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Effects of Intensity of Clipping of Three Range Grasses from Grazed and Ungrazed Areas in West-Central Kansas

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EFFECTS OF INTENSITY OF CLIPPING
ON THREE RANGE GRASSES
FROM GRAZED AND UNGRAZED AREAS IN WEST-CENTRAL KANSAS

being

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THESIS ABSTRACT

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This investigation was an attempt to determine the vigor of various types of range grasses under different intensities of clipping. Three range grasses selected for study were: (1) a tall grass, big bluestem (Andropogon gerardi Vitman); (2) a mid-grass, side-oats grama (Bouteloua curtipendula (Michx.) Torr.); and (3) a short grass, blue grama (Bouteloua gracilis (H. B. K.) Lag. ex Steud.). Sods of these grasses were taken from two areas: (1) an area which had been fairly heavily utilized for several years; and (2) an area which had been protected from grazing for over fifty years.

Limiting factors in this study were that the areas had been subjected to above average growing conditions, i.e., ideal rainfall and temperature, for two years preceding collection of the sods and that the grazed area had been less heavily grazed than it had in the past.

All top growth was removed and sods were transplanted in phytometers and subjected to the following treatments: (1) those plants which were not clipped from beginning to end of the study; (2) those which were clipped weekly to a height of 1.5 inches; and (3) those which were clipped to the crown each week. Three replications for each treatment were established. This phase of the study was carried on for about 12 weeks.

Measurements recorded or calculated included: (1) weekly and cumulative height and weight of new shoot growth; (2) bi-weekly variation in number of shoots; (3) cumulative weight per tiller; (4) length

and weight of new root growth; and (5) shoot-root ratio. In addition, a method of descending paper chromatography was used to measure the amount of readily available carbohydrates at beginning and end of the study to determine gain or loss under different intensities of clipping.

Findings were as follows: (1) When closely clipped, all plants studied were severely restricted in shoot production, new root growth, and production of carbohydrates. (2) Moderate clipping seemed to stimulate shoot growth, but restricted, to some degree, the production of new roots. The production of carbohydrates was not severely affected by moderate clipping. (3) Growth differences in plants from the two areas were not significant except under non-clipped conditions. (4) Shoot-root ratio increased with intensity of clipping. (5) Clipping tended to reduce species significance. (6) Development of flowers caused a decrease in carbohydrate content of plants.

Tables, graphs, and photographs were used to present and illustrate the results of the various studies.

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INTRODUCTION

If proper management of grasslands for maximum productivity is to be maintained, careful studies must be made regarding the effects of various intensities of grazing. Studies on the ability of range grasses to produce maximum forage have indicated that not only production of shoots, but also production of new roots and manufacture and storage of reserve foods, must be considered.

Since shoots contain the food-making or photosynthetic cells of plants, frequent removal of them will cause a marked decrease in the photosynthetic activity and a corresponding decrease in the growth of the roots. This, ultimately, will result in deterioration of the root system and death of the plant (Biswell and Weaver, 1933).

Many studies have been made on the effect of clipping or grazing on the production of forage. Some have also included data on root growth and food reserves; however, little of this work has been done in the area of the Great Plains in which the present study was conducted.

It was the purpose of this investigation to determine the vigor of various types of range grasses under different intensities of clipping. Factors measured included weekly and cumulative height and weight of new shoot growth, variation in number of shoots during the study, length and weight of new root growth, and shoot-root ratio. In addition, carbohydrate determinations were made at beginning and end of the study to determine gain or loss under different intensities of clipping.

RELATED STUDIES

The effect of frequency and intensity of clipping on yield and vigor of various pasture and range grasses, in general, show that yield and vigor decrease as frequency and/or intensity of clipping are increased (Albertson, et al., 1953). Weaver and Hougen (1939), Stoddart (1946), and Cook, et al. (1958) have also made studies that support this statement.

Tomanek (1948) found that, under favorable growing conditions, more frequent harvesting at moderate heights sometimes causes production of greater herbage yields than does a single clipping at the end of the growing season. This was also noted by Cook, et al. (1958) in a study of crested wheatgrass.

Studies by Albertson, et al. (1953), Biswell and Weaver (1933) and Hanson and Stoddart (1940) indicate that frequent and/or intensive clipping of grasses were found to result in a reduced yield and decreased number and spread of roots for a number of species.

Tomanek and Albertson (1953)--in comparing yields, growth in height, and the number of tillers produced per unit area in overgrazed, moderately grazed, and nongrazed pastures near Hays, Kansas--found a greater growth and a greater number of tillers per unit area in the nongrazed than in the heavily grazed pasture. The nongrazed area produced 2,296 pounds of forage per acre, compared to 1,323 for the one heavily grazed.

Weaver (1950) found that overgrazing resulted in poor root growth and permitted little food accumulation. It was shown that the quantity

of roots in a low grade pasture was only 42 per cent as much as on a high grade area.

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

Root penetration of seedling grasses was retarded 35 to 62 per cent, and the dry weight of the roots was reduced 66 to 98 per cent by frequent clipping (Robertson, 1933).

Tall native grasses, such as big bluestem and switchgrass, were found to be more susceptible to clipping than were the shorter ones in a western Kansas study by Riegel (1947). In every case where the grasses were clipped for several months, there was an increase in total height but a decrease in weight.

Laird (1930), according to Biswell and Weaver (1933), provided an exception to findings of other researchers when he concluded that the largest and deepest root system of sod-forming grasses is not necessarily associated with the best and most vigorous top growth. He stated that the mowing of centipede and Bermuda grasses increases root growth.

Conversely, Albertson, et al. (1953), in studying the effect of various intensities of clipping on growth of blue grama and buffalo grass, found that there was a marked decrease in top growth on the closely-clipped locations. This was also shown in root development. Recovery was slow after cessation of clipping.

By applying clipping treatments at two-week intervals, Aldous (1930) found that the density of the vegetation decreased about 60 per cent in

three seasons. Clipping at three-week intervals, however, resulted in only a 13 per cent reduction.

Biswell and Weaver (1933) studied the effects or removal of tops of certain grasses on root growth and yield of top growth. The yield of forage, when clipped at two-week intervals in comparison to yield when clipped at the end of the season, ranged from 14.5 per cent decrease in tops in big bluestem to 63.1 per cent decrease in buffalo grass. The species with greatest reduction in yield of tops also had the least root growth.

Weaver and Darland (1947), in measuring the effects of loss of vigor of various grasses due to clipping, found that dry weight of weakened plants was 32 to 84 per cent less than that of plants which had good to fair vigor. New roots were always shorter and less branched and dry weight was 38 to 94 per cent less than that of the controls. Furthermore, they found that leaves of non-vigorous new tops of six species averaged 15 to 41 per cent narrower. Average diameter of new roots was 13 to 39 per cent less.

Sampson and McCarty (1930), according to Cook, et al. (1958), found a negative correlation between the annual variation of the carbohydrates and the growth rate. Accumulation of food was related to low or declining rates of growth and was greatest near the close of the annual growth cycle.

McCarty (1938), in a study of the carbohydrate content of roots of mountain brome under various growing conditions, indicated that maximum storage of food reserves in the roots of grasses is attained after the plant approaches maturity. If herbage is removed during the growing sea-

son, the plant depletes its reserves in regrowth and full storage potential is never reached.

Stored food reserves generally are reduced more by frequent and close clipping than by a single clipping or less close clipping, according to Bukey and Weaver (1939). They found no change in mineral content of the roots.

In studying Ladino white clover, Moran, et al. (1953) found that defoliation caused a depletion of the carbohydrate reserves in both stolons and roots. The depletion was greater when the carbohydrate level was high than when it was low. The amount of stored carbohydrates was affected by height and frequency of defoliation.

METHODS OF STUDY

Description of Areas

Two adjacent areas which had undergone different methods of treatment during past years were selected for this study. One area is located approximately two miles southwest of the city of Hays in Ellis County, Kansas. The legal description is Sect. 1, TS-14s, R19w. This area, known as the college relict area, has not been subjected to grazing pressure for over fifty years, except by naturally occurring small animals. The other area bounds the above-described range on the south and is commonly known as Pfeifer's pasture. The legal description is Sect. 12, TS-14s, R19w. This area has been fairly heavily utilized over the past few years, resulting in a marked decrease in the more desirable tall and mid grasses.

Initiation of Study

Grasses selected for this study included a tall grass--big bluestem (Andropogon gerardi Vitman), a mid grass--side-oats grama (Bouteloua curtipendula (Michx.) Torr.), and a short grass--blue grama (Bouteloua gracilis (H. B. K.) Lag. ex Steud.). On March 21, 1959, 12 cubes of sod (four inches on each side) for each species were collected from each of the two areas studied. Three sods of each species from each pasture were killed and the roots collected for chemical analysis. The nine remaining sods were planted in galvanized tin phytometers six inches in diameter and 22 inches tall. The soil in each phytometer was a 2:1 mixture of loam and sand. All top growth was removed from the sods and the phytometers were placed in the greenhouse.

The nine sods of each species from each pasture were separated into three groups for treatment as follows: group (1) those whose top growth would be clipped to the crown each week; group (2) those whose top growth would be clipped to a height of 1½ inches each week; and group (3) those whose top growth would not be clipped until the study was completed.

Study of Shoot Growth

Height measurements of the top growth were made weekly and weights of the clipped growth recorded and plotted. At the completion of this phase of the study, the cumulative height and weight measurements were calculated and plotted.

Tiller counts were also made at intervals throughout the study for the purpose of comparing variation in weight of the tops that might be due to unequal density of shoots.

Pictures of top growth were taken three times during the study to illustrate the effect of the variation in treatment over periods of time.

Study of Root Growth

At the culmination of top growth studies, the sods were removed from the phytometers and the soil washed from the roots by means of a very fine water spray (a fog nozzle was used). The extent and abundance of the roots were recorded. Pictures of the sods, showing top and root growth, were taken. Measurements were made of length of new growth, length and frequency of secondary and tertiary roots, and air-dry weight of new roots.

Measure of Carbohydrates

The old roots (upper four inches) of each sod were placed in an oven at 90°C., left for two hours to kill them and then left an additional 24 hours at 70°C. to drive off the moisture (Paech and Tracy, 1955). The elapsed time from completion of washing to placement in the oven seldom exceeded one hour. After drying, the roots were kept in airtight bottles until root washing had been completed. When all roots were dried, they were ground into very fine particles in a power-driven "Wiley Mill." They were again placed in a 70°C. oven for four hours to remove any remaining moisture and then again stored in airtight bottles (Loomis and Shull, 1937).

Three-gram samples of each set of roots were mixed with two grams of precipitated calcium carbonate. These were poured into fritted glass thimbles and subsequently placed in soxhlet extractors (Fig. 1). The reducing sugars (glucose and fructose), sucrose and an unidentified sugar were extracted with 120 ml. of 80 per cent ethanol for 16 hours. The resulting solution was filtered through coarse filter paper. The filtered solutions were made up to equal volumes with 95 per cent ethanol. A crystal of thymol was added to each bottle to preserve the sugars and they were placed in the deep freeze for storage. The residue was allowed to air dry and then retained for starch and fructosan extraction.

For analysis, each sample was heated at 80°C. to drive off all alcohol. A small amount of distilled water was added to prevent the samples from boiling to dryness. The solutions were then filtered through highly retentive filter paper and made up to 300 ml. volume with distilled

Figure 1. Soxhlet extractor installation used for extracting reducing sugars and sucrose.

water. The method above is a modification of a method proposed by Williams and Bevenue (1953).

