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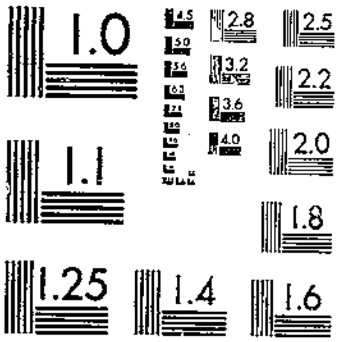

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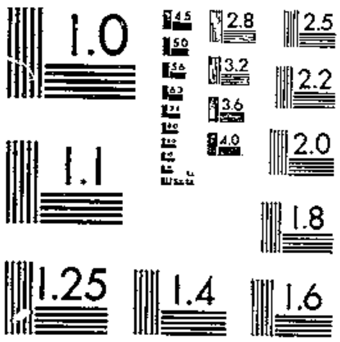

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TECHNICAL BULLETIN No. 409 APRIL 1934

THE INFLUENCE OF PRECIPITATION AND GRAZING UPON BLACK GRAMA GRASS RANGE

BY

ENOCH W. NELSON

Assistant Range Examiner
Division of Range Research, Forest Service

UNITED STATES DEPARTMENT OF AGRICULTURE, WASHINGTON, D.C.

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UNITED STATES DEPARTMENT OF AGRICULTURE
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THE INFLUENCE OF PRECIPITATION AND GRAZING UPON BLACK GRAMA GRASS RANGE

By Enoch W. Nelson[1]

Assistant range examiner, Division of Range Research, Forest Service

CONTENTS

THE IMPORTANCE OF BLACK GRAMA ON SEMIARID SOUTHWESTERN RANGES

The excellent stand and growth of palatable perennials that once covered much of the semiarid range lands of the Southwest afforded abundant feed for a thriving livestock industry. Where such conditions still prevail, and management is adjusted to sustain production of feed within the limits of climatic conditions, livestock production is effective. On most of the range, however, continued overstocking and the consequent accumulation of ill effects of overgrazing, combined with recurring drought, have brought about conditions involving not only heavy losses to the livestock producer but even

[1] The writer gratefully acknowledges his indebtedness to the members of the Jornada Experimental Range staff for field data collected from 1915 to 1927, and to these and other members of the Forest Service for constructive criticism of this report.

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a complete failure of profitable production. How to restore the productivity of these lands is an urgent question, but one with many ramifications. One very important consideration is the preservation of the best of the remaining forage and the extension of its present growth. In this connection, one species of perennial grass growing on a considerable part of the semidesert range deserves primary attention. This is both because of its high palatability and its ability to extend its growth abundantly under moderately favorable circumstances, in which particulars black grama (*Bouteloua eriopoda*) is without a peer.

Originally, black grama was the mainstay of the range,[2] occurring rather abundantly and in almost a pure type over extensive areas of southeastern Arizona, southern New Mexico, western Texas, and south into Mexico. As such stands deteriorated black grama died out to a considerable degree, but the plant still occurs as important range forage on extensive areas, either in almost pure stands or mixed with other perennial grass species. Black grama is characteristically drought-resistant, a quality indispensable to the maintenance of any range forage plant under the climatic conditions prevailing in the Southwest. It is highly palatable and nutritious both in summer and winter, making it a valuable year-long forage plant, especially for cattle. During some winters the stems remain green up to about the second node from the top, and clusters of leaves may come out at the nodes the following spring. Black grama ordinarily cures well on the stalk and retains its nutritive value through the dry spring period when other range forage is parched and harsh.

Although the plant can withstand recurrent grazing by livestock, too heavy utilization impairs its vigor. During drought periods plants so weakened succumb, thereby greatly depleting the stand. It is of the greatest importance, therefore, to know just what degree of grazing use can be applied without injury to black grama ranges.

This bulletin presents the results of study, during the 13 years from 1915 to 1927, inclusive, of the influence of the variable precipitation and several intensities of grazing on the black grama range type on the Jornada Experimental Range (formerly Jornada Range Reserve) and adjacent public-domain range in southern New Mexico. The adoption on southwestern ranges of such principles as this study has brought to light should make the range cattle business of the region much more stable and profitable.

METHODS OF STUDY

The Jornada Experimental Range of the Southwestern Forest and Range Experiment Station,[3] located in southern New Mexico, contains approximately 190,000 acres of grazing land typical of the southwestern semiarid region. It is mainly a flat to slightly rolling plain varying in elevation from approximately 4,100 to 4,700 feet above sea level. The east portion consists of the western slope of the San Andres Mountains, which rise to an elevation of 8,000 feet. Prior to 1904 the land now in the range was poorly watered for livestock grazing. There were a few springs in the mountains and inter-

[2] WOOTON, E. O., and STANDLEY, P. C. THE GRASSES AND GRASSLIKE PLANTS OF NEW MEXICO. N.Mex. Agr. Expt. Sta. Bull. 81, 175 pp., illus. 1912.

[3] Maintained in cooperation with the University of Arizona.

mittent lakes on the flats. Subsequent development of watering places, consisting of deep wells and reservoirs to catch flood waters, made the area a well-watered range unit.

The vegetation of the range consists of approximately 80 percent of perennial grasses and is grouped more or less distinctly into range vegetative types. The perennial grasses of these vegetative types are palatable to cattle either in the summer and fall or year long. Black grama is the dominant species on the year-long grass range.

The aim on the experimental range has, in the main, been so to stock the various pastures as to provide sufficient range feed for the cattle grazing on the range in practically every year. In the original plans all pastures were to be grazed to their capacity, certain ones year long, and others unusually lightly during the summer and fall with stocking heavier throughout the winter and spring in order to utilize the year's feed supply by the close of the spring grazing season. Short feed resulting from drought caused heavier utilization of feed than was originally planned, especially near the watering places. On the open public-domain range there was no control or regulation and the owner of the livestock grazing there utilized the range as he desired, which, in combination with the drought which prevailed in most years, resulted in overstocking in nearly every year up to 1926. Careful record was maintained through the period of the study as to the character and degree of use on each of the main parts of the black grama range. In order to have accurate and specific measurements of changes in the vegetation, plots or quadrats were established on areas representative of each of the main grazing conditions.

In Figure 1 is shown the location of the different series of quadrats used in the study. Each quadrat was 1 meter square, and 38 in all were included. Six of these, located in small fenced areas near headquarters and South Well,[4] were continuously protected from grazing by livestock.

For the most part the grazed quadrats were situated at ½-mile or 1-mile intervals along lines radiating out from the permanent watering places. Grazing was heaviest near these watering places, but gradually diminished at greater distances. The combination of the grazing practice for each range area on the Jornada range and the unfenced public domain, as well as the location of the quadrats, made it possible to segregate and compare with the protected areas the following intensities of grazing: (1) Conservative grazing year after year (10 quadrats); (2) heavy overgrazing year after year (10 quadrats); (3) full use in the better years and slight overgrazing in dry years (9 quadrats); and (4) overgrazing during the summer growing season year after year (3 quadrats). Observations were begun in 1915 and 1916, except on 2 of the protected quadrats, 2 of those conservatively grazed, and the 3 summer-overgrazed; on these 7 plots observations were begun in 1919.

Conservative grazing was considered to be that wherein only 75 to 80 percent of the annual growth of black grama, on the average, was utilized at the end of the grazing season of each year. Lighter graz-

[4] Four of these were first fenced from livestock in 1913, 1 in the spring of 1916, and 1 in 1919.

