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THE EFFECT OF INTENSITY AND FREQUENCY OF CLIPPING ON DENSITY AND YIELD OF BLACK GRAMA AND TOBOSA GRASS[1]

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CONTENTS

THE JORNADA FORAGE-CLIPPING EXPERIMENT

In spite of any difficulties pertaining to finance, economics, and periodically adverse climatic conditions that may beset the stockman of the semidesert grasslands, there probably never will come a time when cattle economically produced by conservative year-long grazing on the native forage will cease to be generally profitable. However, if this source of feed is to be perpetually enjoyed, certain fundamental principles of range conservation that give due consideration to the preservation of the main forage plants are required to be observed in grazing use. This is especially true in the Southwest where one of the most extensive grass areas, comprising some 14 million acres of semidesert grasslands, has developed under an average rainfall of approximately 10 inches annually. These lands, which are restricted to the low hills, valleys, and mesas lying at elevations below the piñon-juniper type in western Texas, southern New Mexico, and southeastern Arizona, are conceded to be chiefly valuable for the grazing of domestic livestock, principally cattle.

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[2] The author acknowledges his indebtedness to J. D. Schoeller, who planned and established the study in 1925 and supervised the work until 1927 while in charge of the Jornada Experimental Range; to R. S. Campbell, who conducted the study until 1926 and supervised it while in charge of the Jornada range from 1927 to 1934; and to many other members of the Forest Service who have contributed constructive criticisms and helpful suggestions.
[3] Maintained at Tucson, Ariz., in cooperation with the University of Arizona.

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Vegetation on these ranges is comprised of great numbers of plants including more than 80 different grasses and numerous other drought-resistant herbaceous plants and shrubs. Practically all the grasses are more or less palatable to cattle, yet black grama (*Bouteloua eriopoda*) (fig. 1) and tobosa grass (*Hilaria mutica*) (fig. 2) are of such importance that they largely determine the degree and extent of grazing under their respective site conditions. Plants other than grasses, either through scarcity in most years or because they are low

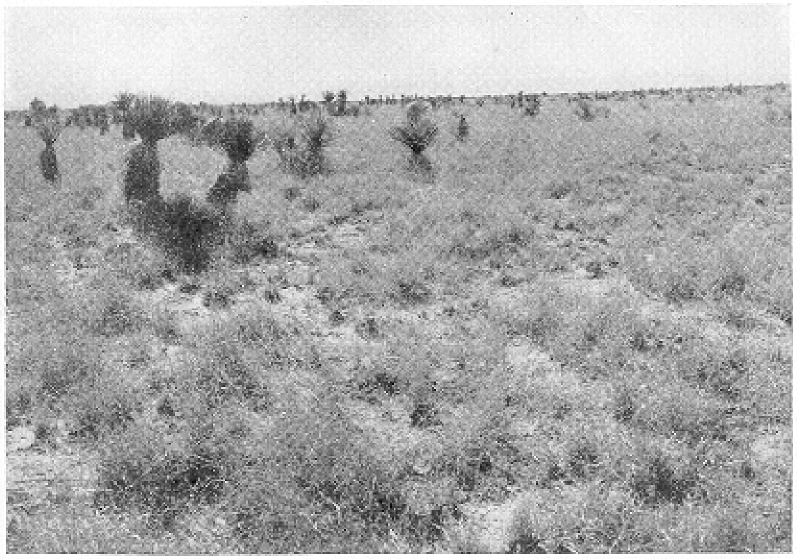

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FIGURE 1.—Black grama as it occurs on a conservatively grazed range. As indicated in this photograph taken May 10, 1934, in pasture 10, Jornada Experimental Range, sound range management aids in maintaining a good stand of black grama. Systematically reserving 25 to 35 percent of the forage crop of the average year in this pasture and deferring grazing until fall and winter each year enabled it to carry its full quota of stock through the 1933–35 drought with no expensive supplemental feeding and no death loss of cattle from starvation.

in palatability, contribute little or nothing to the sustained grazing capacity of these grasslands.

Management for this type of yearlong range to be successful must recognize the seasonal palatabilities and resistance to grazing of these two forage grasses, and grazing must be conducted in a manner that will allow the grasses to maintain their vigor and required rate of reproduction. Unless these measures are observed the range will deteriorate. With range deterioration the stockman, if he continues to carry the same number of cattle, will in the frequent drought periods be required to decide whether he will move part of his herd to better pastures or purchase expensive supplemental feeds. Either practice is unprofitable.

With the prospect of drought always imminent, stockmen operating on these semidesert grassland ranges are now facing the questions of how the existing forage-producing vegetation can be maintained within

the limits of the precipitation on ranges that are still productive, and how, at the same time, natural revegetation and restoration of deteriorated areas can be encouraged.

Proper grazing use is the obvious solution; but the degree of grazing that constitutes proper use of the principal forage grasses must first be accurately ascertained. In an effort to aid in the solution of this problem, study of the responses of two important forage grasses to different intensities and frequencies of controlled harvesting by

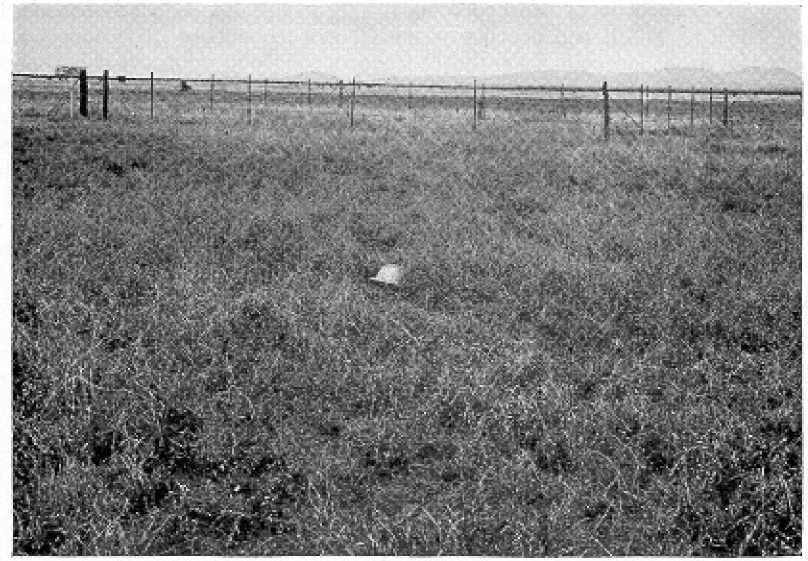

FIGURE 2.—Tobosa grass is the dominant plant of periodically flooded swales. During July, August, and September this grass is a preferred forage plant. With properly located watering places and salt grounds it may be grazed while the leaves and stems are succulent, thus saving the adjacent black grama range for winter use.

clipping was begun by the Forest Service in 1925 and carried on over a period of 11 years, ending with 1935.

The experiment was conducted on the Jornada Experimental Range, which is located near the geographic center of the semidesert grasslands in south-central New Mexico about 50 miles north of the Mexican border. Here, at elevations of 4,100 to 4,700 feet, the conditions of climate, character of vegetation, and soil are typical of these lands.

It is the purpose of this bulletin to describe the conditions under which the experiment was conducted, to summarize the results obtained, and to indicate their value in practical management of semidesert-grassland ranges.

CLIMATE AND SITE OF THE SEMIDESERT GRASSLANDS

Low rainfall is beyond question the most influential of the limiting climatic factors in the semidesert country. Through countless ages the extremely low precipitation, its erratic seasonal distribution, and the ever-recurrent drought have dominated all life in these lands.

Nelson (*10*)[4] in a previous study found that rainfall of the current summer season largely determines the height growth of black grama in that season. The previous year's precipitation, and particularly the rainfall received during the preceding summer, mainly influences changes in the current stand of black grama as compared to that of the previous fall. Later Lister and Schumacher (*9*) confirmed these results in a study involving black grama and two other semidesert grasses and mathematically enumerated the effects of rainfall in terms of height growth and density of the grasses.

The 21-year daily rainfall records taken at the Jornada headquarters from 1915 to 1935, summaries of which are presented in tables 1 and 2, are the most complete available for any single station on the experimental range. It is believed that these data provide a reliable index to the average and extremes of rainfall under which the vegetation of the experimental area is produced. Precipitation records were also taken at both clipping-study areas located 10 miles south of the headquarters station, and these show similar relationships.

TABLE 1.—*Summary of annual and summer (July, August, September) precipitation record, headquarters station, Jornada Experimental Range, 1915–35*

10 years preceding experiment			11-year period of experiment		
Year	Annual	Summer	Year	Annual	Summer
	Inches	*Inches*		*Inches*	*Inches*
1915	7.76	4.86	1925	6.93	3.76
1916	8.88	2.58	1926	17.73	8.53
1917	3.54	2.34	1927	7.69	6.33
1918	8.76	4.41	1928	9.78	3.92
1919	12.78	8.20	1929	11.04	6.18
1920	12.02	5.67	1930	5.73	3.03
1921	5.72	3.49	1931	12.41	4.66
1922	6.69	3.18	1932	12.75	8.00
1923	9.48	3.95	1933	8.59	4.56
1924	5.97	3.87	1934	5.18	1.74
			1935	10.98	6.79
Average	8.16	4.26	Average	9.91	5.23

TABLE 2.—*Monthly distribution of precipitation, Jornada headquarters station, 1915–35*

Month	10 years preceding experiment				11-year period of experiment			
	Maximum	Minimum	Average		Maximum	Minimum	Average	
	Inches	*Inches*	*Inches*	*Percent*	*Inches*	*Inches*	*Inches*	*Percent*
January	0.78	0.00	0.37	4.5	0.92	0.00	0.28	2.8
February	1.16	.00	.35	4.3	1.57	.05	.38	3.9
March	1.50	(1)	.52	6.4	1.40	(1)	.34	3.4
April	.83	(1)	.19	2.3	2.02	(1)	.27	2.7
May	1.45	.00	.33	4.1	2.43	.00	.85	8.6
June	1.53	.00	.36	4.4	2.84	(1)	.48	4.9
July	3.34	.25	1.48	18.1	4.95	.87	1.65	16.7
August	3.28	.32	1.80	22.1	4.51	.38	2.15	21.7
September	2.55	.00	.98	12.0	3.20	.03	1.43	14.4
October	2.63	.00	.93	11.4	2.63	(1)	1.01	10.2
November	1.71	.00	.46	5.6	1.11	.00	.47	4.8
December	1.49	.00	.39	4.8	1.62	.00	.58	5.9

[1] Trace.

[4] Italic numbers in parentheses refer to Literature Cited, p. 31.