From the residue containing the starch and fructosans, one-gram samples were taken and placed in small beakers containing 30 ml. of 0.25 per cent oxalic acid. These were heated at 80°C. for one hour to extract and hydrolyze the starch and fructosans. The solution was filtered through highly retentive filter paper and the residue washed with 12 ml. of hot water. Five drops of taka-diastase were added to one ml. of the filtrate at 45°C. to insure complete hydrolysis (Sprague and Sullivan, 1950).

A modification of the method of descending paper chromatography suggested by Block, et al. (1955) was used to determine the various carbohydrates. Spots of each of the extracts, five microliters in quantity and one centimeter in diameter, were placed on strips of filter paper 3.8 cm. wide and 45 cm. long. The spots were placed just below a fold made seven cm. from the top of the paper (Fig. 2). The chromatograms containing the reducing sugars and sucrose were air dried for 20 minutes and placed in an airtight chromatocab manufactured by Research Specialties Corporation (Fig. 3). They were allowed to come to equilibrium for eight hours in the presence of vapors from a 6:4:3 v/v ratio butanol:pyridine:water mixture. When the equilibrium was established, the above-described solution was added to trays from which the chromatograms were suspended and allowed to leach down the paper and separate the sugars. At the end of 12 hours the chromatograms were removed and placed in an oven at 90°C. for 20 minutes.

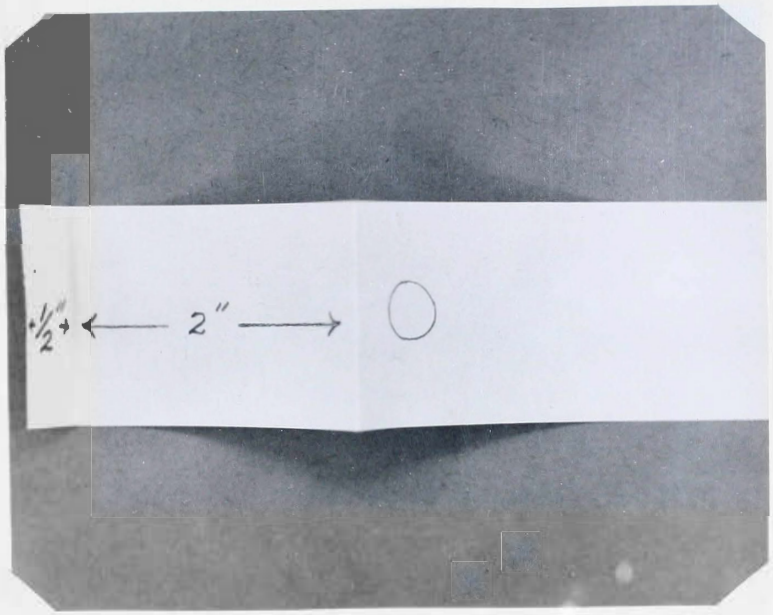


Figure 2. Filter paper strip showing method of folding and area where unknown is placed.

Figure 3. Chromatograms in supporting tray in chromatocab.

The extracts of the hydrolyzed starch and fructosans were treated in the same manner except for being heated with hot air for five minutes before being placed in the chromatocab.

The chromatograms to be used for determination of the reducing sugars, hydrolyzed starch and hydrolyzed fructosans were sprayed with a solution of anilin oxalate containing 0.05 N oxalic acid with 0.9 ml. of anilin per 100 ml. of solution. The chromatograms were then dried in an oven at 105°C. for 20 minutes. The resulting spots were light brown on a light tan background. The chromatograms to be used for sucrose determination were sprayed with a solution containing 0.5 grams of resorcinol and two ml. of concentrated hydrochloric acid to 100 ml. of ethanol. The chromatograms were then dried in an oven at 88°C. for about five minutes. The resulting spots were reddish-brown on a white background, fading on standing to gray spots on a white background. These results agree with those obtained by Dodd (1957).

For qualitative analysis, known standards of sucrose, fructose, and glucose were run at concentrations varying from 0.1 to 10.0 per cent. An R_f value for each sugar was obtained by dividing the distance moved by the solvent front into the distance moved by the sugar (Table I).

For quantitative analysis, the chromatograms of the known sugars were subjected to density measurements by use of a Photo-volt densitometer. The areas obtained for the known standard sugar solutions were plotted on semi-log paper and were used in the determinations of the quantity of the unknown samples. The light transmission curves were plotted on graph paper, and a base line was drawn at the best apparent position (Fig. 4). The areas under the curve were then measured with

TABLE I. R_f values obtained for sucrose, fructose, glucose, and an unidentified sugar using a solvent of butanol:pyridine:water in a v/v ratio of 6:4:3, respectively, and developed at 30°C. for 12 hours.

SUGAR	R_f VALUES X 100
Unidentified sugar	13.0 - 15.0
Sucrose	30.0 - 38.0
Glucose	41.0 - 49.0
Fructose	49.0 - 54.0

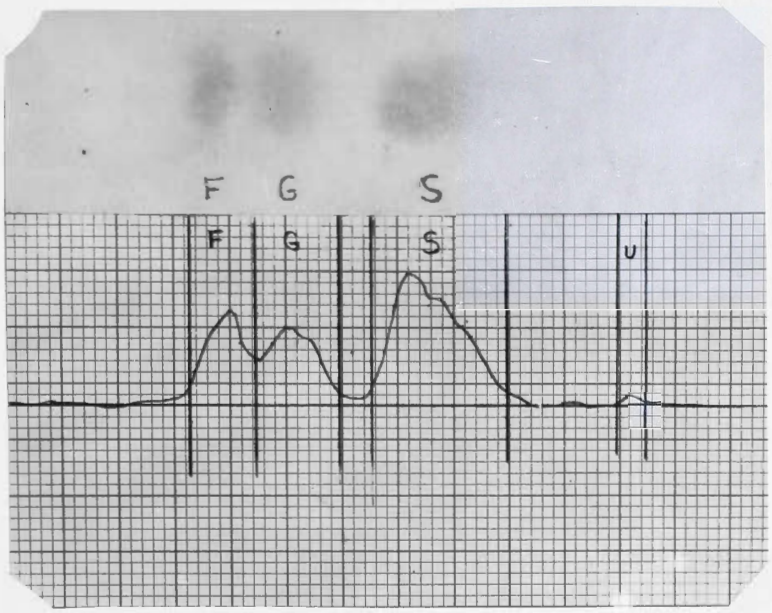


Figure 4. Developed chromatogram and plot of density of carbohydrates.

a planimeter. In the curves that showed slight overlap, the correct dividing line was approximately that drawn from the lowest point of the valley between the peaks of the curves perpendicular to the base line. The resulting area was recorded and compared to the area of a known standard plotted on semi-log paper, and a direct reading in percentage was obtained for the reducing sugars and sucrose (Dodd, 1958). Since the starch and fructosans had been hydrolyzed, the dilution factor and the conversion factor of 0.9 were calculated before the true percentage could be obtained. This was done and found to agree with that calculated by Dodd (1958). Accuracies of ± five per cent have been obtained with this method (Block, et al., 1955).

ENVIRONMENTAL CONDITIONS

The terrain was sloping with no true upland being present, the soil depth ranging from about one to two feet. Sods were taken from southeast-facing slopes in both areas. The top soil in the two areas was dark in color with the sub-soil being light. The soil had high permeability and good texture, being granular on the upper surface. Streaks and spots of calcareous materials were present throughout. The relict area had a much greater abundance of tall and mid grasses and since it was neither grazed nor burned there was considerable mulch. This caused the soil in the relict area to be somewhat richer in organic matter than the adjoining grazed pasture. In addition to being subject to grazing, the grasses in the utilized pasture were also subjected to trampling by livestock.

The 89-year average annual precipitation at a point two miles east of the two areas is 22.90 inches. Of this amount 17.86 inches falls during the growing season, from April 1 through September 30. During the two years preceding the collection of the sods for this study, precipitation was above normal (Table II). In 1957 the annual precipitation was 28.33 inches, of which 23.48 inches fell during the growing season. In 1958, the corresponding figures were 31.21 and 24.82 inches. In neither of these years did prolonged hot or cold periods prevail. During the growing seasons, temperatures, in general, were slightly below normal (Table II).

Soil moistures were not taken in the areas from which the sods were secured. However, they were taken in an upland area approximately one-half mile northwest. The data in Table III indicate that there was suf-

TABLE II. Monthly precipitation, mean temperature and departures from normal during the growing seasons of 1957 and 1958 taken one mile south of Hays, Kansas.

Month	Precipitation (Inches)	Departure From Normal	Average Temp. (°F)	Departure From Normal
1957				
April	2.14	.01	48.9	-4.7
May	4.08	.30	59.9	-3.1
June	6.74	2.47	70.1	-4.1
July	3.11	.56	80.4	-0.2
August	3.92	1.00	78.0	-0.9
September	3.49	1.28	63.8	-6.2
TOTAL 6 Months	23.48	5.62		
Year	28.33	5.43		
1958				
April	1.62	- .51	49.6	-4.0
May	6.81	3.03	64 ?	1.2
June	2.33	-1.94	71.6	-2.7
July	7.82	5.27	74.6	-6.0
August	4.35	1.43	75.7	-3.2
September	1.89	- .32	70.2	0.2
TOTAL 6 months	24.82	6.96		
Year	31.21	8.31		

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

TABLE III. Percentage of available soil moisture at various depths, in inches, during the 1957 and 1958 growing seasons, in an upland adjacent to the study area.

Date	0-6	6-12	12-24	24-36	36-48	48-60
1957						
4-24	16.86	14.14	7.26	0.0	0.0	0.0
5-8	19.11	13.93	12.58	0.0	0.0	0.0
5-23	13.70	13.79	12.23	0.0	0.0	0.0
6-5	6.49	10.13	4.78	0.0	0.0	0.0
6-19	12.17	9.39	7.46	0.0	0.0	0.0
7-3	13.16	8.29	5.16	0.0	0.88	0.0
7-16	1.61	4.56	4.75	3.18	0.0	0.50
7-31	0.49	1.65	2.82	0.0	0.0	0.0
8-15	2.06	0.42	2.79	3.99	6.43	5.74
8-30	3.97	1.96	0.0	0.0	0.0	0.0
9-12	0.0	0.0	0.0	0.0	0.0	0.0
9-25	10.59	9.80	0.0	0.0	0.0	0.0
1958						
5-27	21.17	11.0	12.6	11.9	11.2	0.0
6-10	4.4	5.4	6.7	10.5	12.4	8.0
6-28	10.7	4.5	4.7	9.4	9.3	7.1
7-8	19.8	15.5	7.3	13.0	11.8	4.2
7-23	21.9	17.2	12.5	5.5	6.1	3.9
8-6	12.4	19.2	8.1	6.4	6.6	5.2
8-20	10.6	6.3	4.0	6.4	6.0	4.7
8-26	9.9	9.2	4.8	4.3	4.4	2.4
9-9	4.3	6.5	5.0	2.0	3.2	4.4
9-18	10.4	5.8	5.3	5.5	6.5	7.2

ficient available moisture to encourage growth during both years. In 1957 the available water at lower depths was low or non-existent early in the growing season because of the excessively dry preceding year of 1956. In 1958, however, water was always available at all depths where samples were taken.

RESULTS

The sods were collected and transplanted in phytometers on March 21, 1959. Shoot growth began in the blue grama sods four to six days later. However, the side-oats grama sods required five to seven days and the big bluestem sods six to ten days to initiate growth. In general, plants taken from the ungrazed (relict) area began their growth sooner than did those from the grazed pasture.

It was necessary, especially early in the study, to remove seedlings of plants foreign to the problem that would have provided competition for the grasses under consideration.

