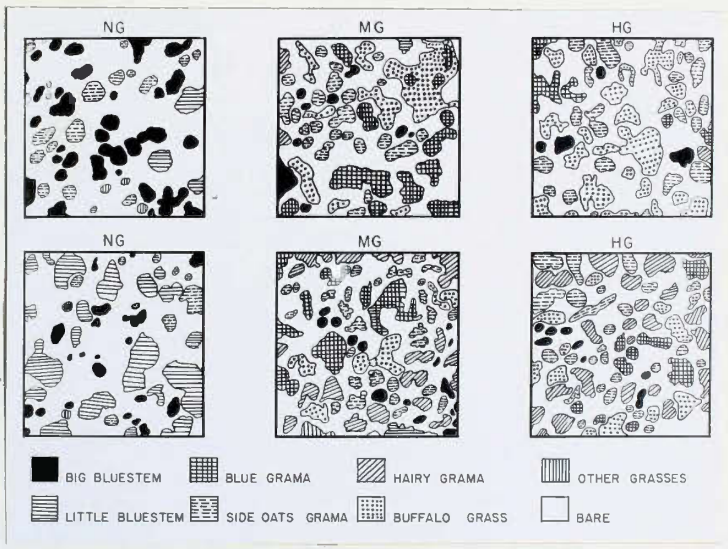

Figure 8. Square meter quadrats showing basal cover and characteristic structure of grasses on deep soil (upper) and shallow soil (lower) on non-grazed (N.G.), moderately-grazed (M.G.), and heavily-grazed (H.G.) pasture.

Shallow Soil. Total basal cover of shallow soil of the non-grazed pasture was 20.30 per cent (Table 6). The most common species was little bluestem making up 13.21 per cent of the basal cover (Fig. 8). Big bluestem and side-oats grama contributed 4.10 and 2.12 per cent, respectively. Blue grama was not common and averaged only 0.50 per cent.

Vegetation on the shallow soil of the moderately-grazed pasture had a basal cover of 34.78 per cent (Table 6). Dominant grasses were side-oats grama, blue grama, and hairy grama providing 3.50, 10.00, and 12.83 per cent of total cover respectively (Fig. 8). Buffalo grass was found mixed with other short grasses and composed 3.35 per cent of the basal cover. Big bluestem and little bluestem made up 2.41 and 1.07 per cent of the cover.

The total basal cover on the shallow soil of the heavily-grazed pasture was 37.74 per cent. The principle grasses were hairy grama, blue grama, and side-oats grama (Fig. 8). They averaged 18.3, 7.52, and 5.39 per cent of the basal cover, respectively. Big bluestem had a basal cover of only 1.74 per cent. Buffalo grass was found mixed with other short grasses and contributed 5.08 per cent of the basal cover.

MONTHLY AND SEASONAL YIELD

Total Yield of Quadrats on Deep Soil. The average total grass yield on deep soil of the non-grazed, moderately-and-heavily-grazed pastures were, respectively, 2,826.7, 1,766.8, and 1,071.1 pounds per acre. Forb yields were 236.1, 643.2, and 182.3 pounds per acre (Table 7).

The yield of grasses and forbs varied among the quadrats according to the depth of the soil. Yield of the grasses per quadrat varied from 2,032.9 pounds to 3,572.8 pounds per acre on deep soil of the non-grazed pasture. Yield of grasses on the moderately-grazed and heavily-grazed deep soil pasture varied from 1,481.3 to 2, 079.3 pounds and 909.6 to 1,279.3 pounds per acre, respectively (Table 7).

Table 7. Total yield of grasses and forbs in each quadrat on deep soil of non-grazed, moderately-grazed, and heavily-grazed pastures

Quadrat No.	Pounds Per Acre								
	Non-grazed			Moderately-grazed			Heavily-grazed		
	Grass	Forbs	Total	Grass	Forbs	Total	Grass	Forbs	Total
1	3572.8	174.6	3747.9	2079.3	499.3	2578.6	1279.3	152.2	1431.5
2	3229.6	185.4	3415.0	1990.3	515.7	2512.0	1228.2	152.2	1380.7
3	3009.7	205.5	3295.2	1909.2	519.8	2429.0	1187.8	153.4	1341.3
4	2962.7	216.4	3179.2	1896.3	538.9	2435.2	1141.2	150.3	1291.6
5	2941.9	235.2	3177.1	1862.3	543.1	2403.4	1046.3	178.2	1226.5
6	2823.8	243.2	3067.0	1744.7	617.5	2362.2	1042.1	177.5	1219.6
7	2714.9	249.8	2964.7	1661.1	683.3	2344.4	1033.3	196.5	1229.8
8	2731.8	252.5	2966.2	1540.4	782.2	2322.6	922.5	191.3	1113.8
9	2160.0	272.7	2432.5	1491.9	841.9	2333.2	919.0	212.9	1131.1
10	2032.9	325.0	2358.9	1481.3	891.3	2372.7	909.8	258.4	1168.1
Average	2820.7	250.1	3062.9	1700.6	643.2	2410.1	1071.1	182.2	1253.4

The variation in the yield of forbs per quadrat from the deep soil of non-grazed, moderately-grazed and heavily-grazed pastures was 174.6 to 326.0 pounds, 499.3 to 891.3 pounds and 152.2 to 258.4 pounds per acre, respectively (Table 7).

Total Yields of Quadrats on Shallow Soil. Average total yields of grasses on the shallow soil of non-grazed, moderately-grazed, and heavily-grazed pastures were 1,721.9, 1,173.0, and 912.0 pounds per acre, respectively. The average total yield of forbs was 638.4, 402.0, and 135.0 pounds per acre (Table 8).

Variation in the yield of grasses among the quadrats was 1,325.2 to 2,231.3 pounds per acre from the shallow soil of the non-grazed pasture. The yield of grasses from the shallow soil of the moderately-grazed and heavily-grazed pastures varied from 978.4 to 1,561.2 pounds and 649.6 to 1,129.2 pounds per acre, respectively (Table 8).

The yield of forbs varied among the quadrats, according the the depth of soil. Yield of forbs from the shallow soil of non-grazed, moderately- and heavily-grazed pastures varied from 395.2 to 985.3 pounds, 246.3 to 569.6 pounds and 102.4 to 190.3 pounds per acre respectively. The average total yield of forbs from shallow soil of the non-grazed pasture was 638.4 pounds per acre which was the highest while the heavily-grazed pasture yielded the lowest (Table 8).