The rainfall of the recent 11 years was on the average a little greater than that of the preceding decade. Average annual rainfall for the 10 years immediately preceding the period of the experiment was 1.75 inches less than the average during the experiment. Average rainfall during the summer or usual growing season (July, August, and September), for the previous decade was 0.97 inch less than for the period of the experiment.

Monthly distribution of rainfall for the recent 11 years and the 10 years preceding, presented in table 2, reveals that during the 10 years previous to the experimental period all months save July and August were at one time or another either completely dry or without a measurable quantity of rain. The experimental period was only slightly better in this respect. Average monthly rainfall was generally higher throughout the period of the experiment, particularly for July, August, and September.

With the exception of the growing seasons of 1926 and 1932 and the extreme drought of 1934 there are no years that might be considered especially unusual. Favorable conditions in 1926 and 1932 are matched by a similar season, 1919, in the previous decade. The drought of 1934 occurred at a fortunate time in the period of the experiment, results having reached a stage where the ill effects produced by clipping were thus tested by extremely adverse climatic conditions.

Temperatures on the experimental range are moderate on the average. The annual mean for the period of record is 56° F. Summer temperatures of 106° occur occasionally, however, and winter temperatures of −8° are not uncommon.

Low temperatures in semidesert regions, as compared to their influence in the more humid regions, play a minor role in the curtailment of plant growth. Grasses may begin growth as early as spring temperatures will permit and continue to grow until the frosts of autumn bring the season to a close. Owing to intermittent periods of drought, however, the average annual frostless period of 206 days is rarely if ever fully utilized by growing plants. Thus, while plants will grow from spring to fall, scant rainfall and high evaporation ordinarily limit such growth to negligible amounts in April, May, and June.

During the growing season, a relative humidity of 10 percent is not uncommon. This dry condition when combined with high temperatures and wind movement often causes a water loss of 0.5 inch daily from a free water surface. Such annual evaporation is equal to roughly 10 times the average annual rainfall.

Soils of the semidesert grassland sites have somewhat unusual characteristics. They possess two common attributes not found in soils of the more humid regions, namely, the absence of any definite humus layer and the presence of a substratum of caliche, or hardpan. This caliche layer, which is almost impervious to water and also to plant roots, is found at depths varying from a few inches to 6 or 7 feet.

Distribution of plants on the semidesert-grassland type of range is very closely linked with the soil type. Black grama and plants commonly associated with it occupy the well-drained sandy and gravelly uplands. Tobosa grass is found in pure stands only on the heavy clay soils of the low-lying, periodically flooded swales. The type of soil is thus one of the chief factors in the distribution of the different plants comprising the semidesert-grassland vegetation.

CHIEF CHARACTERISTICS OF THE TWO GRASSES STUDIED

There need be no confusion in recognizing black grama and tobosa grass, since there are several ways by which they can readily be distinguished. An intimate acquaintance with them reveals that no greater degree of dissimilarity exists between any other two native semidesert-grassland grasses. In comparing them as to site preference, habit of growth, method of reproduction, or season of highest use as forage, the striking differences, rather than the common characteristics which denote their family kinship, are outstanding.

Black grama, which grows only on the well-drained sandy and gravelly soils, occurs in open stands of individual tufts. Tobosa grass, occurring on the periodically flooded swales, might easily be mistaken for a sod grass, especially on a good site where the stems often spread out and cover practically the whole surface. Leaves of black grama are chiefly stem leaves; the greater portion of the basal leaves, developed early in the season, die soon after the stems are produced. Tobosa grass leaves, on the contrary, consist mainly of a mass of basal leaves with but few leaves along the stems. Tobosa grass stems become harsh and woody with advancing age, whereas black grama stems remain for the greater part alive and pliable below the second node, even through the so-called dormant period of winter and early spring. Stems of both plants are solid, the hollow cavities commonly found between the joints of ordinary grasses being completely filled with a compact pith (*3*).

One difference between these plants, which often is used as a ready method of identification, is that the black grama stems, especially near the base, are covered with a matted mass of short, oyster-white, woolly hairs, which have resulted in the plant's being given such locally applied names as "woollyfoot grama" or "hairyfoot grama." Tobosa grass stems are smooth.

Seed heads of the two plants are also quite different. Black grama seed is produced in a number of one-sided racemes which in the cluster have the general appearance of a spreading panicle, an example of which is the seed head of the cultivated oat. Tobosa grass seed on the other hand is produced in a spike-like raceme which resembles a timothy head. However, new plants are produced from seed less frequently than vegetatively. Each plant has its own peculiar vegetative method—black grama by lateral spread and by stolons (prostrate stems above ground (*10*)), tobosa grass beneath the soil by means of rhizomes (modified underground stems).

Black grama is usable as forage for livestock yearlong since it cures well on the stalk, but has its greatest value in the winter and spring period when other plants have dried and are low in palatability. Tobosa grass is good for feed only during its period of growth.

Since each species inhabits a distinctive type and has its own peculiarities, manner of use by livestock, and required method of management, the data obtained from the experiment are presented separately for each species.

OBJECTIVE AND PLAN OF EXPERIMENT

The objective of the study was to determine the effect of different frequencies and intensities of removal of herbage on the density and forage yield of these two principal semidesert grasses with a view of establishing fundamental concepts of the proper degree and intensity of grazing use.

In planning the experiment, directness of attack and simplicity of procedure were given prime consideration. A readily controlled means of harvesting by clipping with shears[5] was used in lieu of actual grazing by cattle.[6]

In clipping, the intensity and frequency of harvesting are always under control, and the weights of the harvest can be accurately determined. With actual grazing, the cropping of the plants cannot be regulated and only with great difficulty can the volume of forage so utilized from small plots be weighed or otherwise measured. It is realized that some effects of actual grazing are impossible of exact duplication by mechanical processes. Most prominent of these are the pulling effect of grazing and the trampling of the plants and ground by the grazing animals.

With properly regulated grazing, under semidesert conditions, pulling and trampling may be safely dismissed as minor factors for the following reasons: Pulling by grazing animals does not ordinarily occur on conservatively grazed black grama and tobosa grass ranges, because perennial grasses of the semidesert grasslands, especially the young plants, develop root systems out of all ordinary proportion to the aerial parts of the plants. Trampling on black grama range reaches a definitely destructive degree only on overgrazed areas where site deterioration by wind erosion has already occurred. Elsewhere it is negligible. Tobosa grass is practically immune to trampling damage as well as to uprooting. The strong root system of this plant is a firm anchor. Even the youngest plant, springing as it does from the underground rhizome, is thoroughly resistant to damage of this character. Packing of the soil does not occur on either black grama or tobosa grass ranges while the natural topsoil remains in place.

Direct application of results from clipped quadrats is recognized, however, to be subject to definite limitations. In clipping, the vegetation is cut uniformly over the quadrat at a predetermined height and date. On properly used range, livestock graze the plants at will, so that the height and time of harvesting may differ more or less from plant to plant and also from year to year, with close utilization in years when forage production is poor and light use in very good years. The persistent clipping of black grama at a height of 2 inches or less in the experiment prevented reproduction and reduced the longevity of the plants, causing a gradual decline in area very similar to the effects of heavy overgrazing on the range year after year reported by Nelson (*10*). The values and limitations of clipped quadrats have been considered in more detail in a previous report (*4*). In spite of these limitations, results from clipped quadrats are of immense value in supplementing actual grazing studies.

Observations made on the experimental plots, and on the open range as well, substantiate the conclusion that the degree to which

[5] As early as 1880, Sorauer, working in Germany, defoliated grapevine cuttings in order to determine the relative amounts of distilled water required by undefoliated and defoliated specimens in the production of new foliage. Von Seelhorst (1910), also in Germany, used frequent croppings to determine the water requirement of pasture grasses under certain conditions. Crozier (1897) in Michigan used frequent mowing to determine the yield of various cultivated grasses. Sampson (1914) on the Wallowa National Forest, Oreg., clipped *Festuca viridula* plants three times each season for 3 years and determined that there was a decrease in yield for each successive year. Various other workers have used artificial methods of clipping in their experiments, namely, Sarvis (1923) with *Stipa comata* in North Dakota; Sampson and Malmsten (1926) with *S. lettermani* and *Agropyron violaceum* in Utah; and McCarty (1927) with *A. smithii* in Colorado. Although no previous work of this kind in the Southwest has dealt with black grama and tobosa grass in pure stands, or with localities where the rainfall averages less than 10 inches annually, experiments employing mechanical clipping are fairly common.

[6] Results attained from actual grazing of livestock on the Jornada range have been reported (*1, 2, 5, 7, 8, 10*).

the leaves and stems of the main forage plants may be removed with safety is a principal factor to be considered in management of semidesert-grassland ranges. Since black grama and tobosa grass constitute the dominant plants of the two main forage types, they serve as the logical bases or practical standards by which the utilization of the respective types should be estimated. When these plants have been grazed on their respective ranges to a degree considered to be proper utilization, the surrounding areas may be regarded as properly utilized regardless of the degree of use of the associated plants.

In order to concentrate the study on the two principal grasses and to eliminate the factors of competition with other plants and that of past grazing use, sites were selected on which each of the species grew in pure stands, and which had been subjected to little or no grazing use during years previous to the initiation of the study. The black grama area had previously been fenced for 12 years and all domestic livestock excluded. No such tobosa grass area was available, but the area selected, although not closed to grazing before the start of the study, bore plants of such vigor as to testify to little or no detrimental effects of previous grazing use.

In addition to the exclusion of all domestic livestock from the experimental areas by fencing, rodents were controlled by periodic poisoning.

Inside each enclosure, eight quadrats, each 1 m. square, were established and permanently marked.

In planning the clipping treatments due consideration was given to the varying conditions connected with the normal grazing preference of cattle and to the growth habit of the plant involved. For example, a 2-inch stubble of black grama is usually left after the initial cropping of this plant by cattle. Recurrent grazing under more intensive use often results in a 1-inch stubble. Therefore, the eight quadrats for the black grama study were divided into two series of four quadrats; one series was to be clipped to a height of 1 inch from the soil line and the other to a height of 2 inches. However, the lowering of the general soil surface below the root collar as a result of erosion made it difficult to maintain an exact measure of the height of clipping. In general, a slightly closer clip than the prescribed 1 and 2 inches occurred in the later years of the experiment.

Tobosa grass is not normally grazed so closely as is black grama. Usually a 4-inch stubble is left by cattle, except under conditions of concentrated stocking, when the grass is often taken to within 2 inches of the ground. Accordingly, the eight tobosa quadrats were divided into two series of four; one series was clipped at a height of 2 inches from the soil line and the other at a height of 4 inches.