Shoot Growth

Tiller or shoot counts

The actual number of tillers was counted in each phytometer at several intervals during the investigation to determine the effect of method of treatment on each sod. The initial estimate of number of blue grama plants was accomplished by counting the tillers in one square inch at two different places in each phytometer and then multiplying the average of these two figures by the area of cover. This method of counting was followed because the numerous tillers present made difficult an accurate total count. In the sods of the other species, tillers were counted.

Table IV gives the average number of tillers of the three replications of each method of treatment. This table is a summary of the data presented in Appendix A. It can readily be seen that there is considerable variation in number of tillers present in the different sods. This

TABLE IV. Average number of tillers per plant (average of three replications) under each treatment at various intervals during the study.

	PLANTS FROM GRAZED PASTURE									PLANTS FROM RELICT AREA								
	Big Bluestem			Side-oats Grama			*Blue Grama			Big Bluestem			Side-oats Grama			*Blue Grama		
DATE	NC	MC	CC	NC	MC	CC	NC	MC	CC	NC	MC	CC	NC	MC	CC	NC	MC	CC
4-11	16	43	25	31	37	23	176	147	147	29	34	23	43	39	34	103	125	73
4-27			22			14			92			21			29			71
5-11	16	45	16	31	37	4	181	128	32	29	33	18	44	40	12	106	124	46
5-25			8			3			3			16			7			12
6-1			7			2			2			12			7			7
6-15	16	40	5	31	33	1	168	109	2	29	22	4	44	28	6	106	97	5
% Lost	0.0	11.1	80.0	0.0	10.8	95.7	.5	25.9	98.6	0.0	35.3	82.6	0.0	30.0	82.4	0.0	22.4	93.2

NC = Not Clipped MC = Moderately Clipped CC = Closely Clipped

*Initial blue grama tiller counts were made by counting the number of tillers present in one square inch at two different locations and multiplying the average of these two figures by the area occupied by grass.

is due to the fact that sods of equivalent size and with equivalent numbers of tillers were extremely difficult to find in the two areas at the time of year they were collected. However, the tiller counts of individual sods will be used to show the significance of variation in weight of shoots both within and between species.

The data in Table IV also indicate one of the effects of clipping on growth of plants. In all species, there was little, if any, variation in the number of shoots from beginning to completion of the study under non-clipped conditions; the one variation in number of tillers in blue grama from the grazed pasture was not significant.

Under moderately clipped conditions, however, losses ranged from 10.8 to 35.3 per cent. Big bluestem plants from the grazed pasture lost 11.8 per cent of their tillers compared to 35.3 per cent in plants from the ungrazed area. A similar occurrence was observed regarding side-oats grama where losses were 10.8 and 30.0 per cent, respectively. However, blue grama showed little variation with losses being 25.9 per cent in plants from the grazed pasture and 22.4 per cent in those from the relict area.

As would be expected, the biggest losses of 80 to 98.6 per cent were obtained under close clipping. Big bluestem showed little difference in loss of shoots in sods taken from the two areas, both being about 80 per cent. Side-oats grama, however, lost 94.7 per cent of the shoots in the sods from the low-grade pasture compared to 82.4 per cent in those from the ungrazed area. Blue grama had losses of 98.6 and 93.2 per cent, respectively. In the case of side-oats grama and blue grama, there were converse relationships between the two degrees of clipping.

It might be mentioned that tiller or shoot counts alone, without the use of weight and height data which will be discussed subsequently, do not seem to be a significant measure of vigor.

Shoot height

The data in Table V show the average increment of top growth each week and the average cumulative height of each grass under each condition. This table is a summary of the data in Appendix B.

Even though the blue grama plants were the first to initiate growth, those of side-oats grama overcame this initial advantage within three to four weeks and exceeded the rate of growth of the blue grama. Big bluestem was the slowest to initiate growth and, when unclipped, failed to achieve the cumulative height of the other two species. Both blue grama and side-oats grama attained full flower which contributed to their increased height; whereas, big bluestem failed to produce any flower stalks.

In comparing each species according to original and experimental treatments, some significant results were observed. The non-clipped big bluestem plants did not show consistent growth rates; the weekly height increases varied from 0.08 inch to 2.67 inches. Also, plants of the non-clipped big bluestem sods from the ungrazed and grazed areas attained almost identical average heights. Under moderate clipping there was no decrease in weekly height accumulation. The moderately clipped big bluestem plants from the ungrazed area grew at a faster rate and achieved an average cumulative height of 33.5 inches compared to 27.85 inches for those from the grazed pasture. The same relationships oc-

TABLE V. Average height gains per week and cumulative height in inches of shoots of plants under each treatment. (NC = Not Clipped; MC = Moderately Clipped; CC = Closely Clipped)

	PLANTS FROM GRAZED PASTURE									PLANTS FROM RELICT AREA								
	Big Bluestem			Side-oats Grama			Blue Grama			Big Bluestem			Side-oats Grama			Blue Grama		
DATE	NC	MC	CC	NC	MC	CC	NC	MC	CC	NC	MC	CC	NC	MC	CC	NC	MC	CC
3-30	0.5	0.3	1.0	1.0	1.5	0.7	1.5	1.5	1.0	1.7	0.0	0.0	1.7	2.7	2.5	2.0	1.5	1.7
4-6	1.8	1.8	2.2	1.3	1.2	1.8	1.2	1.2	2.0	1.8	2.8	2.7	1.6	1.6	2.9	1.8	2.0	2.8
4-13	1.5	1.8	1.3	1.3	1.4	1.1	0.4	1.0	1.3	1.1	2.4	2.6	1.0	1.6	1.6	1.1	1.8	2.1
4-20	0.8	2.0	1.5	0.9	1.7	1.3	0.4	0.9	1.2	1.8	2.8	2.8	0.6	2.0	1.6	0.3	2.5	1.8
4-27	1.2	2.9	1.4	1.2	1.8	1.1	0.8	1.8	1.7	1.5	3.8	3.3	1.7	3.0	2.0	1.3	4.0	2.1
5-4	1.0	2.7	1.3	1.1	3.5	1.3	1.4	3.3	1.8	0.3	4.8	3.0	1.8	4.4	2.3	1.1	3.5	1.5
5-11	0.7	2.7	1.3	0.5	3.5	1.3	0.5	3.3	1.8	0.4	3.7	2.3	1.3	3.7	1.5	1.0	4.0	1.2
5-18	2.6	3.2	1.5	5.5	3.2	1.7	4.5	3.8	1.3	1.6	3.5	2.4	2.0	4.3	1.5	3.8	4.5	1.6
5-25	2.7	2.7	1.8	2.3	3.0	0.7	3.2	3.0	1.0	1.5	3.5	1.8	1.5	3.8	1.3	2.5	3.3	1.0
6-1	1.5	3.5	2.0	1.0	3.3	0.5	1.7	3.3	1.0	0.8	3.0	1.7	0.7	3.2	1.4	1.5	2.7	0.6
6-8	0.1	2.7	1.8	4.2	2.7	0.3	2.2	2.7	0.4	1.4	2.2	1.5	6.0	3.0	2.0	1.8	1.5	0.3
Date Closed	0.5	1.7	1.5	3.5	1.8	0.3	2.2	2.2	0.4	0.9	1.0	0.8	5.0	2.5	1.3	1.3	1.0	0.3
Total Height	14.8	27.9	18.7	23.7	28.5	11.9	19.9	27.8	14.9	14.8	33.5	24.8	24.7	35.7	22.0	19.3	32.3	16.8

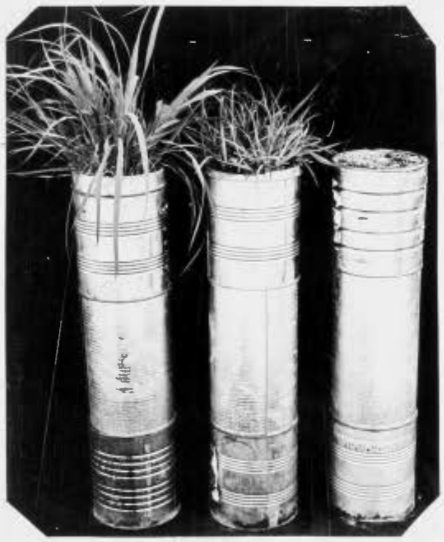
curred under close clipping with the big bluestem plants from the ungrazed area attaining a cumulative height of 21.99 inches to 18.66 inches for those plants from the grazed area. The same relationships were obtained with the other two species.

Figure 5 shows big bluestem plants from each area and under each method of treatment at two different periods during the study. The first period was 23 days after transplanting and after two clippings were made, and the second period was 82 days after transplanting and after 11 clippings. In the first series the non-clipped plants from the grazed pasture were about 3.75 inches tall and those from the protected area about 4.5 inches in height. In the latter series each plant had reached a height of about 14 inches. The shoots on the moderately clipped sods were about 3.75 inches high in all cases. However, the height of the closely clipped plants from the grazed pasture was only 1.25 inches and those from the relict area about 2.5 inches. In the latter stage, after 11 clippings, the few tillers present were about two inches tall in sods from both areas.

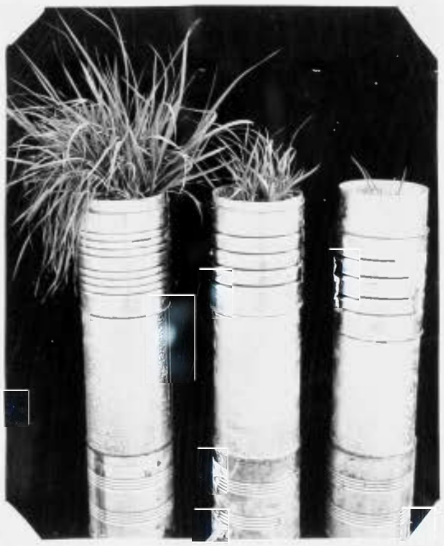
The corresponding sequences from the side-oats grama plants are depicted in Figure 6. At the earlier date, the non-clipped plants were 3.75 and 4.25 inches tall from the grazed pasture and relict area, respectively. At the latter date they were each about 20 inches tall. Under moderate clipping the heights on April 13 were each about three inches tall. On June 13 they had increased to about 4.0 and 4.5 inches, respectively. The closely clipped plants all had heights of about 1.5 inches, but the decrease in tillers was again readily apparent.

Series 1

Series 2



Series 3

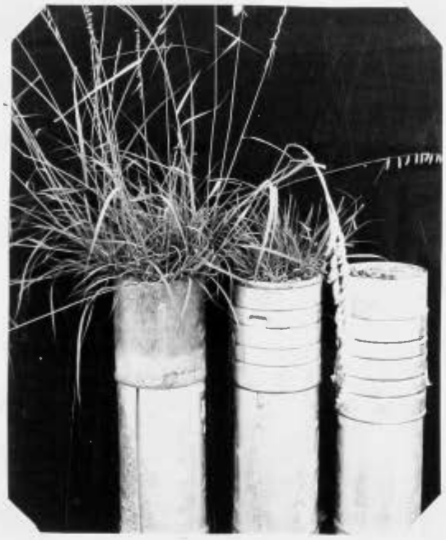


Series 4

Figure 5. Big bluestem plants. Series: (1) from grazed area after 23 days and two clippings; (2) from ungrazed area at same time as 1; (3) from grazed area after 82 days and 11 clippings; (4) from ungrazed area at same time as 3. Phytometers in each picture, from left to right - not clipped, moderately clipped, closely clipped.