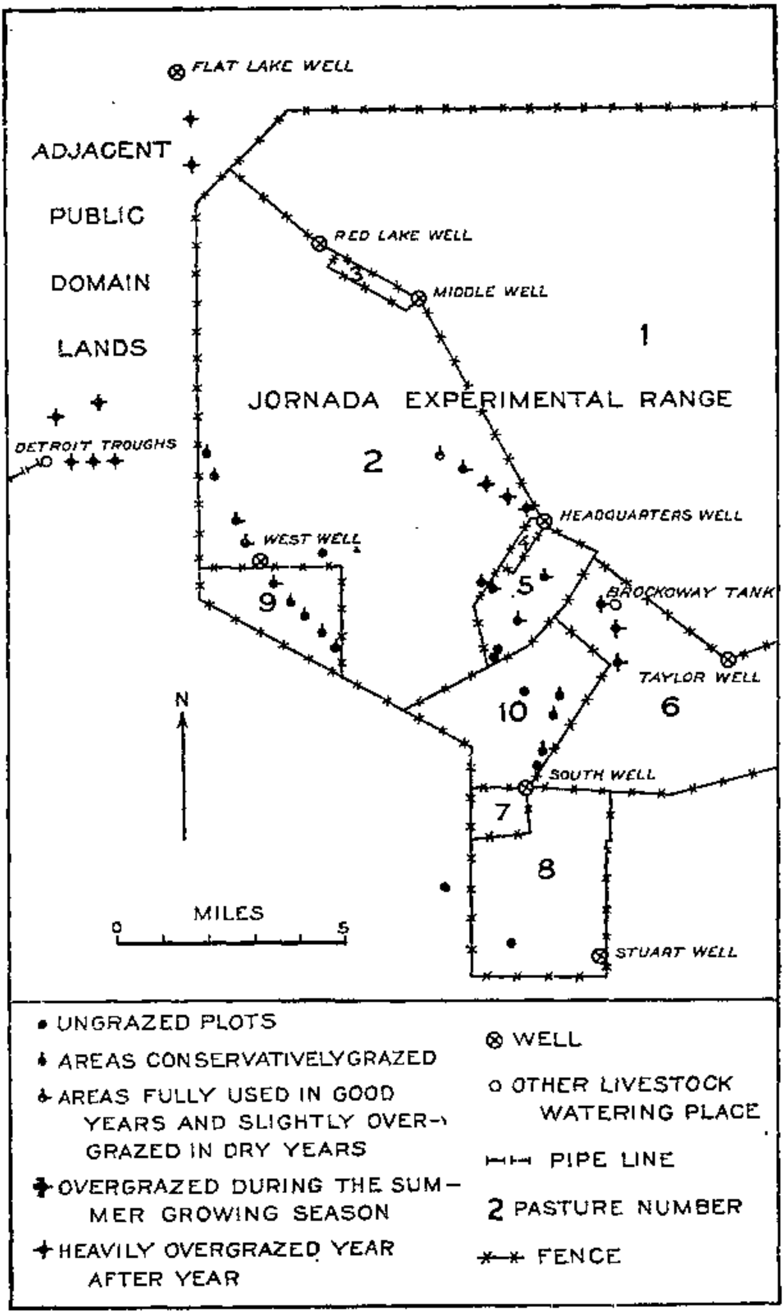

FIGURE 1.—Map of a portion of the Jornada Experimental Range and adjacent public domain, showing the location of the different series of quadrats used in these experiments.

ing use occurred in the better years and heavier use during the driest years. Since all of the forage was not utilized until the end of the grazing year it will be evident that there was light use during the summer growing season each year and the more palatable plants, especially black grama, were given the maximum opportunity permitted under grazing use to make a vigorous growth and reproduce.

Under heavy overgrazing year after year the annual growth of black grama was completely utilized and the range was considerably trampled by the end of the grazing season both in average years and in drought years. Because of the high palatability of the black grama, it was fairly heavily grazed each year from the time that growth started. This degree of use occurred, except at remote distances from permanent water, on the open public-domain range adjacent to the Jornada Experimental Range.

On the areas where full use prevailed in the better years and slight overgrazing in dry years, approximately 85 percent of the annual growth of black grama was utilized at the end of grazing years of more favorable rainfall. There was less trampling and lighter use of the less palatable species than on the areas heavily overgrazed year after year. In dry years the black grama was completely utilized. In most years grazing was moderate during the summer growing season.

The fourth degree of grazing use was comparable to the second, except that the grazing took place during the summer and fall seasons only. The quadrats used to show this degree of grazing were located in small areas of black grama found on interspersed sandy ridges in summer range. Tobosa grass (*Hilaria mutica*) was the important summer range forage and was most palatable during the summer and fall.

After 1925 all of the range areas under study were lightly grazed or ungrazed.

The quadrats were charted each year to determine the changes in area of the vegetation. In the earlier years of the study this was done both in the late spring and near the end of the normal growing season in the fall; later it was done only in the fall. The boundary of each perennial-grass tuft at a point 1 inch above the soil surface was accurately mapped, recorded on a quadrat sheet, and its area computed in square centimeters as the basis of comparison between years. Other perennial herbaceous plants were located on the sheet and the number totaled for each quadrat by species. The annual grasses and weeds were counted by decimeter strips or squares and recorded on the quadrat sheet.

Observations and measurements of black grama and associated grasses were made annually on each quadrat and on the nearby surrounding area, the data recorded including the following: (1) Period of growth; (2) dates of flowering, seed ripening, seed maturity, and seed dissemination; (3) maximum and average height growth of flower stalks and length of leaves; and (4) the general condition of the vegetation and soil. Observations were also made over each range area of the annual forage crop as compared to the average at the close of the summer growing season, and of the extent of utilization of the forage crop at the close of the grazing year.

An accurate record of the forage volume produced in each year on the parts of the range grazed to different intensities would have been desirable. However, no method has been developed to obtain such data accurately and practically on southwestern semiarid ranges under grazing use. While the clipping of black grama on small plots to obtain forage volume has shown distinct values, the results have not proved entirely satisfactory for comparison with forage production on the areas actually grazed. Clipping treatment so far applied to black grama differs from actual grazing and gives different results.[5] For these reasons, the principal comparisons in this bulletin are on the basis of plant area and height growth, definitely measurable quantities indicative of forage production and demonstrably useful in developing practical range management.

Seed germination tests of several of the grasses were made in the laboratory by the United States Bureau of Plant Industry in 1917, 1919, 1920, and 1921; by the New Mexico College of Agriculture and Mechanic Arts from 1922 to 1925, inclusive, and by Carola V. Jackson, University of Chicago, in 1926.

Records of daily maximum and minimum air temperatures and of precipitation were obtained at the Jornada headquarters in cooperation with the United States Weather Bureau for the 12 years from July 1, 1915, to June 30, 1927, inclusive, and precipitation records at South Well and West Well for the 9 years from July 1, 1918, to June 30, 1927, inclusive. Records maintained since 1861 at State College, N.Mex., about 25 miles south of the Jornada headquarters, were also available as a valuable check on the data gathered locally. Records of precipitation at several other Weather Bureau stations in southern New Mexico were also studied to determine the relation of the period of this study to the available long-time record.

BLACK GRAMA ON THE RANGE

Black grama, also referred to as "woolly-foot grama," is a tufted, branching, strong-rooted, long-lived perennial grass easily identified by the characteristically open, flag-like seed heads. The stems are woolly, especially the lower parts, and vary from 3 to 36 inches in height. The longer stems are the result of favorable growing conditions in one or more years, since the stems do not die entirely back to the crown of the plant each year. Furthermore the stems may branch from axillary buds which form at the nodes or joints. The leaves are smooth and narrow and from 1 to 5 inches in length. Variation in stem height and foliage growth is related mainly to climate, soil, and vigor of the plants, which rarely grow dense enough to form a sod. If ungrazed for a number of years, black grama tends to form a rather uneven stand of large tufts. During drought these die out in the center and break up into many smaller tufts. With a return of favorable climatic conditions these smaller tufts enlarge again and may grow together. Where grazed, the tufts are on the average smaller and generally more evenly distributed over the soil surface. Even under grazing use, plants have remained

[5] CULLEY, M. J., CAMPBELL, R. S., and CANFIELD, R. H. VALUES AND LIMITATIONS OF CLIPPED QUADRATS. Ecology 14: 35–39. 1933.

alive for the 13 years that the black grama range has been under intensive study.

The range of black grama extends from western Texas, through New Mexico and Arizona, south into Mexico, where the grass occurs in the semiarid grassland, yucca-grass, or grass-shrub formations of valley and tableland. The main altitudinal range of the species is from 3,500 to 5,500 feet, although it is occasionally found below 3,000 or above 7,000 feet. It occurs mainly in open grassland areas, commonly on the well-drained sandy or gravelly soils of dry mesas so characteristic of southern New Mexico. Here, in what is doubtless its maximum development, it becomes the dominant plant of the climax plant formations. It occurs less commonly in the foothills, only rarely on clay loams and adobe flats, and seldom anywhere under the shade of dense brush.

Black grama is found at its best on the compacted sandy soils of the dry mesas. Here it occurs in almost pure stands (pl. 1, *A*), covering 30 to 40, and occasionally up to 60, percent of the soil surface.

GROWTH HABITS

The period of growth of black grama in southern New Mexico is determined primarily by precipitation and temperature. Occasionally, when precipitation during the fall, winter, and spring is sufficient and temperatures are not too low, some growth of leaves takes place in March and April; with continued favorable moisture, growth continues into the main summer growing period. Continued growth from spring to summer is, however, very unusual; if any growth occurs in the spring it usually ceases in May or June because of the very light precipitation and the severe drying winds common during that period. The main growing season starts with the beginning of the summer rainy period, ordinarily early in July, though it may begin during May or June or as late as August 1 to 15. If rainfall is adequate and evenly distributed growth continues until late September or even through October.

The time of flowering and fruiting varies with the beginning of the summer growing season. With average amount and distribution of rainfall during this period flower stalks are produced in 5 to 7 weeks after growth starts. Hence, ordinarily, the flowering period may be expected the early part of August and the fruiting period the latter part of September. Seed dissemination begins in October and extends into November. Infrequently two flowering periods occur in the same year, as in 1926 on the Jornada Experimental Range. In that year abundant rainfall during May brought on an early flowering period, and excellent rains during July produced a second. However, dry periods in June and again in August prevented the maturing of seed in both growing periods.

The chief methods of revegetation of black grama are by lateral spread and by stolons. In the process of lateral spread, the area of the individual plant is increased by new stems arising from the outer edge of the root crown, a process which is commonly termed "tillering."

In revegetation by stolons (pl. 1, *B*), the flower stalks or stems bend over to the ground or, less frequently, grow horizontally just above the surface of the ground from the base of the parent plant.

On these stolons, small clusters of leaves form from axillary buds at the nodes or joints; these, under favorable climatic conditions, take root and grow into new plants, known as sets. The stems which connect the new plants with the parent plant, if not broken by trampling, persist for 2 years, or until the sets have become established and are no longer dependent on the parent plant for sustentation. At least 60 percent of the sets are formed beyond the second node of the stolon. Ordinarily, the sets of one year are formed on stems produced during the previous year. Formation of stolons and new sets in the same year occurs if there is good rainfall and a long growing season. Good precipitation during May and June may result in stolons being produced before the main summer growing season. The continuous process of revegetation by stolons may be referred to as "progressive revegetation," since plants established by stolons will eventually send out fresh stolons during subsequent favorable growing seasons, and these in turn will establish new plants.