Frequency of harvesting to be applied in the experiment was determined to some extent on the basis of growth habits. Since black grama normally has but few basal leaves and clipping at a height of 1 or 2 inches would result in almost complete defoliation, one quadrat in each height series was clipped every second week, one every fourth week, one every sixth week after growth began, and one only at the end of the growing season. Since tobosa grass with its mass of basal leaves would retain much of its foliage after clipping, the clipping intervals for the four tobosa quadrats in each series were every week, fortnightly, every fourth week, and at the end of the season.

Measurements of the ground covered by the plants, number of tufts, and the weight of the grass clipped from each quadrat were recorded. Density of ground cover as indicated by the basal area of the tufts was measured by means of the Hill chartograph (*6*). Each quadrat was charted at the beginning of the study and annually thereafter at the close of the growing season. The results of these chartings are expressed in square centimeters and represent the aggregate areas of the grass tufts as determined at 1 inch above the ground.

Forage yield from each quadrat was obtained by clipping and is reported as the air-dry weight of the grass in grams.

Rainfall was measured by means of a United States Weather Bureau standard rain gage installed in each of the study plots.

EFFECTS OF PERSISTENT CLIPPING

Effects of clipping viewed in their entirety present a rather complex picture. By treating the two grasses and the different measurements and observations separately, however, the value of each may be appraised. Therefore, the results of the study are presented separately for each grass and are expressed in terms of (1) tuft area, (2) numbers and average size of tufts, (3) forage yield, (4) reproduction, (5) rainfall and length of growing season, and (6) condition of and effect upon site.

BLACK GRAMA

TUFT AREA

At the beginning the density of grass cover on the quadrats was typical of the better grassed areas. Under all degrees of height and frequency of clipping, black grama tuft areas shortly began to show a downward trend. Severe reductions in tuft area on the quadrats clipped to 1 inch appeared early in the experiment, and none of these quadrats, regardless of frequency of harvesting, maintained beyond the second year of treatment a ground cover equal to that at the beginning (table 3).

Plants clipped to 2 inches generally began to lose tuft area by the fourth year of treatment, and then more slowly than did the plants clipped to 1 inch. In this comparison, while the effect of the 1-inch clipping suggests calamity, the more gradual decrease in ground cover of 2-inch clipped quadrats reflects the influences of the different frequencies of harvesting. Tuft areas of these quadrats clipped at 2-week and 4-week intervals showed a net loss of 28.3 and 13 percent, respectively, of original ground cover in the fourth year of clipping. The quadrat clipped at 6-week intervals maintained its original density into the fifth year of clipping, when there was a loss of 19.6 percent. The first net loss on the quadrat clipped at the end of the growing season was 36.3 percent in the seventh year of clipping.

Quadrats clipped to 2 inches regained some of their lost ground cover in 1933, when rainfall was above average on the study area; and following favorable rainfall of 1932 general recovery occurred on the quadrats clipped to 1 inch. During the subsequent 2 years, mainly of drought, tuft area continued to decrease without any striking differences attributable to frequency on quadrats having the same height of clipping. After 10 seasons of clipping to 1 inch and 11 seasons of clipping to 2 inches, the tuft areas present the same results—all quadrats were practically denuded. The condition of these quadrats at the beginning of the experiment and their striking similarity at the end of the experiment are illustrated in figures 3 and 4.

TABLE 3.—*Tuft area of black grama on meter-square quadrats, as affected by clipping, 1925–35*

Height of grass and frequency of clipping	Original tuft area	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	Net loss in original tuft area
	Square centimeters	*Square centimeters*	*Square centimeters*	*Square centimeters*	*Square centimeters*	*Square centimeters*	*Square centimeters*	*Square centimeters*	*Square centimeters*	*Square centimeters*	*Square centimeters*	*Square centimeters*	*Percent*
1 inch:													
2 weeks	1,324	([1])	1,724	1,333	756	317	215	197	111	84	7	38	97.13
4 weeks	1,226	([1])	1,496	1,103	658	463	373	456	227	254	113	5	99.59
6 weeks	950	([1])	1,356	959	601	381	303	321	221	200	20	0	100.00
End of season	987	([1])	803	595	491	459	382	343	384	318	63	0	100.00
2 inches:													
2 weeks	1,539	1,532	2,451	2,276	1,103	751	505	695	727	833	196	33	97.86
4 weeks	1,316	1,210	2,263	2,153	1,144	804	712	722	474	559	158	8	99.39
6 weeks	1,077	1,038	2,049	1,792	1,543	856	642	697	580	759	203	40	96.29
End of season	941	835	1,766	1,624	1,290	1,093	970	599	342	555	54	3	99.68

[1] These quadrats not established until 1926.

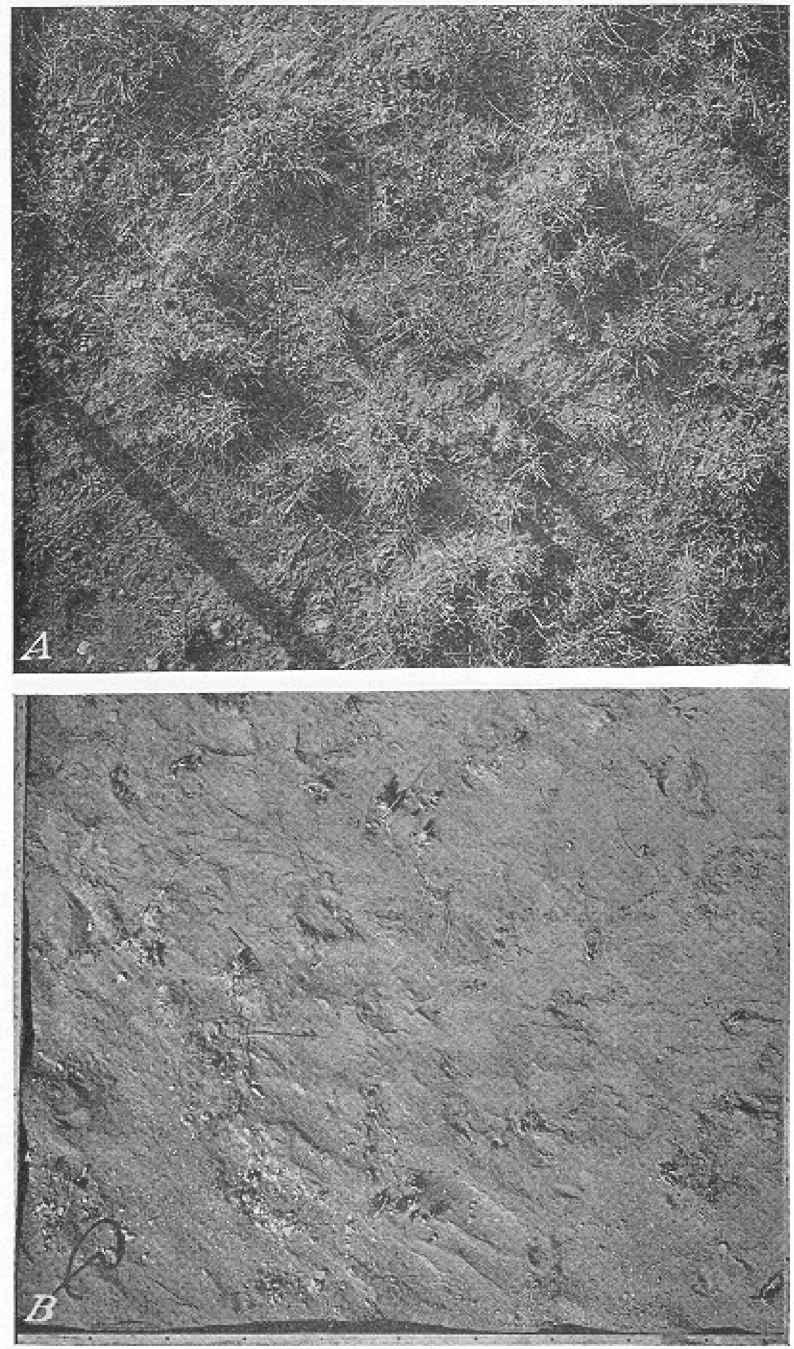

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FIGURE 3.—Ground cover of black grama quadrats as affected by clipping at 1 inch: *A*, The grass cover on the quadrat at the beginning of the experiment in 1926; *B*, the same quadrat in 1935, after 10 years of clipping at the end of each growing season.

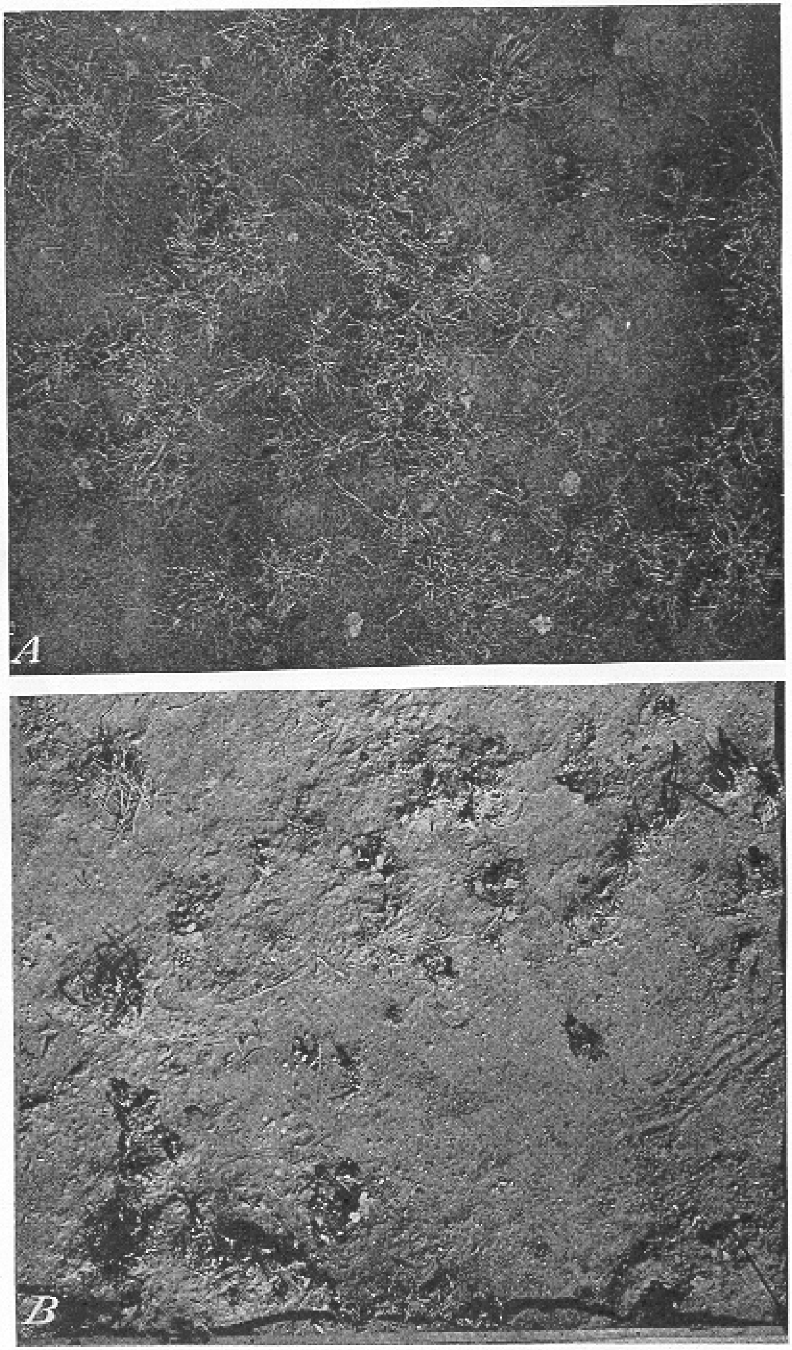

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FIGURE 4.—Ground cover of black grama quadrats as affected by clipping at 2 inches: *A*, The grass cover on the quadrat at beginning of experiment in 1925; *B*, the same quadrat in 1935, after 11 years of clipping at the end of each growing season.