Series 1

Series 2



Series 3

Series 4

Figure 6. Side-oats grama plants. Series: (1) from grazed area after 23 days and two clippings; (2) from ungrazed area at same time as 1; (3) from grazed area after 82 days and 11 clippings; (4) from ungrazed area at same time as 3. Phytometers in each picture, from left to right - not clipped, moderately clipped, closely clipped.

Figure 7 is a presentation of pictures of blue grama in the same order as above. In the non-clipped, previously grazed plants, the height at the earlier date is 3.0 inches while the relict area counterpart is 4.25 inches. After 82 days they were each 18 inches high. The moderately clipped, previously grazed plants advanced from 3.0 to 4.25 inches while those from the relict area were each about 3.0 inches tall at these two periods. The closely clipped plants from the grazed area showed a decrease from 1.25 to 0.4 inches. Those from the ungrazed area had a greater decrease from 2.1 to 0.25 inches. The latter plants were nearly completely dead with only two or three tiny tillers remaining.

Figures 5, 6, and 7 indicate a trend toward loss of vigor under closely clipped conditions; however, the data in Table V, measuring height alone, are not representative of any real trend in variation in vigor.

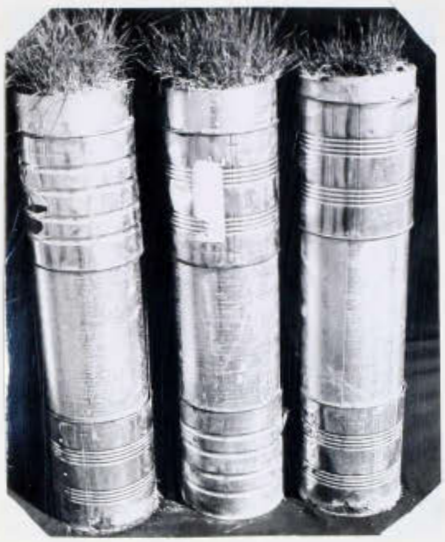
Shoot weight

The data in Table VI are a concise presentation showing the average value of the replications of each species under each treatment. Complete data are given in Appendix C. These tables show weekly and cumulative weight values.

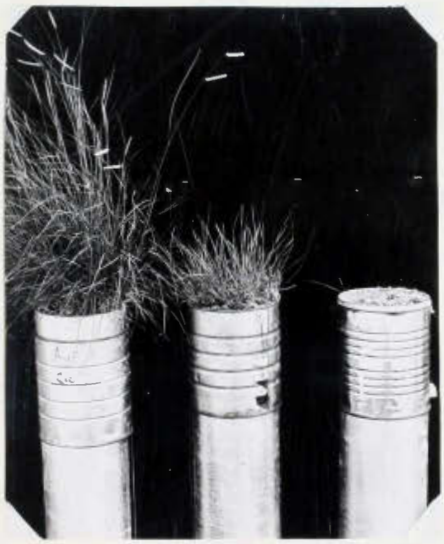
Before the reader progresses any farther, it might be mentioned that these values, without the use of height and tiller counts do not provide sufficient information from which to draw positive conclusions; however, there are some other trends indicated.

The big bluestem plants, from both areas, which were moderately clipped were somewhat slow to initiate growth and took about five weeks

Series 1



Series 2



Series 3

Series 4

Figure 7. Blue grama plants. Series: (1) from grazed area after 23 days and two clippings; (2) from ungrazed area at same time as 1; (3) from grazed area after 82 days and 11 clippings; (4) from ungrazed area at same time as 3. Phytometers in each picture, from left to right - not clipped, moderately clipped, closely clipped.

TABLE VI. Average weight of shoots clipped each week and cumulative weight in grams of plants under each method of treatment.

PLANTS FROM GRAZED PASTURE

	Big Bluestem			Side-oats Grama			Blue Grama		
DATE	NC	MC	CC	NC	MC	CC	NC	MC	CC
3-30		--	.017		--	.014		--	.083
4-6		.086	.303		.125	.314		.053	.415
4-13		.124	.104		.077	.102		.060	.224
4-20		.359	.094		.158	.039		.053	.063
4-27		.364	.049		.351	.015		.158	.091
5-4		.815	.049		.732	.005		.572	.058
5-11		.574	.103		.756	.003		.666	.057
5-18		.534	.071		.752	.002		.732	.031
5-25		.566	.017		.716	.002		.690	.015
6-1		.767	.011		.904	.002		.854	.010
6-8		.754	.007		.525	.002		.897	.007
Close-out		3.138	.003		3.416	.001		2.306	.006
Total Wt.	11.686	8.049	0.832	20.906	8.653	0.400	18.170	7.041	1.057

PLANTS FROM RELICT AREA

3-30		--	--		.037	.194		.038	.159
4-6		.107	.217		.207	.962		.349	.820
4-13		.207	.308		.225	.235		.218	.229
4-20		.206	.123		.268	.184		.234	.065
4-27		.354	.149		.350	.130		.657	.192
5-4		.683	.098		.979	.087		.546	.045
5-11		.450	.040		1.475	.058		.508	.090
5-18		.390	.039		1.343	.049		.675	.013
5-25		.368	.040		1.512	.027		.408	.003
6-1		.428	.020		.691	.032		.406	.002
6-8		.272	.031		.568	.020		.425	Not
Close-out		2.149	.036		2.055	.035		1.546	Meas-urable
Total Wt.	12.780	6.083	1.101	20.038	9.727	2.012	7.633	6.010	1.581

NC = Not Clipped MC = Moderately Clipped CC = Clipped to Crown

to reach their peak weights. The plants from the grazed pasture maintained these peak values but plants from the relict area started a decline immediately after achieving peak growth (the highest weekly increment). The closely clipped plants from the grazed pasture achieved peak weight after the first clipping and then started a rapid decline. The corresponding plants from the relict area seemed to retain vigor through about three clipping periods before starting the decline.

The side-oats grama plants, from both areas, took about six weeks to reach maximum values and maintained these values for three to four weeks before falling off slightly. The closely clipped plants from the grazed pasture reached a peak after one clipping and after three clippings there was scarcely any yield. Those from the relict area also reached their peak after the first clipping but the decrease was less pronounced than it was in its aforementioned counterpart.

The moderately clipped blue grama plants from both areas took about six weeks to achieve peak yields and then leveled off for the remainder of the study. The closely clipped blue grama from the grazed pasture, while never attaining as high a yield for one period as those from the relict area, seemed to withstand the clipping slightly better.

Number and weight of tillers

From Table VII some more conclusive facts concerning the effect of clipping on vigor can be observed. It can be seen in every case that, regardless of cumulative height, the non-clipped plants had a higher yield per tiller than did those under moderate clipping. Furthermore, those plants subjected to close clipping made the lowest yield per til-

TABLE VII. Relationships between average number of tillers per plant and average cumulative weight per plant expressed in weight (in grams) per tiller.

PLANTS FROM GRAZED PASTURE

	Big Bluestem			Side-oats Grama			Blue Grama		
	NC	MC	CC	NC	MC	CC	NC	MC	CC
Avg. No. Tillers	16	42	14	31	36	8	175	128	50
Avg. Cum. Wt.	11.686	8.049	0.832	20.906	8.653	0.400	18.170	7.041	1.057
Avg. Wt./Tiller	.730	.192	.059	.674	.240	.050	.104	.055	.021
Avg. Cum. Ht. (Inches)	14.75	27.85	18.66	23.67	28.51	11.91	19.86	27.76	14.92

PLANTS FROM RELICT AREA

	Big Bluestem			Side-oats Grama			Blue Grama		
	NC	MC	CC	NC	MC	CC	NC	MC	CC
Avg. No. Tillers	29	30	16	44	36	16	105	115	36
Avg. Cum. Wt.	12.780	6.083	1.101	20.038	9.727	2.012	7.633	6.010	1.581
Avg. Wt./Tiller	.441	.203	.069	.455	.270	.126	.073	.052	.044
Avg. Cum. Ht. (Inches)	14.83	33.5	24.75	24.67	35.67	21.99	19.25	32.25	16.82

NC = Not Clipped MC = Moderately Clipped CC = Closely Clipped

ler. The values under non-clipped conditions for big bluestem were 0.730 gram per tiller in those plants from the grazed pasture and 0.441 gram per tiller in those from the relict area; under moderate clipping, the respective values were 0.192 and 0.270 gram per tiller; and, under close clipping in the same order, the values were 0.059 and 0.069 gram per tiller. Similar relationships occurred with side-oats grama and blue grama.

It can further be seen that under non-clipping the sods from the grazed pasture had a better yield per tiller than those from the relict area; however, under both moderate and close clipping, the situation was reversed. This can be seen in the data concerning the aforementioned big bluestem. In side-oats grama yields were (grazed) 0.674 and (non-grazed) 0.455 gram per tiller under non-clipping; whereas, in the same order, the moderately clipped and closely clipped plants yielded 0.240 and 0.050 gram per tiller and 0.270 and 0.126 gram per tiller.

In general, big bluestem plants had a slightly better yield per tiller under non-clipped conditions than side-oats grama and both were considerably higher than blue grama. Their respective values from the grazed area were 0.730, 0.674, and 0.104 gram per tiller. The same conditions prevailed in the plants from the relict area.

Under moderate clipping side-oats grama made the best yield. This is undoubtedly due, at least in part, to its greater cumulative height. Both it and big bluestem continued to show a vastly greater yield than did blue grama. Their values, also from the grazed area were (side-oats grama) 0.240, (big bluestem) 0.192, and (blue grama) 0.055 gram per tiller.

Under close clipping the yields were brought together with all plants in both areas showing poor yields--less than 0.105 gram per tiller.

Height-weight relationships of shoots

Figure 8 is a plot of the mean cumulative height and mean cumulative weight of each group of plants from each area and under each method of treatment.

These data indicate the tendency of clipping to reduce the inherent differences in species. Under non-clipping, the species tended to vary considerably in their height-weight relationships. However, under moderate clipping the species tended to group fairly close together and under close clipping the variation in cumulative weight per species was quite insignificant.

As was previously shown, the greatest cumulative heights were obtained under moderate clipping with little difference between non-clipped and closely clipped plants. However, in cumulative weight the non-clipped grasses yielded best and the closely clipped the poorest. Typical of this were the side-oats grama plants from the grazed area which had average weight yields of 20.906 grams under non-clipped conditions; 8.653 grams under moderate clipping; and 0.400 gram under close clipping. It should be mentioned that this might have been altered with time since most of the non-clipped plants had attained full growth and were in flower (except for big bluestem), while most of the moderately clipped plants were still yielding well and may have surpassed the non-clipped weight yields in time. The closely clipped plants had lost

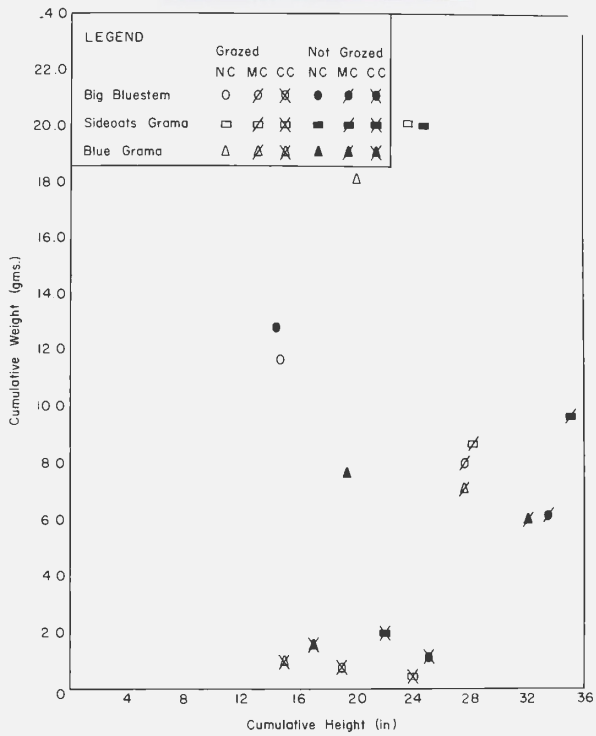


Figure 8. Mean cumulative height versus mean cumulative weight of shoots of each group of plants from each area and under each method of treatment.

nearly all signs of vigor and it is believed that they would not have yielded much more.