ASSOCIATED SPECIES

Soapweed (*Yucca elata*), in scattered stands, is characteristic of the black grama type, especially on the compacted sandy soils of dry mesas. Numerous other plant species, including both perennial and annual grasses and weeds (nongrasslike herbaceous plants), also occur in the black grama type. Most of these are normally scattered and of little importance, but many of them invade the type in profusion in years of abnormal growing conditions or in favorable seasons following the depletion of the black grama stand by drought or overgrazing. All are inferior to black grama in forage value, although many of them furnish some variety in the feed and aid in bolstering up the grazing capacity of the ranges. However, the invasion of the more persistent and aggressive species, owing to competition for the available soil moisture, may delay the reestablishment of black grama. The habits of growth and revegetation of these species, which are largely limited by precipitation and other growing conditions, influence their invasion and stability in the black grama type.

The associated species may be classified roughly as long-lived perennials, short-lived perennials, and annuals. The chief perennial grasses associated with black grama in the Jornada region are the three-awn grasses (*Aristida longiseta robusta*, *A. Pansa*, and *A. purpurea*), and the sand dropseed grasses (*Sporobolus flexuosus* and *S. cryptandrus*). These species are more common on the looser sandy soils of the grama type.

The seed habits of these grasses afford them an advantage in the revegetation of range areas that have been depleted by drought, overgrazing, or other cause. In years when good moisture conditions prevail in the spring, especially in April, substantial foliage growth results. When growing conditions continue favorable, which rarely happens, the three-awn grasses mature their seed by June 15. Under such conditions a second seed crop of these species is produced during the summer growing season of the same year. These grasses are good seeders, and seedlings become established in the same year the seed is scattered or in the year following, if favorable conditions prevail.

The growth and seed habits of the sand dropseed grasses are similar to the three-awn grasses except that they do not produce their better crops of seedlings until the first favorable growing season following a period of drought. This ability of the dropseed grasses to spring up from seed after drought is especially important because it enables them to establish themselves on sandy soils which have become loosened following the depletion of black grama through drought or overgrazing. The more abundant stands of seedlings come in on these depleted areas; in fact there is usually scant seedling establishment where the stand of black grama is dense.

The chief long-lived perennial weed associates are baileya (*Baileya multiradiata*), leatherweed (*Croton corymbulosus*), evolvulus (*Evolvulus pilosus*), *Hoffmanseggia* spp., woolly paperflower (*Psilostrophe tagetinae*), and silvery nightshade (*Solanum elaeagnifolium*). These species ordinarily occur sparsely scattered throughout the black grama type. They are all deep rooted and survive severe drought well, although they develop only scant foliage during such periods.

Snakeweed (*Gutierrezia sarothrae*),[6] a half shrub with growth characteristics similar to those of weeds, is a fairly long-lived plant which almost invariably invades areas that have been depleted of black grama by the persistence of overgrazing for several years. A vigorous stand of the species is one of the best indications of past or present overgrazing in the black grama type. Under favorable climatic conditions it produces abundant seed, resulting in many seedlings which become firmly established where the black grama stand is depleted. Black grama successfully competes with snakeweed if the range is conservatively grazed.

The short-lived perennial weeds most common in the black grama type are spectaclepod (*Dithyraea wislizeni*), and stickleaf, or "whitestem" (*Mentzelia multiflora*). These weeds do not live more than 2 or 3 years. The plants usually do not make much growth until shortly after the beginning of the summer rainy season. They occur in more or less abundance in the more nearly average years, are scarcely noticeable during protracted droughts, and spring forth in great abundance in the first favorable season. They compete somewhat with black grama for soil moisture during these periods.

The more prominent annual plants in the black grama type are several weeds including *Boerhaavia torreyana*, mouse-ear (*Tidestromia lanuginosa*), eriogonum (*Eriogonum* spp.), and six-weeks grasses (*Aristida adscensionis*, *Bouteloua aristidoides*, and *B. barbata*).

Many of the annual weeds make some growth during the late winter and early spring months, except in the extremely dry years. They make excellent growth during the very occasional unusually wet summer or moist, warm, late winter and spring. Ordinarily, however, their growth is dependent on late spring or summer rainfall. In most years when sufficient moisture is available the growth to maturity of annual weeds is more rapid than that of the perennials. The weed seeds, lying very close to the surface in the upper soil layer, are warmed by rising spring temperatures earlier than

[6] *G. sarothrae* is considered in this report to include *G. juncea*, *G. longifolia*, and *G. tenuis* in accordance with the treatment of Dr. S. F. Blake, composite expert of the Bureau of Plant Industry.

are perennial plant roots spread out some distance below the surface. As a result, germination and early growth are in advance of the appearance of the perennials. Ample precipitation during the fall and winter does not always bring weed growth, however, since low temperatures during the late winter and early spring may prevent growth entirely.

These annuals may make some growth even during drought. The scattered light showers that occur at such times are usually sufficient to germinate the seed and allow for some growth, often to maturity. When a favorable year follows a prolonged drought a luxuriant growth of annuals is generally produced, because of the lack of severe competition from the depleted stand of perennial grasses. These annuals produce some range feed in their early stages of growth and serve as protection against wind erosion until perennials take hold.

INFLUENCE OF PRECIPITATION

The natural habitat of black grama is normally one of low rainfall, high temperatures, high evaporation, and relatively severe winds. It is further subjected to marked variation in these factors from year to year and season to season, especially with respect to rainfall. Although the growth, maintenance, and revegetation of black grama vary to some degree with all of these climatic variations, the correlation between variations in rainfall and the response of black grama is noticeably high.

PRECIPITATION RECORDS

From long-time records taken prior to 1920, Jardine and Forsling [7] concluded that in southern New Mexico, in cycles of 8 to 10 years, there may occur 3 or 4 consecutive years during which precipitation is enough below its mean to cause conditions considered by stockmen as drought.

The monthly, seasonal, and annual rainfall for the Jornada headquarters for the period July 1, 1915, to June 30, 1927, and for South Well and West Well from July 1, 1918, to June 30, 1927, are given in table 1. The 12-month period from July 1 to June 30 of the following year is considered the rainfall year because of the influence of precipitation during this period on the maintenance, decline, and spread of the black grama stand from year to year and because the summer growing period which produces the main feed for the year ordinarily begins in July.

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[7] JARDINE, J. T., and FORSLING, C. L. RANGE AND CATTLE MANAGEMENT DURING DROUGHT. U.S. Dept. Agr. Bull. 1031, 84 pp., illus. 1922.

TABLE 1.—*Precipitation during the grazing year and the summer growing season, Jornada Experimental Range*

Grazing year	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	Summer season [1]	Year
HEADQUARTERS														
1915–16	1.40	1.91	1.55	0.00	0.00	[2] 0.25	0.25	0.47	0.70	0.05	1.45	0.00	4.86	8.12
1916–17	.90	.96	.72	2.63	.47	.19	.47	[3] T	T	.02	.39	.05	2.58	6.80
1917–18	.57	1.52	.25	.11	.16	.00	.78	.09	T	T	.05	.09	2.34	3.62
1918–19	1.53	2.88	.00	.96	1.71	.67	.00	.00	1.50	.83	.28	.11	4.41	10.47
1919–20	3.13	2.52	2.55	.64	.72	.50	.69	.42	.35	.03	.97	1.53	8.20	14.05
1920–21	1.50	3.28	.89	2.16	.20	.00	.17	.15	.25	.12	.00	1.00	5.67	9.72
1921–22	1.50	1.26	.73	.16	.17	.21	.30	.00	.00	.30	.00	.11	3.49	4.80
1922–23	.25	1.80	1.13	2.11	.43	.20	.38	1.16	.78	.29	.00	.05	3.18	9.18
1923–24	.68	1.53	1.74	.21	.57	1.49	.16	.11	.51	.15	.19	.11	3.95	7.45
1924–25	3.34	.32	.21	.30	.15	.42	.03	.28	.05	.02	.87	.11	3.87	6.10
1925–26	1.68	1.19	.89	1.50	.00	.31	.49	.05	1.40	.48	2.43	.06	3.76	10.48
1926–27	4.05	.38	3.20	2.63	.04	1.62	.02	.25	.47	T	.00	.08	8.53	13.04
Mean:														
1915–27	1.79	1.63	1.16	1.12	.38	.40	.31	.25	.51	.19	.55	.32	4.57	8.70
1918–27	2.06	1.68	1.26	1.19	.44	.00	.25	.27	.00	.25	.53	.42	5.01	9.54
SOUTH WELL														
1918–19	1.55	0.84	0.00	1.15	0.70	0.31	0.20	0.20	1.06	0.00	0.02	0.42	2.39	6.45
1919–20	1.75	1.63	1.29	.42	.60	.34	.42	.08	.15	.03	.56	1.64	4.67	8.91
1920–21	1.05	3.66	.57	1.83	.15	.00	.00	.11	.10	.06	.00	1.40	5.28	8.93
1921–22	1.69	.67	.79	.11	.23	.27	.57	.00	.07	.23	.00	.19	3.15	4.82
1922–23	.51	2.20	.98	1.03	.49	.19	.06	1.03	.97	.34	.00	.00	3.69	7.80
1923–24	.70	1.74	.38	.40	.57	1.11	.19	.07	.51	.00	.07	.00	2.88	5.80
1924–25	2.81	1.17	.28	.33	.43	.45	T	.09	T	T	1.38	.29	4.26	7.23
1925–26	1.03	1.20	1.87	.93	.00	.18	.53	.00	1.57	.91	2.09	T	4.10	10.42
1926–27	4.01	.25	3.48	2.61	.01	1.84	.03	.34	.51	.00	.00	.10	7.74	13.18
Mean	1.68	1.49	1.07	.98	.35	.52	.22	.21	.55	.17	.46	.45	4.25	8.17
WEST WELL														
1918–19	1.00	1.99	0.17	1.00	0.85	0.45	0.00	0.12	1.25	0.00	0.10	0.03	3.16	6.72
1919–20	2.86	.40	1.70	1.16	.79	.50	.53	.43	.18	.00	.52	2.16	4.96	11.23
1920–21	2.62	4.19	.63	1.95	.21	.00	.00	.00	.01	.00	.00	1.00	7.44	10.61
1921–22	3.87	1.10	.56	.67	.12	.22	.25	.00	.00	.36	.00	.03	5.53	7.18
1922–23	1.50	1.07	.49	1.79	.55	.13	.11	1.64	1.15	.46	.00	.00	3.12	8.95
1923–24	.24	2.65	.64	.39	.50	1.01	.11	.15	.42	.20	.24	.00	3.53	6.55
1924–25	1.40	.12	.30	.28	.13	.22	.04	.07	.09	.15	1.30	.00	1.82	4.10
1925–26	1.50	1.47	1.04	1.04	.00	.36	.55	.00	1.66	.71	1.98	T	4.01	10.31
1926–27	2.48	1.66	4.81	2.53	.12	2.03	.02	.23	.25	.00	.00	.04	8.95	14.17
Mean	1.95	1.63	1.15	1.20	.34	.54	.18	.29	.56	.21	.46	.36	4.72	8.87