NUMBER AND AVERAGE SIZE OF TUFTS

Black grama, occupying as it does the drier sites, is essentially a bunch grass. Under normal conditions and on the better sites the older tufts are nearly uniform in size and conformation and are fairly evenly distributed. Also, the aggregate tuft area measured 1 inch above the ground usually is 10 to 25 percent of the total ground surface, although when so measured very little of the natural spread of the plant is included.

As an index to the condition of the range, fluctuations in number and average area of black grama tufts lose much of their significance unless the manner in which the decrease or increase in size and number occurs is considered. These changes may take place in several ways. The addition of new tufts by reproduction increases the number; and new tufts, by reason of their smaller size, tend to decrease the average area of the plants on the quadrat unless a heavy increase in size of the older tufts has also occurred. The number of tufts may also increase through the partial dying out and breaking up into smaller units of older and larger tufts. This process is generally accompanied by a decrease in the total as well as average area of tufts on the quadrat. Decreases in number may take place when expanding adjacent tufts merge into one larger tuft. This activity is accompanied by an increase in the average size. Also a decrease in number and an increase in the average size of tufts may be caused by the dying out of the smaller and weaker specimens, as under adverse climatic conditions or after excessive grazing—a process characterized by a reduction in total tuft area.

Any combination of these conditions may be present on the same quadrat simultaneously. When, however, the history of the plants is known or the essential points can be determined by observation, the number and average area of black grama tufts form a reliable index to the physical condition of the plants occupying the area under consideration. At the beginning of the study, the number of tufts and their average area on black grama quadrats lacked uniformity (table 4), and at no time during the period of the study did they become equal in these respects.

In the first season (1926), clipping to 1 inch, combined with exceptionally high rainfall, generally stimulated an increase in both number and average area of tufts. The expansion of old tuft area overcame the effect of the smaller new tufts in reducing the average area. The tuft areas on the quadrat clipped only at the end of the growing season increased in number under the same climatic stimulus but decreased in average size. In 1927, the smaller tufts and portions of the larger ones on all quadrats began to die out, with the result that fewer tufts of a slightly smaller average size became the rule on the 4- and 6-week quadrats. From 1928 on to the end of the experiment one loss followed another, until in 1935 only seven small tufts remained on the 2-week quadrat, only one on the quadrat clipped at 4 weeks, and the other two quadrats had no living tufts.

On quadrats clipped to 2 inches, both expansion and consolidation of tufts were taking place between 1925 and 1927, as indicated by increased total tuft area, decreasing number, and increasing average size of tufts. In 1928 a recession in number and average area of tufts began. When the study was completed, in 1935, only a few small tufts were left from the very good stand of black grama of 11 years before.

TABLE 4.—*Number and average area of black grama tufts on meter-square quadrats, as affected by clipping, 1925–35*

Height of grass and frequency of clipping	Start of tests		1925		1926		1927		1928		1929	
	Number	*Square centimeters*	*Number*	*Square centimeters*	*Number*	*Square centimeters*	*Number*	*Square centimeters*	*Number*	*Square centimeters*	*Number*	*Square centimeters*
1 inch:												
2 weeks	82	16.1	(1)	------	95	18.1	73	18.3	73	10.4	35	9.1
4 weeks	128	9.6	(1)	------	122	12.3	93	11.9	69	9.5	47	9.9
6 weeks	92	10.4	(1)	------	108	12.6	80	12.0	74	8.1	51	7.5
End of season	60	16.4	(1)	------	62	13.0	37	16.1	31	15.8	25	18.4
2 inches:												
2 weeks	61	25.2	66	23.2	67	36.6	58	39.2	67	16.5	74	10.1
4 weeks	92	14.3	84	14.4	75	30.2	50	43.1	60	19.1	52	15.5
6 weeks	107	10.1	88	11.8	98	20.9	81	22.1	67	23.0	66	13.1
End of season	97	9.7	83	10.1	79	22.4	58	28.0	53	24.5	49	22.3

Height of grass and frequency of clipping	1930		1931		1932		1933		1934		1935	
1 inch:												
2 weeks	18	11.9	17	11.6	10	11.1	10	8.4	3	2.3	7	5.4
4 weeks	38	9.8	38	10.9	27	8.4	23	11.5	17	6.6	1	5.0
6 weeks	37	8.2	32	10.0	23	9.6	17	11.8	2	10.0	0	.0
End of season	26	14.7	25	13.7	22	17.5	23	13.8	10	6.3	0	.0
2 inches:												
2 weeks	51	9.9	51	13.6	49	14.8	45	18.5	22	8.9	5	6.6
4 weeks	49	14.5	44	16.4	42	11.3	35	15.7	20	7.9	3	2.7
6 weeks	41	15.7	36	19.4	37	15.7	31	24.5	25	8.1	14	2.9
End of season	39	24.9	29	20.7	34	10.1	23	24.1	10	5.4	2	1.5

[1] These quadrats not established until 1926.

FORAGE YIELD

Observations made in large pastures have provided conclusive evidence that forage yield as influenced by stand and height growth varies greatly from year to year (*10*). This variation has often been attributed to the character of the growing seasons, and the effects of grazing have been minimized.

Yields of black grama per square decimeter as affected by the different intensities and frequencies of clipping are presented in table 5 and figure 5. These data bring into the foreground several significant relationships between the weights of the annual forage crop and the clipping treatments.

TABLE 5.—*Air-dry weight of black grama clipped per square decimeter of tuft area, 1925–35*

Height of grass and frequency of clipping	1925	1926	1927	1928	1929	1930	1931	1932	1933	1935[1]	Yield per square decimeter: Total	Yield per square decimeter: Mean annual
	Grams	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
1 inch:												
2 weeks	------	4.560	1.291	0.013	0.463	0.282	0.095	0.075	0.023	0.072	6.874	0.687
4 weeks	------	5.360	1.784	.039	1.408	.519	.253	.106	.307	.000	9.776	.978
6 weeks	------	5.630	1.245	.164	.034	.813	.301	.295	.115	.000	8.597	.860
End of season	------	7.861	2.868	.122	1.166	1.631	.278	.722	.134	.000	14.782	1.478
2 inches:												
2 weeks	2.990	4.576	1.545	.129	1.029	.277	.772	.318	.435	.029	12.100	1.100
4 weeks	4.210	5.125	1.975	.038	1.821	.406	.650	.074	.609	.000	14.908	1.355
6 weeks	4.909	10.007	2.227	.178	4.422	.037	.678	.369	1.177	.058	24.062	2.187
End of season	8.180	11.844	4.512	.124	1.085	.640	.940	.193	.186	.000	27.704	2.519

[1] No new growth in 1934 owing to drought.

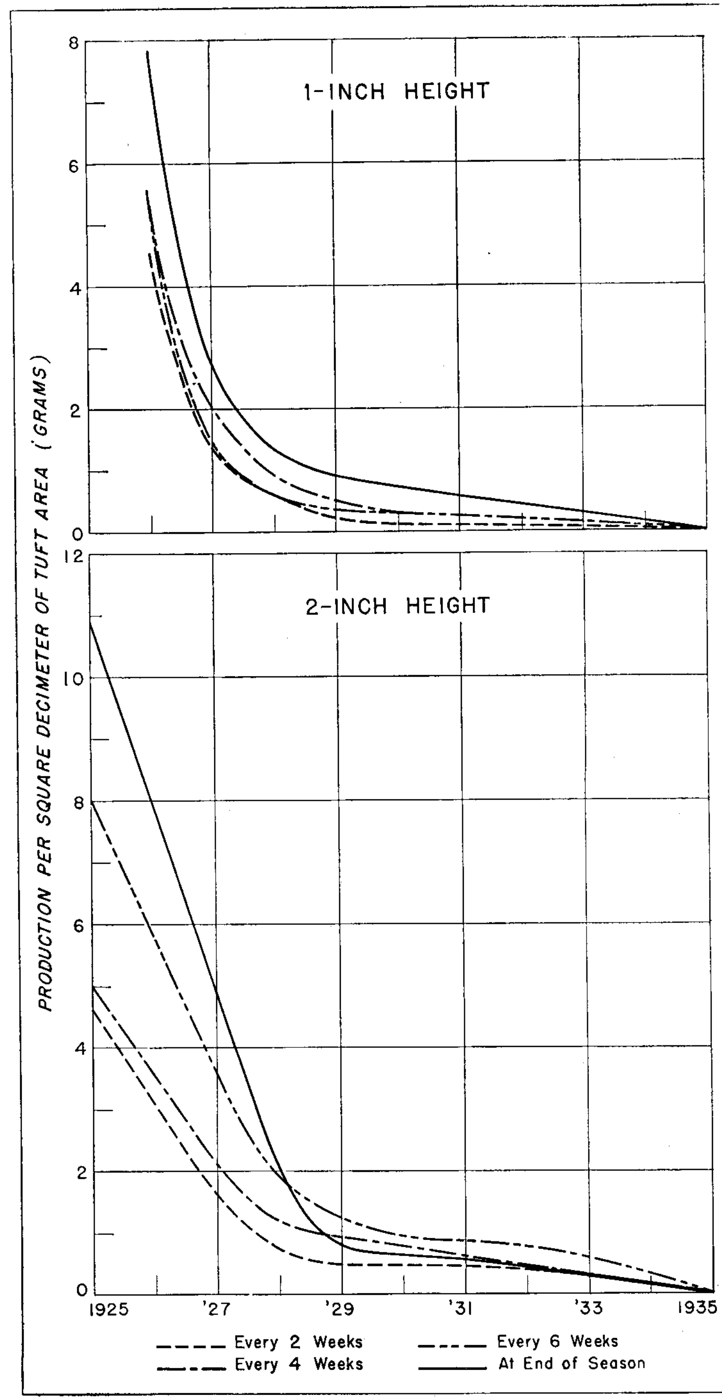

FIGURE 5.—Forage-production trend curves for the different intensities and frequencies in clipping of black grama. (Freehand curves from the data in table 5.)