In general, it can be seen that side-oats grama produced the greatest weight and height with big bluestem second and blue grama last. It must also be mentioned that this plot does not take into consideration the number of tillers.

Additionally, the data show that the plants from the relict area yielded the greatest height under non-clipped and moderately clipped conditions, with close clipping favoring neither. The weight yield data according to area does not form a distinct pattern.

Root Growth

Length, weight, and abundance

From Table VIII, the summary of Appendix D, it is shown that although the length differential between moderately clipped and non-clipped sods was not significant, there was a vast difference in weight. The new roots from the non-clipped plants were four to eight times as heavy as their moderately clipped counterparts. For example, big bluestem, under non-clipped conditions, had new root weights of 12.40 and 10.30 grams in the grazed and non-grazed areas, respectively; whereas, when moderately clipped, the respective weights were 3.18 and 3.08 grams. Similar relationships existed between the non-clipped and moderately clipped side-oats grama and blue grama plants. Since in most cases there were no new roots under closely clipped conditions it was not possible to establish a similar corollary between this method of treatment and the others. It can be seen, in Appendix D, that in reaction to

TABLE VIII. Average length and weight of new roots grown under each method of treatment.

	PLANTS FROM GRAZED PASTURE								
	Big Bluestem			Side-oats Grama			Blue Grama		
MEASUREMENT	NC	MC	CC	NC	MC	CC	NC	MC	CC
Total Length (In.)	26	25.7	0.9	26.3	25.5	0.0	24.9	22.3	0.67
L. of Sec. Roots (Cm.)	1-3	1-5	0.0	2-5	2-6	0.0	5-6	3-5	2
L. of Tert. Roots (Mm.)	1-2	2	0.0	1-2	1-8	0.0	1-2	1-5	0.0
Sec. Roots/Cm.	2	5	0.0	4	6-7	0.0	5	5	0.0
Air Dry Wt. of New Roots (Gms.)	12.40	3.18	0.06	12.54	2.12	0.0	6.06	1.23	70.01
	PLANTS FROM RELICT AREA								
Total Length (In.)	23.9	25.7	1.5	26.3	24.5	0.3	25.3	20.5	0.0
L. of Sec. Roots (Cm.)	1-5	1-5	0.0	1-4	2-5	0.0	5-10	5-10	0.0
L. of Tert. Roots (Mm.)	1-9	1-5	0.0	1-2	1-4	0.0	5-10	5-10	0.0
Sec. Roots/Cm.	4-5	4	0.0	5-6	4-5	0.0	6-7	6-7	0.0
Air Dry Wt. of New Roots (Gms.)	10.30	3.08	0.07	22.15	2.64	70.01	4.95	1.26	0.0

NC = Not Clipped MC = Moderately Clipped CC = Closely Clipped

clipping, the same differences existed in root weights as did in the shoot weights. The same variable, number of tillers, was probably responsible for variation within species. This can be somewhat resolved by shoot-root ratio studies, which will be discussed later in the study.

The average length of secondary and tertiary roots was also determined as well as frequency of occurrence of secondary roots. These data did not seem to form any definite pattern according to species or method of treatment. It might be that the number of samples measured was not sufficient to provide differences.

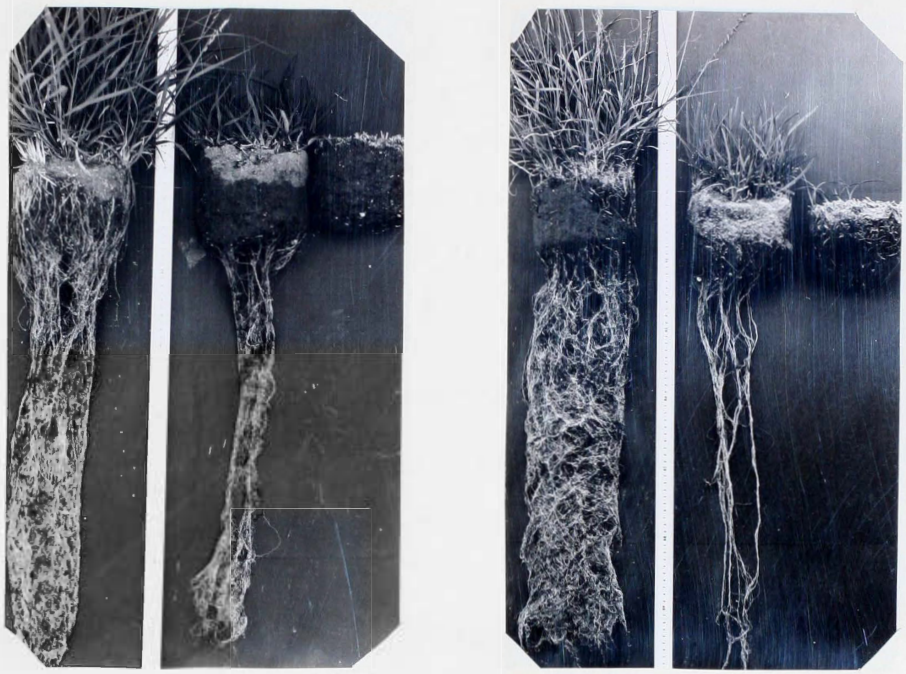
Figures 9, 10, and 11 show representative samples of the tops and roots of big bluestem, side-oats grama, and blue grama, respectively. Series 1 indicates those from the grazed pasture and series 2 those from the relict area. The relative length and abundance of tops and roots under the various treatments can be seen.

The big bluestem plants from grazed and ungrazed areas showed about equal abundance and length of new roots under non-clipped conditions. They were not appreciably longer than those moderately clipped but were considerably more abundant. Under moderately clipped conditions there was little difference between the plants from the two areas and under close clipping there was very little new growth. It was noted that some of the new big bluestem roots were quite fleshy and showed little secondary branching.

The side-oats grama plants from the relict area had a greater abundance of new roots under all conditions than did those from the grazed pasture. They were somewhat smaller in diameter than the corresponding roots from big bluestem; however, under non-clipped conditions they were

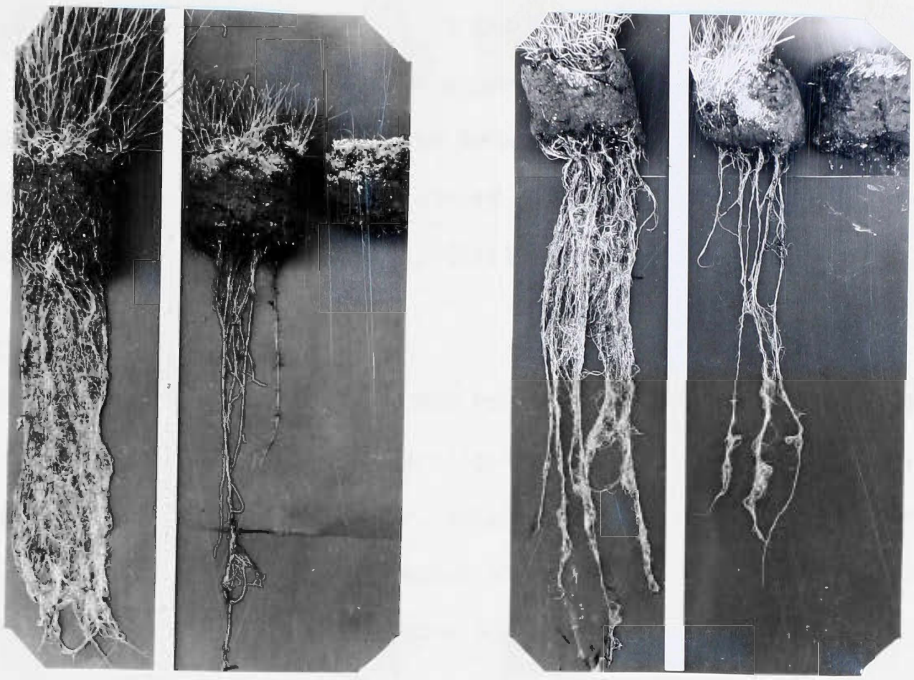
Series 1 Series 2

Figure 9. Big bluestem plants at completion of study. Series 1 - plants from grazed area. Series 2 - plants from ungrazed area. In each picture, from left to right - not clipped, moderately clipped, closely clipped.



Series 1 Series 2

Figure 10. Side-oats grama plants at completion of study. Series 1 - plants from grazed area. Series 2 - plants from ungrazed area. In each picture, from left to right - not clipped, moderately clipped, closely clipped.



Series 1 Series 2

Figure 11. Blue grama plants at completion of study. Series 1 - plants from grazed area. Series 2 - plants from ungrazed area. In each picture, from left to right - not clipped, moderately clipped, closely clipped.

more abundant. The reverse is true under moderately clipped and closely clipped conditions.

The blue grama roots were a little more abundant in plants from the grazed pasture than they were in those from the relict area. As is true of the other two species, the plants under non-clipped conditions showed the greatest abundance. There was no development of new roots under closely clipped conditions. The roots of the blue grama resembled those of side-oats grama but were slightly smaller in diameter.

Length-weight relationships

The relationship of length of new root growth to root weight showed that length differences between non-clipping and moderate clipping are not significant (Fig. 12). However, weight differences are very informative. As previously mentioned, under non-clipping the highest weights were achieved by side-oats grama, with big bluestem second, and blue grama third. Under moderate clipping, the big bluestem had the most new root growth, with side-oats grama second and bl .e grama third. Under close clipping, only big bluestem showed any new root growth.

Clipping does not affect the species significance of roots as it did with shoots. The species tend to remain close together in height and weight and to remain separate from other species. Origin of the sods did not seem to affect root relationships appreciably.

Shoot-root ratio

Table IX indicates the relationship between the weights of shoots as compared to roots. These data do not seem to form any pattern that might indicate differences between previous treatment or species, except

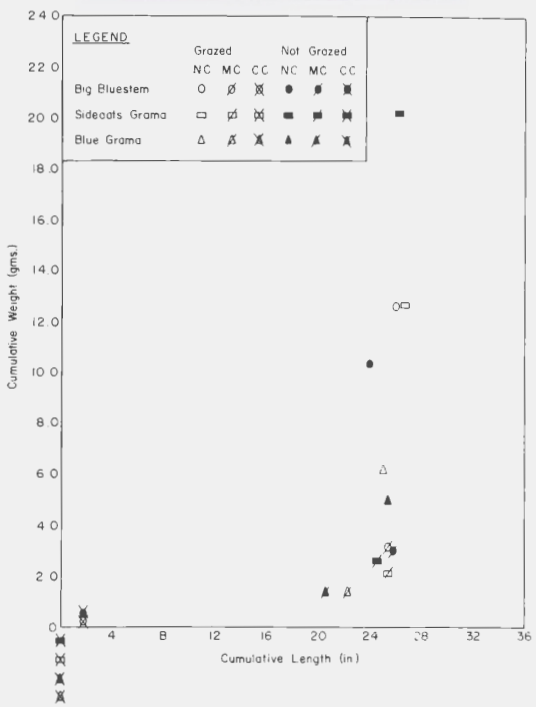


Figure 12. Mean cumulative length versus mean cumulative weight of roots of each group of plants from each area and under each method of treatment.

