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Effects On Different Intensities of Utilization Upon The Underground Parts of Short Grasses In West Central Kansas

Farrel Branson
Fort Hays Kansas State College

EFFECTS OF DIFFERENT INTENSITIES OF UTILIZATION UPON THE UNDERGROUND PARTS OF SHORT GRASSES IN WEST CENTRAL KANSAS

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Farrel Branson, B. S.

Fort Hays Kansas State College

Date July 31, 1947 Approved F. W. Albertson
Major Professor

F. W. Albertson
Chairman Graduate Council

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INTRODUCTION

Work on root systems of forage plants has indicated that a knowledge of root relationships is fully as important in determining the actual conditions of ranges or pastures as is knowledge of the effects of grazing upon aboveground portions of plants. This is especially true in arid or semiarid regions since plants of these areas are frequently subjected to long periods of drought, high temperatures, and high wind velocities. Some xeric plants have a thickened cuticular layer, stomates that open only at night, and other mechanisms that prevent loss of water that is absorbed by the roots. However, in plants of the short grass plains an extensive root system is the primary means of obtaining water that is needed for life processes during periods of stress. If the development of roots is impaired by bad grazing practices there is a reduction in the ability of plants to withstand drought and other adverse climatic conditions. The ability of a plant to produce abundant forage is also decreased by poorly developed underground parts. A knowledge of root systems, therefore, is essential in determining grazing practices that will insure the growth of well developed vigorous plants.

Numerous studies have been made on the effects of grazing upon the aboveground portions of plants but there are few studies of the effects of grazing on subterranean parts of grasses under range conditions. This is undoubtedly due to the fact that the roots of plants are hidden from view by the soil and because viewing them, in most instances, involves a considerable amount of care and work. The primary purpose of this study was to determine some of the effects of different intensities of grazing upon the underground parts of short grasses. The data presented in this paper should be of value to range examiners, range conservationists, or county agents who wish to know the results of different intensities of grazing on the root systems of pasture grasses.

Related Studies

It is logical to assume that the removal of a portion of the photosynthetic tissue will have a detrimental effect on the root systems of plants, due to a decrease in the amount of reserve food stored after its removal. Other injurious effects of grazing of plants observed by Weaver (1930) include: (1) a decrease in the amount of tillering, (2) a decrease in plant vigor, and (3) a lessening of growth and development of roots due to compacting of the soil and to the decrease in the amounts of food reserves accumulated in the roots. Weaver and Darland (1947), in a study of the vigor of range grasses as affected by grazing, found a decrease in root growth with an increase in the intensity of grazing.

The amount of injury to plants due to clipping has been found to vary somewhat with the species clipped, but in general the yield of both aboveground and underground plant parts is greatest in uncut plants (Robertson 1933, Harrison and Hodson 1937).

Tomanek (1947), in an analysis of the aboveground parts of plants in the areas of this study, found a greater basal ground cover and a greater production of forage during the growing season on the pasture grazed moderately, and by far the least amount of forage produced by the overgrazed pasture. Canfield (1939) found that two sets of quadrats of black grama (Bouteloua eriopoda) grass clipped to heights of 1 and 2 inches made substantial gains in tuft area and dry weight during the second year of the experiment (a year unusually favorable for growth), but in following years the losses due to clipping were far greater than the temporary gains. The plants were practically destroyed by ten years of the two treatments.

Burton (1943) employed methods of root removal similar to those used in this study. Roots of seven southern grasses were washed from the soil under 100 square inches of sod at four inch intervals. An analysis of root growth was made by means of total weights and of weight distribution.

In their studies of Great Plains vegetation Weaver and Albertson (Albertson 1937, and Weaver and Albertson 1943) found that root penetration was directly correlated with the depth of moist soil. Preceding the great drought of 1933 to 1940 the penetration of roots of short grasses, buffalo grass (Buchloe dactyloides) and blue grama grass (Bouteloua gracilis), was from 4 to 5 feet, with a maximum penetration of 6 feet. During the drought, however, the roots of these grasses were extremely scarce below 2 feet and in western Kansas and eastern Colorado most of the roots were restricted to the upper foot of soil. They also found that the weights of underground parts in sods of short grasses on ungrazed, moderately grazed, and overgrazed pastures decreased with an increase in the intensity of grazing.

Work by Sprague (1932) on grasses in New Jersey indicated that at least half the root system was newly generated each spring. In that area the depth of root penetration was about 10 inches. Weaver and Zink (1946) found that about three years were required for maximum root development of the dominant grasses of the true prairie.

Biswell and Weaver (1933) studied the effects of clipping on the roots and shoots of prairie grasses. They found that the quantity and the size of tops and roots were reduced in plants subjected to clipping.

Hanson and Staddart (1940) in studying the effects of grazing upon bunch wheat grass (*Agropyron spicatum*) found a slight increase in the lateral spread of roots of grazed plants, but there was a decrease in the depth of root penetration, a decrease in root weights, a decrease in the number of viable seeds and of foliage, and a decrease in food reserves stored in the roots and stem bases of grazed plants.