Weights of grass produced by the quadrats during the first 3 years of the experiment followed a general trend which, with one exception (the 1-inch quadrat clipped at 6-week intervals in 1927 was less productive than the 4-week in that year), reflected the effects of the various frequencies of clipping; i. e., the more frequent the clipping, the less the production. This conformation to the treatment scale is probably the result of two conditions—the reaction of the plants to clipping and the higher-than-average rainfall during this 3-year period (table 1). During the subsequent years of the experiment, when rainfall was generally very much lower, and after the vitality of the plants was markedly impaired, growth became extremely erratic in quantity with regard to the frequencies of harvesting.

The seriously impaired condition of the plants is reflected in the results obtained in 1933. That year the plants received 6.52 inches of rain during the period of growth, a quantity that ordinarily would have produced a heavier-than-usual crop of grass. Little response was reflected, however, in the production of the quadrats for that season, although black grama plants on moderately grazed areas made a satisfactory forage crop. The clipped plants had been adversely affected by the clipping treatments.

In 1934—a year of drought of unprecedented severity—no new growth occurred on any quadrat. Judging from the uniformity of the results obtained in this year it may be concluded that the drought was sufficiently severe to nullify the effects of the clipping treatments. Observations made on areas adjacent to the clipped quadrats, and on farther-removed moderately grazed pastures, also showed the effects of the drought—the forage crop being only 15 to 20 percent of normal.

Differences show up rather definitely in the total yields for the entire period of the experiment (table 5). These figures, for 1-inch as for 2-inch quadrats, maintain the trend indicated by the results obtained from the first 3 years of the experiment, namely, that less frequent harvesting results in a higher unit-area yield of black grama. In each instance the quadrats clipped at the end of the growing season produced a greater quantity than the more frequently harvested areas. Quadrats clipped at 2-week intervals yielded a quantity approximately one-half as great as the yield of the quadrats clipped at the end of the growing season only.

Comparisons of yields from the two degrees of clipping are best obtained from the last column of table 5, since these figures for mean annual yield tend to remove the inequality between the 10-year period for the 1-inch clipping and the 11-year period for the 2-inch clipping.

In every instance, the mean annual production per square decimeter of tuft areas of quadrats clipped at 2 inches exceeded that of the quadrats clipped at the same frequency at a height of 1 inch. In the 1-inch series the quadrat clipped at the end of the growing season was the only one producing a greater quantity of clipped material than any quadrat of the 2-inch series.

Average annual yields of black grama per square-meter plot (taken from the totals of the grass clipped from the quadrats) over the 10- and 11-year periods show trends similar to those obtained from the figures based on the average yield per square decimeter of tuft area:

	Average annual yield (grams)
1-inch height series based on 10 years' data:	
2-week clipping	9.83
4-week clipping	11.07
6-week clipping	9.37
End-of-season clipping	9.65
2-inch height series based on 11 years' data:	
2-week clipping	19.54
4-week clipping	21.44
6-week clipping	32.09
End-of-season clipping	34.34

Compared on the basis of plot production, the average annual yield emphasizes the findings previously stated for comparisons made on the basis of small unit tuft area of plant cover. (1) The 2-inch quadrats were more productive and continued production longer than the 1-inch quadrats; (2) the production from areas clipped at different frequencies at 1 inch appears about equal, but the greater stand at the start of the study on the quadrats clipped more frequently doubtless masks the real effects of these clippings; and (3) the 2-inch series shows a definite response to the frequencies of clipping in that the less frequent clipping produced the greater quantity of grass, even though the initial stand was progressively greater on the more frequently clipped quadrats.

A more striking difference in the plot production as affected by degree of clipping is obtained by comparing the totals of mean annual production per square decimeter. The mean annual production of the 2-inch height series, according to table 5, exceeded that of the 1-inch height by a quantity of forage equal to 79 percent of the 1-inch total mean annual. Although the 3.158 g. per square decimeter increase in average annual forage production is in itself a rather small quantity, when the 79 percent it represents is applied to the thousands of acres included in the average southwestern cattle ranch this figure begins to assume important proportions. This result is clearly an argument against the cropping of all the stems of black grama to a height of 2 inches, or slightly below, since it is clear that this degree of grazing is too severe and eventually kills the plants.

REPRODUCTION

Black grama plants, as already noted, reproduce in three ways—infrequently by seed in the ordinary manner, more commonly by vegetative means, that is, by lateral spread of tufts and by stolons (fig. 6). Clipping of all black grama stems to any of the prescribed heights or frequencies of harvesting proved highly detrimental to the production of new plants by either seed, lateral spread, or stolon.

Although harvesting at the close of the season usually removed the seed crop before any seed dissemination took place, this cannot be regarded as greatly influencing the natural increase of black grama. Interference with vegetative reproduction is more serious. Lateral spread of tufts was seriously hampered on all quadrats, but to a lesser degree on those clipped to 2 inches.

Prior to 1928 a number of new plants (sets) were produced on the quadrats by rooting of stolons, as follows:

	Number
1-inch height series:	
2-week clipping	21
4-week clipping	3
6-week clipping	22
End-of-season clip	1
2-inch height series:	
2-week clipping	0
4-week clipping	5
6-week clipping	13
End-of-season clip	8

The occurrence of the new plants apparently had no consistent relationship to the clipping treatment. No new plants from stolons made

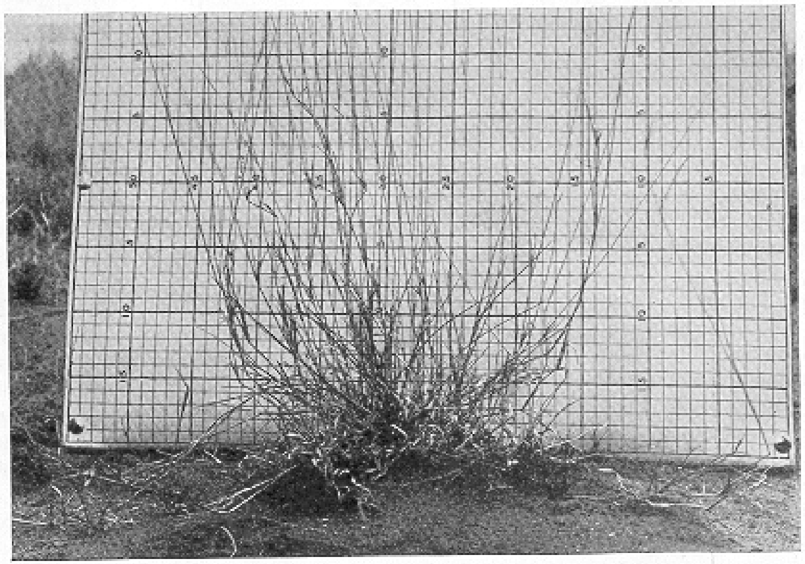

FIGURE 6.—Black grama propagates chiefly by lateral spread and by stolons. When not grazed too closely, roots that develop at each joint of the stolons or prostrate stems are able to extend into the light sandy soil and eventually produce a new plant, such as those at the right and left of the plant pictured. The parent feeds the new plant by means of the connecting stolons until it is firmly established.

their appearance on any clipped quadrat after 1928, and none of the plants that rooted prior to that year survived.

RAINFALL AND PERIOD OF PLANT GROWTH

The longest growing season during the period embraced by the experiment occurred in 1926 (table 6). Beginning May 18, growth continued for a period of 176 days ending November 9. During this season 11.95 inches of rain (double the average quantity) was fairly well distributed. The equivalent of this unusually favorable season is not, however, required to produce a fair yield of black grama forage. A period of 6 weeks of favorable moisture between July 1 and September 30 will nearly always produce a reasonably good forage crop if the range is not overgrazed.

TABLE 6.—*Period of growth and total rainfall for period*

Year	Growth began	Growth ended	Period of growth	Total rainfall for period	
				Black grama	Tobosa grass
			Days	*Inches*	*Inches*
1925	July 21	Oct. 17	89	7.01	7.01
1926	May 18	Nov. 9	176	11.95	12.41
1927	July 25	Oct. 1	69	5.58	7.57
1928	July 20	Oct. 5	78	3.75	4.34
1929	July 22	Oct. 14	85	3.91	4.15
1930	Aug. 11	Nov. 3	85	3.35	4.00
1931	July 1	Nov. 4	127	5.79	5.91
1932	Aug. 9	Nov. 1	85	4.16	6.27
1933	June 20	Oct. 17	120	6.52	6.83
1934	(1)	(1)	0	1.57	1.75
1935	Aug. 13	Oct. 15	64	5.14	5.57
Average			[2] 98	[3] 5.34	[3] 5.98

[1] No growth.
[2] Average based on 10 years.
[3] Average based on 11 years.

Clipping had apparently little effect on the time of beginning or ending of the growth period during the early years of the experiment. In the later years, however, growth did not start as early on clipped quadrats as on unclipped adjacent areas. From this observation it appears that clipping shortens the growing period to some extent. It has also been observed that closely cropped black grama requires more moisture to promote growth than do unclipped plants.

The data obtained at the experimental plot presented in table 6 indicate the period and amount of effective growing-season rainfall year by year for the period of the experiment. Comparisons of these data and forage-production data (table 5) indicate that highly unfavorable rainfall conditions tend to suppress the normal responses to different intensities and frequencies of clipping.

SITE

Semidesert vegetation, sparse as it is, exerts a beneficial influence on the site, especially in the areas of sandy and gravelly soils of the black grama type of ranges. The stems and basal leaves of the grass plants serve as a windbreak and protect the soil from excessive wind erosion. One of the principal agencies contributing to deterioration of the clipped black grama quadrats was the blowing away of the top layer of sand (figs. 3 and 4). All flower stalks and most of the basal leaves were removed by clipping, leaving the soil exposed to excessive blowing. Loss of topsoil through blowing and washing was perceptible in 1926, and in 1928 the soil level had been lowered an inch or more. This left many of the clipped black grama plants perched on the tops of small hummocks. In this process the roots near the surface were exposed and killed. When the protection afforded by old stems was removed, the sand mulch, which is so effective in water conservation on black grama sites, was lost, thus adding to the detrimental effects of the clipping treatments.