MONTHLY YIELD

Deep Soil. The vegetation on the deep soil of the non-grazed pasture yielded 3,062.9 pounds per acre during the growing season (Table 9). Grasses contributed 2,826.7 pounds and the remaining 236.1 pounds were produced by forbs. The vegetation was clipped initially on July 1, and yielded 1,590.8 pounds per acre. Grasses and forbs contributed 1,410.2 and 189.6 pounds

Table 8. Total yield of grasses and forbs in each quadrat on shallow soil of non-grazed, moderately-grazed, and heavily-grazed pastures

Quadrat No.	Pounds Per Acre								
	Non-grazed			Moderately-grazed			Heavily-grazed		
	Grass	Forbs	Total	Grass	Forbs	Total	Grass	Forbs	Total
1	2231.3	395.2	2626.5	1561.2	246.3	1087.5	1129.2	102.4	1231.6
2	2129.4	468.3	2597.7	1379.3	276.3	1655.6	1125.5	106.2	1231.7
3	2012.3	455.8	2468.2	1341.9	276.5	1618.5	1111.2	110.1	1221.3
4	1718.5	469.4	2187.9	1241.3	339.7	1581.1	1061.2	113.7	1175.0
5	1888.2	389.7	2278.0	1102.4	329.4	1431.9	925.9	115.2	1041,1
6	1652.4	684.6	2337.0	1059.2	419.3	1278.6	841.2	124.2	965.4
7	1591.9	736.3	2328.2	1071.5	479.5	1551.0	765.4	141.3	906.7
8	1529.7	758.2	2287.9	1015.4	551.7	1567.1	772.3	164.7	937.1
9	1340.8	841.6	2182.1	978.8	531.7	1511.1	739.1	182.5	921.4
10	1325.2	985.3	2310.6	978.4	569.6	1548.1	649.6	190.3	840.0
Average	1721.9	638.4	2360.4	1173.0	402.0	1575.0	912.0	135.0	1047.3

Table 9. Monthly yield in pounds per acre of grasses and forbs on the deep soil of non-grazed, moderately-grazed, and heavily-grazed pastures

Month	Non-grazed			Moderately-grazed			Heavily-grazed		
	Grass	Forbs	Total	Grass	Forbs	Total	Grass	Forbs	Total
June	1401.2	189.6	1590.8	997.7	505.6	1503.3	513.9	132.8	646.8
July	799.4	29.4	828.8	281.0	54.5	335.5	198.7	21.6	220.3
August	407.4	10.7	418.2	308.1	46.3	354.4	228.7	17.4	246.2
September	218.7	6.4	225.1	180.0	36.8	216.9	129.8	10.4	140.1
Total	2826.7	236.1	3062.9	1766.8	643.2	2410.1	1071.1	182.2	1253.4

per acre, respectively. Total vegetation yield for July, August, and September was 828.8, 418.2, and 225.1 pounds per acre. In July, grasses and forbs yielded 799.4 pounds and 29.4 pounds per acre, respectively. The grasses contributed 407.4 pounds and 218.7 pounds per acre during August and September. The yield of forbs during August and September was negligible.

The vegetation clipped during the first clipping contributed 51.3 per cent of the total vegetation of the growing season. The vegetation clipped in July, August, and September contributed, respectively, 27.0, 13.6, and 7.4 per cent of the total season yield (Fig. 9).

The total seasonal yield of vegetation on deep soil of the moderately-grazed pasture was 2,410.1 pounds per acre, of which grasses and forbs contributed 1,706.8 pounds and 643.2 pounds per acre, respectively (Table 9). The total yield of vegetation for June was 1,503.3 pounds of which grasses yielded 997.7 pounds and forbs 505.6 pounds per acre. The vegetation clipped in June was 62.36 per cent of the total seasonal yield. The yield of vegetation in July was 335.5 pounds per acre, or 13.9 per cent of the total seasonal yield. In August, yield of vegetation was slightly more than the yield in July, and averaged 14.7 per cent of the total seasonal yield of vegetation. In September, yield of vegetation was 8.9 per cent of the total seasonal yield and was composed of 180.0 pounds of grasses and 36.8 pounds of forbs.

The vegetation of the deep soil of the heavily-grazed area yielded 1,253.4 pounds per acre during the season (Table 9). Total yields of vegetation for June, July, August, and September were 646.6, 220.3, 246.2, and 140.1 pounds per acre, respectively. The yield for the month of June contributed 51.5 per cent of the total seasonal yield of the vegetation. June forage yields were 513.9 pounds and 132.6 pounds per acre of grasses

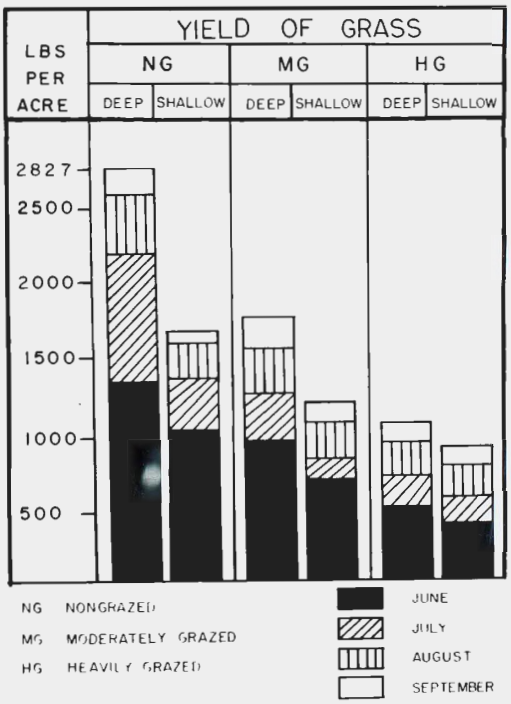

Figure 9. Monthly yield of grasses on the deep and shallow soil of the non-grazed, moderately-and heavily-grazed pastures. Initial clipping produced the higher yield in each type of soil and pastures.

and forbs, respectively. The vegetation yield for July was 17.5 per cent of the total yield of vegetation during the season; July yields were 198.7 pounds per acre of grasses and 21.6 pounds per acre of forbs. The yield of grasses and forbs in August was 228.7 pounds and 17.4 pounds respectively, which contributed 18.2 per cent of the total seasonal yield of vegetation. The yield of vegetation in August was slightly more than the yield of vegetation in July. The total yield for September was 140.1 pounds per acre which contributed 11.2 per cent of the total seasonal yield of the vegetation. Grasses and forbs averaged 129.6 pounds and 10.4 pounds per acre, respectively.