TABLE IX. Shoot-root ratios of plants from a grazed pasture and a relict area which have been subjected to different intensities of clipping.

PLANTS FROM GRAZED PASTURE

	Big Bluestem			Side-oats Grama			Blue Grama		
MEASUREMENT	NC	MC	CC	NC	MC	CC	NC	MC	CC
Wt. of Shoots	11.686	7.989	0.832	20.906	8.653	0.400	18.170	7.041	1.057
Wt. of New Roots Gms.	12.40	3.18	0.06	12.54	2.12	0.0	6.06	1.23	70.01
Shoot/Root Ratio	0.94	2.51	13.87	1.67	4.08	---	3.00	5.72	---

PLANTS FROM RELICT AREA

Wt. of Shoots	12.780	6.083	1.101	20.038	9.727	2.012	7.633	6.010	1.581
Wt. of New Roots Gms.	10.30	3.08	0.07	22.15	2.64	70.01	4.95	1.26	0.0
Shoot/Root Ratio	1.24	1.98	15.73	0.90	3.68	---	1.54	4.77	---

NC = Not Clipped MC = Moderately Clipped CC = Closely Clipped

under moderate clipping in which the plants from the grazed pasture exhibited a higher shoot-root ratio than those from the relict area. The data did show that the shoot-root ratio increased as clipping intensity increased.

Carbohydrate content

Sucrose, fructosan, and starch made up the major amount of the available carbohydrates in all samples. The reducing sugars, fructose and glucose, supplied only small amounts of the total carbohydrates (Table X). For purposes of simple calculation, the sugars which were present in amounts less than 0.1 per cent were rounded off at this figure. The percentage error would not exceed the ± five per cent margin of error for total available carbohydrates that Block, et al. (1955) allowed for this method of analysis.

At the time sods were collected, big bluestem had the largest percentage of available carbohydrates. Side-oats grama was second and blue grama had the least (Fig. 13). In comparing grazed to ungrazed areas, big bluestem had 11.3 per cent and 10.5 per cent, respectively. Side-oats grama had 10.2 per cent in both areas, and blue grama had 7.7 per cent in the grazed area and 8.1 per cent in the ungrazed.

Big bluestem had the highest percentage, 18.5 per cent (grazed) and 17.6 per cent (ungrazed), in the non-clipped plants. Under moderate clipping the percentages were 14.2 and 11.5 per cent, respectively; and, in the same order, under close clipping the percentages were 4.2 and 3.9.

Side-oats grama contained the highest percentage of carbohydrates under moderate clipping. Under non-clipped conditions the percentages

TABLE X. Average percentages of unidentified sugar, sucrose, glucose, fructose, starch and fructosan in the top four inches of roots of big bluestem, side-oats grama and blue grama. (X = At time sods were collected; NC = Not clipped; MC = Moderately clipped; CC = Closely clipped)

PLANTS FROM GRAZED PASTURE

	Big Bluestem				Side-oats Grama				Blue Grama			
CARBOHYDRATE	X	NC	MC	CC	X	NC	MC	CC	X	NC	MC	CC
Unidentified Sugar	<0.1	0.2	0.1	<0.1	<0.1	0.2	0.2	<0.1	<0.1	0.5	0.2	<0.1
Sucrose	2.6	7.3	5.6	2.2	1.8	4.6	5.4	2.1	2.3	4.5	3.9	2.1
Glucose	<0.1	0.3	0.2	<0.1	<0.1	0.2	0.2	0.1	<0.1	0.3	0.1	<0.1
Fructose	<0.1	0.4	0.2	<0.1	<0.1	0.2	0.3	0.1	<0.1	0.4	0.1	<0.1
Starch	4.1	4.7	3.9	1.1	4.1	2.8	3.4	0.8	2.4	1.1	2.8	0.5
Fructosan	4.3	5.6	4.2	0.9	4.0	3.0	4.2	0.8	2.7	3.6	2.6	0.7
Total Carbohydrates	11.3	18.5	14.2	4.4	10.2	11.0	13.7	4.0	7.7	9.4	9.7	3.6

PLANTS FROM RELICT AREA

Unidentified Sugar	<0.1	0.2	0.1	<0.1	<0.1	0.1	0.2	<0.1	0.1	0.4	0.2	<0.1
Sucrose	2.3	6.6	5.1	3.0	2.0	5.1	5.9	1.4	2.7	4.5	4.2	2.4
Glucose	<0.1	0.3	0.1	<0.1	0.1	0.2	0.3	0.1	<0.1	0.3	0.2	<0.1
Fructose	<0.1	0.3	0.3	<0.1	<0.1	0.2	0.4	0.1	<0.1	0.3	0.1	<0.1
Starch	3.7	4.8	2.9	0.4	3.5	3.2	3.7	0.8	2.3	3.1	3.4	0.7
Fructosan	4.2	5.4	3.0	0.7	4.4	3.5	4.1	1.2	2.8	3.8	3.3	0.7
Total Carbohydrates	10.5	17.6	11.5	4.4	10.2	12.3	14.6	3.7	8.1	12.4	17.4	3.9

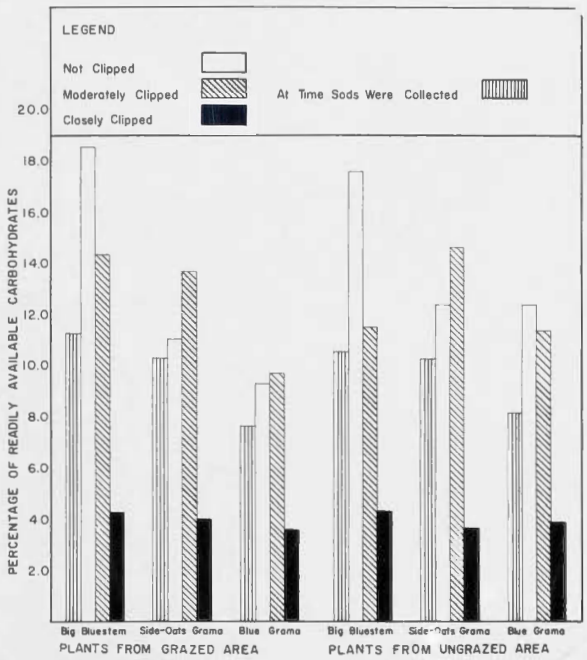


Figure 13. Percentage of readily available carbohydrates under various methods of treatment.

were 11.0 (grazed) and 12.3 (ungrazed). Moderately clipped plants had 13.7 and 14.6 per cent and closely clipped plants had 4.0 and 3.7 per cent.

Blue grama had 9.4 per cent in the grazed area and 12.4 in the ungrazed area under non-clipped conditions. Under moderate clipping the percentage in the grazed area rose slightly to 9.7 per cent; however, it decreased from 12.4 to 11.4 per cent in the ungrazed area. Under close clipping, the percentages were 3.6 and 3.9, respectively.

The variation between non-clipped and moderately clipped plants was probably due to degree of flowering. This will be discussed later.

In general, big bluestem had slightly more carbohydrates present in plants from the grazed area; however, both side-oats grama and blue grama had the higher percentages in plants from the ungrazed area. The variation is probably within the margin of error in the cases of big bluestem and side-oats grama; however, the difference does seem significant in the case of blue grama.

Under non-clipped conditions big bluestem had significantly more carbohydrates by weight than did either side-oats grama or blue grama. Under moderate clipping, however, the results were less significant with variations being resolved to some degree. Close clipping caused complete removal of significant differences between species. These results correlate, fairly well, with the data concerning weight of shoots.

DISCUSSION

A limiting factor in this study was that the plants under consideration had been exposed to two years of ideal growing conditions and plants in the grazed area were in a more vigorous condition than normal. In 1957 rainfall during the growing season was 31.5 per cent above normal and in 1958 it was 40.0 per cent above normal. In addition, temperatures were slightly below normal. No extensive periods of drought or high or low temperatures occurred during the two years prior to collection of the sods.

Studies of effect of clipping on the number of shoots indicated that there was considerable variation in the vigor of individual shoots. Under moderate clipping (1.5 inches) there was some decrease in the number of shoots in all cases. Losses in big bluestem and side-oats grama were greater in plants from the ungrazed area (35.3 and 30.0 per cent, respectively) than on the grazed area, where the losses were 11.8 and 10.8 per cent. In blue grama little variation occurred. Here losses were 25.9 per cent (grazed) and 22.4 per cent (ungrazed). This might be due to the fact that blue grama, being a short grass, is not affected appreciably by either grazing or resting. It is less likely that blue grama would be overgrazed than it would be for side-oats grama and big bluestem, since a higher percentage of the photosynthetic material would be removed from the taller grasses. Under close clipping all plants lost nearly all their tillers and under non-clipping there was no significant variation in tiller count from beginning to completion of the study.

Height measurements were a less significant measure of variation in vigor than either shoot count or shoot weight. The weekly increments

were quite inconsistent, fluctuating from 0.08 inch to 2.67 inches of new growth per week. Moderate clipping stimulated the greatest cumulative height and would probably have yielded considerably more had the study been continued for a longer time. Close clipping and non-clipping resulted in nearly equal cumulative height in all species. Height growth was nearly completed in all closely clipped plants because nearly all tillers were dead. In the non-clipped plants growth was completed in side-oats grama and blue grama; however, big bluestem had not yet begun to send out flower stalks. Because of the fact that the side-oats and blue grama had attained flower, their cumulative height under non-clipping was greater than that of the big bluestem. Side-oats grama achieved the greatest height. Height measurements, alone, were found to be an invalid measure of any trend in vigor. Height increments throughout the study showed no specific tendency toward a gradual decrease; however, weight and number of shoots did show a consistent decrease.

Weight seemed to be the most valid measure of vigor of the individual measurements; however, here again the fact that the side-oats grama and blue grama had attained flowering gave a false impression of superiority over big bluestem. Also the variation in number of tillers created misconceptions.

The most valid interpretation of vigor through the study of shoots seemed to be weight per tiller. Despite the handicap of being compared to tillers of plants that had produced flowers, big bluestem yielded the highest weight per tiller (0.730 gram) under non-clipped conditions in plants from the grazed area. Side-oats grama from the grazed area had an average weight per tiller of 0.674 gram while blue

grama under the same conditions yielded 0.104 gram per tiller. In the relict area the non-clipped plants of the same species had weight per tiller approximately 30 to 40 per cent less than those from the grazed area. It is believed that the plants from the relict area may have been sod bound and needed additional clipping to stimulate growth.

Under moderately clipped and closely clipped conditions yields per tiller decreased progressively; however, the differences in area were not significant. This seems to support the hypothesis in the preceding paragraph.

In root growth much the same relationships within and between species existed concerning development of new roots as it did with new tops. Non-clipped plants showed the most new root growth. Moderately clipped plants, in general, achieved almost as great total length but were less abundant. Under close clipping, however, only big bluestem had any new root growth and even it was negligible.

The ratio of shoots to new roots does not show any site differences except under moderate clipping, in which the plants from the grazed area had a higher shoot-root ratio than did those from the relict area. Without exception the shoot-root ratio increases as clipping intensity increases.

Certain controlled conditions must be maintained if reproduceable data are to be obtained by analysis of carbohydrates through paper chromatography. It was found that R_f values were changed by variation in room temperature and also by age of the butanol-pyridine-water solution. It was attempted to keep room temperature at 70°F. $\pm$ 3°. Also fresh solutions of the developing solvent were made up each time new

analyses were to be made. Starch and fructosans along with sucrose made up the major portion of the available carbohydrates. The reducing sugars formed a very small percentage of the total readily available carbohydrate.