McCarty (1938), in Utah, observed a decline in the amount of acid-hydrolyzable hemicellulose present during the periods when carbohydrate storage was greatest and an increase in hemicellulose when sugars and starch fractions were least. He suggested that this inverse ratio indicated a possible source of less complex carbohydrates and may, therefore, be considered a stored food. It was further concluded that relatively high concentrations of sugars and starch in the basal organs and newly developed shoots of mountain brome (*Bromus carnatus*) are associated with resistance to low temperatures and essential to winter survival of the plants. McCarty and Price (1942), in central Utah, found that the quantity of reserve carbohydrates in roots and stem bases decrease with a decrease in the interval between cutting of shoots. They found the lowest reserves in plants clipped during the growing season, but when clipped at the beginning and at the end of the growing season, near-normal carbohydrate reserves were attained.

METHODS

Removal and Treatment of Samples

This study was made during the fall and winter of 1946. A representative site was selected in each pasture from which samples were to be removed. Barbed wire exclosures were constructed in each pasture to exclude cattle from the areas (Fig. 1). A one-half square meter of sod four inches in depth was removed from each pasture in one-fourth square meter sections (Fig. 2). The shoot growth was removed from each sod by means of clipping shears after which the debris and litter were removed by hand and by washing the partially decayed material from the sods.* Debris and litter are considered important because their relative amounts indicate, to some extent at least, the past treatment and present conditions of the pastures studied. All the sods removed only to a depth of four inches were placed on a rack with a fine screen (16 mesh) bottom and the soil

* The terms "debris" and "litter" as used in this paper include the partially decayed plant material not attached to the plant that did not pass through the screen of the washing rack.

Figure 1. Barbed wire exclosure in the overgrazed pasture. Root samples were taken from the exclosure.

Figure 2. Removal of one-half square meter of sod in one-fourth square meter sections. The wooden form was used to facilitate the removal and shaping of the sods.

washed from the roots. All portions of the plants were then dried, weighed, and stored in air-tight jars for future chemical analyses.

After the removal of the one-fourth square meter sods, a trench 4 feet wide and 8 feet long was dug to the maximum depth of root penetration. Two columns of soil 8" by 8" were taken from opposite ends of the trench. These columns were removed in one-foot intervals to the maximum depth that roots were found (Fig. 4).

For the samples removed from below the surface four inches it was necessary to soak the blocks for at least 12 hours before the soil could be efficiently separated from the roots. All live plant material was killed by heating to 100° C. for 30 minutes before the drying process was continued. Material that was partially decayed or appeared to be dead was removed before the roots were weighed. All the underground parts of plants were dried to a constant weight at 60° to 70° C. and only the dry weights reported.

The number of roots in circles 4 inches in diameter was determined at depths of 4 and 12 inches and thereafter at foot intervals as each soil block was removed.

Phytometer Studies

Three sods were removed from representative areas of each pasture on January 26, 1947. At that time the soil was frozen to a depth of about 4 inches. The sods were trimmed to 6 inches in diameter and 4 inches in depth; then placed in phytometers that were 15 inches in depth. The first set of phytometers had been filled with

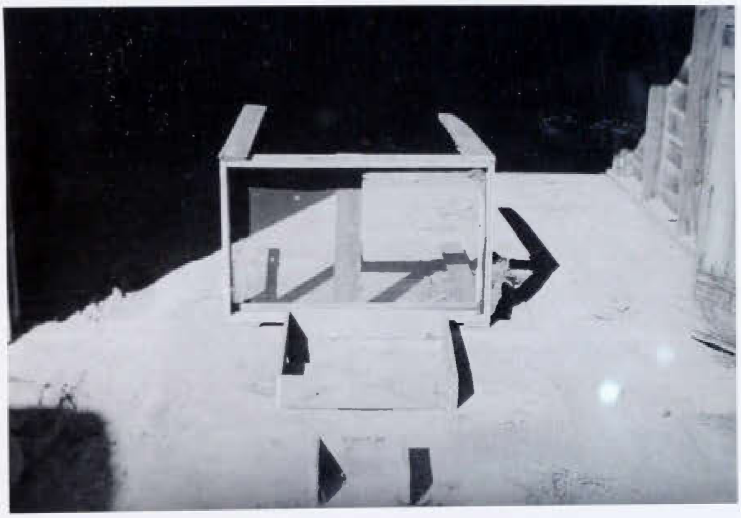

Figure 3. Equipment used in the removal of roots: an 8" by 8" form, a one-fourth square meter form, and a screen-bottomed washing rack.

Figure 4. Removal of 8 by 8 inch columns. The first two feet have been removed from the column of soil.

screened and moistened loam soil. A new group of sods was brought from the pastures to the greenhouse February 23, 1947. The portion of the phytometers below the sods of this group was filled with moist sand.

The phytometers containing the sods were placed in the greenhouse and the plants watered and measured for rate of growth at 7-day intervals. The relative rate of breaking of dormancy was observed and recorded in each series. After the plants had grown in both sets of phytometers for periods of eleven and nine weeks respectively, the sods were removed and the roots below the sods washed free of soil particles. The number and length of roots were determined, then the root and shoot growth was clipped from the sods. The material clipped from the sods was dried in an oven and weighed.

Chemical Analyses

Dried samples of plant material that had been removed from the first 4 inches of soil in each pasture were ground and analyzed for reducing sugars, sucrose, starch, and hemicellulose. Two 12-gram samples of the oven dried material from each of the three pastures studied were used for the complete analyses.