The average total seasonal yield of vegetation from the deep soil of the non-grazed, moderately-and heavily-grazed pastures were 3,062.9 pounds, 2,410.1 pounds, and 1,253.4 pounds per acre, respectively. The moderately- and heavily-grazed pastured yielded 78.7 per cent and 40.9 per cent of the total yield of vegetation from the deep soil of the non-grazed pasture (Fig. 10).

Shallow Soil. The total seasonal yield of the vegetation on shallow soil of the non-grazed pasture was 2,360.4 pounds per acre of which 1,721.9 pounds per acre were grasses and 638.4 pounds per acre were forbs (Table 10). The yield of the vegetation for June was 1,578.5 pounds per acre which was 66.9 per cent of the total seasonal yield. Total June yield was composed of 1,048.3 and 530.2 pounds per acre of grasses and forbs, respectively. July yields were 406.1 which was 17.2 per cent of the total seasonal yield of vegetation. Grasses and forbs contributed, respectively, 361.3 pounds and 44.7 pounds per acre.

The vegetation clipped in August yielded 263.1 pounds per acre which was 11.4 per cent of the total seasonal yield. Grasses yielded 225.2 pounds per acre and the remaining 37.9 pounds was contributed by forbs. The total

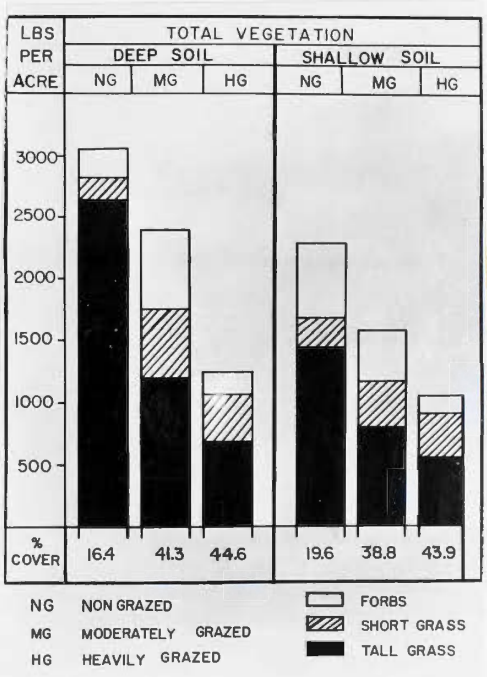

Figure 10. Total yield of vegetation on deep and shallow soil of non-grazed (N.G.), moderately-grazed (M.G.), and heavily-grazed (H.G.) pastures.

Table 10. Monthly yield in pounds per acre of grasses and forbs on the shallow soil of non-grazed, moderately-grazed, and heavily-grazed pastures

Month	Non-grazed			Moderately-grazed			Heavily-grazed		
	Grass	Forbs	Total	Grass	Forbs	Total	Grass	Forbs	Total
June	1048.3	530.2	1578.5	702.2	333.7	1036.1	400.9	108.6	509.5
July	361.3	44.7	406.1	144.7	9.8	154.5	158.0	10.7	168.8
August	225.2	37.9	263.1	236.1	11.6	247.7	209.3	9.0	218.9
September	87.1	25.6	112.7	130.4	7.0	137.4	144.4	7.3	152.1
Total	1721.9	638.4	2360.4	1173.4	402.1	1575.5	912.6	135.6	1049.3

yield of vegetation for September was 112.7 pounds per acre which was 4.7 per cent of the total seasonal yield and the major portion in the yield was contributed by the grasses which was 87.1 pounds per acre.

The vegetation removed during the season from shallow soil of the moderately-grazed area was 1,575.5 pounds per acre (Table 10). The grasses yielded 1,173.4 pounds per acre. The yield of vegetation during June was 1,036.1 pounds which was 65.2 per cent of the total seasonal yield, in which 702.2 pounds and 333.7 pounds were contributed by forbs. Yields of 154.5, 247,7, and 137.4 pounds were obtained in July, August, and September which contributed 9.7, 10.5, and 8.2 per cent of the total yield of vegetation, respectively. The major portion of the production was contributed by grasses which yielded 144.7, 236.1, and 130.4 pounds per acre during July, August, and September, respectively.

The total yield of the vegetation from shallow soil on the heavily-grazed area during the season was 1,049.3 pounds per acre, of which 912.6 pounds was contributed by grasses (Table 10). The remaining 135.6 pounds was made up by forbs. The vegetation removed during June was 509.5 pounds per acre and contributed 48.5 per cent of the total seasonal yield of vegetation. Grasses yielded 400.9 pounds per acre while the remaining 108.6 pounds was produced by forbs. The vegetation clipped during July, August, and September was 168.8, 218.9, and 152.1 pounds per acre which comprised 16.1, 20.8, and 14.5 per cent of the total yield, respectively.

GROWTH OF PLANTS

Deep Soil of Non-grazed Pasture. The total height of big bluestem removed during the season was 38.3 inches (Table 11). Before the initial clipping big bluestem measured 19.2 inches tall, which was 50.5 per cent of the total height. The height of big bluestem in July, August, and

Table 11. Height of various grasses on deep soil when clipped monthly in non-grazed, moderately-grazed, and heavily-grazed pastures

Location	Month	Height of plant in inches				
		Big bluestem	Little bluestem	Side-oats grama	Buffalo grass	Blue grama
Non-grazed	June	19.2	10.2	12.4	4.4	3.9
	July	9.3	7.3	6.6	1.8	1.6
	August	5.1	3.5	6.1	2.9	2.4
	September	4.7	3.1	3.8	2.2	2.0
	Total	38.3	30.4	30.9	11.3	9.9
Moderately grazed	June	10.6	--	8.5	6.4	6.5
	July	6.2	--	4.6	2.8	2.9
	August	4.1	--	5.8	4.9	4.8
	September	3.0	--	4.3	2.3	2.4
	Total	23.9	--	23.2	16.4	16.9
Heavily grazed	June	6.2	--	5.2	4.9	4.8
	July	3.4	--	3.1	2.4	2.9
	August	3.1	--	4.5	4.0	4.8
	September	2.5	--	3.6	3.2	3.5
	Total	15.2	--	16.4	15.1	16.0

September, was 9.3, 5.1 and 4.7 inches and contributed 2..3, 13.3 and 12.3 per cent of the total height, respectively.

The total height of little bluestem was 30.4 inches, during the growing season (Table 11). The height of little bluestem before the initial clipping was 16.2 inches and was 53.2 per cent of the total height. The height of little bluestem decreased progressively with each succeeding clipping. The height in July, August, and September was 7.3, 3.6 and 3.1 inches, respectively.