[1] July, August, September. [2] Interpolated. [3] T=Trace.

A study of the data in table 1 shows that precipitation in the Jornada area is highly variable. The headquarters, South Well, and West Well are all less than 8 miles apart (fig. 1). Analyses made from this table show that the amount of precipitation varies significantly between (1) years, (2) the four seasons of summer, fall, winter, and spring, (3) the three stations, (4) years for the same season, and (5) years for the same station. While there is doubtless an influence on black grama in some degree of each of these significant variations in precipitation, the study has not been carried far enough to show conclusively the influence of each. In range management the stand and vigor of black grama in any one year are mainly influenced by the precipitation of the 12 months preceding, beginning July 1. The influence of the other variations on plant growth shows up only locally or in occasional years or seasons.

The average annual precipitation at the Jornada headquarters for the 12-year period of 8.70 inches, and the average for July, August, and September (the usual summer rainy season and the main growing period) of 4.57 inches, compare well with the long-time average annual precipitation of 8.57 inches and the summer-season average of 4.76 inches recorded at State College. The annual precipitation at State College ranged from as low as 3.94 in 1874–75 to as high as 16.13 inches in 1902–3, as compared to the low year on the Jornada of 3.62 inches in 1917–18 at headquarters and the high of 14.17 inches in 1926–27 at West Well.

During the 12-year period July 1, 1915, to June 30, 1927, according to the data recorded at the Jornada headquarters, the second, third, seventh, and tenth years were materially below the average annual precipitation for the 12-year period. Of the others, the fifth (1919–20) and the twelfth (1926–27) were materially above average in annual precipitation.

It is, of course, important to understand to what degree the general averages of precipitation during the 12-year period recorded at Jornada headquarters are representative of the long-term averages for this region. The records at State College and at other points in the Southwest indicate a general deficiency in precipitation for the period 1915–27. The average annual precipitation for the period July 1, 1915, to June 30, 1927, inclusive, at State College was 7.82 inches, or 8.8 percent below the long-time mean. The deficiency in average annual precipitation at El Paso, Tex., Elephant Butte Dam, and Deming, N.Mex., for the period 1915 to 1927 as compared to the long-time means for these stations, varied from 14.6 to 15.6 percent. The average deficiency for the four stations amounted to 13.2 percent for the period. It seems reasonable, therefore, to assume that the deficiency at Jornada headquarters from 1915 to 1927 was approximately 10 percent, or that the long-term mean precipitation at this station would be about 9.63 inches. On this basis, annual precipitation for 5 of the 12 years during which this study was conducted was above the computed mean—for 2 of them approximately 4 inches above; whereas for 7 years it was below the computed mean—for 5 of them 2 inches and more below.

For the 9-year period (July 1, 1918, to June 30, 1927) Jornada headquarters received an average annual rainfall of 9.54 inches; West Well, 8.87; and South Well, 8.17 inches. It is possible that the differences in rainfall between the several stations, as in the individual years, are more the result of uneven distribution of showers than a difference in the long-time mean annual precipitation. Ordinarily the summer rains in the semiarid region in which the Jornada range is located occur as showers covering a comparatively small area. In an occasional year, as in 1925–26, individual rains are more general and cover more extensive areas.

The average summer precipitation during the 12-year period from 1915–16 to 1926–27 at the headquarters ranch was 4.57 inches. From July 1, 1915, to June 30, 1927, there was an average deficiency in the summer precipitation at the State College station as compared to the long-time mean of 13.4 percent. At El Paso, Elephant Butte Dam, and Deming the summer deficiency based on years of complete records varied from 8.2 percent at El Paso, to as much as 17.7

percent at Elephant Butte Dam. The average deficiency for the four stations amounted to 13.1 percent. In view of the high deficiency at State College and Elephant Butte Dam, it appears reasonable to assume that the Jornada headquarters had a summer deficiency in these 12 years of at least 13 percent. Assuming that there was 13 percent deficiency, the long-term mean summer rainfall at the headquarters is 5.25 inches.

Thus in the 12-year period on the Jornada Experimental Range, only two growing seasons, 1919 and 1926, had 3 inches more rain than the computed long-time mean, and one other, 1920, had about one half inch more; the other years were below the computed mean. Of these, two groups of years are particularly significant—one of 5 years (1921–25) all approximately 1¼ to 2 inches below; and one of 2 years (1916–17) more than 2½ inches below the computed mean. These two groups of years represent low summer precipitation and uncertain plant growth. The summers of 1916 and 1917 were each more deficient in rainfall than any of the summers from 1921 to 1925, but the longer succession of dry summers in the latter period bred conditions more severe for plant growth.

To summarize, the relatively fair to good rainfall for several years prior to 1915 [8] was followed by deficient rainfall during the summer growing season or throughout the year on large areas of the experimental range annually from 1915 to 1918, inclusive. This dry period was followed by 2 years of favorable rains over most of the range. From the summer of 1921 until the spring of 1926, rainfall was again deficient, either during the summer season or year long, or both, over practically all parts of the range. This period of deficiency was followed by favorable rains, starting in the spring of 1926 and extending through the summer growing season of 1927. Rainfall at South Well and West Well was lower in most years than at the headquarters. It was much drier at these outlying stations in 1918–19; at West Well there was more rainfall in 1921–22 but less in 1924–25 than at the headquarters.

PRECIPITATION AND PLANT GROWTH

Because of the fact that on the average approximately 90 percent of the range forage production in southern New Mexico is concentrated in the summer growing season and only 10 percent occurs in the spring, it is very important to study the influence on growth and reproduction not only of the quantity of rainfall but also of its seasonal distribution. This influence is apparent in the period and volume of growth of the important grasses each year, the density of the stand, the number and size of the tufts, the methods of reproduction, including the formation and the germination of seed and the establishment of seedlings, the lateral spread of the tufts, and the formation of stolons and establishment of sets. In these connections it is important to observe not only the precipitation during the particular season in question, but also the possible effect of excessive drought or rainfall during the preceding years.

As already indicated, rainfall of sufficient quantity to start appreciable growth of black grama does not occur in most years until

[8] LINNEY, C. E., and GARCIA, F. CLIMATE IN RELATION TO CROP ADAPTATION IN NEW MEXICO. N.Mex. Agr. Expt. Sta. Bull. 113, 132 pp. 1918.

July, when the normally heavy and frequent storms of July, August, and September are sufficient to make growth continuous during those months. Summer growth may start, however, in the normally dry period of May and June if sufficient rainfall occurs at that time, as in 1920 and 1926. In 1920, because of copious rains the latter part of May, forage started to grow the first week of June and continued growing throughout June, July, and August. In 1926 the exceedingly heavy rainfall in May brought early growth, which the deficiency in June retarded. Growth started up again with heavy rainfalls in July but was once more arrested by a deficiency in August. Such uneven seasonal rainfall, if abundant, as it was in 1926, produces a substantial forage crop.

The summer of 1924 is an example of the influence of unsatisfactory distribution of moisture during the summer. The rainfall of that summer occurred as heavy showers during July. This started good growth but was followed by a protracted dry spell during which there was not sufficient precipitation to maintain growth. When adequate summer rains do not start until the first of August or later, as in the summers of 1917, 1922, and 1923, the growing season is materially shortened, resulting in a greatly reduced forage crop. This is especially true when a late season is accompanied by deficient rainfall.