Two grams of calcium carbonate were added to each sample that gave an acid reaction. The sugars were extracted from each sample by means of hot alcohol. The solution was heated with 150 cc. of 50 percent alcohol and the washings made to volume with 95 percent alcohol. The solution was clarified with neutral lead acetate solution; then the lead removed with sodium carbonate. This clarified solution was used for the determination of reducing sugars and sucrose. The reducing power of an aliquot was determined by the use of Fehling's solution, the reduced copper being determined by the gravimetric method. This portion was reported as reducing sugars. A second aliquot of the clarified solution was hydrolized with concentrated hydrochloric acid according to the process described in Official Methods (1945). The solution was neutralized and the reducing power determined. The difference between these two determinations was reported as sucrose.

The residue remaining from the sugar extraction was dried in an oven, then transferred to a flask with 100 cc. of water and heated for one-half hour at the boiling point. After cooling to 37° C., 6 cc. of saliva and a few drops of toluene were added to the suspension. The suspension was agitated and transferred to an incubator where it remained for 12 hours at 37° C. The liquid was decanted and washed from the residue into a volumetric flask, then cleared and 200 cc. of the clarified solution hydrolyzed by refluxing for 3 hours with 10 cc. of concentrated hydrochloric acid. The solution was neutralized and the reducing power of an aliquot determined. This fraction was reported as total starch.

In the determination of hemicellulose the residue was refluxed in 2.5 percent hydrochloric acid for 2.5 hours, after which the suspension was filtered and the extract neutralized and diluted to 250 cc. in a volumetric flask. The solution was cleared, deleaded, and the reducing power of an aliquot determined. The calculations were based on the ash-free dry weight of the samples.

PRECIPITATION

In west central Kansas the years from 1933 to 1940 were extremely dry (Table I). During these years above normal precipitation occurred only once, when in 1935 the total precipitation was 5.89 inches above average. This long period of drought so reduced the cover of short grasses that many of the pastures had the appearance of cultivated fields. Following 1940, the annual precipitation exceeded the average. Above normal precipitation continued through 1946, the year that samples were collected for this study. During these moist years that followed the drought a near-normal cover of grasses was regained by the pastures.

DESCRIPTION AND HISTORY OF AREAS STUDIED

Pastures chosen for this study are within a fi e-mile area near Collyer, Kansas. This region is about 100 miles east of the Colorado line and 90 miles south of the Nebraska line. The elevation is about 2580 feet above sea level. The pastures are typical of this area where wheat is the most important agricultural crop produced. They are rather small, each including from 60 to 80 acres of grassland. Ordinarily the more rolling lands found in these areas are reserved for pasture purposes.

A history of the grazing practices followed on each pasture was obtained from the operator. The ungrazed pasture had not been grazed since the drought which ended in 1940, and during the drought years it supported only two saddle horses for approximately 3 months of each year.

Table I. Precipitation in inches at Quinter, Kansas during 15 years. The Quinter station is 7 miles west of the areas studied.

Year	Total Precipitation	Departure from Normal	
		Above	Below
1932	21.70	2.27	
1933	15.01		4.42
1934	10.90		8.53
1935	25.32	5.89	
1936	16.86		2.70
1937	11.48		8.08
1938	17.99		1.57
1939	14.54		5.02
1940	18.89		0.67
1941	28.49	8.93	
1942	22.12	2.56	
1943	20.92	1.36	
1944	31.32	11.56	
1945	20.00	0.24	
1946	32.33	12.57	
Average	20.52	1.24	

The pasture was subject to considerable dusting during the drought but did retain enough cover to insure a good supply of forage during those extremely dry years. At the time of this study the two dominant grasses, buffalo grass and blue grama grass, covered most of the pasture. The average height of buffalo grass was 4.5 inches and that of blue grama grass was 6 inches. The average height of blue grama flower stalks was 14 inches (Fig. 5).

Throughout the pasture there were areas about ten feet in diameter that were composed almost entirely of weedy annuals. These were high areas near cultivated fields and were probably eroded by wind during the drought. The persistence of the weedy areas in the pasture may be due to the wind erosion these areas were subject to during the drought. The plants most numerous in these areas were lamb's quarter (Chenopodium album), knotweed (Polygonum aviculare), sunflower (Helianthus annuus), Russian thistle (Salsola pestifer), and little barley (Hordeum pusillum). Ragweed (Ambrosia psilostachya) and sedge (Carex gravida) were also found in these areas. Blue grama was far more abundant in the weedy areas than buffalo grass. Native forbs were numerous in this pasture.

The moderately grazed pasture (Fig. 6) had an average annual stocking rate of 10.7 acres per animal unit for the 15 years previous to 1946. The vegetative cover of short grasses was composed of a greater amount of buffalo grass than that observed on the nongrazed pasture. The cover of grass during the drought was reduced to a few scattered clumps, but the cover was quickly restored during the moist years that followed the dry ones.

Figure 5. The nongrazed pasture. Weedy areas are visible in the background and some open spaces are shown in the foreground.

Figure 6. The moderately grazed pasture. Uniformly grazed short grasses form a dense cover in this pasture.

In the moderately grazed pasture the average height of blue grama grass was 4.5 inches--its flower stalks extended to 11 inches. The average height of buffalo grass was 3.5 inches. The most prominent forbs were salmon colored mallow (Malvastrum coccineum), thistle (Cirsium ochrocentrum), horsetail (Erigeron canadensis), and prairie cone flower (Ratibida columnaris). Weeds that were most numerous were little barley, and sticktight (Lappula heterosperma). These weeds were found in areas that were heavily dusted and in open spaces between clumps of grass. They were relatively few in number.

