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Forage Yield and Carbohydrate Content of Underground Parts of Grasses As Affected By Clipping

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FORAGE YIELD AND CARBOHYDRATE CONTENT OF UNDERGROUND PARTS OF GRASSES AS AFFECTED BY CLIPPING

being

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by

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INTRODUCTION

Many farm lands in the Great Plains remain as pasture and are vitally essential to the farmer who depends on these untillable areas to supply a large share of the feed needed by his livestock during the grazing season. Livestock numbers are increasing steadily to meet the demands of a growing population for more meat. Pastures must support larger and larger herds. Therefore, it becomes increasingly important to follow a grazing system which will allow for maximum herbage production with a minimum of harm to the forage plant.

Sustained forage production depends to a great extent on the degree of grazing to which the forage plant has been subjected and the ability of the plant to withstand heavy utilization (McCarty 1938). Perennial grasses, because of favorable growth habits, are well adapted to grazing in the Great Plains. Preservation of these grasses depends upon the manufacture and storage of carbohydrates in excess of those required for current growth. Any system of grazing that permits frequent removal of much of the photosynthetic area, thereby preventing manufacture and storage of carbohydrates, is injurious and, if continued, may result in destruction of the grass (McCarty 1938).

In any system of herbage removal, whether by clipping or grazing, it is important to know the effects of defoliation upon the herbage yield and amount of carbohydrates stored in the underground parts. If a high rate of productivity is to be maintained, some knowledge is necessary concerning the intensity of use to which each grass species can be subjected. The experiment reported herein is an effort to determine the influence of different clipping treatments on the herbage yield and carbohydrate content of the roots, rhizomes, and crowns of a mixture of blue grama (Bouteloua gracilis (H.B.K.) Lag. ex Steud.) and buffalo grass (Buchloe dactyloides (Nutt.) Engelm.), big bluestem (Andropogon gerardi Vitman.), and western wheat grass (Agropyron smithii Rydb.).

Blue grama and buffalo grass are warm-season short grasses. Under climax conditions, they are co-dominants of the deep upland soils. The species composition in the clipping plots was about 5 per cent blue grama and 95 per cent buffalo grass. Three important perennial forbs in this site were western ragweed (Ambrosia psilostachya DC.), red false mallow (Malvastrum coccineum (Pursh) A. Gray.), and prairie coneflower (Ratibida columnaris (Sims) D. Don.). Important annual weeds were horse-weed (Leptilon canadense (L.) Britton.), and little barley (Hordeum pusillum Nutt.).

Big bluestem is a tall, sod-forming, warm-season grass which occurs typically on lowland and hillside areas. Abundant forbs of this community were tooth-leaved primrose (Meriolix serrulata (Nutt.) Walp.), lead plant (Amorpha canescens Pursh), sensitive briar (Morongia uncinata (Willd.) Britton), and several goldenrods (Solidago spp.).

Western wheat grass is a cool-season mid grass which occurs primarily on the lowlands. Ordinarily it grows only during the spring and fall. However, when it is grazed or clipped heavily it continues growth through the summer months (Hopkins et al. 1952).

Sometimes it occurs as pure stands but more often as an upper story to the short grasses or mixed with other mid grasses. Western ragweed was the most abundant forb but few weeds occurred in this area.

REVIEW OF LITERATURE

Since 1840, when Liebig maintained that if plants were supplied with the small amounts of mineral constituents found in the ash, the remainder of their substance could be gathered from the surrounding air, much knowledge has accumulated concerning the role of carbohydrate accumulation and use in the organism.

Tomanek (1948), working in the same general area as this study, found that moderately grazed short grass produced a higher seasonal yield than where grazing was either light or heavy.

Quadrats of little bluesteam and big bluesteam in eastern Nebraska, closely clipped for two seasons, produced lower total yields than the controls (Weaver and Hougen 1939). Yield of little bluestem was 49 and 46 per cent less and that of big bluestem was 28 per cent less. Yields from quadrats frequently clipped during 2 years was 60 per cent less in little bluestem and 37 per cent less in big bluestem than those quadrats similarly clipped for one year. Two seasons of close clipping reduced the weight of underground plant parts of little bluestem 41 per cent. Weaver and Darland (1948) found that heavy grazing of prairie led to degeneration to bluegrass and decreased forage production. Dry weight of underground plant materials of several grasses decreased as grazing intensity increased (Weaver 1950).

Hanson and Stoddart (1940) reported that carbohydrate food reserves of bunch wheat grass (<u>Agropyron</u> <u>inerme</u>) were reduced 19.4 per cent in heavily grazed plants as compared to protected plants. As a result there was a marked reduction in depth and spread of roots, production of viable seeds, and size and number of plants. Consequently, its dominant position was taken over by sagebrush.

An inverse correlation was found between seasonal fluctuations of the carbohydrates and growth rate of <u>Stipa</u> <u>pulchra</u> (Sampson and McCarty 1930). Grazing or clipping once or twice early in the growth cycle did not prevent accumulation of maximum amounts of carbohydrates but removal of herbage later did decrease carbohydrate storage.

McCarty (1935, 1938) concluded that starch and sugars were the most potent stored foods. For incipient root and shoot growth, the plant depended completely upon the stored carbohydrates for energy and building material. When the plant reached the stage where it manufactured carbohydrates, they were used immediately and only when growth declined did storage begin.

Root reserves of all clipped plants were found to be lower than those of unclipped plants in a study of grasses and herbs of the Wasatch Mountains (McCarty and Price 1942). Storage of carbohydrates was cyclic and related to the annual growth cycle in that carbohydrate storage was at a minimum during periods of greatest growth.

Graber (1930) found that root growth and top growth varied inversely with the frequency of defoliation of several grasses.

When frequent removal of top growth prohibited their replenishment, carbohydrate reserves became a limiting factor if regeneration of top growth was stimulated by a soil with abundant nitrogen. The maximum competitive efficiency of the beneficial grasses occurred when soil fertility was combined with those practices of grazing which maintained a high level of reserve foods. Graber et al. (1927) studied the response of several herbaceous plants to removal of top growth and found that there was a decrease of organic reserves in the roots and retardation of both root and top growth following frequent defoliation. The amount of winter injury also increased with low concentrations of reserve materials in the roots.

A marked decrease in the percentage of invert sugar and hydrolyzable material was observed by Bukey and Weaver (1939) when two prairie grasses were severely clipped.

Alfalfa plants grown in the darkroom produced top growth until the soluble carbohydrates in the roots reached a low of 3 to 5 per cent (Albert 1927). Storage of carbohydrates and root growth did not occur until rate of top growth was slow. Seeding of alfalfa with various cereals and grasses led to the conclusion by Rather and Harrison (1930) that in order for alfalfa to survive in a grazed mixture it must be sown with a grass which is at least as palatable as the alfalfa. Grandfield (1935) found that early and frequent cutting of alfalfa resulted in a lower content of the roots.

No effort was made to review all of the voluminous literature on effects of clipping and grazing upon the plant but rather to illustrate important trends.

METHODS OF STUDY

The experimental sites were located on the Fort Hays Kansas State College farm about 2.5 miles west of Hays. Three plots were staked out in May, 1951, in relatively pure stands of each of the grasses to be studied. Two plots consisted of 9 square meter quadrats each and one contained 5 quadrats (Fig. 1). The short grass area had not been grazed for about 10 years and the western wheat grass and big bluestem relict areas had never been grazed by domestic livestock. Clipping treatments were as follows:

	Non-clipped Treatment A	Moderately clipped Treatment B (3 week intervals)	Heavily clipped Treatment C (2 week intervals)
		Stubble height	(inches)
Short grasses	Control	2	½
Big bluestem	Control	3	1
Western wheat grass	Control	7	3

The control quadrats were clipped about 0.5 inch above the soil in the late fall of each year in order to obtain yield. New quadrats were used the following year. Forage was clipped by hand and the herbage was air dried, weighed, and converted to yield in pounds per acre. Although clipping with shears has been criticized as an artificial means of studying the effect of grazing, it seems the

Fig. 1. Heavily clipped (left) and moderately clipped (right) western wheat grass plots located in a small ravine. Bare areas are due to removal of root samples for chemical analysis. September, 1952.

most sound method of studying forage plant physiology because clipping permits accurate measurement of herbage yield (Stoddart 1946).

Three sods of each grass were removed from each treatment on January 12, 1952. These were placed in phytometers in the greenhouse to observe the effects of the clipping of the previous growing season. At the time of sod removal, the soil was frozen to a depth of 6 inches. The sods were trimmed to 6 inches in diameter and 4 inches in depth and placed in phytometers 27 inches deep. The phytometers were filled with 2 parts screened loam soil and 1 part screened sand. The plants of the transplanted sods were clipped to 0.5 inch stubble height. They were watered regularly and measured for rate of growth at 7-day intervals. The time of breaking dormancy was observed and recorded. After they had grown for a period of several weeks, the sods were removed and the roots below the sods were washed free of soil. Determinations were made on number, length, and diameter of roots emerging from the sods.

Root samples for chemical analysis were removed from each treatment monthly from July, 1951, until October, 1952, with the exception of December, 1951, and February and March, 1952. The samples consisted of culm bases, crowns, rhizomes, and roots to a depth of 4 inches. Soil was removed with a fine spray of water. The underground parts were blotted dry, placed in an oven at 90° C. for 30 minutes, and finally dried for 14 hours at 70° C. Preparation of the material for drying was usually completed within two hours after its removal from the field. Following the grinding of the samples, they were again dried at 80° C. and stored in air-tight glass bottles (Loomis and Shull 1937).