TOBOSA GRASS

TUFT AREA

It will be recalled that the design of the tobosa grass-clipping experiment differed from that of the black grama study only in that the tobosa grass was clipped at heights of 2 and 4 inches, with clipping intervals of 1, 2, and 4 weeks and at the end of the season. Tuft areas of the eight quadrats were charted for the first time in the early summer of 1925, soon after the quadrats had been established. These measurements, shown in table 7, column 2, represent the area of ground cover before clipping.

The quadrat chartings show a considerable variation between the degrees of cover on the individual areas. These differences are less between the aggregate areas of each height series than between the areas within each height series. Tuft area of tobosa grass on quadrats clipped during the growing season was below that on the quadrat clipped at the end of the season as shown:

	Percent
2-inch series:	
1 week	38.3
2 weeks	33.6
4 weeks	25.8
4-inch series:	
1 week	45.4
2 weeks	26.0
4 weeks	27.7

During the first (1925) season of clipping, in a period of 89 days in which the rainfall totaled about 7 inches (table 6), the tuft area on both the 2-inch and 4-inch quadrats clipped at weekly intervals had more than doubled. Similar though smaller increases had also occurred on the quadrats of both series clipped at 2- and 4-week intervals. Quadrats clipped only at the end of the growing season had sustained small losses during the same period. Thus in one season the combination of favorable rainfall, the clearing away of old grass that had accumulated during past years, and the stimulating effect of harvesting practically reversed the tuft area and clipping frequency relation which had existed at the beginning of the experiment.

Even greater increases in ground cover occurred in 1926, but the unusually heavy, well-distributed rainfall of that season probably minimized any harmful effects of clipping in that year. Whatever the responsible cause may be, the increases were not clearly expressions of effects of different clipping treatment. It is significant that in the 2-inch series the three quadrats clipped during the growing season attained the high point in their tuft areas during that year.

The results in 1928 were unusual in that all of the quadrats clipped to 2 inches except the one clipped at weekly intervals made slight gains, while all of the 4-inch quadrats, with heavier stands than the 2-inch, lost some of their tuft areas.

In 1929, 4-inch harvesting took the lead over the 2-inch harvestings. Whereas all of the quadrats clipped to 2 inches lost tuft area, the entire series clipped to 4 inches gained, although the 1929 growing season was one of the lowest in rainfall of the whole period.

Marked decreases in tuft area began to occur in 1930 on the quadrats clipped to 2 inches, and annual weeds invaded those clipped during the growing season. No invading plants appeared on any of the 4-inch quadrats, or on the end-of-season quadrat of the other series.

TABLE 7.—*Tuft area of tobosa grass as affected by clipping, 1925–35*

Height of grass and frequency of clipping	Original tuft area	1925	1926	1927	1928	1929	1930	1931	1932	1933	1934	1935	Net gain or loss in original tuft area
	Square centimeters	*Square centimeters*	*Square centimeters*	*Square centimeters*	*Square centimeters*	*Square centimeters*	*Square centimeters*	*Square centimeters*	*Square centimeters*	*Square centimeters*	*Square centimeters*	*Square centimeters*	*Percent*
2 inches:													
1 week	757	1,697	3,615	2,994	2,850	2,707	1,834	2,562	1,776	1,606	1,807	384	−49.27
2 weeks	814	1,484	3,133	3,004	3,081	2,772	1,717	2,146	1,689	1,736	1,172	140	−82.80
4 weeks	910	1,150	3,101	2,637	2,981	2,686	1,714	2,420	2,198	2,155	1,784	1,006	+10.55
End of season	1,226	1,161	2,522	2,517	3,204	3,123	2,703	2,748	2,912	3,525	2,577	2,437	+98.78
4 inches:													
1 week	701	1,776	3,299	3,859	3,740	5,758	3,893	4,424	3,490	4,205	2,980	2,085	+197.43
2 weeks	951	1,326	2,951	3,155	2,577	4,504	3,578	4,184	2,799	3,199	2,254	2,122	+123.13
4 weeks	929	1,242	3,177	3,740	2,665	4,258	3,111	4,142	3,238	3,351	2,127	1,403	+51.02
End of season	1,235	1,161	2,944	3,503	2,218	3,039	3,811	4,313	3,425	3,483	2,826	551	(1)

[1] Burrowing rodents destroyed the greater part of the grass cover in winter of 1934.

In the succeeding years, the quadrats of the 2-inch series, in addition to losses in tuft area and the invasion of annual weeds, began to show other definite indications of loss of vitality, in that the general appearance of the plants was not that of healthy tobosa grass. The condition of the 2-inch and the 4-inch quadrats at the end of the eleventh year of clipping (1935) is well illustrated by figures 7 and 8.

A striking summary of the effects of the different clipping treatments is expressed in the last column of table 7. These figures show that the greatest losses of tuft area occurred on the 2-inch quadrats clipped at intervals of 1 and 2 weeks. A point worthy of attention is that the greatest gains occurred on the 4-inch quadrats clipped at these same intervals. The 197-percent gain on the 4-inch quadrat clipped at weekly intervals indicates that this intensity of use of tobosa grass may be considered a beneficial treatment, as well as the one producing the highest quality of forage.

NUMBER AND AVERAGE SIZE OF TUFTS

Although tobosa grass is the nearest approach to a sod grass of any species native to the semidesert grasslands it has always a tendency to form clumps with bare spaces between. The vigor and age of the plants, character of the site, intensity of past use, and favorable or unfavorable climatic conditions of previous years influence the number and size of the tufts.

The number of tufts at the beginning of the study varied on the individual quadrats. Apparently the only relationship existing between number of tufts and total tuft area was a tendency toward a greater proportion of individual tufts on the quadrats having the lowest total tuft area (table 8). There was also a discernible tendency for the average area of the individual plants to vary directly as the total tuft area of the quadrat. During the early years of the experiment and prior to 1930, there was a gradual reduction in the number of tufts and an increase in their average size, with a more marked change in 1928. This came about through the merging of adjacent tufts as the total tuft area of the quadrats increased.

In the later and unusually dry season of 1930 the smaller and less substantially established plants died out entirely, and many of the larger tufts broke up into smaller units through the partial dying of the grass in these larger clumps. The number and the average area of tufts were affected less in this manner on the quadrats clipped to 4 inches than on those of the 2-inch series.

Plants on the quadrats clipped to 2 inches and harvested at 1- and 2-week intervals were definitely failing after 1931 even in the face of above-average rainfall in most years. The end-of-season quadrats of the 2-inch series and the three periodically harvested quadrats of the 4-inch series maintained their numbers and average areas of tufts remarkably well through the severe test of the 1934 drought. A comparison of the number and the average area of tufts as given for the various quadrats in the 1935 column of table 8 leaves no doubt regarding the advantages of limiting the harvesting of tobosa grass to 4 inches. The ill effects of frequent harvesting to 2 inches are also obvious.

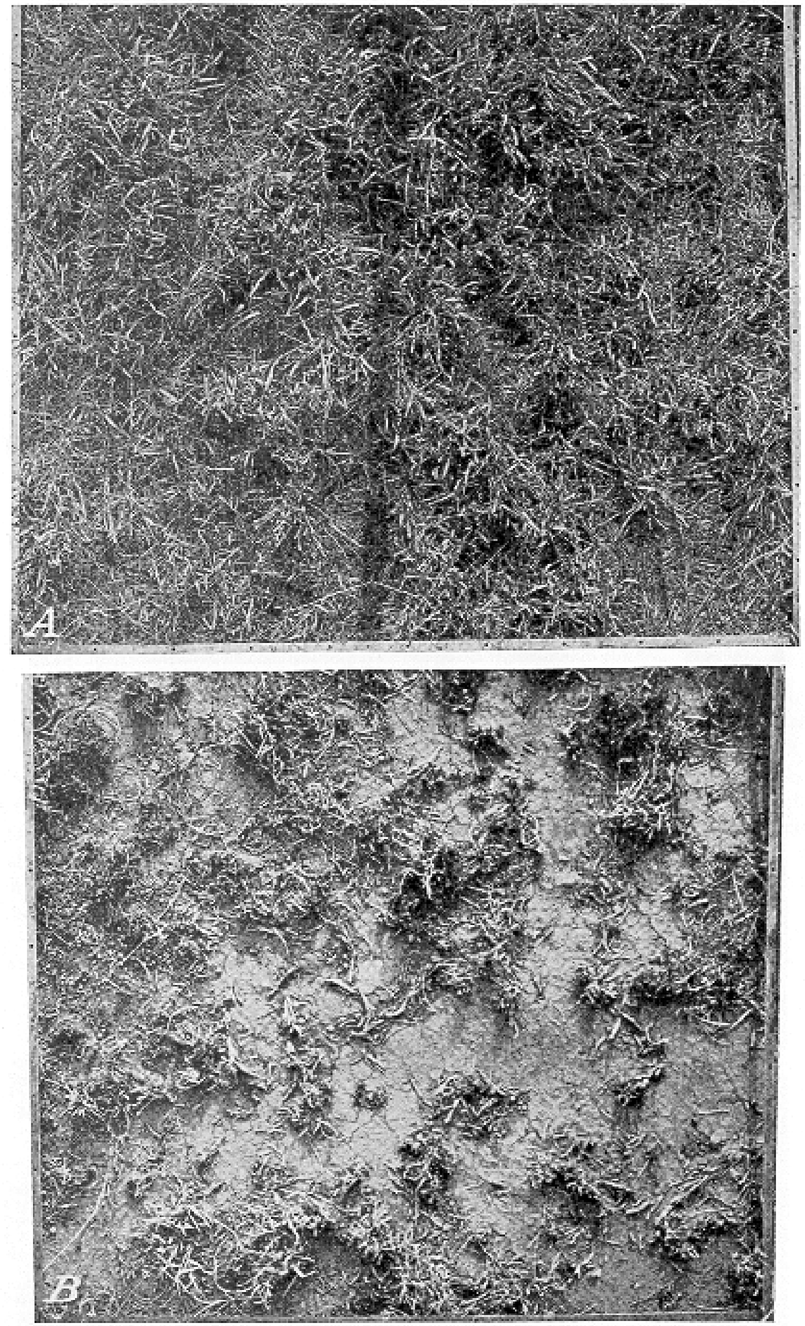

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FIGURE 7.—A tobosa grass quadrat clipped at a height of 2 inches at weekly intervals for 11 years. *A*, Condition of quadrat at the beginning of the experiment in 1925; *B*, the same quadrat after clipping in 1935.