The overgrazed pasture (Fig. 7) had an average annual stocking rate of 2 acres per animal unit during the 15 years preceeding this study. Most of the short grasses were killed during the drought --a few small tufts of grass that were separated by several yards could be found. As was true in the other pastures, the recovery of this pasture following the drought was rather rapid though weeds persisted for a longer period than in pastures that were stocked at a more moderate rate. At the time this study was made the short grass cover was predominately buffalo grass. The average height of the grasses was three-fourths of an inch (even in an exclosure that was in existence during most of the growing season the height of the grasses seldom exceeded one inch). Flower stalks of blue grama grass averaged 7 inches in height. Remnants of weeds were numerous in the open spaces. These included little barley, sticktight and wind flower (Anemone caroliniana). Forbs were few in number, salmon colored mallow being the most abundant forb.

Figure 7. The overgrazed pasture. Closely cropped short grasses extend throughout this pasture.

RESULTS

Soils of the Areas Studied

The soil of the region is a silt-loam of the Holdrege-Hall series. The soil horizons in each of the three pastures were similar in most respects. The A horizon extended to approximately 18 inches in each pasture. At this depth the marked decrease in the amount of organic matter was indicated by a change in the color of the soil from dark to light brown. Below the depth of 18 inches the color changed from light brown to a yellowish brown with an increase in depth. The zone of carbonation was not definite. It first occurred at about 28 inches and flakes of calcium carbonate were found to a depth of 72 inches. No "hardpan" was observed.

There were slight differences in soil structure under each type of pasture treatment. In the overgrazed area the structure was somewhat granular throughout the solum but below this level it was prismatic. The soil was slightly prismatic even at 60 inches in depth. Below the granular solum in the moderately grazed pasture the structure was columnar to approximately two feet, then it gradually merged into a massive, structureless condition. In the nongrazed pasture the solum was granular in structure and this merged into a massive condition at about 18 inches, where the organic matter markedly decreased. These differences in structure seem to be due to the different degrees of trampling of the soil by cattle in the three pastures.

Weight of Vegetation and Number of Roots Under the Three Intensities of Utilization

The first phase in the removal of the underground parts of the grasses under the three types of pasture treatment was that of determining the weight in the first four inches of sods one-half square meter in area. The overgrazed pasture yielded 355.6 grams of underground parts, the moderately grazed 384.7, and the nongrazed 466.5 grams (Table II).

The amount of shoot removed from the overgrazed sod was 34.0 grams while that of the moderately grazed and nongrazed was 104.9 grams and 204.4 grams respectively. It can be seen from these data that on the overgrazed pasture shoot production was considerably less than that of the moderately grazed and nongrazed pastures and also that there was an increase in the root-shoot ratio with an increase in the intensity of grazing.

The amount of litter and debris found on each pasture showed a trend similar to that of root and shoot production. The smallest amount was found on the overgrazed and the greatest on the nongrazed pasture.

The weight of roots removed from 8" x 8" columns, to the full depth of root penetration, show that a larger percentage of the total weight of roots is found in the upper 12 inches on the overgrazed pasture than in the other two ranges (Table III). In the order of decreased intensity of grazing there were 78.4, 72.1, and 71.8 percent of the roots in the first 12 inches of soil. This shows that there

Table II Dry weights of vegetation removed from one-half square meters.

Kind of Vegetation	Overgrazed	Moderately Grazed	Nongrazed
Root (0 - 4")*	355.6 grams	384.7 grams	466.5 grams
Debris and litter	229.6 "	436.7 "	530.0 "
Shoot	34.4 "	104.9 "	204.4 "
Total vegetative material	619.6 grams	926.3 grams	1200.9 grams

* Includes root crowns.

Table III Dry weights of roots of grasses removed from two 8" x 8" columns to the maximum depth of root penetration.

	Overgrazed		Moderately Grazed		Nongrazed	
Depth in Inches	Grams	Percent of Total	Grams	Percent of Total	Grams	Percent of Total
0 - 4	57.5)	78.4	60.1)	72.1	75.7)	71.8
4 - 12	27.3)		28.8)		25.9)	
12 - 24	9.2)	21.6	13.1)	27.8	16.4)	28.2
24 - 36	8.6)		10.0)		12.9)	
36 - 48	3.6)		8.0)		7.5)	
48 - 60	1.4)		2.5)		2.6)	
60 - 72	0.6)		.7)		.5)	
Total Weights	108.2		123.2		141.5	

was an increase in the percent of root weights present in the first 12 inches of soil with an increase in the intensity of grazing. The total weights of roots removed from each of the three pastures to a depth of 6 feet were 108.2 grams from the overgrazed, 123.2 from the moderately grazed, and 141.5 grams from the nongrazed pasture. The relative amount of root found in the overgrazed pasture was remarkably high for the amount of shoot produced.

The average maximum depth of root penetration was nearly the same in each pasture. Soil moisture seemed to be the primary factor limiting the maximum penetration of roots, although at the time this study was made the soil in the moderately grazed and nongrazed pastures was moist to a greater depth than root penetration.