The carbohydrates determined were hemicellulose, starch, sucrose, and reducing sugars. A 3.5 to 4 gram portion of each sample was used for the complete carbohydrate analysis. It was extracted about 15 hours with hot 80 per cent alcohol. The alcohol extracted the sugars; the starch and hemicellulose remained in the extraction thimble.

The alcoholic extract was placed in a volumetric flask, made up to volume and an aliquot was placed on the steam bath and evaporated until the odor of alcohol had disappeared. The resultant solution was placed in a volumetric flask and cleared with lead acetate, made up to volume, filtered, deleaded with sodium oxalate, and again filtered. An aliquot of the remaining solution, with a few drops of invertase added, was allowed to stand overnight at room temperature. This fraction was reported as sucrose. The reducing sugars were determined on the original cleared solution (Official Methods 1945).

The residue remaining from the sugar extraction was dried. Boiling distilled water was added and the container placed on a water bath at 100° C. for one-half hour. After cooling, 6 ml. of invertase, a few drops of toluene, and approximately 0.1 gram of sodium chloride were added; this suspension was allowed to set for about 15 hours at 37° C. with frequent agitation. Subsequently, the container was placed in boiling water for 1 hour to arrest enzymatic action. The solution was filtered from the residue and an aliquot of the former was hydrolyzed with 2.5 ml. of concentrated hydrochloric acid. After neutralizing and clearing, the reducing power of this solution was determined. This fraction, reported as starch, contains both true starch and watersoluble starch (McCarty and Price 1942).

The residue remaining after starch separation was transferred to an Erlenmeyer flask, and 20 ml. of hydrochloric acid (sp. gr. 1.125), diluted to 200 ml. with distilled water, was added. The hydrolysis was carried out on a gas heated hot plate for 2.5 hours, care being taken to keep the volume constant. The suspension was allowed to cool, neutralized with sodium hydroxide, and made up to volume. Upon filtering and clearing, the reducing power was determined by use of aliquot portions of this filtrate. This fraction was reported as hemicellulose.

All fractions were reduced by equal portions of a copper sulfate and an alkaline tartrate solution. The copper oxide was filtered, washed, dried, weighed, and the results converted to a sugar equivalent by means of the Munson-Walker tables (Official Methods 1945). All determinations were made in duplicate and the results reported as per cent of the moisture-free original sample. The chemical analyses were conducted in the Chemistry Department laboratory.

Sods 6 inches square and 4 inches deep were removed at the close of this study to determine the effect of two years clipping on the weight of the underground parts. The soil was carefully removed with a fine spray of water after which the roots were dried 14 hours at 70° C. and the weights recorded.

ENVIRONMENTAL CONDITIONS

The soils of the short grass plots were about 9 feet deep and had a high content of silt and clay. The big bluestem plots were located on shallow, rocky soils on the hillsides (Fig. 2). This soil varies considerably due to erosion but has a high water retaining capacity because of large amounts of clay in the cracks of parent rock. The soils of the western wheat grass plots were of an immature nature. The soils have been described by Albertson (1937).

The 82-year precipitation average at Hays, Kansas, is 23.05 inches of which 18.03 inches or about 77 per cent falls during the growing season, April to September, inclusive. The precipitation, average temperatures, and departures from normal for growing seasons of 1951 and 1952 are presented in Table I.

TABLE I

PRECIPITATION, AVERAGE TEMPERATURES, AND DEPARTURES FROM NORMAL FOR GROWING SEASONS OF 1951 AND 1952 AT HAYS, KANSAS[1]

Month	Precipitation (inches)	Departure from normal	Average temperature	Departure from normal
		1951		
April	3.47	1.26	48.5° F.	-4.4
May	7.29	3.78	62.3	-0.1
June	13.13	9.04	67.3	-5.4
July	4.69	1.82	75.4	-3.9
August	3.16	0.08	76.8	-1.1
Sept.	5.71	3.44	63.1	-6.1
		1952		
April	2.92	0.71	49.4	-3.5
May	1.98	-1.53	61.7	-0.7
June	0.17	-3.92	81.4	8.7
July	1.87	-1.00	79.8	0.5
August	1.66	-1.42	79.5	1.6
Sept.	0.46	-1.81	70.3	1.1

[1] Climatological Data, U. S. Department of Commerce, Weather Bureau, Topeka, Kansas.

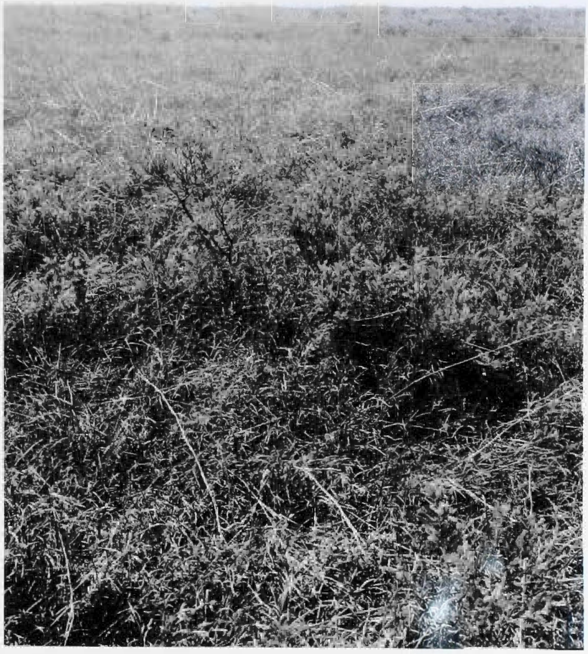

Fig. 2. Big bluestem relict area. Note abundance of lead plant which appears as dark spots in the background and light spots in the foreground. September, 1952.

Precipitation for 1951 was considerably above normal while temperatures for the same period were below normal resulting in cool, moist weather, ideal for plant growth. In contrast, during 1952, precipitation was far below normal while temperatures were above average. There were 34 days during the 1953 growing season when temperatures were 100° F. or above but only 2 days of comparable temperature during 1951.

Ample soil moisture for rapid plant growth was present during the entire 1951 season. For example, average available moisture in the upper 2 feet of upland soil in June was approximately 17.5 per cent and at no depth was it less than 4.5 per cent. Even as late as August 20, when the soil is usually depleted of moisture, there was still about 7 per cent present to at least a depth of 5 feet. But in 1952, available moisture was present only in May and June and averaged only 1.9 per cent and 4.3 per cent, respectively, to a depth of 5 feet. Most of the moisture was below 2 feet. In July and August, some moisture was available in the upper few inches of soil following light rain showers but was mostly depleted below 2 feet. In September, no moisture was available to a depth of 5 feet.

RESULTS

The grasses had already attained considerable growth when clipping began in June, 1951. Heavy spring rains had made the experimental plots inaccessible prior to this time. Clipping was resumed the following year in May.

Herbage Yields

Blue Grama and Buffalo Grass. Total yield of grass for 1951 from the control quadrats (Treatment A) was 3,866.1 pounds per acre as compared to 2,079.7 pounds in the moderately clipped quadrats (Treatment B) and 2,884.6 pounds in the heavily clipped quadrats (Treatment C) (Table II). About one-half of the total herbage produced was removed from the moderately and heavily clipped quadrats at the initial clipping in June. The yield of grass in these two treatments remained near 500 or 600 pounds during July and August but decreased to only 118.4 and 235.7 pounds in September from treatments B and C, respectively. The monthly yield from the heavily clipped quadrats was consistently higher than where clipping was only moderate. About 700 pounds more grass was removed from the former in June and about 100 pounds more in September, but yields in July and August were only slightly higher. Yields of weeds and forbs were 288.2, 186.5, and 311.7 pounds per acre from treatments A, B, and C, respectively. At the end of 1951, the grass on the control quadrats was about 7.5 inches tall with dense cover. There were several stolons of buffalo grass 4-5 inches long that were seldom rooted, indicating that the mulch was so think as to be detrimental to rooting. The forbs showed poor growth and were widely scattered; weeds were seldom present (Fig. 3). Weeds and forbs practically disappeared from treatment B by the fall of 1951. Cover of grass was dense and stolons were rooted. It appeared that many more seeds of buffalo

TABLE II

MONTHLY AND TOTAL YIELDS IN POUNDS PER ACRE OF SHORT GRASS, BIG BLUESTEM, WESTERN WHEAT GRASS, AND WEEDS AND FORBS IN EACH SITE DURING 1951

SHORT GRASS					
Control (A)	June	July	August	Sept.	Total
Short grass					3,866.1
Weeds & Forbs					288.2
Total					4,154.3
Moderately clipped (B)					
Short grass	859.7	513.2	588.4	118.4	2,079.7
Weeds & Forbs	168.4	8.9	9.2	0.0	186.5
Total	1,028.1	522.1	597.6	118.4	2,266.2
Heavily clipped (C)					
Short grass	1,508.4	530.4	610.1	235.7	2,884.6
Weeds & Forbs	282.8	18.9	8.3	1.7	311.7
Total	1,791.2	549.3	618.4	237.4	3,196.3