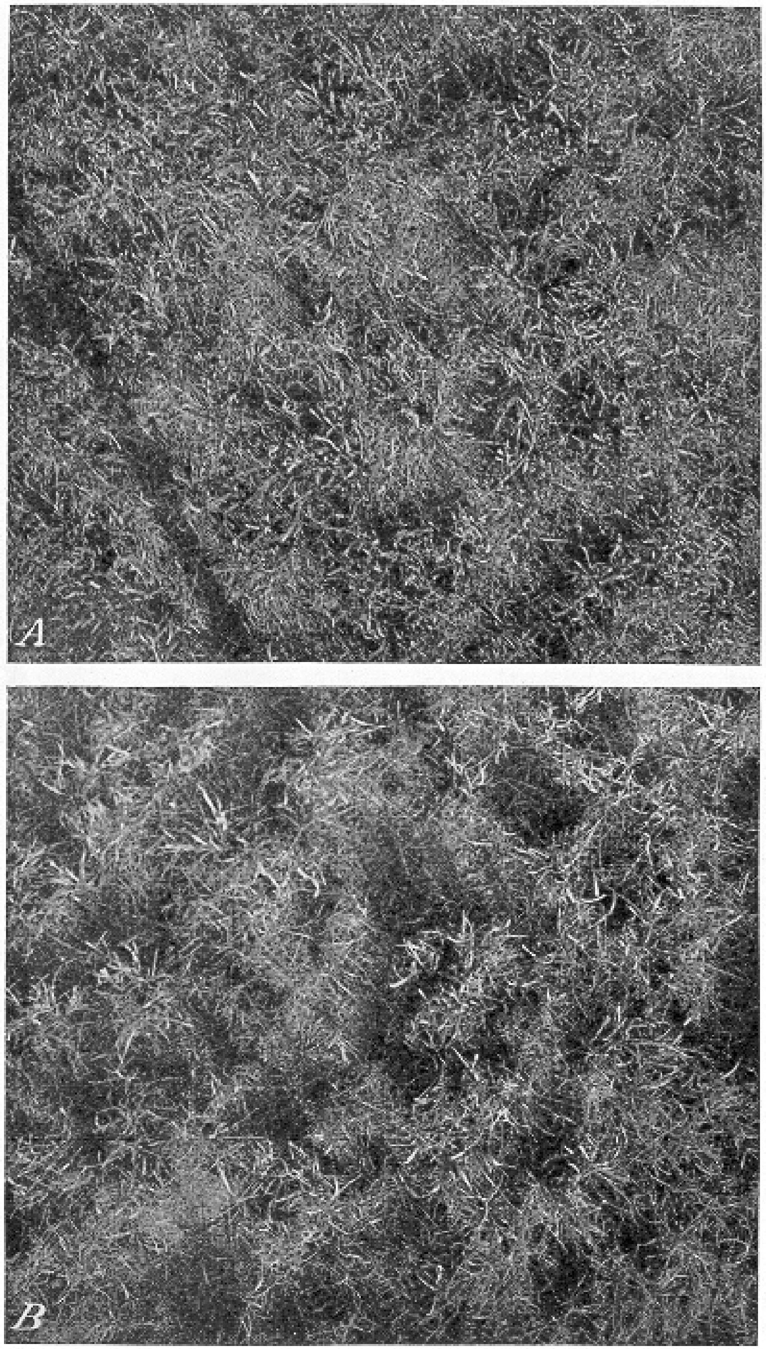

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FIGURE 8.—A tobosa grass quadrat clipped to 4 inches at weekly intervals over a period of 11 years: *A*, Condition of quadrat at the beginning of the experiment in 1925; *B*, the same quadrat in 1935 after clipping.

TABLE 8.—*Number and average size of tobosa grass tufts on meter-square quadrats, as affected by clipping, 1925–35*

Height of grass and frequency of clipping	Start of tests		1925		1926		1927		1928		1929	
	Number	*Square centimeters*	*Number*	*Square centimeters*	*Number*	*Square centimeters*	*Number*	*Square centimeters*	*Number*	*Square centimeters*	*Number*	*Square centimeters*
2 inches:												
1 week	158	4.8	127	13.4	118	30.6	114	26.3	59	48.3	77	35.2
2 weeks	153	5.3	146	10.2	134	23.4	127	23.7	78	39.5	71	39.0
4 weeks	210	4.3	150	7.7	125	24.8	92	28.7	45	66.2	66	40.7
End of season	175	7.0	208	5.6	199	12.7	124	20.3	59	54.3	75	41.6
4 inches:												
1 week	212	3.3	147	12.1	104	31.7	113	34.2	58	64.5	19	303.1
2 weeks	152	6.3	146	9.1	114	25.9	117	27.0	72	35.8	34	132.5
4 weeks	191	4.9	165	7.5	129	24.6	87	43.0	76	35.1	49	87.1
End of season	164	7.8	188	6.2	163	18.1	93	37.7	67	33.1	56	65.0

Height of grass and frequency of clipping	1930		1931		1932		1933		1934		1935	
2 inches:												
1 week	88	20.8	75	34.2	84	21.1	92	18.1	79	22.9	20	19.2
2 weeks	103	16.7	84	25.5	79	21.4	89	19.5	110	10.7	19	7.4
4 weeks	84	20.4	72	33.6	65	33.8	85	25.4	78	22.9	31	32.5
End of season	76	35.6	83	33.1	72	40.4	84	42.0	98	24.3	62	39.3
4 inches:												
1 week	52	74.9	52	85.1	98	35.6	63	66.7	82	36.3	76	27.4
2 weeks	46	77.8	42	99.6	79	35.4	72	44.4	55	41.0	63	33.7
4 weeks	63	49.4	43	96.3	63	51.4	65	51.6	60	35.4	39	36.0
End of season	41	93.0	35	123.2	53	64.6	73	47.7	66	42.8	25	[1] 22.0

[1] Burrowing rodents destroyed the greater part of the grass cover in the winter of 1934.

FORAGE YIELD

The data in table 9 represent average annual yields per square decimeter from the tobosa grass quadrats, computed by the same methods as were used in the black grama study. In the process of evaluating these data it is, however, essential that certain characteristics of tobosa grass, which cannot be readily assigned numerical values and yet affect the application to range management of the results obtained experimentally, should be considered along with the actual weights of grass clipped. These are:

TABLE 9.—*Air-dry weight of tobosa grass clipped per square decimeter of tuft area, 1925–35*

Height of grass and frequency of clipping	1925	1926	1927	1928	1929	1930	1931	1932	1933	1935 [1]	Yield per square decimeter: Total	Yield per square decimeter: Mean annual
2 inches:	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*	*Grams*
1 week	15.02	15.57	10.44	0.75	16.02	3.83	8.60	0.14	2.93	1.38	74.68	6.79
2 weeks	15.92	12.01	11.07	.53	15.66	3.86	7.43	.16	7.64	.50	74.78	6.80
4 weeks	17.61	11.14	10.05	.33	16.91	2.96	8.51	.26	8.67	6.70	83.14	7.56
End of season	22.18	14.73	15.91	.05	19.26	4.25	10.22	.06	8.11	16.90	112.27	10.21
4 inches:												
1 week	16.70	12.24	13.87	.96	23.98	5.78	11.99	.45	10.26	9.55	105.78	9.62
2 weeks	9.17	5.58	7.86	.49	13.61	3.46	8.05	.03	5.52	5.42	59.19	5.38
4 weeks	11.92	6.29	7.85	.37	11.67	3.01	8.16	.14	5.70	13.29	68.40	6.22
End of season	14.56	5.82	8.07	.16	18.35	1.72	6.34	.11	4.01	2.72	61.86	5.62

[1] No new growth in 1934 owing to drought.

(1) Tobosa grass is normally grazed by cattle to a height of about 4 inches. (2) Palatability is practically confined to the period of growth. (3) Frequent cropping of this grass during the growing season operates to maintain a supply of tender, succulent foliage. (4) Highest usability combined with greatest sustained productivity provides an index to the actual values of the results obtained in this experiment.

With the foregoing points in mind, data concerning weights of tobosa grass may be examined with a clearer idea of their true significance. As an example of a comparison that might otherwise lead to a wrong conclusion, where the total production per square decimeter for the period from all the quadrats clipped at 2 inches is compared to similar total production of all quadrats clipped at 4 inches, a balance of 49.64 g. in favor of the former is evident. When the end-of-season quadrats are eliminated from the picture, however, the result is quite different and total production per square decimeter of 2-inch and 4-inch quadrats is found to be almost equal. The second example is valid because it deals only with grass that may be considered good usable forage, while the first comparison included mature plants that are inferior forage. Thus, this instance demonstrates that, in the long run, 2-inch clipping produces no greater yield than 4-inch clipping even per small unit of tuft area.

Selection of the most productive combined frequency and height of clipping of palatable forage is less difficult. The superiority of the weekly harvesting at a height of 4 inches is evident from the total yield. This is borne out by comparisons for the 10 individual years when forage was produced (1934 out). Excluding from the comparison quadrats clipped at the end of the season, production from the quadrat clipped weekly at 4 inches exceeded the production of any of the others in 7 of the 10 years.

In only two instances—in 1926 and again in 1929 on the quadrat clipped weekly—did any quadrat of the 2-inch series equal the high production per square decimeter of the first year of clipping. Quadrats of the 4-inch series equalled their first year of production in four instances—three quadrats of the series in 1929 and the 4-week quadrat in 1935. Whether or not the plants still retain the capacity to produce as much forage as they did at the beginning of the experiment should be an index to the present physical condition of the plant. Although the low rainfall in 1934 precluded an actual demonstration of this condition, it can be safely assumed that the relation between the production for the eleventh year of the experiment (1935) and the mean annual for the same quadrat is an indication of the differences in vitality and sustained producing capacity of tobosa grass that result from different intensities and frequencies of clipping.

A significant comparison may be drawn from these data relating to production per square decimeter, considering only the quadrats that were clipped during the growing season: During the first 3 years of clipping, 1925–27, the three quadrats of the 2-inch series taken together produced 118.83 g., which is considerably greater than the total production of 91.48 g. of the 4-inch series in the same period. From 1928 to 1935, however, the 4-inch series produced a total of 141.89 g. as compared to only 113.77 g. on the 2-inch series.

Average annual yields per meter-square quadrat under the different intensities and frequencies of clipping, computed without regard to existing differences in tuft area, are as follows:

	Average annual yield (grams)
2-inch series:	
1-week clipping	175.68
2-week clipping	159.75
4-week clipping	163.06
End-of-season clipping	249.57
4-inch series:	
1-week clipping	368.55
2-week clipping	173.90
4-week clipping	178.46
End-of-season clipping	162.89

When compared in this manner on the basis of production per entire plot, and excluding those clipped at end of season, the average annual production of the quadrats occupies in general about the same relative positions with regard to the 1-week 4-inch quadrat as in the analysis based on production per unit of tuft area. The average annual yield of the 2-inch end-of-season clipped quadrat is reduced to second place when all are considered. However, the main point is that the superior yield obtained from clipping to a height of 4 inches at weekly intervals is emphasized more than ever. When quality of forage as well as quantity is considered there remains little room for doubt that the 4-inch clipping at weekly intervals provides a better index to a proper grazing use of tobosa grass.