The number of roots found in four-inch circles was consistently larger at all depths in the moderately grazed pasture (Table IV). The percentage of roots extending below 4 inches was 36.1 in the overgrazed pasture, 56.6 in the moderately grazed, and 54.3 percent in the nongrazed pasture. Only 7.9 percent of the roots found at 4 inches in the overgrazed pasture extended to 48 inches, while 15.9 or nearly twice as great a percentage extended to this depth in the moderately grazed and nongrazed pastures. The fact that the average number of roots was less in the nongrazed pasture than in the moderately grazed while the weights showed a different relationship may be accounted for by the following: (1) a larger proportion of the weight of roots was concentrated in the first foot of soil in the moderately grazed pasture, (2) the roots of blue grama are larger than those of buffalo grass--

Table IV Average number of roots found in circles four inches in diameter to a depth of 72 inches and the percent of roots extending below four inches.

Depth in Inches	Overgrazed		Moderately Grazed		Nongrazed	
	Number	Percent	Number	Percent	Number	Percent
4	152.5		160.0		148.0	
12	55.0	36.1	90.5	56.6	80.5	54.3
24	31.5	20.7	49.0	30.6	45.0	30.4
36	17.0	11.1	41.5	25.9	32.5	22.0
48	12.0	7.9	25.5	15.9	23.5	15.9
60	5.5	3.6	9.5	5.9	12.5	8.4
72	1.5	1.0	3.0	1.9	2.5	1.7
Total	275.0		375.0		344.5	

blue grama constituted 40.9 percent of the total cover on the nongrazed pasture but on the moderately grazed area it was only 14.9 percent (Tomanek, 1947), (3) the roots of ungrazed plants are larger than those of grazed plants (Weaver and Darland, 1947) and (4) there was considerably less branching of the roots of the nongrazed plants which might, to some extent, account for their increased weight.

Phytometer Studies

The sods placed in the greenhouse were observed for a period of time in order to study the development of new roots and shoots. The first series were left in the phytometers for a period of eleven weeks. In this series some of the roots reached the bottom of the phytometers, a condition that makes the measurement of maximum root length difficult. The second series were in the phytometers only nine weeks. The time interval of the second group was more nearly the optimum time for phytometers of the size used in this study.

The rate of breaking of dormancy gives some indication of the vigor of plants. Incipient growth was observed first in the plants that had not been grazed, followed in order by those which had been moderately grazed, and last in the plants that had been subjected to overgrazing.

There was some variation in the growth of grasses in the series of phytometers with loam under the sods (Fig. 12). The total production of roots and shoot were the following: 13.105 grams by the overgrazed, 14.646 grams by the moderately grazed, and 20.789 grams by the

Figure 8. Plants growing in phytometers filled with screened loam soil.

Figure 9. Sods removed from phytometers filled with soil.

Figure 10. Plants growing in phytometers filled with sand.

Figure 11. Sods removed from phytometers filled with sand.

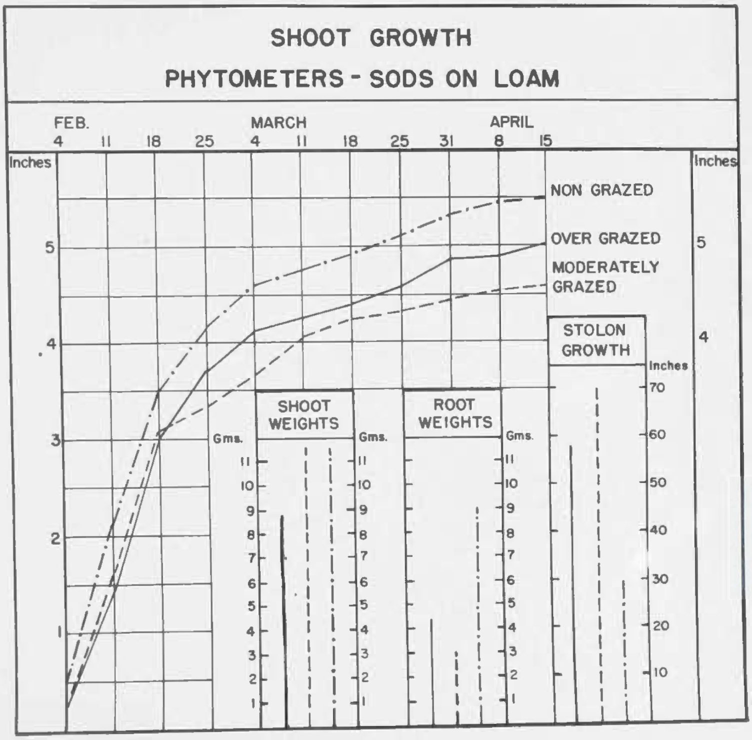

Figure 12. Growth of grasses in phytometers filled with screened loam soil.

nongrazed group (Table V). These amounts varied directly with intensity of grazing to which the plants had been subjected. The growth in height of the grasses differed from the amounts of shoot growth produced, that of the moderately grazed being less than that of the nongrazed or overgrazed. However, the growth of stolons of the moderately grazed plants was so extensive that the total weight of shoot growth equaled that of the nongrazed plants. There was a smaller amount of buffalo grass in the nongrazed group and it is probable that the few buffalo grass plants present in these phytometers were weakened by competition with the blue grama grass. In all the phytometers where an unusual amount of stolon growth occurred there was a decrease in root production. In one phytometer of the moderately grazed series where there was an enormous amount of stolon growth only a few small roots were produced. These data suggest that the amount of root growth may vary inversely with the amount of shoot growth.