Plant growth is also affected by uneven geographical distribution of rainfall. For example, in the summer of 1919, in contrast with the even distribution of rainfall and the good growth which occurred over most of the range, the West Well area suffered a considerable setback. An excellent rain the first week of July and good moisture conditions during that month started forage growth at least one week earlier than on the other parts of the range, but by the end of August forage growth had practically ceased in that part of the range because of the scant precipitation locally in that month. Rainfall in September improved conditions only slightly. The uneven distribution of rainfall in a season when rainfall was not abundant seriously reduced the volume of growth and maturity of the vegetation near West Well.

During the 12-year period for which precipitation and growth records were taken on the Jornada range only 3 years had sufficient winter and spring moisture to encourage early spring growth although in these years such growth was appreciable. It is obvious, therefore, that winter-spring precipitation cannot be depended upon to produce a substantial forage crop in southern New Mexico. On the other hand the unusually dry winter and spring of 1921–22, which were accompanied by high winds, serious wind erosion and sand deposition, had a disastrous influence on the stand of black grama.

HEIGHT GROWTH

Height growth was found to be a useful index to relative vigor and volume production of range grasses in different years. Black grama flower stalks on the ungrazed plots on the Jornada averaged 35.2 cm. (13.9 inches) in height from 1917 to 1927, inclusive. As shown in table 2 there was a rather direct relation between summer rainfall and height growth. It was found that a summer growing season with precipitation much above the average resulted in a greater than average height growth, while a deficiency in precipitation during this period resulted in a stunted height growth for that season regardless of the conditions which prevailed during the previous year. An added inch of summer precipitation results in an average increase of height growth of 3.6 cm.

TABLE 2.—*Relation of rainfall during current summer[1] season at headquarters and South Well to average height growth of black grama flower stalks on areas continuously protected from livestock grazing, 1917 to 1927*

Year	Average rainfall	Average stem height	Year	Average rainfall	Average stem height	Year	Average rainfall	Average stem height
	Inches	*Centimeters*		*Inches*	*Centimeters*		*Inches*	*Centimeters*
1917	[2] 2.34	[2] 33.0	1921	4.52	30.3	1925	5.28	33.3
1918	3.49	[2] 22.0	1922	3.41	28.3	1926	10.42	50.0
1919	6.44	42.7	1923	3.74	28.0	1927	6.28	38.0
1920	7.82	50.3	1924	4.06	31.7	Average	5.25	35.2

[1] Covers actual current growing season, including rainfall in May and June when this was effective.
[2] Average on one area only.

PLANT AREA

The marked variation in precipitation characteristic of southern New Mexico has a very definite effect upon the stand of black grama. The tendency of a deficiency to reduce plant vigor and tuft area is no less evident than that of an above-average supply to build up plant vigor and area. The more pronounced changes in plant area ordinarily followed when one or other of the conditions prevailed from the beginning of one to the end of the subsequent summer growing season or longer, although intervening seasonal differences also have their effect in a smaller degree. This is shown in table 3 in plant area on the representative quadrats protected from grazing on the Jornada Experimental Range, in relation to the important summer and annual precipitation in their vicinity during the period 1915–27.

TABLE 3.—*Changes in area of black grama per square meter, at 1 inch above the ground, on ungrazed quadrats, in relation to precipitation of current summer and previous year at headquarters and South Well*

Year	Average precipitation		Average plant area	Year	Average precipitation		Average plant area
	Previous year[1]	Summer[2]			Previous year[1]	Summer[2]	
	Inches	*Inches*	*Cm²*		*Inches*	*Inches*	*Cm²*
1915	[3] 10.77	[3] 4.80	548.2	1923	8.49	3.42	60.0
1916	[3] 8.12	[3] 2.58	537.1	1924	6.62	4.06	125.7
1917	[3] 6.80	[3] 2.34	461.7	1925	6.66	3.96	100.7
1918	[3] 3.02	3.40	337.4	1926	10.45	8.14	283.4
1919	8.40	6.44	227.4	1927	13.41	6.28	277.9
1920	11.48	5.48	433.4				
1921	9.33	3.32	534.3	Average	8.39	4.44	310.8
1922	4.81	3.44	107.6				

[1] Precipitation for previous year covers July 1 to June 30.
[2] Summer rainfall covers July, August, and September of current growing season.
[3] Rainfall record for headquarters only.

The stand of black grama was unusually good in 1915. It had recovered from the severe drought of 1907 to 1912, partly because of the favorable climatic conditions of 1913, 1914, and 1915, and partly owing to the practice of conservative grazing during some of that time. A decline in area as a result of continued drought during 1916, 1917, and 1918 was followed by a partial recovery under the more favorable growing conditions of 1919 and 1920, and another, even more severe decline of longer duration as a result of deficient rainfall in 1921 and succeeding years. With the aid of the unusually favorable moisture supplies of 1926 and 1927, some areas recovered slightly and others more completely.

Since the main growth of black grama is produced during the summer months, the rainfall during that period might be expected to have the greatest effect on the change in area of plant cover in that year as compared to the area of the previous year. Actually, however, the current summer rainfall in itself has no significant effect on such change. The lack of influence of current summer rainfall is indicated by the practically negligible average decrease in plant area between 1915 and 1916, even though the summer precipitation of 1916, including that of June, was much below normal. Also, summer rainfall much above normal in 1919 failed to offset the loss of vigor from previous drought.

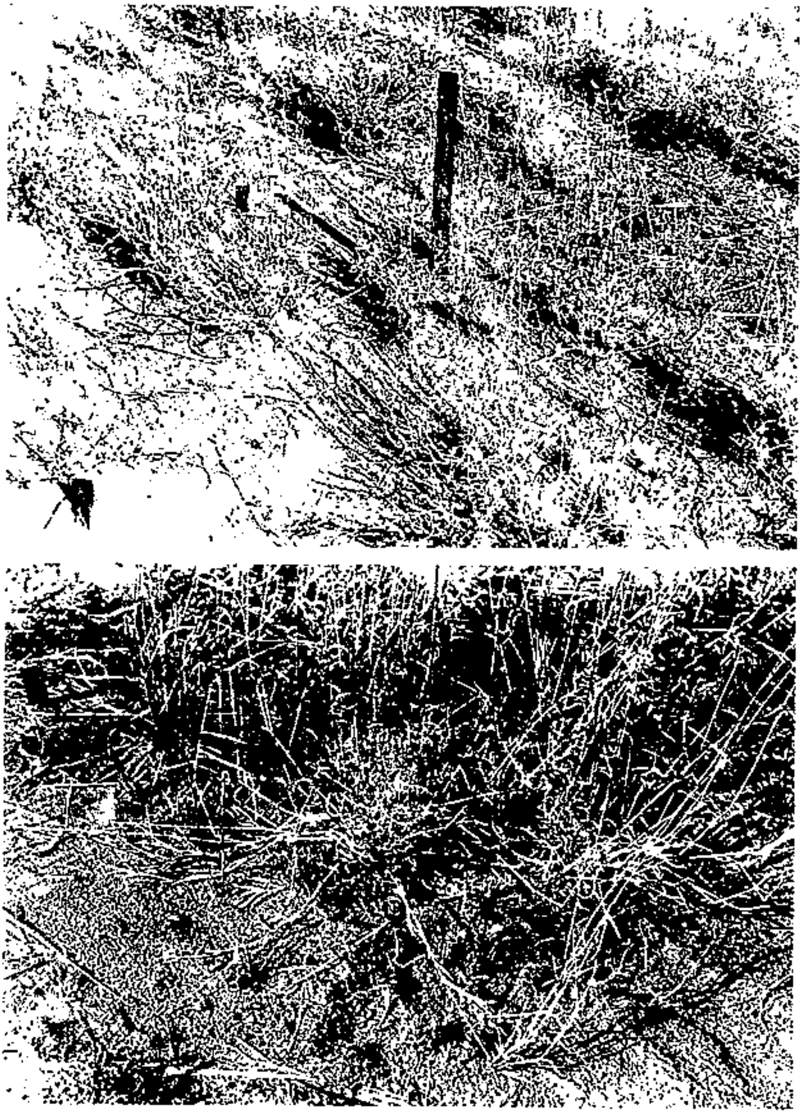
Much depends upon the vigor of the vegetation as a result of growing conditions during the preceding year, particularly the preceding summer and spring.

The influence of the preceding year's precipitation is very evident in the records of change of plant area. An added inch of precipitation during the previous year results in an average increase of plant area of about 37 cm^2 per square meter, and if this added inch be concentrated in the previous summer, with a constant precipitation during the rest of the year, the result is an average change of 56 cm^2. These findings are of the utmost significance to range management on semidesert ranges where black grama is or should be dominant.

Illustrations of the influence of previous years' precipitation on change in plant area are as follows:

Following a deficiency in rainfall of about 1.9 inches at headquarters in 1916–17, an average decline of about 14 percent in plant cover occurred between the fall of 1916 and that of 1917. This was followed by a further decline in 1918 of nearly 27 percent following the unusual drought of 1917–18. A still further decline of 33 percent after slightly below normal rainfall in 1918–19 reflected a cumulative loss of vigor as the result of drought. Again with only 4.81 inches on the average for the year 1921–22, and unusually scant rainfall after September 1921, an extremely severe decline in plant cover occurred, part of which, however, was due to loss of cover through erosion by wind of the sandy soil from roots and, more particularly, to deposition of wind-blown sand in plant tufts during the spring of 1922. Contrasted to these declines are increases in 1920, 1921, and 1926 following years of above-average precipitation.