Carbohydrate differences between plants from the grazed and ungrazed areas were within the range of experimental error with the exception of blue grama, which seemed to build up more carbohydrate in plants from ungrazed than from the grazed area.

Big bluestem, in general, maintained higher percentages of available carbohydrates than either side-oats grama or blue grama. This was probably due to the larger storage area per root in big bluestem. A lesser percentage of the root is devoted to epidermal and sclerified tissue. Also, big bluestem has large rhizomes in which occurs extremely high carbohydrate storage (Meyer and Anderson, 1958). Side-oats grama had slightly higher values than blue grama. This also is probably due to the factors above - the side-oats grama being rhizomatous, whereas the blue grama is a bunchgrass with no rhizomes.

It was noted that, in big bluestem from both areas and blue grama from the ungrazed area, the greatest percentages of carbohydrate occurred in non-clipped plants, while in side-oats grama from both areas and blue grama from the grazed area, the moderately clipped plants contained the highest percentages of carbohydrates. This is probably due to the fact that the big bluestem plants did not reach the period of anthesis and the blue grama from the ungrazed area had few heads, whereas the other plants were in full flower. It has been shown by Meyer and

Anderson (1958) and Hyder and Sneva (1959) that during the time of flowering plants utilize large amounts of their available carbohydrates.

It was further noted that moderate clipping tended to bring carbohydrate quantities closer together and reduce the species significance. Close clipping tended to completely remove any species significance due to variation in quantity of carbohydrate. Somewhat the same phenomena, as was mentioned earlier, occurred in the relationships of weight of shoots as affected by clipping.

In studying these data in general, it is concluded that if good growing conditions prevail, grazing to a height of 1.5 inches will yield more height and ultimately more weight of utilizable forage than will be obtained under non-grazing or under extremely close grazing. This can also be accomplished without appreciable depletion of carbohydrate reserves. Extremely close grazing repeated frequently can only result in severe damage or death of the plant. The data further indicate that under the good growing conditions, plants that are utilized do retain as much vigor as those which are rested or protected from grazing.

SUMMARY

A number of studies concerning the effects of frequency and/or intensity of clipping on vigor of range grasses have been made. Additionally, some studies have been carried out concerning the effect of actual grazing on vigor. However, few of these studies have been done in the mixed prairie and few have attempted to study the effect of intensity of clipping on plants that had previously been subjected to different degrees of utilization. It was the purpose of this problem to study these factors and try to relate the results with the results of previous investigations.

A tall grass--big bluestem (Andropogon gerardi Vitman), a mid grass--side-oats grama (Bouteloua curtipendula (Michx.) Torr.), and a short grass--blue grama (Bouteloua gracilis (H. B. K.) Lag. ex Steud.) were selected as being typical representatives of the different kinds of range grasses preferred by cattle in the Great Plains. Two areas, one grazed and one not grazed, were selected in hopes that some differences might be demonstrated between grasses that had been subjected to fairly heavy utilization over a prolonged period of time as opposed to those which had been protected for a number of years.

Phytometer studies of new top growth under different intensities of clipping were made. Weight and height of new shoot growth as well as variation in number of shoots were measured throughout the study. At the completion of the phytometer study, weight and length of new root growth were measured and the original roots were preserved for chemical analysis.

A method of descending paper chromatography was employed to determine the percentages of various carbohydrate fractions and total readily available carbohydrates present in the original roots at the start of the study and at completion of the study.

In general, the data showed that, when closely clipped, all plants studied were severely restricted in shoot production, new root growth, and production of carbohydrates.

Moderate clipping seemed to stimulate shoot growth, but restricted to some degree the production of new roots. The production of carbohydrates was not severely affected by moderate clipping.

Differences in plants from the two areas were not significant except under non-clipped conditions. Under non-clipping, big bluestem and side-oats grama plants from the grazed area achieved growth superior to that of the same plants from the ungrazed or relict area. Blue grama plants showed no significant variation. This leads to the conclusion that plants need some clipping or grazing stimulation to achieve highest production and that plants which do not have this stimulus may become sod bound and have restricted growth.

It was also found that the shoot-root ratio increased with intensity of clipping.

Additionally, it was noted that clipping tended to reduce species significance; that is, that as clipping intensity is increased growth variations in the tall grass, mid grass and short grass were reduced.

Under moderate clipping, big bluestem and side-oats grama seemed to be the most vigorous, yielding the most forage and retaining the highest percentage of available carbohydrates. Blue grama yielded considerably

less forage, but still retained a significant percentage of available carbohydrate.

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LITERATURE CITED

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APPENDIX

APPENDIX A. Number of sheets per plant under each treatment at various intervals during the study.

PLANTS FROM GRAZED PASTURE

	Big Bluestem									Side-oats Grama									*Blue Grama								
	NC			MC			CC			NC			MC			CC			NC			MC			CC		
Replication	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
DATE																											
4-11	19	11	18	71	38	21	23	16	35	33	26	34	57	30	23	20	17	30	176	176	176	176	132	132	176	88	17
4-27							17	8	40							12	12	17							104	60	11
5-11	19	12	18	73	37	24	16	1	32	33	25	35	57	30	23	5	3	3	184	176	184	144	124	116	32	19	4
5-25							8	1	16							3	2	3							3	2	
6-1							6	1	14							1	1	3							2	2	
6-15	19	12	18	66	33	20	5	1	9	33	25	35	52	26	22	1	1	2	144	176	184	128	108	92	1	1	

PLANTS FROM RELICT AREA

	Big Bluestem									Side-oats Grama									*Blue Grama								
	NC			MC			CC			NC			MC			CC			NC			MC			CC		
Replication	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
DATE																											
4-11	25	33	28	36	35	30	14	17	37	49	40	40	39	37	40	44	50	17	44	88	176	176	66	132	132	44	
4-27							11	18	35							24	50	14							128	40	
5-11	25	34	28	34	34	29	10	12	33	51	40	41	40	37	42	4	26	6	48	92	176	176	64	132	83	19	
5-25							10	9	29							2	15	4							19	5	
6-1							9	9	17							2	15	4							10	4	
6-15	25	34	28	23	26	18	1	4	6	51	40	41	29	32	23	1	13	4	48	92	176	132	34	124	8	2	

*The number of tillers in blue grama sods were determined by counting the number of tillers in one square inch at two different areas on each sod and multiplying by the area of the cover.

NC - Not Clipped MC - Moderately Clipped CC - Closely Clipped

PLANTS FROM GRAZED AREA

Big Bluestem

	Not Clipped			Moderately Clipped			Closely Clipped		
	1	2	3	1	2	3	1	2	3
3-30	Sod Changed	1.5	Just Start	Just Start	1	Just Start	0.5	1.5	1.0
4-6	2	0.25	3.0	2.5	1.0	2.0	2.0	2.0	2.5
4-13	2	1.25	1.25	2.0	1.5	1.75	1.5	1.0	1.25
4-20	0.75	1.0	0.75	2.0	1.75	2.25	2.0	1.0	1.5
4-27	1.25	0.75	1.5	3.0	3.0	2.75	1.5	0.75	2.0
5-4	1.25	1.25	0.5	3.0	3.0	2.0	2.0	0.5	1.5
5-11	0.50	1.0	0.5	3.0	3.0	2.0	2.0	0.5	1.5
5-18	2.75	2.5	2.5	4.0	3.0	2.5	1.5	1.5	1.5
5-25	1.5	2.5	4.0	3.5	2.5	2.0	2.0	1.75	1.75
6-1	2	1.5	1.0	4.0	3.5	3.0	2.0	2.0	2.0
6-8	0	0	0.25	1.5	3.5	3.0	1.5	2.0	2.0
Date Closed	0.5	0.5	0.5	1.0	2.0	2.0	1.5	1.5	1.5
Total	14.5	14.0	15.75	29.5	28.75	25.25	20.0	16.0	20.0

Side-oats Grama

3-30	1	1	1	1.5	1.5	1.5	1.0	0.5	0.5
4-6	1	1.5	1.25	1.0	1.0	1.5	1.5	1.5	2.5
4-13	1	1.0	1.75	1.5	1.25	1.5	1.0	1.0	1.25
4-20	0.25	1.0	1.5	1.75	1.5	1.75	1.5	1.0	1.25
4-27	0.5	1.5	1.5	2.0	1.75	1.5	1.5	0.75	1.0
5-4	1.25	1.0	1.0	4.5	3.0	3.0	1.5	1.25	1.25
5-11	0.5	0.5	0.5	4.5	3.0	3.0	1.5	1.25	1.25
5-18	4.5	6.5	5.5	4.0	3.0	2.5	2.0	1.0	2.0
5-25	4.0	2.0	1.0	3.5	3.0	2.5	1.0	0.5	0.5
6-1	1.0	1.0	1.0	4.0	3.0	3.0	0.5	0.5	0.5
6-8	5.0	7.0	0.5	3.5	3.0	1.5	0.25	0.25	0.25
Date Closed	4.0	6.0	0.5	2.5	2.0	1.0	0.25	0.25	0.25
Total	24.0	30.0	17.0	34.25	27.0	24.25	13.5	9.75	12.5

Blue Grama

3-30	1.5	1.5	1.5	1.5	1.5	1.5	1.0	1.0	1.0
4-6	1.5	1.0	1.0	0.5	1.5	1.5	2.0	2.0	2.0
4-13	0.0	0.5	0.75	0.5	1.0	1.5	1.5	0.75	1.5
4-20	0.5	0.75	0.0	0.5	1.0	1.25	1.25	1.0	1.25
4-27	0.5	1.25	0.5	1.5	1.75	2.0	1.75	1.25	2.0
5-4	1.0	1.5	1.75	3.0	3.25	3.5	2.0	1.25	2.25
5-11	0.5	0.5	0.5	3.0	3.25	3.5	2.0	1.25	2.25
5-18	4.5	4.5	4.5	3.5	4.0	3.75	1.5	1.0	1.5
5-25	3.5	3.5	2.5	3.0	3.0	3.0	0.5	1.0	1.5
6-1	1.5	1.5	2.0	3.0	3.5	3.5	1.0	1.0	1.0
6-8	2.5	2.0	2.0	2.5	2.5	3.0	0.25	0.25	0.75
Date Closed	2.5	2.5	1.5	2.0	2.5	2.0	0.25	0.25	0.75
Total	20.0	21.5	18.0	24.5	28.75	30.0	15.0	12.0	17.75

PLANTS FROM RELICT AREA

Big Bluestem

	Not Clipped			Moderately Clipped			Closely Clipped		
	1	2	3	1	2	3	1	2	3
3-30	Just Start	3.0	2.0	Just Start	Just Start	Just Start	Not Start	Just Start	Just Start
4-6	3.5	1.0	1.0	2.5	3.0	3.0	2.25	2.5	3.25
4-13	0.75	1.0	1.5	2.5	2.25	2.5	2.75	2.0	3.0
4-20	1.75	2.0	1.5	2.5	3.0	2.75	3.0	2.5	2.75
4-27	1.5	1.0	2.0	4.5	3.5	3.5	3.5	3.25	3.0
5-4	0.0	0.5	0.5	5.0	5.0	4.5	3.0	3.0	3.0
5-11	0.75	0.25	0.25	3.5	3.5	4.0	2.25	2.25	2.25
5-18	1.75	0.75	2.25	4.0	3.0	3.5	2.5	2.0	2.75
5-25	1.0	1.0	2.5	3.0	3.5	4.0	1.75	1.5	2.25
6-1	0.5	0.5	1.5	3.0	3.0	3.0	2.0	1.5	1.5
6-8	1.0	0.25	3.0	2.0	2.5	2.0	2.0	1.5	1.0
Date Closed	0.5	0.25	2.0	0.5	1.0	1.5	1.0	1.0	0.5
Total	13.0	11.5	20.0	33.0	33.25	34.25	26.0	23.0	25.25