BIG BLUESTEM					
Control (A)					
Big bluestem					3,958.7
Forbs					431.3
Short grass					0.0
Total					4,390.0
Moderately clipped (B)					
Big bluestem	906.4	1,032.6	600.4	146.4	2,685.8
Forbs	354.5	41.4	2.8	1.3	400.0
Short grass	15.4	8.3	6.2	2.7	32.6
Total	1,276.3	1,082.3	609.4	150.4	3,118.4
Heavily clipped (C)					
Big bluestem	1,198.9	572.1	525.7	97.9	2,394.6
Forbs	538.9	54.1	23.2	6.8	623.0
Short grass	37.4	4.9	6.8	2.3	51.4
Total	1,775.2	631.1	555.7	107.0	3,069.0

(Continued)

TABLE II (continued)

MONTHLY AND TOTAL YIELDS IN POUNDS PER ACRE OF SHORT GRASS, BIG BLUESTEM, WESTERN WHEAT GRASS, AND WEEDS AND FORBS IN EACH SITE DURING 1951

WESTERN WHEAT GRASS					
Control (A)	June	July	August	Sept.	Total
Western wheat grass					8,157.2
Weeds & Forbs					411.9
Short grass					0.0
Total					8,569.1
Moderately clipped (B)					
Wheat grass	2,328.4	161.0	38.1	16.4	2,543.9
Weeds & Forbs	36.8	88.9	169.7	84.4	379.8
Short grass	0.0	15.5	21.8	8.4	45.7
Total	2,365.2	265.4	229.6	109.2	2,969.4
Heavily clipped (C)					
Wheat grass	3,213.1	195.9	134.4	48.4	3,591.8
Weeds & Forbs	45.2	25.0	41.0	25.2	136.4
Short grass	16.7	25.9	53.3	8.4	104.3
Total	3,275.0	246.8	228.7	82.0	3,832.5

Fig. 3. Typical view of non-grazed short grass about 7 inches tall. Forbs are predominantly western ragweed. September 3, 1951.

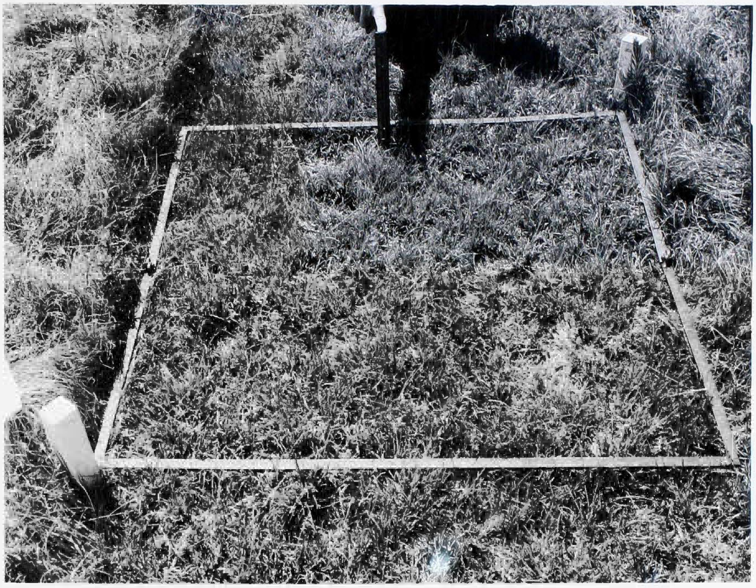

Fig. 4. Moderately clipped short grass. Note relatively dense cover. September 3, 1951.

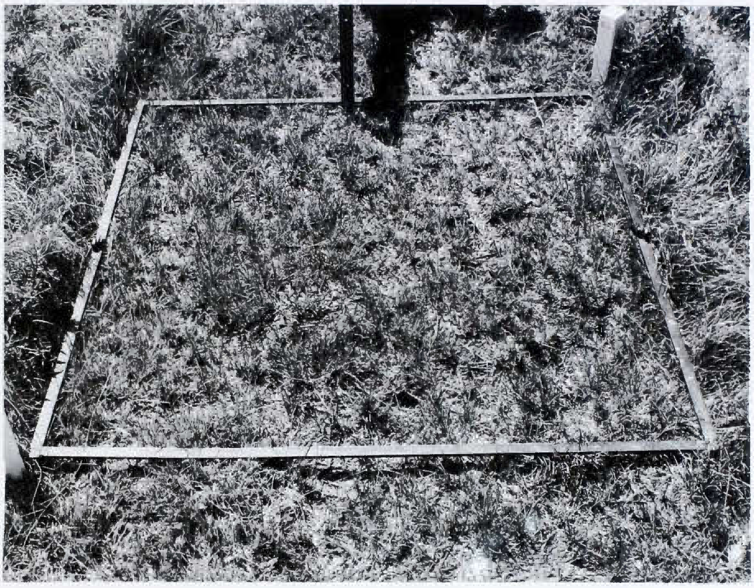

Fig. 5. Heavily clipped short grass with many open bare areas. September 3, 1951.

grass were produced than in treatment A (Fig. 4). Close clipping of treatment C prohibited production of seeds or stolons, and perennial weeds and forbs were almost entirely lacking. All of the mulch had either been removed or blown away and exposed much bare soil (Fig. 5).

In 1952, highest grass yield was again from the control quadrats, which produced 880.3 pounds per acre. Treatments B and C yielded 739.8, and 567.3 pounds, respectively (Table III). As in 1951, the initial clipping produced about one-half the total grass yield in both treatments. Yield declined rapidly during the summer until only 28.0 and 18.9 pounds were produced in September under moderate and heavy clipping, respectively. The latter produced more grass in July and August but yield in May, June, and September was greatest from the moderately clipped quadrats. Basal cover of blue grama and buffalo grass in treatments A, B, and C was 44.23, 65.13, and 43.73 per cent, respectively, after two years of clipping. Yield of weeds and forbs was again greatest in the heavily clipped quadrats. Total was 502.1 pounds which almost equalled the yield of grass. They produced 212.0 pounds from treatment B but only 174.5 pounds in the control quadrats. There was a 61 per cent increase of weeds and forbs in heavily clipped quadrats but only a 14 per cent increase in moderately clipped quadrats in 1952 over 1951.

Big Bluestem. Control quadrats produced the most grass in this site also. In 1951, yield was 3,958.7, 2,685.8, and 2,394.6 pounds per acre from treatments A, B, and C, respectively. Maximum

TABLE III

MONTHLY AND TOTAL YIELDS IN POUNDS PER ACRE OF SHORT GRASS, BIG BLUESTEM, WESTERN WHEAT GRASS, AND WEEDS AND FORBS IN EACH SITE DURING 1952

SHORT GRASS						
Control (A)	May	June	July	August	Sept.	Total
Short grass						880.3
Weeds & Forbs						174.5
Total						1,054.8
Moderately clipped (B)						
Short grass	393.4	192.7	77.1	48.6	28.0	739.8
Weeds & Forbs	128.2	51.3	14.1	15.2	3.2	212.0
Total	521.6	244.0	91.2	63.8	31.2	951.8
Heavily clipped (C)						
Short grass	243.0	132.2	90.2	83.0	18.9	567.3
Weeds & Forbs	335.3	72.3	62.4	29.6	2.5	502.1
Total	578.3	204.5	152.6	112.6	21.4	1,069.4

BIG BLUESTEM						
Control (A)						
Big bluestem						1,105.4
Forbs						267.0
Short grass						0.0
Total						1,372.4
Moderately clipped (B)						
Big bluestem	181.5	438.0	158.1	102.9	34.9	915.4
Forbs	51.7	38.2	5.8	2.3	0.0	98.0
Short grass	0.0	6.0	4.0	1.2	0,0	11.2
Total	233.2	482.2	167.9	106.4	34.9	1,024.6
Heavily clipped (C)						
Big bluestem	299.0	229.9	100.7	94.2	14.9	738.7
Forbs	89.9	25.0	5.8	6.7	0.0	127.4
Short grass	1.8	4.2	3.0	0.0	0.0	9.0
Total	390.7	259.1	109.5	100.9	14.9	875.1

(Continued)

TABLE III (continued)

MONTHLY AND TOTAL YIELDS IN POUNDS PER ACRE OF SHORT GRASS, BIG BLUESTEM, WESTERN WHEAT GRASS, AND WEEDS AND FORBS IN EACH SITE DURING 1952

WESTERN WHEAT GRASS						
Control (A)	May	June	July	August	Sept.	Total
Western wheat grass						2,348.8
Weeds & Forbs						70.3
Short grass						0.0
Total						2,419.1
Moderately clipped (B)						
Wheat grass	492.7	299.7	82.9	0.0	0.0	875.3
Weeds & Forbs	55.5	111.0	50.1	17.6	0.0	234.2
Short grass	3.6	10.3	5.3	2.3	0.0	21.5
Total	551.8	421.0	138.3	19.9	0.0	1,131.0
Heavily clipped (C)						
Wheat grass	645.7	108.6	34.7	0.0	0.0	789.0
Weeds & Forbs	120.2	38.3	61.5	21.4	0.0	241.4
Short grass	39.2	11.6	6.3	4.5	0.0	61.6
Total	805.1	158.5	102.5	25.9	0.0	1,092.0

monthly production from the moderately clipped grass was 1,032.6 pounds in July. This decreased to 600.4 pounds in August and 146.4 pounds in September. Except for the initial clipping, treatment B produced more forage each month than treatment C. Obviously, initial clipping at 1 inch would yield more than the 3-inch clipping. This difference amounted to nearly 300 pounds. The initial yield of grass from the heavily clipped quadrats was 1,198.9 pounds but this decreased to about 550 pounds during July and August, and to 97.9 pounds in September. A small amount of short grass was present as an understory in this habitat, but yield was only 32.6 pounds in treatment A and 51.4 pounds in B. Monthly yield declined steadily from June to September. No short grass was present in the control. Yield of forbs was comparatively high in all treatments. Maximum was 623.0 pounds where clipping was most severe. In both clipped plots, more than 85 per cent of the total forb yield was removed at the initial clipping. At the end of the 1951 growing season, the foliage of big bluestem in the control quadrats was about 22 inches tall but flower stalks ranged from 44 to 48 inches high. Flower stalks were produced repeatedly in treatment B from one clipping to the next. When last clipped on September 28, they were 22 to 26 inches tall. Grass appeared healthy and vigorous and cover was disturbed very little (Fig. 6). Mulch and litter was 2 to 6 inches thick when clipping began but some of it was removed at initial clipping, especially in treatment C where stubble height was 1 ince (Fig. 7). Weedy species began appearing in treatment C during the summer but disappeared after

Fig. 6. Moderately clipped big bluestem. September, 1952.