Side-oats grama had a total height of 30.9 inches during the growing season (Table 11). In June, side-oats grama averaged 12.4 inches which contributed 40.1 per cent of the total height. In July, August, and September, the height of side-oats grama was 6.6, 8.1, and 3.6 inches, respectively. The height of side-oats grama decreased in July and increased in August and again decreased in September.

The total height of blue grama and buffalo grass was 9.9 and 11.3 inches, respectively. Before the initial clipping, the measurements of blue grama and buffalo grass were 3.9 and 4.4 inches, respectively, contributing nearly 39.0 per cent of the total height of each. Height decreased in July and averaged 1.6 and 1.8 inches for blue grama and buffalo grass, respectively. The height for both species increased in August and averaged 2.4 and 2.9 inches. The height of blue grama averaged 2.0 inches and buffalo grass averaged 2.2 inches in September.

Deep Soil of Moderately-grazed Pasture. The common species on the deep soil of moderately-grazed pasture were big bluestem, side-oats grama, blue grama, and buffalo grass. The total height of big bluestem was 23.9 inches during the growing season (Table 11). The height during the month of June, July, August, and September was 10.6, 6.2, 4.1, and 3.0 inches, respectively. The height of big bluestem in June contributed 44.3 per

cent of the total growth of the season and decreased progressively with each succeeding clipping.

The total height of side-oats grama was 23.2 inches during the growing season. Before the initial clipping, the measurement of side-oats grama was 8.5 inches which contributed 36.6 per cent of the total height. The height of side-oats grama in July decreased and averaged 4.6 inches while the average height in August increased to 5.6 inches. The height of side-oats grama in September again decreased to 4.3 inches.

The total height of blue grama and buffalo grass was 16.9 and 16.4 inches, respectively. In June, the height of blue grama and buffalo grass was 6.8 and 6.4 inches, and contributed nearly 40 per cent of the total height of the seasonal growth of each. The average height of blue grama and buffalo grass in July was 2.9 and 2.5 inches, respectively. In August the height of blue grama and buffalo grass increased and averaged 4.8 and 4.9 inches while the height decreased in September to 2.4 and 2.3 inches, respectively.

Deep Soil of Heavily-grazed Pasture. Under heavy intensity of grazing growth of big bluestem and side-oats grama were greatly reduced. Average total heights were respectively, 15.2 and 10.4 inches (Table 11). Before the initial clipping, the measurement of big bluestem and side-oats grama was 6.2 and 5.2 inches, respectively and contributed 36.6 per cent and 31.7 per cent of the total height during the growing season.

The height of big bluestem and side-oats grama in July was 3.4 inches and 3.1 inches. The height of big bluestem decreased while that of side-oats grama increased in August. The height of big bluestem and side-oats grama in September was 2.5 and 3.0 inches respectively.

The total height of blue grama and buffalo grass was 10.0 and 15.1 inches (Table 11). In June the initial height of blue grama and buffalo grass was

4.8 and 4.9 inches. The height was reduced in July to 2.9 and 2.4 inches, respectively, but increased in August to 4.8 and 4.6 inches. In September the height was again decreased to 3.5 and 3.2 inches.

Shallow Soil of Non-grazed Pasture. After many years of complete protection of the area, average total growth of big bluestem and side-oats grama on shallow soil was 27.7 and 24.5 inches, respectively, which was considerably less growth than occurred on the deep soil (Table 12). The growth of little bluestem was slightly more on shallow soil than on deep soil and averaged 34.5 inches. Growth of blue grama on deep and shallow soil was approximately the same with a total height of 9.1 inches.

Average height of big bluestem in June was 12.8 inches which was 46.2 per cent of the total seasonal growth (Table 12). Height of big bluestem decreased progressively with each succeeding clipping. Heights in July, August, and September were 6.7, 4.4, and 3.8 inches and contributed, respectively, 24.1, 15.8, and 13.7 per cent of the seasonal growth.

Total height of little bluestem was 34.5 inches during the growing season (Table 12). In June little bluestem averaged 18.2 inches which was 52.7 per cent of the total seasonal growth. Average total growth for July, August, and September was 8.9, 4.3, and 3.1 inches, respectively, and contributed 25.7, 12.4, and 8.9 per cent. Average total growth of little bluestem at the end of the growing season was greater than big bluestem.

Average total height of side-oats grama was 24.8 inches during the growing season (Table 12). Before initial clipping the height of side-oats grama was 10.2 inches and contributed 41.1 per cent of the total seasonal growth. In July, the height decreased and averaged 4.1 inches. In August growth of side-oats grama increased to 6.4 inches which contributed 25.8 per cent of the total growth. In September growth again decreased to 3.4 inches.

Table 12. Height of various grasses on shallow soil when clipped monthly in non-grazed, moderately-grazed, and heavily-grazed pastures

Location	Month	Height of plant in inches				
		Big bluestem	Little bluestem	Side-oats grama	Buffalo grass	Blue grama
Non-grazed	June	12.8	18.2	10.2	--	3.5
	July	6.7	8.9	4.8	--	1.4
	August	4.4	1.3	0.4	--	2.3
	September	3.8	3.1	3.4	--	1.9
	Total	27.7	34.5	24.8	--	9.1
Moderately grazed	June	8.6	--	8.4	5.8	6.5
	July	4.9	--	5.1	2.5	2.7
	August	3.3	--	7.2	5.1	4.9
	September	3.0	--	4.2	2.7	2.6
	Total	19.8	--	24.9	16.1	16.7
Heavily grazed	June	6.4	--	4.0	4.2	4.0
	July	3.5	--	2.9	2.5	2.7
	August	3.3	--	3.7	3.9	4.0
	September	1.7	--	2.0	2.8	2.9
	Total	14.9	--	12.6	13.4	14.2

Total average height of blue grama was 9.1 inches and averaged 3.5, 1.4, 2.3, and 1.9 inches in June, July, August, and September, respectively (Table 12).

Shallow Soil on Moderately-grazed Pasture. Total growth of side-oats grama, blue grama and buffalo grass did not differ much when compared to growth on deep soil of the same pasture. Total height of big bluestem, however, decreased to an average of 19.8 inches compared with growth on deep soil. Total height of big bluestem in June was 8.6 inches which contributed 43.4 per cent of the total seasonal growth. In July, August, and September, the average height of big bluestem was 4.9, 3.3, and 3.0 inches, respectively (Table 12).

Before the initial clipping height of side-oats grama was 8.4 inches. Height was reduced in July and averaged 5.1 inches but increased in August to 7.2 inches and decreased again in September. The average total seasonal height of side-oats grama was 24.9 inches (Table 12).