There is doubtless a combined effect of inadequate current summer and preceding year's rainfall, especially as indicated by the declines in stand in the years 1917, 1918, 1922, and 1923. In addition to the effect of the extremely high winds and shifting sand in the spring,



[illegible] ... was heavy enough to furnish sheep or cattle feed for all but the first 3 years.

the vigor of the plants was so low and the competition for the inadequate soil moisture of 1922 so great from the heavy stand of black grama attained in 1921 that whole tufts died out. Although the year 1922–23 was only slightly below average in annual rainfall, the dry summer growing season and the extremely low vigor of black grama caused a further decline in 1923.

The favorable influence of high rainfall both in the preceding year and during the current summer is especially shown by the large increase in 1920 and in 1926 as compared to the years immediately preceding. In 1920 the vigor of the vegetation was built up by the good moisture supply of the previous summer, and the copious rainfall which started in May and continued throughout August brought about an excellent gain in plant area.

NUMBER AND SIZE OF TUFTS

The amount of vegetation on the ground and the number and size of tufts of black grama in relation to available moisture appears to be of importance in maintaining or improving the stand or even in causing a decline in vegetative cover. The material decline in stand between 1921 and 1922, accompanied by the dying out of whole or large parts of tufts, as a result of inadequate moisture to sustain the stand, has already been referred to. In general, favorable rainfall tends to build up larger tufts on ungrazed range, which ordinarily grow together to form a smaller number of tufts on any given area. Upon the gradual depletion of the available soil moisture during a drought, there is first a drying out in the center of the large tufts, which leaves a ring of small tufts on the outside of the dead center. If the drought period continues, the smaller tufts are further depleted and some of them die.

Table 4, presenting the variation in number and size of black grama tufts on several representative areas ungrazed by livestock, shows that there was a breaking up of the large tufts into smaller tufts in the dry year of 1918 and a still further contraction, with general depletion of stand, into 1919. Similarly in 1922 and in 1925, dry years, tufts were smaller than in the years preceding. In years of good rainfall, tufts grew together again, but, as shown by intensive study of plant areas on the ground, the greatest increase took place out from the edge of the original tufts in a direction where there was very little interference from dead crown and root material and less competition by other tufts for available soil moisture. With continued favorable growing conditions, the tuft area increased rapidly. Such coalescing of tufts occurred especially in 1920, 1921, 1924, 1926, and 1927. Figure 2 shows the variation in size and number of tufts as the result of breaking up of tufts and of subsequent expansion of tufts on a representative quadrat. There was a breaking up and increase in number on this quadrat during the dry period from 1916 to 1919, an expansion in size and reduction in number during the favorable conditions from 1919 to 1921, and a severe dying out from extreme drought conditions from 1921 to 1923, followed again by another expansion in size and reduction in number during the period from 1924 to 1926.

TABLE 4.—*Variation in number and size of black grama tufts, exclusive of new stolon areas, on representative ungrazed quadrats* [1]

Year	Total average area of tufts	Average number of tufts	Average size of tuft	Year	Total average area of tufts	Average number of tufts	Average size of tuft
	Cm²	*Number*	*Cm²*		*Cm²*	*Number*	*Cm²*
1916	579.0	40.0	13.2	1923	20.5	9.2	3.2
1917	523.5	35.5	14.9	1924	104.8	6.8	15.4
1918	398.5	44.0	9.1	1925	78.0	10.2	7.6
1919	243.2	80.8	3.0	1926	228.5	9.5	24.1
1920	432.0	60.5	7.1	1927	211.5	8.2	25.8
1921	462.2	50.2	9.2				
1922	51.5	14.5	3.6	Average	294.3	31.2	9.4

[1] Data averaged from 2 quadrats for 1916, 1917, and 1918, and averaged from 4 quadrats for all other years.

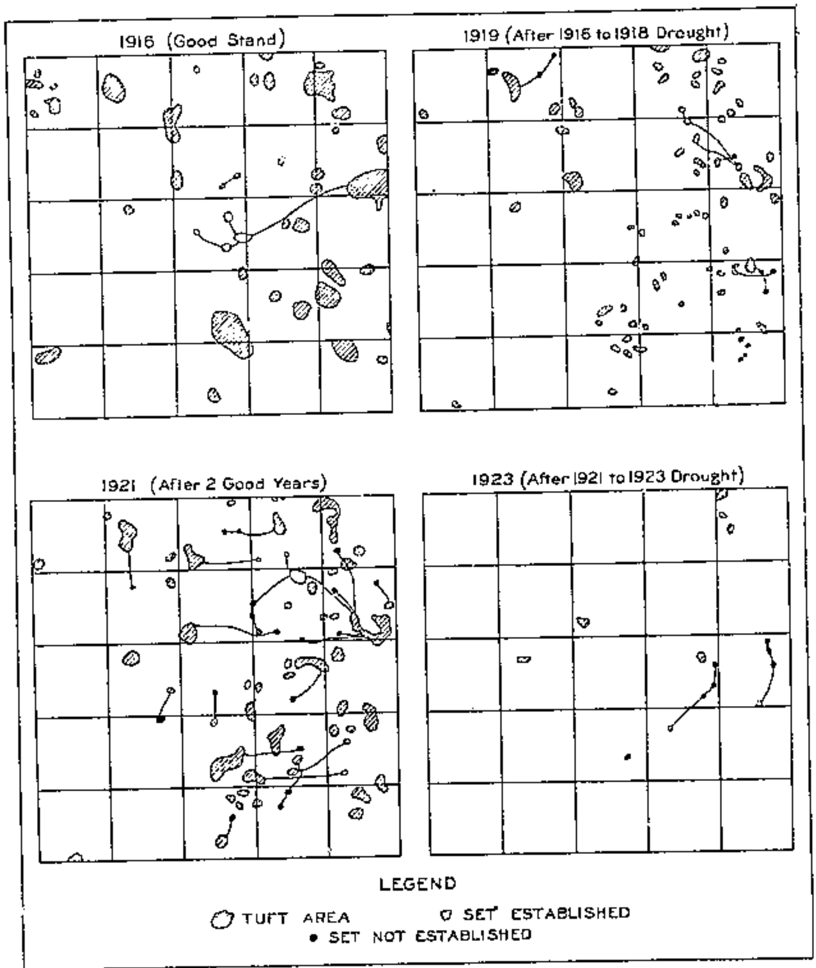


FIGURE 2.—Variation in size and number of black grama tufts on an ungrazed quadrat over an 8-year period.

PRECIPITATION AND REVEGETATION

Where unfavorable climatic conditions or overgrazing or a combination of the two have destroyed almost completely the stand of native grasses, further usefulness of the range is dependent upon the ability of the remnants of the stand to revegetate. This, in turn, will largely depend upon the influence of rainfall upon the several processes or methods of revegetation of black grama and its associated species.

Table 5 gives the germination percentage of the seeds of black grama and its associates during several years, by laboratory test, together with the growing conditions in the summers the seed was produced. In spite of the extremely low viability of black grama seed as a general rule, a fair amount of viable seed is produced occasionally, as in 1917 and 1923. Observations during the dry years following these seed crops failed to show any black grama seedlings, owing doubtless to the effect of drought at the time of germination. In 1919 when conditions were most favorable for a forage crop little viable seed was produced. Further studies at the Jornada have shown that in some very favorable growing years, when viable black grama seed was produced, seedlings were found the following year.[9] As a general rule, however, a large percentage of the florets fail to develop well-matured seed.

TABLE 5.—*Germination percentages of seed of black grama and associated range grasses under different summer growing conditions, 1917–26* [1]

Year	Summer growing conditions	Germination		
		Black grama	Red three-awn	Sand dropseed
		Percent	*Percent*	*Percent*
1917	Poor (droughty)	27.5	40.0	2.0
1919	Excellent	10.5	82.0	.0
1920	Excellent, but seed maturity poor	2.0	65.0	.0
1921	Fairly good	----	20.0	.0
1922	Poor (droughty)	4.0	7.0	.0
1923	Fairly good	40.7	90.6	3.0
1924	Poor	.0	----	.0
1925	Fairly good	2.0	59.0	1.0
1926	Intermittently good and poor	2.0	[2] 17.0 55.0	[2] 42.0 75.0

[1] Tests for 1917–21 were made by the Bureau of Plant Industry; those for 1922–25 by the New Mexico College of Agriculture and Mechanic Arts; and that for 1926 by Carola V. Jackson, of the University of Chicago.

[2] Two crops were produced in 1926. The hard seed coats of the sand dropseed were pricked to approximate the abrasive action of the wind-blown surface of the sandy soil in which the seed lies dormant during drought. This treatment accounts for the great increase in germination percentage.