In the phytometers with sand under the sods the trend of vegetative production followed a more definite progression (Fig. 13). The total amounts of roots and shoot removed from these sods were 3.010 grams from the overgrazed, 6.005 from the moderately grazed, and 7.310 grams from the nongrazed sods (Table V). The rate of shoot growth was consistently greatest by the nongrazed plants and least by the overgrazed plants. In this series too the stolon growth was most significant in the moderately grazed plants. The amount of shoot produced by the overgrazed group was a great deal less than that of the moderately grazed and nongrazed plants. The amount of shoot growth of the

Table V Total root and shoot weights of plants grown in phytometers.

Phytometers with loam under sods

	Series	Overgrazed	Moderately Grazed	Nongrazed
		Grams	Grams	Grams
Shoot weights	1 - 1	3.9	3.1	3.1
	2 - 1	2.6	3.9	4.9
	3 - 1	2.3	4.6	3.6
Root weights	1 - 1	0.855	1.640	3.470
	2 - 1	1.340	1.166	3.154
	3 - 1	2.110	0.240	2.565
Total		13.105	14.646	20.789

Phytometers with sand under sods

	Series	Overgrazed	Moderately Grazed	Nongrazed
		Grams	Grams	Grams
Shoot weights	2 - 2	0.5	3.1	3.1
	3 - 2	1.5	2.1	2.6
Root weights	2 - 2	0.650	0.140	0.820
	3 - 2	0.360	0.665	0.790
Total		3.010	6.005	7.310

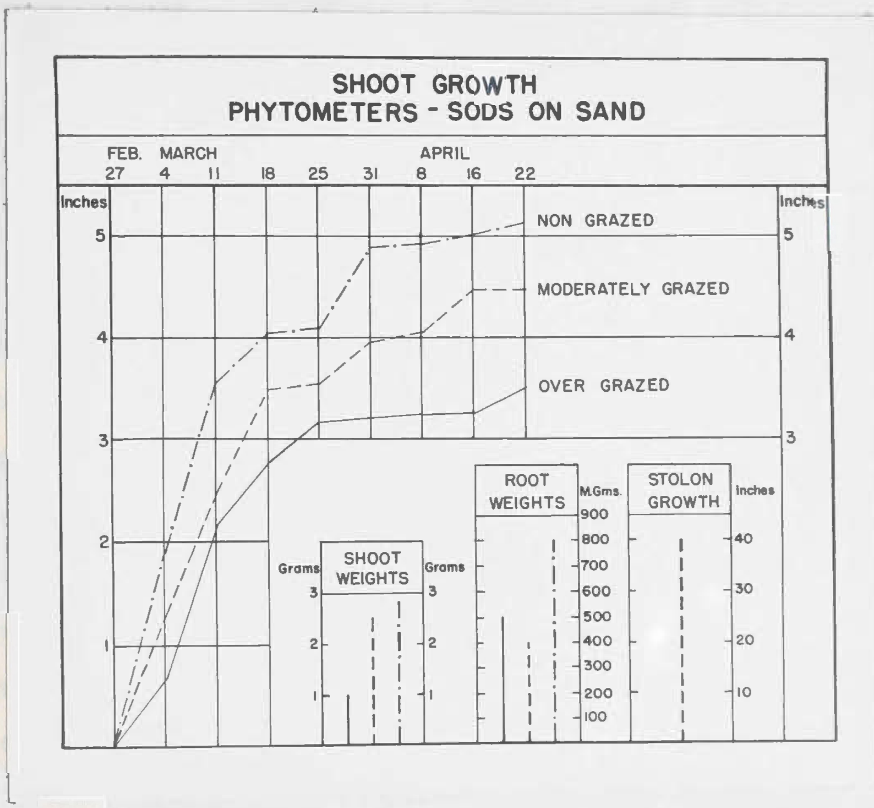

Figure 13. Growth of grasses in phytometers filled with sand.

moderately grazed plants nearly equaled that of the nongrazed plants. The total amount of roots of the overgrazed plants exceeded that of the moderately grazed plants. This relationship of root growth was evidently due to the greater stolon growth of the moderately grazed series. One phytometer of the moderately grazed group that had few stolons produced a larger amount of roots than any of the overgrazed sods.

On all of the phytometers mentioned above the debris was clipped to one-half inch from the soil surface when they were placed in the greenhouse. In another series none of the debris was removed from the sods (Figs. 14 and 15). In this group the growth of grasses was proportionate to the shading effect of the debris from the growth of the previous year. The maximum height of the overgrazed grasses was 3.38 inches, that of the moderately grazed was 7.25 inches, and the grasses of the nongrazed sod reached 10.50 inches (Table VI). The amount of roots produced followed the opposite trend: 660 milligrams by the overgrazed sod, 250 milligrams by the moderately grazed, and 140 milligrams of roots produced by the nongrazed plants. These plants grew in the phytometers for a period of nine weeks. It is evident from this study that an unusually large amount of shoot growth causes a decrease in the amount of root produced.

Chemical Analyses

A chemical analysis of roots and crowns from the three pastures was made from samples collected during the fall and winter. The

Figure 14. Grasses growing from sods from which the debris was not removed.

Figure 15. Sods removed from the above phytometers. There is a noticeable decrease in root growth with an increase in the amount of debris from the previous year.

Table VI Growth of grasses from which the debris had not been removed.