Fig. 7. Heavily clipped big bluestem. September, 1952.

several clippings. Flower stalks were only 10 to 14 inches tall.

In 1952, total grass yields were 1,105.4, 915.4, and 738.7 pounds per acre, respectively, from treatments A, B, and C (Table III). Maximum yield in the moderately clipped quadrats was 438.0 pounds in June, but there was a steady decline during the rest of the summer. Only 34.9 pounds were produced in September. In the heavily clipped quadrats, yield decreased steadily from 299.0 pounds in May to only 14.9 in September. There was no increase from May to June in treatment C after clipping began as had been evident in Treatment B. Yield of short grass was much lower in 1952 than 1951. The total was 11.2 and 9.0 pounds in treatments B and C. Yield of forbs was also lower in 1952. The greatest amount, 267.0 pounds, was produced in the control quadrats, and the least, 98.0 pounds, from the moderately clipped quadrats. The first clipping in May produced about 53 and 70 per cent of the total forb yields from treatment B and C. Yields declined rapidly during the summer and no grass was produced in September.

Western Wheat Grass. Total grass production during 1951 was 8,157.2, 2,543.9, and 3,591.8 pounds per acre in treatments A, B, and C, respectively (Table II). The spring growth cycle of western wheat grass was nearing completion when clipping began; thus, about 90 per cent of the grass produced in the moderately and heavily clipped quadrats was removed when first clipped in June. In treatment B, production at the initial clipping in June was 2,328.4 pounds, but total

Fig. 3. Moderately clipped western wheat grass.

yield in July, August, and September was only 215.5 pounds (Fig. 8). The heavily clipped quadrats produced 3,213.1 pounds to June 30 and only 378.7 pounds the remainder of the season. Short grass made considerable gains in this community in the clipped quadrats; it yielded 45.7 pounds in treatment B and 104.3 pounds in treatment C (Fig. 9). Since western wheat grass in treatment B was clipped at 7 inches, no short grass was removed until it had attained that height. Only 16.7 pounds of short grass was produced in the heavily clipped quadrats in June but the rapid increase in yield during July and August indicated significant trends toward degeneration. No short grass was produced in the control quadrats. Forbs produced 411.9, 379.8, and 136.4 pounds in treatments A, B, and C, respectively. The long, attenuated, twisted stems of western ragweed in the control quadrats indicated keen competition for light.

In 1952 yields of western wheat grass from treatments B and C were 875.3 and 789.0 pounds, respectively (Table III). Greatest yield was from the control which produced 2,348.8 pounds. Total yield from both clipping treatments was produced in May, June, and July; no growth occurred in August or September. Yield at the May 3 clipping was about 56 and 82 per cent of the total from the moderately and heavily clipped quadrats, respectively. Short grass production was 21.5 pounds in treatment B and 61.6 pounds in treatment C. This represents 47 and 59 per cent as much as was produced in 1951 in treatments B and C, respectively. Total production of weeds and

Fig. 9. Heavily clipped western wheat grass in the foreground. Light colored areas are short grass. Background is similar to the control quadrats.

forbs was 234.2 and 241.4 pounds per acre from the moderately and heavily clipped quadrats, respectively, but the control yielded only 70.3 pounds.

At the close of the 1951 growing season, western wheat grass was about 32 inches tall but it was only 22 inches tall in 1952.

Carbohydrate Content

Blue Grama and Buffalo Grass. Total sugar and starch content of the underground parts in the control quadrats varied with the growth of the grasses. When growth was rapid in the spring, total readily available carbohydrates[2] were low and when the grass was approaching dormancy in the fall they reached their peak (Fig. 10). A low of 8.13 per cent was reached by July 31, 1951; this increased to a maximun of 12.04 per cent by January 6, 1952, followed by a drop to 8.82 per cent by May 6. A peak of 12.00 per cent was reached again by June 10. This was followed by a steady decline to 8.62 per cent by August 29, and another increase to 11.11 per cent by October 18. Thus, growth of the grass had declined and storage of carbohydrates had increased during the interval between August 29 and October 18. An increase in sugar content as winter approaches has been associated with resistance to winter-killing (Graber 1927). McCarty (1938)

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[2] Total readily available carbohydrates in this paper refers to the sum of the reducing sugars, sucrose, and starch.

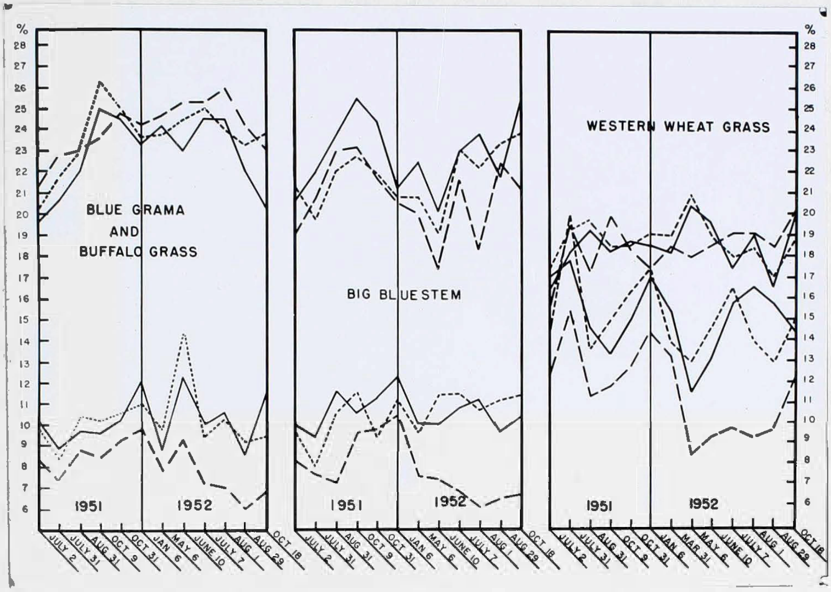

Fig. 10. Per cent total readily available carbohydrates (lower) and hemicellulose (upper) in control (solid line), moderately clipped (short dash), and heavily clipped (long dash) Short grass, big bluestem and western wheat grass on dates indicated.

concluded that larger amounts of soluble carbohydrates during the winter months, when the plant is subjected to the dessicating influence of low relative humidity and deficient soil moisture, results in an increased water-holding capacity. Hardening of the plant also is affected by the increase of sugars during the autumn. Reducing sugar content remained mostly below 0.50 per cent both years and was never as high as 1 per cent (Table IV). Amount of sucrose varied much more than the other carbohydrates; starch content was never more than 1.41 per cent. Generally, the hemicellulose fraction varied inversely to the total available carbohydrates (i.e., high total sugar content, low hemicellulose content). It varied from a low of 19.60 per cent when clipping began to a high of 24.94 per cent on January 6, 1952, and slight flucuations during the following months. By October 18, when total available carbohydrates were high, hemicellulose had declined to 20.11 per cent.