Total height of blue grama and buffalo grass was 16.7 and 16.1 inches, respectively. In June average height was 6.5 inches and 5.8 inches. Growth in July was reduced to 2.7 and 2.5 inches, respectively. In August the height was increased to average 4.9 and 5.1 inches, respectively. Growth at the last clipping had decreased and averaged 2.6 and 2.7 inches (Table 12).

Shallow Soil of the Heavily-grazed Pasture. The growth of big bluestem and side-oats grama was greatly reduced when heavily utilized. The average total height of big bluestem and side-oats grama was 14.9 and 12.6 inches, respectively (Table 12). Growth was reduced nearly 50 per cent in big bluestem and side-oats grama as compared to the vigor of the same species in the same type of soil of the non-grazed area. In June big bluestem and side-oats grama averaged, respectively, 6.4 and 4.0 inches.

Big bluestem decreased in height in each succeeding clipping while the height of side-oats grama increased in August and then decreased in September.

Total height of blue grama and buffalo grass was, respectively, 14.2 and 13.4 inches (Table 12). Height in June was 4.6 and 4.2 inches and contributed 32.3 and 31.3 per cent of the total season's growth. Short grasses responded very poorly to the late rains in August and average height for blue grama and buffalo grass was only 4.0 and 3.9 inches, respectively. Growth of short grasses was also reduced in September.

On deep soil of the non-grazed pasture average total height of big bluestem and side-oats grama was greater than the height of the same species on the moderately-and heavily-grazed pastures. Big bluestem and side-oats grama grew best on deep soil of the non-grazed pasture than on the other pastures and they produced a greater number of leaves and long culms with flower heads (Fig. 11 and 12). Growth of big bluestem and side-oats grama on the heavily-grazed pasture was greatly reduced with a fewer number of leaves and short, thin culms with only a few flower heads.

In some locations growth of blue grama on the non-grazed pasture is favored and produces a greater number of leaves and culms with longer flowering head, compared to the growth of the same species on the moderately-and heavily-grazed area (Fig. 13). But under dense shade of dominant tall grasses, total height of blue grama on deep soil was greatly reduced even more than the growth of blue grama on the moderately-and heavily-grazed pastures. Height of blue grama was greatest when clipped on the moderately-grazed pasture and only slightly decreased when clipped on the heavily-grazed pasture.

Figure 11. Representative sample of big bluestem from moderately-grazed, non-grazed, and heavily-grazed pastures. (left to right)

Figure 12. Representative sample of side-oats grama from heavily-grazed, non-grazed, and moderately-grazed pastures. (left to right)

Figure 13. Representative sample of blue grama from heavily-grazed, non-grazed, and moderately-grazed pastures. (left to right)

AMOUNT OF ORGANIC MATTER

Deep Soil. The amount of organic matter in three different pastures was affected by the various intensities of grazing (Table 13). The surface 6 inches of soil contained more organic matter than deeper soil depths.

On the deep soil of the non-grazed pasture the surface 6 inches of soil contained the highest amount of organic matter in comparison to the surface soil of the moderately and heavily-grazed areas (Fig. 14). The amount of organic matter in the surface 6 inches of deep soil of the three pastures varied from 6.64 to 1.96 per cent, while in the 6 to 12 inch layer organic content varied from 5.5 to 1.4 per cent, respectively (Table 13). Deep soil of the moderately- and heavily-grazed pastures contained 3.15 and 1.96 per cent organic matter in the surface 6 inches and 1.82 and 1.40 per cent in the 6-to 12-inch depths, respectively.

Shallow Soil. The surface 6 inches of soil on the non-grazed area contained 3.9 per cent of organic matter which was the highest in comparison with organic matter content of the surface layer on shallow soils of each pasture (Table 13). The surface 6 inches of the moderately-grazed pasture contained 1.5 times more organic matter while surface soil of the non-grazed pasture had nearly 2 times more organic matter while the surface soil of the heavily-grazed pasture. Similarily, at the 6-to 12-inch soil depth, the moderately-grazed pasture had 2 times more organic matter than the same layer of heavily-grazed pasture.

The surface 0-to 6-inch and 6-to 12-inch of soil from the non-grazed deep soil site contained 1.7 times and 2.7 times more organic matter than the same soil layers in the shallow soil site. The surface 0-to 6-inch and 6-to 12-inch of deep and shallow soil of the moderately-grazed pasture contained nearly the same amount of organic matter. Similarly there was

Table 13. The per cent organic matter present at two depths in deep and shallow soil on non-grazed (N.G.), moderately-grazed (M.G.), and heavily-grazed (H.G.) pastures

Depth in Inches	Deep Soil			Shallow Soil		
	N.G.	M.G.	H.G.	N.G.	M.G.	H.G.
0-6	6.64	3.15	1.96	3.90	2.94	1.92
6-12	5.50	1.82	1.40	2.07	1.74	0.91

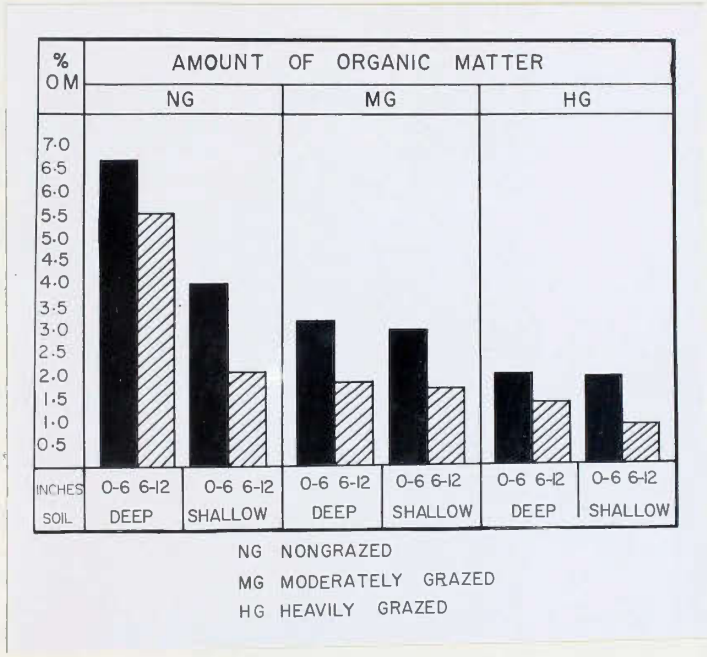

Figure 14. Per cent organic matter at 2 depths in deep and shallow soil of the non-grazed, moderately-and heavily-grazed pastures.

very little difference in the content of organic matter in the surface 0-to 6-inch layer of the deep and shallow soil of the heavily-grazed pasture. The 6-to 12-inch depth of deep and shallow soil of the heavily-grazed pasture contained 1.40 and 0.91 per cent respectively. In general, non-grazed and shallow soil contained higher amounts of organic matter due to heavier cover of mulch.