Total production per plot after 1931, when the stand of the quadrats clipped at 2 inches began to fail, shows an even more striking advantage for clipping to 4 inches. Average annual yields per plot for the years 1932, 1933, and 1935 are as follows:

	Average annual yield (grams)
2-inch series:	
1-week clipping	18.87
2-week clipping	45.34
4-week clipping	86.65
4-inch series:	
1-week clipping	215.42
2-week clipping	97.48
4-week clipping	127.33

For this period the plot clipped at a height of 4 inches at weekly intervals produced more than 11 times as much as the plot clipped at 2 inches at weekly intervals. Moreover, the plot clipped weekly at 4 inches far exceeded the production of any of the other plots.

REPRODUCTION

Because of the habit of reproducing by rhizomes, new tobosa grass plants arising near the edges of old tufts cannot be distinguished from the stems which occur with the expansion of the older plants (fig. 9). For this reason, an accurate count of reproduction on tobosa grass quadrats was impossible. However, it is known that many new plants came in on the clipped quadrats, all of which were produced vegetatively.

Clipping definitely stimulated reproduction, especially in the early years of the experiment. Apparently clipping aided in activating buds which otherwise might have remained dormant.

RAINFALL AND PERIOD OF PLANT GROWTH

Although actual rainfall records at the tobosa clipping-study plot were obtained from a standard rain gage set up inside the enclosure within a few feet of the clipped quadrats, nevertheless owing to the heavy inflow of water from higher adjacent lands, rain-gage measurements are of little direct value in determining the quantity of water received by the tobosa grass plants. Indirectly these records show the time that the rains occurred and the distribution throughout the period of growth (table 6).

Usually the first rains of the summer are torrential in character and flood the low swales occupied by tobosa grass. Until this flooding occurs, little or no growth takes place. Ordinarily the period of growth for tobosa grass is the same as that for black grama in the near vicinity (table 6).

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FIGURE 9.—Bisect of tobosa grass plant. New tobosa grass plants usually are produced vegetatively and rarely from seed. The sun-baked top of heavy clay soils occupied by the grass is not easily penetrated by the young rootlets of the seedlings. Tobosa plants overcome this difficulty by sending out underground stems which burrow beneath the hard-baked surface and send up shoots wherever there is an unoccupied space large enough to support a new plant. The scaly, oversized, rootlike stems beneath the ruler in the photograph are rhizomes.

SITE

Sites occupied by tobosa grass are generally restricted to the clay or adobe soils of the low, periodically flooded swales. Soils of this character would be highly susceptible to surface erosion when the plant cover is harvested were it not for the fact that the nearly level lay of the land and the usual bolson character eliminate the possibility of surface drainage. On the other hand, denuded areas in tobosa country are greatly affected by wind erosion, which removes the thin cover of mixed plant material and topsoil essential in preserving the porosity of the heavy clay soil immediately beneath. When this topsoil is lost, evaporating waters leave a colloidal residue that seals the pores of the clay, thus impeding the percolation of water and cutting off the aeration of the soil. Slick clay flats supporting no perennial grasses and few plants of any kind are common examples of this effect.

Clipping to 2 inches resulted in the loss of a portion of the litter of dead leaves and stems and of the mulch composed of this material mixed with soil, which also added to the detrimental effects of clipping. This condition was worse on the 2-inch quadrats clipped at 1- and 2-week intervals, and may play an important part in decline in the production in the late years. Those clipped at a height of 4 inches showed little or no indications of wind erosion after 11 years of clipping (figs. 7 and 8).

SUMMARY AND CONCLUSIONS

Clipping experiments on semidesert black grama range indicate clearly that persistent cropping of all herbage of this grass to a 2-inch height or less eventually results in destructive reduction of tuft area regardless of frequency of seasonal harvesting; it reduces forage yield to zero; it prevents survival and even establishment of reproduction of the forage grass; it entirely outweighs all beneficial effects of above-average rainfall; and the end result is rapid and critical deterioration of the black grama site through excessive wind and water erosion.

Black grama quadrats clipped periodically during the growing season to a height of 1 inch made substantial gains in tuft areas the first year, one of unusually favorable growth, but these gains were short-lived. Losses in the second and third season more than consumed these increases and continued to the end of the experiment. Similarly, quadrats periodically clipped to 2 inches made early gains that were wiped out by subsequent losses. The 1-inch end-of-season quadrat lost from the beginning of the experiment. The similarly clipped 2-inch quadrat maintained a total tuft area above that of the beginning only into the seventh year.

There were several fluctuations in the tuft areas of the quadrats during the 11 years covered by the experiment, but the general dominant trend prevailed to such a degree that by the end of the 1935 growing season not one quadrat of either the 1-inch or the 2-inch black grama series retained as much as 4 percent of the original tuft area. This condition was due in part to clipping and in part to the loss of sand mulch about the base of the plants. The harvesting of all grass stems permitted the sand mulch that is so essential to the well-being of black grama plants to be swept away by the winter and spring winds.

With the loss of black grama goes total loss of forage yield unless it is replaced in whole or in part by other grasses or worth-while plants. The average yield of black grama on the 1-inch quadrats was 1 g. per square decimeter of tuft area annually. A similarly computed yield from the 2-inch series was 1.79 g. This extra 0.79 g. equals a 79-percent advantage over clipping at 1 inch; but both treatments were too severe to be endured by black grama.

It may be concluded that the persistent grazing by cattle, during or even at the end of the grazing season, of all stems of black grama, in pure stands on semidesert sandy ranges, down to 2 inches or less will practically destroy the black grama stand in a period of 10 years; it can be expected to reduce the forage yield by one-half in 3 or 4 years and practically to zero in 8 or 9 years.

Cropping of all the black grama stems to 2 inches or closer involves wiping out all reproduction from seed or stolons and curtails lateral spread of tufts. Prior to 1928 a number of new plants from stolons were rooted on the less frequently clipped quadrats of both the 1- and 2-inch series. But none of the sets survived, because of the weakened condition of the parent plants. After 1928 no reproduction from stolons occurred, although an occasional stolon escaped the shears. To reproduce, the stem joint must be in contact with a mulch of loose soil. Practically no sand mulch remained on the clipped quadrats after 1928. Accordingly it may be concluded that persistent summer grazing of black grama down to 2 inches or less will cause site deterioration. Regardless of whether the method employed is close clipping or overgrazing, such treatment can always be expected to induce removal of the top layer of soil by wind, and on sloping ground by water and wind.

An indication of the influence of rainfall on plant growth in years that are better than average is gained from the quadrat clipped once each year to 2 inches. This quadrat in 1925, with a summer seasonal rainfall of 7.01 inches (in figures rounded to the nearest 0.1 g.), produced 8.2 g. of grass, dry weight, per square decimeter of tuft area; and in 1926, with 11.95 inches of summer rain, 11.8 g. per square decimeter was harvested. After 9 years, this same quadrat produced, in 1933, with a seasonal rainfall of 6.52 inches, less than 0.2 g. of air-dry grass per square decimeter of tuft area. Many more comparisons might be made, but these are sufficient to demonstrate that on ranges grazed as heavily as, and at a comparable time to, the clipping, rainfall ceases finally to be the principal limiting factor.

The clipping experiment with tobosa grass, conducted as it was to 2- and 4-inch heights, and on a grass the forage value of which practically vanishes with maturity, produced somewhat different results. These indicate that clipping first induces an expansion of tuft area, but the rate and extent of expansion are dependent on clipping frequency, and the permanency of increases in tuft area is governed by its closeness. Cropping all herbage to 2 inches represents greater utilization than tobosa grass can withstand, but clipping to 4 inches encourages growth of tuft area, maintains a high yield of valuable forage, and stimulates vegetative reproduction. Expansion of tobosa grass tuft areas was in part due to a tendency of the plants to expand laterally when vertical growth is cut off.

By the end of the first season, quadrats clipped at intervals had increased their tuft areas in direct proportion to the frequencies of clipping. The indication is that an increase in tobosa ground cover may be expected during the first year on areas closely grazed during the growth period; also that areas cropped at weekly intervals have a tendency to increase tuft area at a greater rate than those less frequently grazed. Not all of these increases, however, were permanent. The three quadrats of the 2-inch series clipped at intervals during the period of growth supported, in 1925, before being cropped, an aggregate ground cover of 24.81 $dm.^2$ After 11 years these same quadrats retained a ground cover of 15.30 $dm.^2$, showing a net loss of 9.51 $dm.^2$, or 38 percent. After 11 seasons of clipping, the 4-inch quadrats had increased in tuft area from 25.81 to 56.10 $dm.^2$—a net gain of 117 percent.

During drought, serious losses of tuft area, from which the plants do not readily recover, may be expected in tobosa grass when all herbage is cropped at a height of 2 inches at 1- and 2-week intervals. It may be concluded, indeed, that successive seasons of frequent grazing of all herbage of tobosa grass to a height of 2 inches will in a few years result in evidence of overutilization—tuft area will drop, plants will lose vigor, and unpalatable weeds will begin to invade the site—all showing that overgrazing of the range prevails.

Harvesting at frequent intervals during the growing season, if not too close, has a distinct advantage over less frequent harvesting in that the accumulation of overaged, less palatable forage is prevented. Therefore, tobosa grass areas which are cropped as often as once each week produce the highest quality of forage. A comparison of the mean annual yields per square decimeter for weekly clipping presents a well-defined advantage of the 4-inch series. These averages for 11 years are: 2-inch, 6.79 g.; 4-inch, 9.62 g., or 41.6 percent in favor of weekly clipping to a height of 4 inches. The 4-inch quadrat, however, yielded 110 percent more total forage over the 11-year period than did the 2-inch quadrat; and during the years 1932 to 1935, more than 11 times as much. An additional advantage of the 4-inch clipping that overshadows these differences in yields is the fact that all of the plants subjected to clipping to 4 inches were in good physical condition at the end of 11 years of this treatment, but those clipped to 2 inches were not. Apparently frequent clipping of the stems stimulates rhizomes. Ultimately, however, this stimulus is dissipated if the plants are clipped too close, and the stand disintegrates, and yield falls off markedly.

The lack of permanent damage to site from any intensity of clipping except that at 2 inches at 1- and 2-week intervals is explained by the fact that areas commonly occupied by tobosa grass are the heaviest clay soils, which are not easily eroded by wind action. Although these soils contain a high silt fraction and are highly susceptible to water erosion, the lack of drainage in these flat-bottomed swales leaves very little opportunity for adverse water action.

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