The values of all fractions from moderately clipped quadrats closely parallel those of the control quadrat (Fig. 10). Total available carbohydrates present was 9.64 per cent on July 2 but decreased about 15 per cent by July 31, 1951. They increased then to 10.52 per cent by August 31 and maintained that level until October 31; a peak of 11.19 per cent was reached on January 6, 1952. By May 6, there was a decline to 9.73 per cent followed by an increase to 14.26 per cent by June 10. During the next 4 months, the available carbohydrates maintained a fairly uniform content between 9.37 and 10.40 per cent. In many instances, the values of the total available

TABLE IV

PER CENT REDUCING SUGAR, SUCROSE, STARCH, TOTAL READILY AVAILABLE CARBOHYDRATES, AND HEMICELLULOSE IN CONTROL, MODERATELY CLIPPED, AND HEAVILY CLIPPED SHORT GRASS

Date of sample removal	Reducing sugar	Sucrose	Starch	Total readily avail. CHO	Hemi-cellulose
		CONTROL (A)			
7- 2-51	.78	8.63	.60	10.01	19.60
7- 31-51	.46	6.78	.89	8.13	20.70
8- 31-51	.41	8.33	1.08	9.82	21.98
10- 9-51	.51	7.92	1.27	9.70	24.94
10-31-51	.56	8.20	1.40	10.16	24.50
1- 6-52	.59	10.19	1.26	12.04	23.00
5- 5-52	.26	7.77	.79	8.82	24.06
6- 10-52	.44	10.67	.89	12.00	22.71
7- 7-52	.34	8.91	.90	10.15	24.32
8- 1-52	.25	9.27	1.02	10.54	24.27
8- 29-52	.31	7.41	.90	8.62	22.01
10-18-52	.46	9.24	1.41	11.11	20.11
		MODERATELY CLIPPED (B)			
7- 2-51	.42	8.62	.60	9.64	20.00
7- 31-51	.49	6.85	.84	9.18	21.58
8- 31-51	.15	9.45	.92	10.52	22.97
10- 9-51	.58	7.95	1.94	10.47	26.20
10-31-51	.76	8.56	1.25	10.57	24.96
1- 6-52	.75	9.04	1.40	11.19	23.07
5- 6-52	.22	8.59	.92	9.73	23.27
6- 10-52	.42	12.91	.93	14.26	23.89
7- 7-52	.53	8.08	.81	9.42	24.36
8- 1-52	.34	9.07	.99	10.40	24.01
8- 29-52	.40	8.08	.89	9.37	23.18
10-18-52	.32	7.64	1.46	9.42	23.67

(Continued)

TABLE IV (continued)

PER CENT REDUCING SUGAR, SUCROSE, STARCH, TOTAL READILY AVAILABLE CARBOHYDRATES, AND HEMICELLULOSE IN CONTROL MODERATELY CLIPPED AND HEAVILY CLIPPED SHORT GRASS

HEAVILY CLIPPED (C)

Date of sample removal	Reducing sugar	Sucrose	Starch	Total readily avail. CHO	Hemi-cellulose
7- 2-51	.13	7.65	.50	8.28	21.40
7- 31-51	.17	6.75	.68	7.60	22.69
8- 31-51	.51	7.48	.82	8.81	23.03
10- 9-51	.60	7.27	.82	8.69	23.53
10- 31-51	.59	7.66	1.20	9.25	24.83
1- 6-52	.94	7.64	1.02	9.60	23.75
5- 6-52	.15	7.05	.60	7.80	24.31
6- 10-52	.50	8.32	.52	9.34	24.86
7- 7-52	.34	6.87	.44	7.65	24.82
8- 1-52	.27	6.34	.58	7.19	25.95
8- 29-52	.36	5.36	.40	6.12	24.26
10- 18-52	.47	6.02	.63	7.12	22.68

carbohydrates were higher in treatment B than in the control quadrats. In treatment B, the hemicellulose content increased from a low of 20.00 per cent on July 2 to a peak of 26.20 per cent on October 9, 1951, but it declined by January 6, 1952, to 23.07 per cent. There followed a slow increase until July 7 and then a decline until August 29. On October 18, 23.67 per cent hemicellulose was present.

Total available carbohydrates of the heavily clipped quadrats was consistently lower than that of the other two treatments during both years of the experiment. Amount was 17 per cent less when the first root sample was removed 19 days after the first clipping and remained lower throughout the entire two years (Fig. 10). Total carbohydrates of treatment A varied from 7 to 20 per cent more than that of treatment C during 1951 and until May 6, 1952, when the detrimental effects of clipping became more apparent. From this time on differences in carbohydrate content became progressively greater until the final sample was removed on October 18 when underground parts of heavily clipped quadrats contained 36 per cent less total available carbohydrates than those of the control. A minimum of 7.60 per cent total available carbohydrates was present on July 31, 1951, but increased to 9.60 per cent by January 6, 1952. Generally, there was an increase each month in total available carbohydrates during this interval. They declined about 19 per cent from January 6 to May 6, 1952, but increased a like amount by June 10. From the latter date until August 29 there was a decline during which the roots lost 35 per cent of their total available carbohydrates.

Except on January 6, the reducing sugars were generally lower in the heavily clipped quadrats. Sucrose exceeded 8 per cent only once during the experiment in these quadrats but was seldom below 8 per cent in the other treatments. On August 29, 1952, sucrose content was only 5.36 per cent. The values for starch remained mostly between 0.50 and 0.80 per cent and exceeded 1 per cent only during the fall and winter. Hemicellulose followed much the same pattern as in the other treatments. In 1952, when total available carbohydrates were declining rapidly during the summer, hemicellulose content was increasing. On August 1, hemicellulose had reached a peak of 25.95 per cent but there was only 22.68 per cent on October 18.

Big Bluestem. Trends of total available carbohydrates of the control quadrats were similar to those of the unclipped short grasses in that amount was low when growth began and high as dormancy approached (Fig. 10). Per cent present was 9.82, 9.41, 11.93 on July 2, July 31, and August 31, respectively. The amount remained relatively high through the winter; a peak of 12.14 per cent was reached on January 6, 1952. During May and early June 9.93 per cent was present. There was a gradual increase to 11.39 per cent on August 1. Somewhat less was present during August when flower stalks were growing rapidly. During both years, total carbohydrates were declining in treatment A in early fall while those of treatment B were increasing. The reducing sugar portion of these carbohydrates varied from a high of 1.65 per cent on January 6 to a low of 0.10 per cent on August 29, 1952 (Table V). Other amounts of 0.97, 1.00, and 1.08 per cent occurred in July and August, 1951. Sucrose exceeded 10 per cent only once and was seldom above 9 per cent. It varied only slightly and usually was low when growth began and high when growth ceased. Starch content was usually above 1 per cent but was as low as 0.60 per cent on July 2, 1951, and 0.66 per cent on June 10, 1952. Hemicellulose content, as in the short grasses, was low in the winter when amounts of sugars and starch were high. It began at 20.20 per cent on July 2 and climbed rapidly, increasing to 25.66 per cent, by October 9, 1951. It decreased just as rapidly to 20.64 per cent by mid-winter. Variations ranged from 19.67 to 23.63 per cent until the last of August; hemicellulose content increased to a peak of 26.39 per cent by October 18.

Values of the total available carbohydrates of the moderately clipped plots were generally slightly less but sometimes exceeded those of the control quadrats (Fig. 10). There was 9.70 per cent total available carbohydrates present on July 2, 1951, but with rapid growth they decreased to 8.10 per cent by July 31. There were several fluctuations during late summer and fall but the plants finally went into the winter with reserves amounting to 11.37 per cent as indicated by samples removed on January 6, 1952. When growth was beginning the following spring, the May 6 sample decreased to about 9 per cent, but the values remained about 11 per cent or slightly above during the remainder of the 1952 season. Reducing sugar content

TABLE V

PER CENT REDUCING SUGAR, SUCROSE, STARCH, TOTAL READILY AVAILABLE CARBOHYDRATES, AND HEMICELLULOSE IN CONTROL, MODERATELY CLIPPED AND HEAVILY CLIPPED BIG BLUESTEM

Date of sample removal	Reducing sugar	Sucrose	Starch	Total readily avail. CHO	Hemi-cellulose
CONTROL (A)					
7- 2-51	.97	8.25	.60	9.82	20.20
7- 31-51	1.00	7.58	.83	9.41	21.81
8- 31-51	1.08	9.63	1.22	11.93	23.92
10- 9-51	.62	8.57	1.13	10.32	25.66
10-31-51	.88	9.12	1.27	11.27	24.14
1- 6-52	1.65	9.27	1.22	12.14	20.64
5- 6-52	.44	8.55	.92	9.91	22.28
6- 10-52	.43	8.84	.66	9.93	19.67
7- 7-52	.55	9.05	1.22	10.82	22.98
8- 1-52	.39	10.02	.98	11.39	23.63
8- 29-52	.10	8.53	1.01	9.64	22.28
10-18-52	.76	8.06	1.40	10.22	26.39
MODERATELY CLIPPED (B)					
7- 2-51	.82	7.88	1.00	9.70	21.08
7- 31-51	.33	6.72	1.05	8.10	19.91
8- 31-51	.53	8.92	1.21	10.66	21.86
10- 9-51	.56	9.78	1.23	11.57	22.92
10-31-51	.45	7.49	1.18	9.12	21.96
1- 6-52	1.59	8.95	.83	11.37	20.71
5- 6-52	.30	7.89	1.01	9.20	20.77
6- 10-52	.73	9.69	1.10	11.52	19.22
7- 7-52	.41	10.11	.96	11.48	22.98
8- 1-52	.38	9.53	.91	10.82	22.41
8- 29-52	.54	9.61	1.00	11.15	23.15
10-18-52	.49	9.27	1.65	11.41	23.33

(Continued)

TABLE V (continued)

PER CENT REDUCING SUGAR, SUCROSE, STARCH, TOTAL READILY AVAILABLE CARBOHYDRATES, AND HEMICELLULOSE IN CONTROL, MODERATELY CLIPPED, AND HEAVILY CLIPPED BIG BLUESTEM

HEAVILY CLIPPED (C)

Date of sample removal	Reducing sugar	Sucrose	Starch	Total readily avail. CHO	Hemi-cellulose
7- 2-51	.34	7.11	1.01	8.46	18.97
7- 31-51	.36	6.53	.80	7.69	20.58
8- 31-51	.47	6.20	.81	7.48	22.95
10- 9-51	.53	7.76	1.18	9.47	23.01
10-31-51	1.04	7.26	1.28	9.58	21.90
1- 6-52	2.18	7.90	.68	10.76	20.55
5- 6-52	.23	6.20	.60	7.13	20.13
6- 10-52	.43	6.11	.60	7.14	17.93
7- 7-52	.59	5.81	.52	6.92	21.45
8- 1-52	.28	5.26	.50	6.04	18.82
8- 29-52	.15	5.64	.61	6.40	22.94
10-18-52	.23	5.60	.80	6.63	21.90

was generally lower in these quadrats than those of treatment A (Table V). A peak of 1.59 per cent was present on January 6, 1952, the only time the fraction exceeded 1 per cent. Sucrose content of the moderately clipped quadrats was usually lower than those of the control quadrats in 1951 but in 1952 the reverse was more often true. The root samples contained less than 1 per cent starch only during mid-winter and early summer of 1952. The most starch, 1.65 per cent, was present on October 18, 1952. Hemicellulose content was almost always lower in the moderately clipped quadrats than in the control quadrats (Fig. 10). During 1951, the extremes were 19.91 per cent on July 31 and 22.92 per cent on October 9. It decreased by January 6, 1952, and again by June 10, but with increases each month except one, a peak of 23.33 per cent was reached by October 18.