	Overgrazed Sods			Moderately Grazed Sods			Nongrazed Sods		
	Bda.*	Bda. Stolons	Bgr.**	Bda.	Bda. Stolons	Bgr.	Bda.	Bda. Stolons	Bgr.
Shoot Growth	3.38"	7.5"	3.5"	7.25"	3.25"	6.75"			10.5"
Root Growth									
Length of roots	12.50 inches			10 inches			6.25 inches		
Number of roots	54			14			12		
Weight of roots	.660 grams			.250 grams			.140 grams		
Weight of Shoot	1.1 grams***			9.2 grams*			11.5 grams*		
Total Weights of Shoot and Root	1.760 grams			9.450 grams			11.640 grams		

* Buffalo grass.
** Blue grama grass.
*** Includes the debris from the growth of the previous year.

amounts of sugars and starch present were 5.956 percent in the moderately grazed and 6.095 percent in the nongrazed plants. The total amount of carbohydrates stored in the underground parts of the overgrazed plants was extremely low--only .59 of one percent being present (Table VII). The extremely low total carbohydrate storage in samples from the overgrazed pasture was undoubtedly due to the severe utilization of the plants by cattle.

The analyses showed that the amounts of starch present in the grasses somewhat exceeded the amounts of sugars except in the overgrazed pasture where the percent of sugars, particularly sucrose, exceeded the starch content. The fact that the samples were removed from the overgrazed pasture earlier than from the other two pastures may partially explain the high sugar-starch ratio in this pasture. The differences in amounts of hemicellulose present in samples from the three pastures were not significant, though it was present in larger amounts in samples removed at later dates.

DISCUSSION AND SUMMARY

The aboveground and underground portions of plants differ in a number of important respects when they are subjected to different intensities of grazing. The effects of grazing on the underground parts of pasture grasses were determined on an overgrazed, a moderately grazed, and a nongrazed pasture. Samples were removed from each of the three pastures and the following determinations were made: (1) the amounts of shoot, debris and litter, and the underground parts in the

Table VII The percent of carbohydrates stored in the roots and crowns of grasses following 15 years of different intensities of utilization.

	Overgrazed	Moderately Grazed	Nongrazed
Date of sample removal	10-26-46	12-14-46	11-31-46
Hemicelluloses	11.416	13.834	12.396
Reducing sugars	0.151	1.613	0.448
Sucrose	0.310	0.391	1.314
Total sugars	0.461	2.004	1.762
Starch	0.129	3.952	4.337
Total sugars and starch	0.590	5.956	6.095

first four inches of soil one-half meter square, (2) the weight and number of roots found in columns 8" by 8" to the maximum depth of root penetration, (3) the relative vigor of grasses in sods removed from each pasture and grown in the greenhouse, and (4) the relative amounts of carbohydrates stored in the underground parts of the grasses.

The results of most phases of the study revealed that there is a decrease in the number of desirable characteristics of pasture grasses that is proportionate to the increase in the intensity of utilization the plants are subjected to, although the plants of the moderately grazed pasture equaled the nongrazed in some respects. The total amount of vegetative material removed from one-half square meters was 619.2 grams from the overgrazed, 926.3 grams from the moderately grazed, and 1200.9 grams from the nongrazed.

The average maximum penetration of roots was nearly the same under the three types of pasture treatment. However, both the number and the amounts of roots produced in the overgrazed were considerably less than in the other two pastures. The amounts of roots below two sods, each of 64 sq. in., were 108.2 grams from the overgrazed, 123.2 grams from the moderately grazed, and 141.5 grams from the nongrazed pasture. The number of roots found at different soil depths was least in the overgrazed pasture and largest in the moderately grazed pasture. The fact that the moderately grazed pasture exceeds the nongrazed in this respect is apparently incongruous with the weights of roots found but may be explained by the following: a greater portion of the roots were concentrated in the first foot of soil in the moderately grazed than in the nongrazed pasture, blue grama grass roots are larger than those of buffalo grass (a larger percent of the grass cover was blue grama in the nongrazed than in the moderately grazed pasture), non-grazed plant roots are larger than those of plants that are grazed, and there was less branching in the roots of the nongrazed plants.

Plants grown in the greenhouse from sods removed from the three pastures showed a decrease in vigor with an increase in the intensity of utilization. Two groups of sods from each pasture were grown for periods of eleven and nine weeks. In both series the relative vigor of the grasses from the nongrazed pasture was the greatest and plants from the overgrazed pasture were least vigorous. In the first group, due to the large amount of stolon growth, the weight of tops of the moderately grazed plants equaled that of the nongrazed, however, the amount of root growth of the moderately grazed plants was even less than that of the overgrazed plants of this group. The nongrazed plants were the first to break their dormant period and produce new shoot growth. New shoots were then grown by the moderately grazed plants and last by the overgrazed plants. In all the groups of phytometers the greatest total production of root and shoot was by the nongrazed plants and least by the overgrazed plants.

In one series of sods from the three pastures, from which none of the debris had been removed the growth in height of shoots was by far the greatest on sods where there was the most debris from the growth of the previous year. In this series the maximum height attained by the grasses was 3.38 inches by the overgrazed, 7.25 inches by the moderately grazed, and 10.50 inches by the nongrazed plants. This growth was proportionate to the shading effect of the debris. The root growth of the sods bore the opposite relationship--it was least where the shoot growth was greatest. In sods of other phytometers that produced a large amount of stolon growth there was also a decrease in root growth. From these data it is evident that in plants of the species studied an excessive amount of shoot growth causes the root production to be curtailed.

The amount of carbohydrates stored in the underground parts of the grasses from the three pastures was nearly the same in the nongrazed and moderately grazed pasture but was extremely low in the overgrazed plants. The amounts of carbohydrates exclusive of hemicelluloses were 6.095 percent in the nongrazed, 5.956 percent in the moderately grazed, and only 0.590 percent in the underground parts of grasses from the overgrazed pasture.