SOIL pH

Deep Soil. The pH of the surface six inches of soil was 6.3, 7.1, and 7.5 on the non-grazed, moderately-grazed, and heavily-grazed pastures, respectively (Table 14). The pH of the 6-to 12-inch layer of the non-grazed pasture was 6.5, while that of the moderately-grazed and heavily-grazed pasture was 7.6 and 7.8, respectively. The pH of the surface six inches of soil was reduced more than the pH of the 6-to 12-inch layer in each structure.

Shallow Soil. The pH of the surface six inches of soil was 6.8, 7.7, and 7.8 on the non-grazed, moderately-grazed, and heavily-grazed pastures, respectively (Table 14). The pH of the 6-to 12-inch layer of the heavily-grazed pasture was 8.0 which was highest compared to the pH of the same layer of the moderately-grazed and non-grazed pastures. The pH of the latter was 7.4 while the former was 7.9.

AMOUNT OF MULCH

Deep Soil. The non-grazed pasture contained 5,381.2 pounds per acre of mulch on the surface (Table 15). Mulch yields from moderately-grazed and heavily-grazed areas were 784.3 and 201.2 pounds per acre, respectively. Owing to less foilage and greater abundance of short grass, the moderately- and heavily-grazed pastures yielded less mulch than did the non-grazed

Table 14. Soil pH at two depths in deep and shallow soils of non-grazed, moderately-and heavily-grazed pastures

Location	Soil pH			
	Deep Soil		Shallow Soil	
	0-6 inches	6-12 inches	0-6 inches	6-12 inches
Non-grazed	6.3	6.4	6.8	7.4
Moderately-grazed	7.1	7.3	7.7	7.9
Heavily-grazed	7.5	7.6	7.8	8.0

Table 15. Yield of mulch in pounds per acre on the deep and shallow soil of non-grazed, moderately-and heavily-grazed pastures

Location	Deep Soil	Shallow Soil
Non-grazed	5381.2	1438.6
Moderately-grazed	784.4	288.7
Heavily-grazed	201.2	54.3

pasture, which has been protected from grazing and fire since 1902. The deep soil of the moderately-grazed pasture yielded 3.9 times more mulch than the deep soil of the heavily-grazed pasture.

Shallow Soil. The amount of mulch collected from the surface of the shallow soil of the heavily-grazed pasture, amounted to 54.3 pounds per acre which was the lowest of the other shallow soil sites (Table 15). The shallow soil of the moderately-and non-grazed pasture yielded, respectively, 288.7 pounds and 1,438.6 pounds per acre. Shallow soil of the non-grazed pasture had nearly 5 times more mulch than the shallow soil of the moderately-grazed pasture. The latter produced nearly 5.3 times more mulch than the shallow soil of the heavily-grazed pasture.

Deep soil of the non-grazed pasture yielded nearly 3.7 times more than the shallow soil of the same pasture. The deep soil of the moderately-and heavily-grazed areas produced nearly 2.6 times and 3.7 times more mulch than the shallow soils, respectively (Fig. 15).

UTILIZATION

Total yield of the protected quadrats clipped monthly on the non-grazed, moderately-grazed, and heavily-grazed pastures was 3,062.9, 2,410.0, and 1,253.4 pounds per acre respectively.

Total yield from the protected five new quadrats clipped only at the end of the grazing season on the non-grazed pasture was 2821.5 pounds per acre which was 241.4 pounds less than the total yield of the quadrats clipped monthly. The loss in yield may partially be due to late clipping when the vegetation was dry and some of the basal leaves had fallen from the plant.

Total vegetation harvested from the grazed quadrats of the moderately-grazed pasture was 1,089.5 pounds per acre and was composed of 792.5 pounds

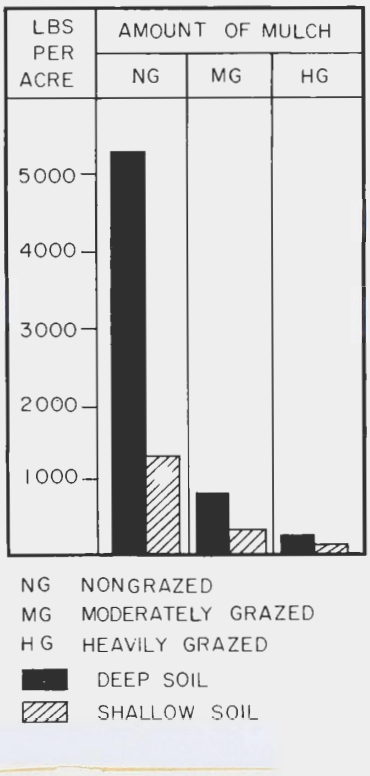

Figure 15. Amount of mulch collected from deep and shallow soil of the non-grazed, moderately-and heavily-grazed pastures.

of grasses and 297.0 pounds of forbs per acre. Total yield of vegetation from the heavily-grazed pasture was 276.1 pounds per acre and was composed of 235.7 pounds of grasses and 40.4 pounds of forbs per acre (Table 16).

The vegetation utilized by livestock during the grazing season from the moderately-grazed and heavily-grazed pastures was 1,320.6 pounds and 977.3 pounds per acre and amounted to 54.8 and 78.1 per cent utilization of the total yield of vegetation, respectively (Fig. 16).

Grass utilization by livestock from the moderately-grazed and heavily-grazed pastures was 55.1 and 77.9 per cent. Forbs utilization was 46.1 per cent on the moderately-grazed pasture and 77.4 per cent on the heavily-grazed pasture.

DISCUSSION AND CONCLUSIONS

The most limiting factor in growth of vegetation in the mixed prairie is the cyclic climate (Weaver and Albertson, 1956). During the growing season of 1960, when this study was conducted, a drought period occurred which retarded vegetative growth. In each case the heavily-grazed pasture was first affected by drought followed by moderately-grazed and non-grazed pastures. Vigor or growth of vegetation seemed to be adversely affected by intensity of grazing and disappearance of mulch. Loss of forage and mulch increases soil temperature and surface evaporation, thus fostering a condition less favorable for plant growth.

On the mountain ranges in the Northwest, Pickford and Reid (1950) reported that an average leaf length of not less than 3 inches should be left to maintain the mulch and thus maintain climax species of bluebunch wheatgrass, sandberg bluegrass, and green fescue.