Uneven distribution of precipitation during the summer growing season may prevent the maturity of what appears to be the making of a good seed crop. In 1920, for example, favorable growing conditions existed during June, July, and August, and during these months black grama made excellent foliage and flower-stalk growth, but in September the rather scattered light showers that fell allowed the plants to dry up and only a poor seed crop matured. The uneven

[9] CAMPBELL, R. S., and CANFIELD, R. H. ANNUAL REPORT, JORNADA RANGE RESERVE, 1927. (Mimeographed.)

distribution of rainfall in 1926, which resulted in very rapid growth of black grama in May, retardation during June, revival of growth during July, and drying up of the grass during August, greatly interfered with the production of flowers and their fertilization and but little seed was produced that year.

NATURAL RESEEDING

The production of black grama flower stalks and flowers varies from a luxuriant crop during extremely favorable growing seasons to practically none during drought. However, only a few black grama seedlings in occasional years were observed during the period 1915 to 1927 on the Jornada Experimental Range. This scarcity is doubtless due to the failure of the species to mature its seed satisfactorily and to the poor viability of that seed. Several grass and weed species associated with black grama have considerable advantage over it in the production and viability of seed and establishment of seedlings. Of these species, red three-awn and the sand dropseed grasses are typical. Good seedling stands of the three-awn grasses, the sand dropseed grasses, and numerous weeds became established in the more favorable years, especially in years of above-average precipitation following drought. Red three-awn produces and matures its seed crop earlier in the season and more rapidly than black grama. It matures some viable seed every year regardless of rainfall, and in favorable years yields a large crop generally with a high degree of viability (table 5). In the erratic growing season of 1926 the plants under observation produced two seed crops. An especially good stand of seedlings became established in 1920, following the excellent seed crop of 1919; these increased rapidly in area. Red three-awn is not so long-lived a plant as black grama. It usually lives only 4 or 5 years, and in droughty years, such as 1922, it may be practically killed out. Therefore, only its ability to produce viable seed in abundance and to become reestablished through seedlings enables it to hold its place as an important forage plant.

During favorable summer growing seasons the sand dropseed grasses yield very large crops of seed, and ordinarily some seed is produced every year. Judging by laboratory germination tests made in the years up to 1926 (table 5), it might have been supposed that very little of this seed was viable. In that year, however, Jackson [10] employed a new method in testing this seed. The unusually hard seed coat was pricked or abraded, to approximate the effect of the constant rubbing given dormant seed by wind-blown sand during drought. The results amply confirmed the theory that it is this abrasive action of the sand which enables the seed to germinate when the first favorable growing conditions occur. Further substantiation is found in the fact that in years following drought good stands of sand dropseed seedlings invariably appear, especially in rather loose, exposed sandy areas. Even though there was only a scant stand of plants on the range from 1918 to 1922, inclusive, sufficient seed was available after 2 years of drought to start a stand of seedlings during the short intervals of good precipitation in 1923.

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[10] JACKSON, C. V. SEED GERMINATION IN CERTAIN NEW MEXICO RANGE GRASSES. Bot. Gaz. 86: 270–294, illus. 1928.

The climatic conditions of 1926 brought an exceedingly good seedling crop as well as a good seed crop on older plants. These grasses are of importance both as forage and because of their ability to reestablish themselves quickly after a drought. Their exceedingly rapid increase in density aids also in holding the loose, drifting sand, and thus prepares the way for the reestablishment of the slower black grama.

LATERAL SPREAD BY TILLERING OF BLACK GRAMA TUFTS

Since black grama is so uncertain in its habits of seeding and germination, revegetation by lateral spread and by stolons must be depended on for its maintenance and improvement. The increase in area by lateral spread during a given growing season depends chiefly upon the vigor built up in the preceding year from favorable climatic conditions. It is also dependent upon the intensity of grazing and the density of the vegetation. In favorable growing years the increase in area by this method may be nearly 200 percent if the stand is thin at the start.

In 4 different years from 1915 to 1927, as shown in table 4, the black grama range was improved through lateral spread of the tufts. Marked increases resulted in 1920 and 1926 as compared to the preceding year from the increased plant vigor built up by the favorable precipitation of the preceding growth year and favorable growing conditions in the current summer. A small increase was shown in 1921 even with subnormal summer rainfall that year, doubtless as a result of the accumulated vigor from the favorable conditions of the 2 preceding growth years. From the very low plant areas of 1923 there was a fairly high percentage increase in 1924, possibly owing to the ability of the scant stand of vegetation to make effective use of available rainfall during this period, even though this was average or below. In general, the rainfall in other years was insufficient to bring about any noticeable spread of tufts.

A study of the records of individual quadrats indicates that the percentage of increase by lateral spread was influenced by the stand of black grama at the beginning of each period of increase. The greatest increases occurred on the quadrats of least area. Probably there was a greater supply of soil moisture available for each individual plant tuft. Thus, on two quadrats, the area of black grama varied from 192 to 194 cm^2 in 1919 and showed an average increase by tillering of 129 percent in 1921. Two others, which in 1919 had the greatest area of black grama (266 and 321 cm^2), increased only 64 percent in the same period. Again, in 1925, the area of black grama declined to an average of 44 cm^2 on two low-density quadrats. By the close of the 1926 season these two showed an average increase of 267 percent. The other two quadrats, with 82 and 141 cm^2 in 1925, had increased only 163 percent by the fall of 1926. In none of these cases did a high-density quadrat have as great an increase as a low-density quadrat.

REVEGETATION BY STOLONS FROM OLD TUFTS

The other important method of natural reproduction or revegetation of black grama is by stolons. The record of average production of stolons and the establishment and maintenance of sets for representative areas from 1915 to 1927 is shown in table 6.

TABLE 6.—*Revegetation by stolons of black grama on ungrazed areas*

Year	Average on ungrazed quadrats				Year	Average on ungrazed quadrats			
	New stolons	Rooted sets present	Area of sets	Area increased		New stolons	Rooted sets present	Area of sets	Area increased
	Number	*Number*	Cm^2	Cm^2		*Number*	*Number*	Cm^2	Cm^2
1915	6.0	9.0	27.0	-------	1923	0.8	0.2	0.8	[1]
1916	2.0	8.0	21.5	[1]	1924	.8	1.0	3.0	2.2
1917	3.5	9.5	32.0	10.5	1925	9.0	6.2	11.2	8.2
1918	11.0	5.5	15.5	[1]	1926	20.2	22.0	78.5	67.3
1919	8.0	3.5	8.5	[1]	1927	17.8	17.8	91.8	13.3
1920	31.8	22.2	42.0	33.5					
1921	18.8	14.2	52.0	10.0	Average	10.7	9.3	29.7	-------
1922	2.8	1.5	2.8	[1]					

[1] Decrease in area.

The production of flower stalks or culms that eventually become stolons is largely limited to years of average or better than average rainfall, although a small number may be produced in seasons of below-average precipitation. Ordinarily, the year of favorable growing conditions required for new sets to be produced must be followed by another favorable year for the sets to become rooted. For example, in 1919 an excellent crop of flower stalks was produced, some of which bent over sufficiently to become stolons, and a large number of unrooted sets developed at the nodes. Of these a relatively small number, mostly near the ends of the stolons, became rooted that season. During 1920, which also was a favorable year, the formation of stolons continued and, owing to the increased weight of new foliage growth at each unrooted set, many of both years' sets took root and became established. An occasional 1920 flower stalk also became a stolon. Some of the 1920 sets succumbed in 1921 because of poor root systems or competition from plants, but other sets became better established and increased slightly in area. Another excellent crop of stolons was produced in 1926 in spite of a very small number of old tufts; and 1927 was also favorable for the production and establishment of new sets. The greater increase in area of established sets in 1926 and 1927 as compared to 1920 and 1921 was probably the result of less interference from a greatly depleted stand of old tufts.

Apparently rainfall did not influence the manner in which the stolons either extended out radially from the base of the tuft along the surface of the ground or bent over from different parts of the tuft as shown in figure 3. However, the variation in the length of the stolons—from 10 to 50 cm—depends largely upon rainfall.

The number of stolons per tuft varies from 1 to 9, and there appears to be no relationship between the size of a black grama tuft and the number of stolons produced. It is further apparent that a high density of black grama is not necessary for the formation of a large number of stolons and establishment of sets; for example, a good number of stolons were produced and sets established with a relatively low density in 1926 and 1927.

Measurements made on one large tuft in 1920 indicate that up to a certain point the number of established sets increases with the distance from the parent tuft. Six percent of the established sets were within a distance of 7 cm of the tuft, 28 percent were 7 to 10 cm from the tuft, 58 percent 10 to 20 cm, and 8 percent beyond 20 cm. Further checks of other tufts indicated that similar percentages would generally hold true.

Old black grama tufts competed somewhat with the new sets, but the competition was not serious enough, with the stand present during the period of the study, to retard the increase of the established new sets by lateral spread, except in the drier years. In a large number of instances the old tuft and the new plants from stolons grew together and formed a large irregular tuft. As shown in figure 4 some established new plants eventually have a greater area than the original parent tuft. Generally such sets are established a sufficient distance from the old tufts to enable them to spread rapidly without much competition from the older plants.