Side-oats Grama

3-30	2.0	1.5	1.5	3.0	2.5	2.5	2.0	3.0	2.5
4-6	1.5	1.75	1.5	1.5	1.25	2.0	2.5	3.75	2.5
4-13	1.25	1.25	0.5	1.25	1.5	2.0	1.5	2.5	0.75
4-20	0.75	0.0	1.0	1.5	2.5	2.0	1.5	2.25	1.0
4-27	1.5	1.0	2.5	3.25	2.75	3.0	1.75	3.0	1.25
5-4	1.75	1.5	2.0	4.0	4.5	4.5	2.0	3.0	2.0
5-11	0.5	2.25	1.0	3.0	4.0	4.0	1.0	2.5	1.0
5-18	2.75	2.25	1.0	4.0	4.5	4.5	1.0	2.5	1.0
5-25	2.0	2.0	0.5	3.5	4.0	4.0	1.0	2.0	1.0
6-1	0.5	1.0	0.5	2.5	3.5	3.5	0.5	2.5	1.25
6-8	5.5	7.5	5.0	3.0	4.0	2.0	2.0	2.0	2.0
Date Closed	5.0	7.0	3.0	3.0	3.5	1.0	1.0	1.5	1.5
Total	25.0	29.0	20.0	33.5	38.5	35.0	17.75	30.5	17.75

Blue Grama

3-30	2.5	1.5		2.0	1.0	1.5	2.0	2.0	1.0
4-6	2.0	1.5		1.5	2.5	2.0	3.0	3.0	2.5
4-13	0.5	1.75		2.25	1.75	1.25	2.25	2.25	1.75
4-20	0.0	0.5		2.5	3.0	2.0	1.75	1.75	1.75
4-27	1.0	1.5		3.75	4.5	3.75	2.25	2.0	2.0
5-4	1.5	0.75		3.5	4.0	3.0	1.5	1.5	1.5
5-11	1.0	1.0		3.5	4.5	4.0	1.5	1.0	1.0
5-18	4.5	3.0		4.0	5.0	4.5	2.0	1.5	1.25
5-25	3.5	1.5		4.0	3.0	3.0	1.0	1.0	1.0
6-1	1.0	2.0		3.0	2.0	3.0	0.25	0.5	1.0
6-8	1.5	2.0		1.0	1.5	2.0	0.25	0.25	0.5
Date Closed	1.0	1.5		0.5	1.0	1.5	0.0	0.25	0.5
Total	20.0	18.5		31.5	33.75	31.5	17.75	17.0	15.75

Destroyed

APPENDIX C. Weekly weight gain and cumulative weight of shoots of each plant under each condition.

PLANTS FROM GRAZED AREA

	Not Clipped			Moderately Clipped			Closely Clipped		
	1	2	3	1	2	3	1	2	3
Big Bluestem									
3-30				--	--	--	.004	.036	.010
4-6				.140	.091	.026	.161	.139	.610
4-13				.092	.176	.052	.071	.063	.190
4-20				.413	.516	.149	.049	.087	.146
4-27				.410	.500	.182	.046	.045	.057
5-4				.961	1.103	.381	.050	.061	.035
5-11				.713	.786	.222	.132	.132	.044
5-18				.720	.702	.184	.060	.114	.040
5-25				.702	.761	.234	.010	.012	.028
6-1				.931	1.111	.258	.004	.004	.024
6-8				1.011	1.000	.250	.002	.002	.016
*Date Closed Total Weight	12.517	10.499	12.041	3.229 9.282	4.364 11.110	1.818 3.754	.002 .591	.002 .697	.004 1.204
Side-oats Grama									
3-30				--	--	--	--	--	.042
4-6				.210	.061	.106	.192	.107	.343
4-13				.088	.052	.092	.108	.087	.110
4-20				.153	.151	.169	.061	.022	.034
4-27				.635	.244	.173	.019	.010	.015
5-4				1.429	.410	.358	.004	.006	.004
5-11				1.453	.433	.383	.003	.004	.002
5-18				1.312	.506	.437	.003	.002	.002
5-25				1.014	.577	.558	.002	.002	.002
6-1				1.174	.718	.819	.002	.002	.003
6-8				.832	.515	.229	.002	.002	.002
*Date Closed Total Weight	25.796	31.930	4.992	4.017 12.317	3.101 7.193	3.125 6.449	-- .396	-- .244	.002 .560
Blue Grama									
3-30				--	--	--	.080	.079	.091
4-6				.016	.073	.071	.443	.241	.562
4-13				.018	.071	.091	.236	.113	.324
4-20				.022	.062	.074	.081	.057	.050
4-27				.133	.160	.182	.107	.041	.126
5-4				.414	.672	.629	.044	.042	.088
5-11				.514	.839	.645	.049	.038	.084
5-18				.604	.901	.690	.033	.016	.045
5-25				.599	.845	.627	.017	.012	.015
6-1				.672	1.012	.878	.009	.007	.014
6-8				.670	1.171	.850	.004	.002	.014
*Date Closed Total Weight	24.088	15.129	15.292	2.043 5.705	2.612 8.418	2.262 6.999	.002 1.105	.002 .653	.014 1.412

*Date closed weight of the moderately clipped plants included the basic $1\frac{1}{2}$" of shoot that was the clipping height during the study.

PLANTS FROM RELICT AREA

	Not Clipped			Moderately Clipped			Closely Clipped		
	1	2	3	1	2	3	1	2	3
Big Bluestem									
3-30				--	--	--	--	--	--
4-6				.076	.129	.116	.075	.142	.433
4-13				.210	.198	.214	.138	.259	.527
4-20				.102	.268	.281	.068	.131	.169
4-27				.462	.484	.491	.086	.162	.200
5-4				.540	.736	.772	.048	.114	.132
5-11				.317	.483	.551	.021	.039	.061
5-18				.321	.416	.432	.018	.028	.071
5-25				.264	.431	.410	.019	.031	.069
6-1				.339	.438	.506	.018	.020	.022
6-8				.208	.322	.287	.023	.030	.039
*Date Closed Total Weight	17.607	11.735	8.998	1.144 4.883	2.646 6.551	2.656 6.816	.014 .528	.028 .884	.065 1.790
Side-oats Grama									
3-30				.052	.018	.042	.149	.372	.060
4-6				.214	.179	.228	.807	1.662	.416
4-13				.224	.207	.243	.203	.431	.071
4-20				.213	.329	.261	.076	.414	.062
4-27				.288	.461	.302	.161	.211	.018
5-4				1.027	.582	1.327	.020	.221	.020
5-11				1.526	1.362	1.538	.021	.136	.018
5-18				1.477	1.592	.976	.014	.120	.012
5-25				1.366	1.697	1.473	.011	.061	.008
6-1				.311	1.474	.287	.004	.083	.010
6-8				.266	1.094	.344	.004	.030	.026
*Date Closed Total Weight	23.328	21.637	15.150	1.877 8.841	2.352 11.333	1.937 9.008	.008 1.479	.049 3.790	.047 .768
Blue Grama									
3-30				.114	--	--	.311	.094	.072
4-6				.391	.207	.448	1.356	.644	.459
4-13				.286	.116	.252	.366	.212	.109
4-20				.300	.202	.200	.088	.052	.055
4-27				.728	.664	.578	.153	.050	.373
5-4				.624	.580	.434	.074	.018	.042
5-11				.690	.517	.318	.062	.017	.191
5-18				.842	.621	.561	.021	.006	.012
5-25				.482	.203	.539	.002	.002	.006
6-1				.515	.192	.512	.002	.002	.002
6-8				.177	.278	.821	--	--	--
*Date Closed Total Weight	10.721	7.056	5.121	2.732 7.881	.478 4.058	1.427 6.090	-- 2.435	-- 1.096	-- 1.211

*Date closed weight of the moderately clipped plants included the basic 1½" of shoot that was the clipping height during the study.

APPENDIX D. Length and weight of new roots grown under each method of treatment.

PLANTS FROM GRAZED PASTURE

	NC			MC			CC		
MEASUREMENT	1	2	3	1	2	3	1	2	3
Big Bluestem									
Total Length (In.)	26.0	24.8	27.2	25.2	28.0	24.0	0	2.8	0
L. of Sec. Roots (Cm.)		1 - 3			1 - 5			None	
L. of Tert. Roots (Mm.)		1 - 2			2			None	
Sec. Roots/Cm.		2			5			None	
Air Dry Wt. of New Roots (Gms.)	12.75	9.91	14.53	3.12	3.54	2.87	0	0.19	0
Side-oats Grama									
Total Length (In.)	26.0	28.8	24.0	27.6	24.8	24.0	0	0	0
L. of Sec. Roots (Cm.)		2 - 5			2 - 6			0	
L. of Tert. Roots (Mm.)		1 - 2			1 - 8			0	
Sec. Roots/Cm.		4			6 - 7			0	
Air Dry Wt. of New Roots (Gms.)	11.76	16.29	9.57	2.59	1.76	2.01	0	0	0
Blue Grama									
Total Length (In.)	26.0	25.2	23.6	18.4	24.8	23.6	0	0	2.0
L. of Sec.Roots (Cm.)		5 - 6			3 - 5			2	
L. of Tert. Roots (Mm.)		1 - 2			1 - 5			0	
Sec. Roots/Cm.		5			5			0	
Air Dry Wt. of New Roots (Gms.)	11.16	4.45	2.56	.80	1.06	1.82	0	0	0.01

NC - Not Clipped MC - Moderately Clipped CC - Closely Clipped

APPENDIX D. (Continued)

PLANTS FROM RELICT AREA

	NC			MC			CC		
	1	2	3	1	2	3	1	2	3
Big Bluestem									
Total Length (In.)	23.6	24.0	24.0	25.6	27.6	24.0	0	0	4.4
L. of Sec. Roots (Cm.)		1 - 5			1 - 5			0	
L. of Tert. Roots (Mm.)		1 - 9			1 - 5			0	
Sec. Roots/Cm.		4 - 5			4			0	
Air Dry Wt. of New Roots (Gms.)	7.00	11.32	12.57	3.18	4.28	1.78	0	0	0.23
Side-oats Grama									
Total Length (In.)	26.4	26.4	26.0	24.0	24.4	25.2	0	0.8	0
L. of Sec. Roots (Cm.)		1 - 4			2 - 5			0	
L. of Tert. Roots (Mm.)		1 - 2			1 - 4			0	
Sec. Roots/Cm.		5 - 6			4 - 5			0	
Air Dry Wt. of New Roots (Gms.)	23.43	28.57	14.46	2.64	4.29	0.98	0	<0.1	0
Blue Grama									
Total Length (In.)	31.2	18.0	26.8	24.0	13.6	24.0	0	0	0
L. of Sec. Roots (Cm.)		5 - 10			5 - 10			0	
L. of Tert. Roots (Mm.)		5 - 10			5 - 10			0	
Sec. Roots/ Cm.		6 - 7			6 - 7			0	
Air Dry Wt. of New Roots (Gms.)	4.85	4.24	5.77	1.17	0.14	2.46	0	0	0

NC - Not Clipped MC - Moderately Clipped CC - Closely Clipped