Deep soil on the non-grazed pasture had adequate mulch to cover the open spaces and to retard evaporation. No erosion occurred on this area

Table 16. Yield in pounds per acre of forage from grazed and ungrazed quadrats and amount utilized under different intensities of grazing

Treatment	Non-grazed			Moderately-grazed			Heavily-grazed		
	Grass	Forbs	Total	Grass	Forbs	Total	Grass	Forbs	Total
Protected	2826.8	236.1	3062.9	1766.8	643.2	2410.0	1071.1	182.3	1253.4
Protected	2664.2	157.3	2821.5	-	-	-	-	-	-
Grazed	-	-	-	792.5	297.0	1089.5	235.7	40.4	276.1
Amount Utilized	-	-	-	974.4	346.2	1320.6	835.4	141.9	977.3

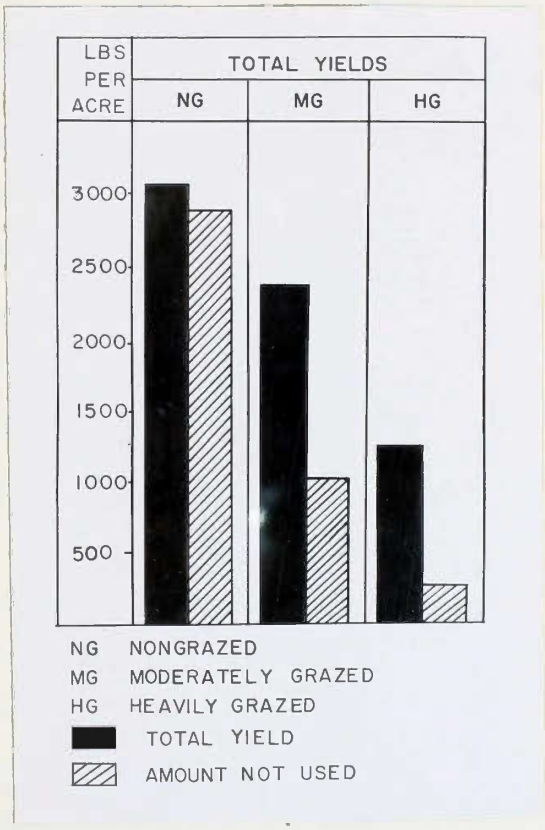

Figure 16. Yield of vegetation from protected plants clipped monthly (total yield) and only once at the end of the grazing season (not used). Utilization was determined from differences between total yields and amount not used.

which supported primarily tall grass. On the moderately-grazed and heavily-grazed pastures insufficient mulch was present on deep and shallow soil to adequately cover all bare areas. Erosion occurred on both pastures but was most severe on the heavily-grazed pastures (Fig. 7).

Composition of species varied according to depth of soil and intensity of grazing. Deep soil of the non-grazed pasture had generally more favorable conditions for growth than deep soil of the other two pastures. Big bluestem was dominant on deep soil of the non-grazed pasture. On shallow soil of the non-grazed pasture open bare spaces were common and provided a habitat for little bluestem which became dominant and averaged 64.9 per cent of the total composition of the vegetation.

Similarly buffalo grass was dominant on deep soil of the moderately-grazed and heavily-grazed pastures and buffalo grass endures closer grazing because of a greater amount of leaf surface close to the ground (Tomanek, 1948). Hairy grama is an indicator of open and shallow soil and was found abundant on the shallow soil of the moderately-grazed and heavily-grazed pastures. Blue grama was a co-dominant on shallow soil along with buffalo grass of the moderately- and heavily-grazed pastures.

Little bluestem was the important decreaser with grazing, which agrees with the data of Launchbaugh (1955). Little bluestem was the dominant grass on shallow soil of the non-grazed pasture, and was also found in lesser amounts on the moderately-grazed but was totally absent on both soils of the heavily-grazed pasture.

Side-oats grama was found on deep and shallow soils of each pasture and increased in composition on both soils as grazing intensity increased. Different species of vegetation were found in localities where they were best adapted, grazing being the controlling factor but other factors undoubtedly influence vegetation growth and composition. Weaver and

Clements (1938) pointed out that drier habitats support xeric vegetation and wetter habitats support a mesic type.

Basal cover was greater in the heavily-grazed pasture and least on the non-grazed pasture (Nelson, 1934, Tomanek and Albertson, 1953). Heavy grazing intensity reduced total yields of vegetation (Schwan et al., 1943, Kipple and Costello, 1960, Stapledon and Milton, 1930, Kelting, 1954, Branson and Weaver, 1953, Tomanek and Albertson, 1953). The basal cover on the deep soil of the non-grazed pasture was 16.41 which yielded 3,062.9 pounds per acre of vegetation. The amount of mulch collected from the same area was 5,381.2 pounds per acre. Per cent organic matter in the upper 6 inch soil layer was 6.6 per cent while that from the 6 to 12 inch layer was 5.5 per cent. It is a well known fact that more organic matter will be present in soil when the quantity of mulch is high. Organic matter results in more favorable bacterial activities, good aeration, decreased soil temperature evaporation, increased water holding capacity and generally is an important contributing factor influencing vegetational yield and growth.

A heavy mulch cover on deep soil of the non-grazed pasture prevented certain plants from making sufficient contact with soil to insure germination. Also dense foliage, shade of tall grasses and competition for space and moisture were contributing factors to reduction of the yield of forbs on this area.

Deep soil of the moderately-grazed pasture had a basal cover of 41.32 per cent and was dominated by buffalo grass, blue grama, and side-oats grama. Tall grasses were disappearing under grazing intensity and were replaced by short grasses. Basal cover increased due to the increase of short grasses but total yield of vegetation decreased from this area. Total yield of vegetation was 2,410.1 pounds per acre. The mulch collected was

784.4 pounds per acre and the organic matter content in the surface 6 inch layer of soil and in the 6-to 12-inch layer was 3.15 and 1.82 per cent, respectively. Due to the absence of tall grasses, less mulch was collected than from deep soil of the non-grazed pasture and consquently the soil contained less organic matter. Factors of the environment were, therefore, not as favorable as existed on the non-grazed pasture, resulting in declining range condition and a decrease in yield of vegetation. Forbs were abundant because of less competition for light and other factors and produced a greater amount than the non-grazed and heavily-grazed pasture.