Heavy clipping in this site had the same results as in the short grasses in regard to total available carbohydrates, which were nearly always low after the first clipping. They exceeded the value for the moderately clipped quadrats on October 31, 1951, but were much lower in 1952 (Fig. 10). Total available carbohydrates of plants from the heavily clipped quadrats averaged only 18 per cent less than those of the control in 1951, but at one time in 1952, they were 47 per cent less. The carbohydrates in these quadrats totaled 8.46 per cent on July 2, 1951, but declined by August 31 to a low of 7.48 per cent. On January 6, 1952, a peak of 10.76 per cent was reached but it decreased about 34 per cent by May 6. A downward trend continued until August 1 when a low of 6.04 per cent was present.

By October 18, this had increased to 6.63 per cent. Reducing sugar values were generally lower than those of either of the other two treatments. However, the January sample contained 2.18 per cent, the highest amount present in any of the treatments (Table V). Sucrose content was also generally lower. Values were usually above 7 per cent in 1951 but below 6 per cent in 1952. Starch content exceeded 1 per cent in only 3 samples, all removed during the first year. During the second year, the amount was 0.68 per cent on January 6 which decreased until August 1 to 0.50 per cent. During August and until October 18, starch increased to 0.80 per cent. Amount of hemicellulose was about the same as in the other treatments in 1951 but values for the heavily clipped quadrats for 1952 were generally lower than those of treatments A and B. Hemicellulose varied from a low of 18.97 per cent on July 2 to a high of 23.01 per cent on October 9, 1951. During 1952, the general trend was upward but it fluctuated from about 18 per cent in the spring to about 23 per cent in the fall. Hemicellulose content of all treatments followed much the same patterns.

Western Wheat Grass. Total amounts of carbohydrates in this rhizomatous species were considerably greater than in the other grasses. Carbohydrate reserves in the control quadrats followed a pattern closely related to the normal growth cycle of this species (Fig. 10). Largest amounts in the control, which varied from 17.75 and 16.27 per cent during the summers to 17.10 per cent during the winter, occurred during periods when this grass was relatively inactive. Lows of 13.45 and 11.75 per cent were present in samples removed during early October and May when growth was fairly rapid. It is apparent then that storage of carbohydrates occurs rather rapidly over a relatively short period during the latter part of the growth period. Reducing sugar values remained low, as in the other grass species. A maximum of 1.08 per cent was present on January 6, 1952, but 0.75 per cent was usually the maximum (Table VI). Generally, greater amounts of reducing sugars were present in 1951 than in 1952. Sucrose reached a peak of 10.11 per cent on March 31, 1952, but generally remained between 9 and 10 per cent. It usually declined slightly during periods of growth and increased during approaching dormancy. Starch content was much higher in this species of grass than in the others contained in this study. Starch fluctuated usually between 4 and 7 per cent but on May 6, 1952, reached a minimum of only 2.52 per cent. The greatest amount of starch was present on August 29, 1952, when the peak was 7.10 per cent. Hemicellulose content was not as high in this species but followed the same inverse correlation to total available carbohydrates. In some instances, total available carbohydrates exceeded the amount of hemicellulose present. Trend of hemicellulose was generally upward during 1951 and until May 6, 1952, when it reached a peak of 20.59 per cent. During the fall and winter it remained about 18.5 per cent. The values varied from a high of 19.76 per cent on June 10 to a low of 16.77 per cent on August 29, 1952.

TABLE VI

PER CENT REDUCING SUGAR, SUCROSE, STARCH, TOTAL READILY AVAILABLE CARBOHYDRATES, AND HEMICELLULOSE IN CONTROL, MODERATELY CLIPPED AND HEAVILY CLIPPED WESTERN WHEAT GRASS

Date of sample removal	Reducing sugar	Sucrose	Starch	Total readily avail. CHO	Hemi-cellulose
CONTROL (A)					
7- 2-51	.71	9.88	6.41	17.00	16.46
7- 31-51	.85	9.91	6.99	17.75	18.25
8- 31-51	.19	8.53	5.73	14.45	19.21
10- 9-51	.58	8.76	4.11	13.45	18.37
10-31-51	.80	9.10	4.95	14.85	18.80
1- 6-52	1.08	9.80	6.22	17.10	18.55
3- 31-52	.31	10.11	4.92	15.34	18.39
5- 6-52	.24	8.99	2.52	11.75	20.59
6- 10-52	.26	9.17	3.96	13.39	19.76
7- 7-52	.26	9.93	5.40	15.59	17.44
8- 1-52	.34	9.88	6.05	16.27	18.85
8- 29-52	.21	8.54	7.10	15.85	16.77
10-18-52	.64	9.37	4.27	14.28	19.68
MODERATELY CLIPPED (B)					
7- 2-51	.97	9.48	3.49	13.94	17.25
7- 31-51	1.30	11.94	6.72	19.96	19.17
8- 31-51	.19	8.00	5.73	13.92	19.73
10- 9-51	1.12	7.95	5.89	14.96	18.59
10-31-51	.90	9.20	6.10	16.20	18.70
1- 6-52	.86	10.35	6.21	17.42	19.15
3- 31-52	.20	9.22	4.58	14.00	19.06
5- 6-52	.38	9.04	3.51	12.93	21.03
6- 10-52	.36	8.23	6.07	14.66	19.16
7- 7-52	.66	9.32	6.53	16.51	17.97
8- 1-52	.21	8.61	5.35	14.17	18.44
8- 29-52	.54	7.52	4.95	13.01	17.09
10-18-52	.74	9.30	4.58	14.62	18.89

(Continued)

TABLE VI (continued)

PER CENT REDUCING SUGAR, SUCROSE, STARCH, TOTAL READILY AVAILABLE CARBOHYDRATES, AND HEMICELLULOSE IN CONTROL, MODERATELY CLIPPED, AND HEAVILY CLIPPED WESTERN WHEAT GRASS

HEAVILY CLIPPED (C)

Date of sample Removal	Reducing sugar	Sucrose	Starch	Total readily avail. CHO	Hemi-cellulose
7- 2-51	.83	8.08	3.10	12.01	14.29
7- 31-51	1.43	8.78	5.35	15.56	19.51
8- 31-51	.43	7.39	3.35	11.17	17.25
10- 9-51	.50	6.64	4.59	11.73	19.79
10-31-51	.40	7.10	5.10	12.60	18.50
1- 6-52	.63	8.58	5.49	14.70	17.51
3- 31-52	.41	8.24	4.80	13.45	18.57
5- 6-52	.42	5.57	2.79	8.78	18.01
6- 10-52	.62	6.33	2.42	9.37	18.69
7- 7-52	.52	5.93	3.28	9.73	19.16
8- 1-52	.21	5.59	3.77	9.57	19.11
8- 29-52	.42	5.79	3.53	9.74	18.22
10-18-52	.54	7.75	3.88	12.17	20.09

The curve for treatments A and B followed each other rather closely throughout the experiment (Fig. 10). This indicates the 7-inch clipping was not a hindrance to storage of carbohydrates. In fact, samples from the moderately clipped quadrats contained slightly more reserve foods after two years of clipping than did those of the unclipped grasses. At many other times, also, root reserves of the former were higher than those of the latter. More available carbohydrates were present in treatment B during the fall storage period of 1951 and spring storage period of 1952. Although total amount of carbohydrates stored during dormant periods in treatments A and B were nearly the same, treatment B began storing earlier or had more carbohydrates present when storage began. In July, 1952, the moderately clipped grasses began utilizing its carbohydrates a month earlier than the control. This indicates further that western wheat grass continues growth when clipped or grazed. Maximum amounts of carbohydrates were again reached in the summer and winter and minimums in spring and fall. They ranged from 16.20 to 19.96 per cent during dormant periods to as low as 12.93 per cent during rapid growth. Reducing sugar values were high, remaining near 1 per cent or above in 1951, with the exception of August 31, when only 0.19 per cent was present. In 1952, the values were lower, fluctuating from 0.20 per cent on March 31 to 0.74 per cent on October 18. Sucrose varied from 11.94 per cent in the summer to 7.95 per cent in the early fall of 1951. After an increase of 10.35 per cent on

January 6, 1952, the values varied little, but were as low as 7.52 per cent on August 29. Starch values in these quadrats were about the same as in the control quadrats. There was usually more starch present in the moderately clipped quadrats during periods of growth but more present in the control quadrats during dormant periods. Hemicellulose content was generally slightly higher during 1951 in these quadrats as compared to the control quadrats. In 1952, it reached a peak of 21.03 per cent on May 6, but with slight flucuations during the remainder of the year, the trend was downward.