BIBLIOGRAPHY

1. Association of Official Agricultural Chemists, Official and Tenative Methods of Analysis of the Association of Official Agricultural Chemists. Sixth Edition; Washington, D.C: Published by the Association of Official Agricultural Chemists, 1945. 932pp.

Contains procedures for the analysis and examination of the products of or essential to agriculture.

2. Albertson, F. W., "Ecology of the Mixed Prairie of West Central Kansas," Ecological Monographs, 7:481-547, October, 1937.

A thorough and interesting study of the environmental factors and vegetation of three types of mixed prairie.

3. Biswell, H. H., and J. E. Weaver, "Effect of Frequent Clipping on the Development of Roots and Tops of Grasses in Prairie Sod," Ecology, 14:368-389, October, 1933.

A study of the effects of the removal of tops on root growth in soil on regeneration and yield of aerial parts.

4. Burton, G. W., "A Comparison of the First Years Root Production of Seven Southern Grasses Established From Seed," Journal of the American Society of Agronomists, 35:192-196, March, 1943.

An analysis of root growth of grasses by determining the total amounts of roots below 100 square inches of sod removed at four-inch intervals.

5. Canfield, R. H., The Effect of Frequency and Intensity of Clipping on Density and Yield of Black Grama and Tobosa Grass. Washington, D.C: Government Printing Office, 1939. 32pp. (U. S. D. A. Technical Bulletin no. 681, May, 1939.)

Presents conclusive results of continuous clipping treatments extending over a period of ten and eleven years.

6. Hanson, W. R., and L. A. Stoddart, Effects of Grazing Upon Bunch Wheat Grass. Washington, 1940. pp. 278-289. (Reprinted from Journal of the American Society of Agronomy. Vol. 32, no. 4, April, 1940.)

Gives the quantitative differences in the growth and development of grazed and ungrazed plants. The paper also contains data on relative amounts of carbohydrates stores in grazed and ungrazed underground plant parts.

7. Harrison, C. M., and C. M. Hodson, "Response of Certain Perennial Grasses to Cutting Treatments," Journal of the American Society of Agronomy, 31:418-430, May, 1939.

Gives yields of tops and roots of five grasses cut weekly at three different heights.

8. Loomis, W. E., and C. A. Shull, Methods in Plant Physiology. New York: McGraw-Hill Book Company, Inc., 1937. 472pp.

Contains laboratory procedures of experimental plant physiology and a chapter on statistical treatment of results.

9. McCarty, E. C., The Relation of Growth to the Varying Carbohydrate Content in Mountain Brome. Washington, D. C., 1938. 24pp. (U. S. D. A. Technical Bulletin no. 598, January, 1938.)

A detailed field and laboratory study of the character of growth and the time and amount of carbohydrate storage in mountain brome grass.

10. McCarty, E. C., and R. Price, Growth and Carbohydrate Content of Important Mountain Forage Plants in Central Utah as Affected by Clipping and Grazing. Washington, D. C., 1942. 51pp. (U. S. D. A. Technical Bulletin no. 818, March, 1942.)

Contains both season and year-long growth and carbohydrate-nutritional data for two species of perennial forage grasses and two species of broadleaf herbaceous perennial forage plants native to the Wasatch Mountains in Central Utah.

11. Robertson, J. H., Effect of Frequent Clipping on the Development of Certain Grass Seedlings. Lancaster, Pa., 1933. pp. 425-447. (Reprinted from Plant Physiology, Vol. 8, July, 1933.)

Deals with the effects of the removal of tops upon the development of various species of grass seedlings.

12. Sprague, H. B., Root Development of Perennial Grasses and Its Relation to Soil Conditions. Baltimore, Md., 1933. pp. 189-209. (Reprinted from Soil Science, Vol. 36, no. 3, September, 1933.)

An interesting quantitative study of grass roots as affected by different cutting and fertilizer treatments.

13. Tomanek, G. W., _Pastures of Western Kansas in Relation to Intensity of Utilization in Past Years._ Master's Thesis (unpublished). Fort Hays Kansas State College, 1947. 52pp.

A detailed study of composition, yields, and growth of grasses of five pastures subjected to different intensities of grazing.

14. Weaver, J. E., "Underground Plant Development in its Relation to Grazing," _Ecology,_ 11:543-567, July, 1930.

Gives the effects of grazing upon prairie grasses.

15. Weaver, J. E., and F. W. Albertson, "Resurvey of Grasses, Forbs, and Underground Plant Parts at the End of the Great Drought," _Ecological Monographs_, 13:65-117, January, 1943.

A comprehensive report on environmental factors and growth and yield of plants of the true and mixed prairie at the end of the drought and during the following wet year.

16. Weaver, J. E., and R. W. Darland, "A Method of Measuring Vigor of Range Grasses," _Ecology,_ 28:146-161, April, 1947.

A test of vigor of grasses by means of sods removed from ranges and grown in a greenhouse under conditions favorable to vigorous growth.

17. Weaver, J. E., and Ellen Zink, _Annual Increase of Underground Materials in Three Range Grasses._ Brooklyn, N. Y., 1946. pp. 115-127. (Reprinted from Ecology, Vol. 27, no. 2, April, 1946.)

Deals with seasonal increase of roots of certain forage grasses.