Basal cover of deep soil of the heavily-grazed pasture was 44.63 per cent. The increase in basal cover was due to an increase in the amount of buffalo grass in the composition. Basal cover increased with increased intensity of grazing while the yield of vegetation, amount of mulch, and organic matter content were greatly decreased. Because of increased grazing intensity, the surface soil was hard, water infiltration was slow, and erosion was severe. Because of reduced growth and yield of vegetation, mulch and organic matter, range condition was decidedly below potential productive capacity and showed signs of further deterioration.

Similarly the yield of vegetation, amount of mulch, and per cent organic matter was more on the shallow soil of the non-grazed pasture than the moderately-grazed and heavily-grazed pastures.

Shallow soil of the non-grazed pasture yielded 638.4 pounds per acre of forbs which was highest of all the pastures. Seeds of many forbs able to contact the soil for germination because of sparse vegetation and less cover of mulch. Less shade and composition for space and water were contributing factors in increase of the yield of forbs on this area. Forbs were numerous on the heavily-grazed area but cattle might have utilized a greater amount in the beginning of the grazing season, resulting in decreased yield.

A close relationship was found between total yield and seasonal growth on deep and shallow soil of each pasture. Initial height of big bluestem, side-oats grama and little bluestem was greater on deep and shallow soil of the non-grazed pasture than on the other two pastures. Growth of plants was greater when first clipped than at later clippings. More vegetation on all the pastures was harvested at the first clipping than later. In July growth of plants decreased due to drought and clipping which resulted in decreased vegetation yield. In August, growth of plants increased over July measurements due to receipt of moisture. At the final clipping yield of vegetation decreased in all the pastures.

CONCLUSIONS

The following conclusions may therefore be drawn from the data collected during 1960-61.

1. Basal cover increases with increased intensity of grazing.
2. Tall grasses decrease and short grasses increase as the intensity of grazing increases.
3. Growth of grasses decreases with increased intensity of grazing.
4. Yield of vegetation, amount of mulch and per cent organic matter decreases with increased intensity of grazing.
5. Little bluestem decrease with utilization and is one of the first species to vanish under heavy grazing.
6. Deep soil produces a higher yield of vegetation, amount of mulch, and organic matter in each pasture than shallow soil.
7. The surface soil layer contains more organic matter than deeper layers and deep soils contain a higher percentage than shallow soil.

SUMMARY

Three pastures were selected for study to determine the relationship of vegetation to depth of soil and different intensities of grazing. The study was conducted on native pastures located 2.5 miles southwest of Hays, Kansas. The study sites were selected to determine the differences that

occurred when the pasture was continuously non-grazed, moderately-grazed and heavily-grazed. The selection of the study areas was based on observations and general appearance of the vegetation. Topography of the pastures was rolling and undulating, typical of the mixed prairie. Tall grasses were found on the lowlands, mid grasses on the brow of the hills and short grasses on the top of the hills.

The non-grazed area was approximately 35 acres in size and had been protected from grazing and fire since 1900. The vegetation was in climax stage, dominated by big bluestem in the lowlands and little bluestem on the brow of the hills.

The moderately-grazed area was approximately 800 acres in size and had been moderately-grazed since its acquisition in 1902, and was dominated by buffalo grass, blue grama, hairy grama, and side-oats grama.

The heavily-grazed area was located adjacent to the non-grazed area and comprised approximately 120 acres. The area was dominated by buffalo grass, blue grama, and hairy grama.

Vegetation on the non-grazed, moderately-grazed and heavily-grazed areas showed considerable variations in basal cover and composition, seasonal yield of forage, amount of mulch, organic matter and utilization. Sites with deep and shallow soil were selected to study vegetational variations with respect to soil variations in each pasture. Soil depth was measured by probing with a soil auger. When depth was less than 12 inches, soil was considered as shallow soil and depth greater than 12 inches considered deep soil. Ten quadrats, one square meter each, were selected on deep and shallow soil of each pasture. In moderately-grazed and heavily-grazed pastures, the quadrats were protected from grazing by use of "teepee" exclosures.

A detailed study of differences of the vegetation and soils of the three pastures was made by studying the following factors: basal cover and composition, monthly yield of vegetation, growth of grasses in height, counting of forbs with 3 feet by 1 foot rectangle, textural classification of the soil, amount of organic matter and soil pH, amount of mulch, and the utilization of vegetation by livestock.

The study was begun in early June, 1960, and data were collected during the growing season. Basal cover and composition were determined by the point transect method while the structure of vegetation was studied by charting two typical quadrats from each depth of soil in each pasture. Vegetation was clipped on the first day of each month from July to October, inclusive. Grasses and forbs were clipped and weighed separately. Immediately before each clipping height growth was measured. Forbs were counted on two rectangular plots (3 feet by 1 foot) placed adjacent to the quadrat at diagonal corners. Per cent sand, silt, and clay was determined by the hydrometer method. The amount of organic matter was found by wet digestion method described by Bear (1955) while soil pH was determined by the electrometer. At the end of the growing season, mulch was collected from each quadrat and weighed.

Utilization of grasses by weight was determined on the grazed pastures by selecting five new quadrats irrespective of the depth of soil and harvesting the remaining forage at the end of the grazing season. The difference in weight from the ungrazed and grazed areas was an indication of the utilization of vegetation by livestock.

Basal cover was less on the deep and shallow soil of non-grazed pasture when compared with that of moderately-grazed and heavily-grazed pastures. Basal cover was highest on the heavily-grazed pasture. Species composition varied according to the intensity of grazing and habitat. On deep soil of

the non-grazed pasture, big bluestem was dominant while little bluestem dominated the site with the shallow soil. On deep soil of both moderately- and heavily-grazed pastures, buffalo grass, blue grama, and side-oats grama were dominant on shallow soils.

Deep and shallow soils of non-grazed pastures yielded the highest amount of vegetation, mulch, and organic matter, as compared to the yields from the deep and shallow soils of the moderately-grazed and heavily-grazed pastures. Similarly, deep soil yielded a higher amount of vegetation, mulch, and organic matter than shallow soil in each pasture.

The upper 0-to 6-inch layer of deep and shallow soil contained a greater amount of organic matter than the 6-to 12-inch layer of deep and shallow soil in each pasture. Deep soil contained a higher percentage of organic matter than shallow soil in each pasture.

Total vegetation harvested from the grazed quadrats of the moderately-grazed and heavily-grazed pasture was 1,089.5 and 276.1 pounds per acre. The total yield of the monthly clipping was 2,410.0 and 1,253.4 pounds. Vegetation utilized by livestock from the moderately-grazed and heavily-grazed pastures was 1,320.6 and 977.3 pounds per acre. Moderately-grazed pasture was utilized 54.8 per cent while heavily-grazed pasture was utilized 77.4 per cent.

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