General storage pattern of the western wheat grass clipped to a stubble height of 3 inches follows a similar trend to that of the other treatments (Fig. 10). Amounts, however, were significantly less when the first root sample was removed and remained lower throughout both years of the experiment. For example, on August 1, 1952, total available carbohydrates of the heavily clipped quadrats was 40 per cent less than those of the control; but, just the year before, on July 31, treatment C had only 12 per cent less carbohydrates than treatment A. During the period January 6 to May 6, 1952, total available carbohydrates in treatments A, B, and C decreased 30, 25, and 40 per cent, respectively. Although the trend was generally upward during the remainder of 1952, it will be remembered that there was no yield of forage during August or September. The grass had gone into dormancy early because of the drought and had grown very little during the summer. Reducing sugar values remained about the same in this treatment as in the others (Table VI). On January 6, 1952, reducing sugars were low as compared to those of treatments A or B. Generally, the values varied between 0.40 and 0.63 per cent but at one time were as low as 0.21 per cent. Sucrose values were much lower in treatment C quadrats. Never did they exceed 9 per cent nor did they go below 5 per cent. They were usually lower during the second year of clipping. Starch values were also much lower, especially during the second year. A minimum of 2.79 per cent starch was present on May 6, 1952, and reached a maximum of only 3.88 per cent when the experiment was terminated. Hemicellulose content was low, only 14.29 per cent, when clipping began, but increased to 19.51 per cent by July 31, 1951. The values remained mostly between 17 and 20 per cent the remainder of the experiment.

Phytometer Studies

The western wheat grass sods, which were transplanted into phytometers, had small green shoots visible underneath the mulch when they were removed from the field in January. They began growing as soon as they were placed in the greenhouse. The short grass began growing about a week after transplanting and the big bluestem about 2 weeks. The short grass was allowed to grow 9 weeks, big bluestem 7 weeks, and western wheat grass 10 weeks. Total height of the grasses after this growth period is presented in Table VII. Grasses from the control quadrats grew the most each week and attained the greatest height (except for big bluestem under treatment B).

Heavily clipped grasses produced the least growth indicating further the effects of frequent and intensive removal of forage. They produced 62, 65, and 84 per cent of the height produced by the control in the short grass, big bluestem, and western wheat grass, respectively.

TABLE VII

HEIGHT OF GRASSES FROM TREATMENTS A, B, AND C GROWN IN PHYTOMETERS

Treatment	Short grass	Big bluestem	Western wheat grass
	Total height (inches)		
Control (A)	10.5	13.0	25.0
Moderately clipped (B)	8.0	13.0	24.0
Heavily clipped (C)	6.5	8.5	21.0

There was little growth of weeds and forbs in any of the phytometer studies from the control quadrats. However, there was a large number in those from the moderately clipped quadrats and a heavy infestation, especially of weedy annuals, in the heavily clipped grasses. Approximately two months after transplanting the sods, the heavily clipped short grass had 13 stolons, one of which was 16.5 inches long. The control and moderately clipped short grass had 4 stolons each, averaging about 6 inches long. On the same date, the heavily clipped short grass sod had numerous flower stalks but there were only 2 in the moderately clipped and one in the control quadrats. However, the latter two treatments each eventually produced more than treatment C. Clipping in the field likewise caused a decline in flower stalk and seed production in treatment C. Figure 11 shows the phytometers at the end of 7 weeks. The number and average diameter of roots emerging from the phytometer sods are shown in Table VIII.

TABLE VIII

NUMBER AND DIAMETER OF ROOTS EMERGING FROM PHYTOMETER SODS OF GRASSES CLIPPED 1 YEAR

	Short grass		Big bluestem		Western wheat grass	
	Roots	Diameter	Roots	Diameter	Roots	Diameter
Control (A)	51	.41 mm	7	.89 mm	64	.56 mm
Moderately clipped (B)	30	.47 mm	7	1.0 mm	42	.66 mm
Heavily clipped (C)	35	.33 mm	9	.77 mm	32	.29 mm

The roots had grown to the bottom of all phytometers before they were washed free of soil and could not be measured for length. Branching was more profuse in the control quadrats in all grasses; there was an abundance of laterals along the entire extent of the roots. In every case, although moderate clipping reduced the number of roots, the diameters were larger than the control. Roots of the heavily clipped grasses were smallest of the three treatments. Obviously, carbohydrates cannot be stored in a smaller root to the extent that

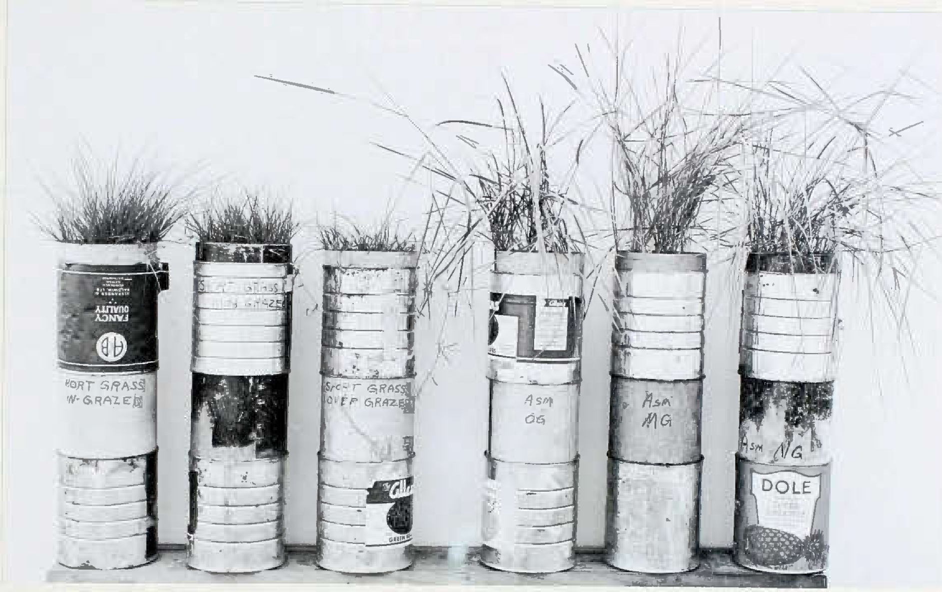

Fig. 11. Short grass and western wheat grass in phytometers after 9 and 10 weeks growth, respectively. From left to right: control, moderately clipped, and heavily clipped short grass; and heavily clipped, moderately clipped, and control quadrats of western wheat grass. Note long stolons emerging from heavily clipped short grass.

they can in larger roots.

Root Weights

A study was made in the fall of the second year of the effect of the 2 years of clipping on amount of plant material in the upper 4 inches of soil. Underground parts from the control quadrats were heaviest (with the exception of the moderately clipped short grass) and those from the heavily clipped quadrats were lightest (Table IX). Generally, the weight of underground plant parts decreased as clipping intensity increased (Fig. 12). The effect was least on the short grass quadrats, where there was a slight increase under moderate clipping and very little decrease under heavy clipping. Moderate clipping of big bluestem and western wheat grass decreased the weights of underground parts about 14 and 25 per cent, respectively, but decrease under heavy clipping was 38 and 36 per cent. These results merely verify numerous observations in the field on the inability of taller grasses to withstand excessive removal of top growth.

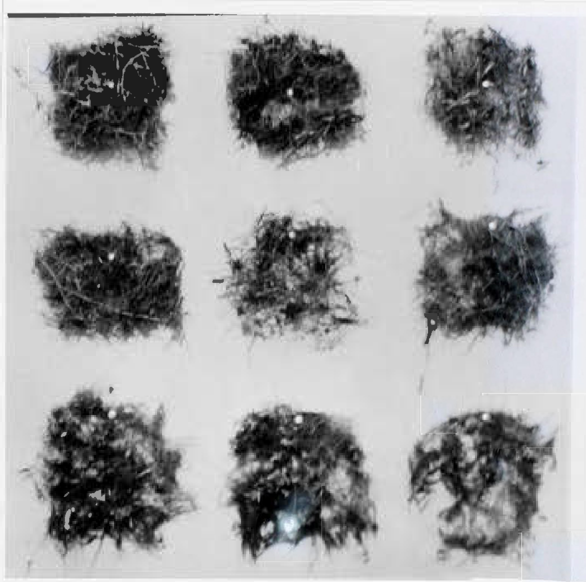

Fig. 12. Underground plant parts at end of second year from control, moderately clipped, and heavily clipped (left to right) big bluestem, western wheat grass, and short grass (top to bottom).

TABLE IX

AVERAGE WEIGHTS OF UNDERGROUND PLANT PARTS OF 4 SODS REMOVED AT THE END OF THE EXPERIMENT

Treatment	Short grass	Big bluestem	Wheat grass
	Weight in grams		
Control (A)	15.7	23.9	20.2
Moderately clipped (B)	17.4	20.5	15.1
Heavily clipped (C)	14.1	14.9	12.9

DISCUSSION

Although considerable work has been done concerning the effect of clipping or grazing upon carbohydrate reserves stored in the roots and other underground plant parts, very little appears to have been done in the Great Plains, especially with the particular grasses contained in this study. It was hoped that concrete evidence would be found to support the conclusions of many investigators that intensive clipping or grazing is detrimental to plant growth.

Response of the grasses to clipping in 1951 and 1952 was similar in many respects. The control quadrats produced the highest total yield both years. In the moderately and heavily clipped quadrats, the initial clipping produced a large percentage of the total yield. In big bluestem and short grass plots, the yield of the following month was also high or sometimes even exceeded that of the month before. This clipping stimulus is also evident in the sudden increase of carbohydrates after initial clippings (Fig. 10). Harrison and Hodgson (1939) found that cutting some grasses at 3 inches resulted in more new growth production at first then cutting them at 6 inches. Removal of more tissue from the plant cut closely resulted in a more favorable relationship of carbohydrates to nitrogen. But after some of the reserve carbohydrates had been used, the proportion of carbohydrates to nitrogen in the plants cut at three inches was too low to produce the most favorable growth.

Since growing conditions in 1952 were much poorer than in 1951, it would be expected that all treatments would show a decline in grass yield. A comparison of the amount of decrease is presented in Table X.

TABLE X

PERCENTAGE DECLINE FROM 1951 TO 1952 OF YIELDS OF SHORT GRASS, BIG BLUESTEM, AND WESTERN WHEAT GRASS IN TREATMENTS A, B, AND C

Treatment	Short grass	Big bluestem	Western wheat grass
Control (A)	77	72	71
Moderately clipped (B)	64	66	66
Heavily clipped (C)	80	70	78

The moderately clipped quadrats show the least decline despite combined effects of clipping and drought. Yields from treatment C declined in most, except in big bluestem, where the largest decrease was in the control. Treatment A and C in the short grass decreased considerably more than B.

Rapid growth of the short grass understory in the clipped quadrats of western wheat grass was due to the removal of the competitive influence of the taller wheat grass. Many studies (Weaver and Albertson 1940, Albertson and Weaver 1946) have shown that heavy grazing causes degeneration of mixed prairie to short grass. Short grass was not adapted to growth on the shallow, rocky soil of the big bluestem site; this fact, along with the vigorous growth habits of big bluestem and the 1952 drought, almost led to complete disappearance of the short grass understory.

Weeds and forbs of the short grass and western wheat grass plots are mostly not preferred by grazing animals. Their yield is significant only in that soil moisture and nutrients could be better utilized by more valuable forage plants. Forbs present on the big bluestem site, however, were, for the most part, high protein forage plants and readily eaten by livestock.

Much valuable forage was removed from the moderately clipped quadrats without significant depletion of the total reserves; but continued removal of a large part of the photosynthetic area of the heavily clipped grasses would eventually result in their complete destruction. For example, total available root reserves of moderately clipped short grass averaged about 1.7 per cent more each month than the control during two years of clipping, and those of big bluestem and western wheat grass averaged only about 0.4 and 0.5 per cent less, respectively. However, carbohydrate reserves of the heavily clipped grasses averaged 21.2, 26.1, and 23.6 per cent less than those of the control quadrats of short grass, big bluestem, and western wheat grass, respectively.

The role of hemicellulose as a reserve food is most uncertain. As has been illustrated (Fig. 10), changes in the amount of hemicellulose and total readily available carbohydrates are more or less in inverse proportion. For example, during the fall when readily available carbohydrates were increasing, hemicellulose content was decreasing. This behavior suggest that conversions from hemicellulose were added to total available carbohydrates and utilized in the metabolic functions of the plant. These results indicate that hemicellulose may be considered as available stored food. But McCarty (1938) suggests that any transformation from hemicellulose to starch or sugar is apparently very slow, possibly so slow as to fail to supply sufficient soluble sugars to satisfy the demand when such foods are being utilized at a rapid rate. McCarty concludes that hemicellulose is employed largely as structural material.

This experiment was conducted only 2 years but results indicate that a system of moderate grazing should be preferred because it has been shown not to decrease root reserves appreciably and, consequently, high yeilds of forage are maintained. Indeed, moderate grazing may lead to a more vigorous, healthy, plant growth, and thus, increase the root reserves. The high content of carbohydrate reserves in this treatment, together with the minimum decrease in yields, further strengthens the concept that moderate grazing is even more desirable than allowing the pasture to remain idle. The heavily clipped quadrats suffered the greatest loss in most cases, not only in herbage yields but also in carbohydrate reserves. The lower reserves will lead, undoubtedly, to reduced vigor, fewer seed stalks and viable seeds, more winter killing, and a much reduced root system.

SUMMARY

A field and laboratory study was made in 1951 and 1952 to determine the effects of different intensities and frequencies of clipping upon a mixture of blue grama (Bouteloua gracilis (H.B.K.) Lag. ex Steud.) and buffalo grass (Buchloe dactyloides (Nutt.) Engelm.), big bluestem (Andropogon gerardi Vitman.), and western wheat grass (Agropyron smithii Rydb.). Blue grama and buffalo grass are warm-season short grasses occurring intermingled on the deep upland soil. Big bluestem is a warm-season tall grass which grows on shallow, rocky soil of hillsides and deep immature soil of lowlands. Western wheat grass grows primarily during the cool season. It is a midgrass and occurs on immature soils of ravines and swales and on disturbed areas. These grasses were growing in relatively pure stands in areas ungrazed for many years.

Experimental quadrats in each of the areas consisted of an unclipped control (treatment A), quadrats clipped moderately every 3 weeks (treatment B), and quadrats clipped heavily every 2 weeks (treatment C). The clipping was at 2 inches and 0.5 inch in short

grass, 3 inches and 1 inch in big bluestem, and 7 inches and 3 inches in western wheat grass. The herbage removed was air dried, weighed, and computed on a pounds per acre basis. Once each month from July, 1951, to October, 1952, (with the exception of several winter months) root samples to a depth of 4 inches from each treatment in each of the grasses were removed, washed, dried, and ground. Later they were analyzed for reducing sugars, sucrose, starch, and hemicellulose. Sods were removed in January, 1951, and placed in phytometers to find the effects of the previous years clipping upon root and top development. Equal size sods were removed at the close of the study from each treatment and weights of the underground parts compared.

The rainfall for growing season of 1951 was about 37.5 inches but in 1952 it was about 9.0 inches. This, along with other factors, made 1951 ideal for plant growth and 1952 extremely poor.

Yields of grass in 1951 and 1952 and percentage decline are presented in Table XI. Yields were greatest from treatment A both years.

TABLE XI

TOTAL YIELDS OF SHORT GRASS, BIG BLUESTEM, AND WESTERN WHEAT GRASS IN TREATMENTS A, B, AND C IN 1951 AND 1952 AND PERCENTAGE DECLINE THE SECOND YEAR

	1951			1952			% decline		
	A	B	C	A	B	C	A	B	C
Short grass	3866.1	2079.7	2884.6	880.3	739.8	738.3	77	64	80
Big bluestem	3958.7	2685.8	2394.6	1105.4	915.4	738.7	72	66	70
Western wheat grass	8157.2	2543.9	3591.8	2348.8	875.3	789.0	71	66	78

In 1951, except for big bluestem, treatment C yielded more than treatment B; but in 1952, more forage was produced under treatment B. Decline in yield from 1951 to 1952 was least in the moderately clipped quadrats.

Carbohydrate reserves followed a pattern closely related to the normal growth cycle of the grasses. The trend of carbohydrates was downward when growth was rapid; but as dormancy approached, they increased and a peak was usually reached in the winter. The warm-season grasses of treatment A utilized carbohydrate reserves extensively until August, 1951, when storage of reserves occurred until a peak was reached in January. In 1952, reserves were low only in the spring. In treatment A of western wheat grass, utilization of carbohydrates occurred during August and September, 1951, March and April, and August, and September, 1952. Maximum amounts of reserves were present on August 1 both years and during the winter. Treatment B reserves followed closely those of treatment A large amounts of forage were removed from these quadrats without depletion of the reserve foods. Treatment C reserves were significantly lower, expecially during 1952. Heavy clipping reduced carbohydrates an average of 21.2, 26.1, and 23.6 per cent in short grass, big bluestem, and western wheat grass, respectively. Losses during 1952 ranged from 35 to 47 per cent less than the control. Reducing sugar and starch content of the warm season grasses was rarely more than 1 per cent but amounts of starch in western wheat grass was usually 2 to 7 per cent. Sucrose was by far the largest contributor to available reserve foods. Hemicellulose varied inversely as total readily available carbohydrates.

Grasses transplanted into phytometers from treatment A plots attained the greatest height (except in big bluestem). Heavily clipped grasses produced 62, 65, and 84 per cent of the height produced by the control in the short grass, big bluestem, and western wheat grass, respectively. In addition, number and diameter of roots were reduced. There were sometimes fewer roots under moderate clipping, but they were considerably larger than those of any other treatment.

Weights of roots removed at the close of the study were greatest from the control quadrats (except for moderately clipped short grass). Moderate clipping of big bluestem and western wheat grass decreased weights of underground parts 14 and 25 per cent, respectively, but decrease under heavy clipping was 38 and 36 per cent. The effect of clipping was least on short grass.

Effects of heavy and frequent clipping were reduced vigor as indicated by reduction of yield and decline in root reserves, decrease in quantity and size of roots, and encroachment by species of low forage value.

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