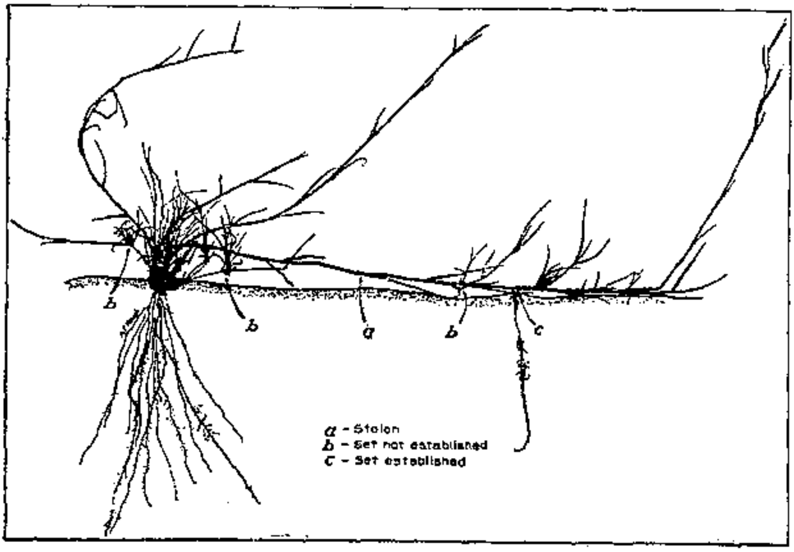

FIGURE 3.—Method of revegetation of black grama by stolons.

The manner in which the disastrous effect of drought on the maintenance of new plants established from stolons is aggravated when tufts are many and density is high is clearly indicated by the heavy mortality during the winter, spring, and summer of 1922. Only a few sets survived the drought which began in 1921 and ended in 1925. Some of the survivors, however, produced stolons in 1926 and 1927 from which new plants originated.

This method of revegetation is chiefly of value in that it makes it possible for black grama to establish new plants at some distance from old established tufts, with the result that the increase in area is greater than would be possible from lateral spread of old tufts alone.

INFLUENCE OF GRAZING INTENSITY ON BLACK GRAMA

In order to determine the degree of utilization of black grama range that will give the best economic use and at the same time perpetuate the range, it is important to consider the specific influence of different degrees of use upon black grama and its important associated species. This is even more necessary in years of drought when area of black grama may fall as low as 10 or 11 percent of the maximum stand, and 20 percent of the average over a 13-year period, and when volume of growth may also be seriously reduced.

In earlier investigations on the Jornada, Jardine and Hurtt[11] compared conditions on the experimental range conservatively grazed for several years with those on unfenced public range, originally similar in character, and found on the uncontrolled range that serious overgrazing had extended to a distance of 4 miles from

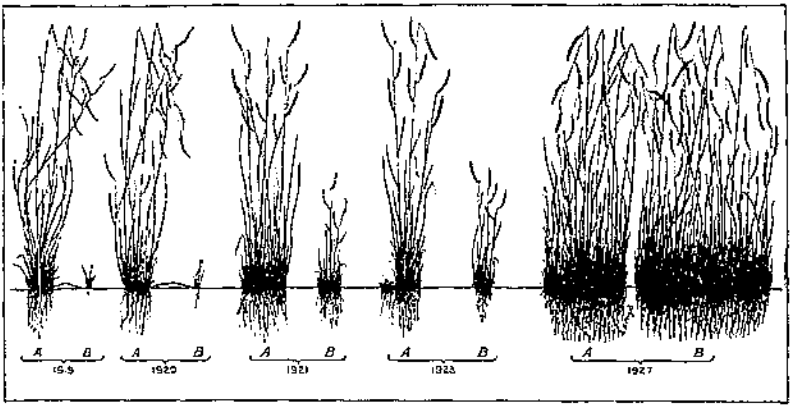

FIGURE 4.—Progress of revegetation by stolons: *A*, original black grama tuft; *B*, black grama plant from stolon.

permanent watering places. The study showed that the combined area of black grama, three-awn, and sand dropseed grasses at one half mile from watering places on the experimental range was equal to that approximately 4½ miles out from water on the unfenced range. Beyond these respective distances there were no differences in plant area. On the outside range black grama alone failed perceptibly within 3¾ miles of water and was gone completely within one half mile. At 1 to 2 miles on the open range the plant area was not over one third of the normal area on the experimental range.

Jardine and Forsling[12] found that black grama, where it was being seriously overgrazed, declined in area in time of drought to 18 percent of the area on similar ungrazed range, implying an extreme shortage in the forage crop. They found the grazing capacity of the overgrazed range prior to drought to be approximately 82 percent of that of similar fenced range that had been lightly grazed during the summer and slightly undergrazed for the year as a whole during

[11] JARDINE, J. T., and HURTT, L. C. INCREASED CATTLE PRODUCTION ON SOUTHWESTERN RANGES. U.S. Dept. Agr. Bull. 588, 32 pp., illus. 1917.

[12] JARDINE, J. T., and FORSLING, C. L. See footnote 7, p. 10.

a period of 3 years. During drought the overgrazed range declined in grazing capacity to 51 percent of the similar fenced range. In addition to the reduction in grazing capacity on the overgrazed range, the shortage of forage resulted in excessive losses of livestock from starvation, in the stunting of young animals, and in greatly reduced calf crops.

INFLUENCE OF CONSERVATIVE GRAZING

The results obtained over the 13-year period from 1915 to 1927 indicate clearly that forage production on black grama range may be maintained under conservative grazing as well as or better than under complete protection from grazing (pl. 2, *C*). In dry years the range feed on many of the conservatively grazed areas was utilized to the point of slight overgrazing but in years with average or better growing conditions utilization by the end of the grazing year seldom exceeded 80 to 85 percent of the black grama foliage produced each year. Under these conditions the grass stand held up as well as or better than on the ungrazed check areas where weather alone was the chief influencing factor.

HEIGHT GROWTH

The height growth of black grama under conservative grazing averaged 34.7 cm (13.7 inches) from 1919 to 1927, inclusive—only slightly less than the average of 37 cm (14.6 inches) on ungrazed areas for the same period. As shown in table 7, this average relationship is generally typical. The considerably lower heights in the dry years of 1922 and 1924 are probably due to the fact that the use of the range in these years amounted to a slight overgrazing. There was, however, no sustained effect of the heavy grazing in these bad years.

TABLE 7.—*Average height of black grama stems under conservative grazing and on ungrazed range*

Year	No grazing	Conservative grazing	Year	No grazing	Conservative grazing	Year	No grazing	Conservative grazing
	Cm	*Cm*		*Cm*	*Cm*		*Cm*	*Cm*
1919	42.7	40.1	1923	28.0	33.7	1927	38.0	36.4
1920	50.3	47.9	1924	31.7	21.9			
921	30.3	28.5	1925	33.3	40.3	Average	37.0	34.7
1922	23.3	16.6	1926	50.0	46.9			

PLANT AREA

In most years, as shown in table 8, there was little difference between the yearly fluctuations in plant area on conservatively grazed range and on ungrazed range—the years 1918, 1922, 1923, and 1924 being the notable exceptions. The stand of black grama on the conservatively grazed range never reached as great an average area in the maximum years as on the ungrazed range nor dropped so low when the effects of drought were most severe. For the 13 years as a whole the average density of black grama was practically the same on conservatively grazed range as on the ungrazed range. The extreme dry weather in the winter, spring, and summer of 1922 that caused a severe decline on the ungrazed range had less effect on the grazed range except for several localities that had unusually heavy stands of black grama. In the fall of that year the grazed exceeded the ungrazed range in area of black grama by 38 percent. From then until 1927 the black grama on the conservatively grazed range was more vigorous and the stand was maintained at a higher point. Rapid improvement was evident during 1926 and 1927 under very light grazing.

TABLE 8.—*Average plant area of black grama on conservatively grazed and ungrazed areas, 1915–27*

Year	On ungrazed range	On conservatively grazed range		Year	On ungrazed range	On conservatively grazed range	
		Area	Comparison with ungrazed range			Area	Comparison with ungrazed range
	Cm²	*Cm²*	*Percent*		*Cm²*	*Cm²*	*Percent*
1915	548.2	507.0	92.5	1923	60.0	156.6	261.0
1916	537.1	494.6	92.1	1924	125.7	198.8	158.2
1917	461.7	387.5	83.9	1925	106.7	150.4	141.0
1918	337.4	213.0	63.1	1926	283.4	336.5	118.7
1919	227.4	194.6	85.6	1927	277.9	475.2	171.0
1920	433.4	365.8	84.4	Average	310.8	312.6	100.6
1921	534.3	435.0	81.6				
1922	107.6	148.2	137.7				

REVEGETATION BY NATURAL RESEEDING, LATERAL SPREAD, AND STOLONS

The failure of black grama to reseed naturally under conservative grazing could hardly be attributed to this use of the range, since in favorable growing seasons the production of flower stalks was not materially hindered thereby. Failure was due rather to the inability of black grama, even on ungrazed range, to mature seed, as well as to the poor viability of the seed.

Natural revegetation by lateral spread was the most effective means of increasing the area of black grama on the conservatively grazed range. There were three 2-year periods of increase in area by lateral spread, culminating, respectively, in 1921, 1924, and 1927, and these corresponded essentially to similar increases on ungrazed range except that the black grama stand on the ungrazed range decreased slightly in 1923 and 1927. This indicates that as rapid recovery from drought may be expected under conservative grazing as under no grazing.

In general, revegetation by stolons was not as effective on grazed as upon ungrazed land, either in good years or poor years, but, nevertheless, it remains an important means of restoring, in favorable growing years, the stands that have become depleted by drought, and thereby of increasing the black grama on conservatively grazed ranges, as is shown in figure 5.

Under conservative grazing some flower stalks remained to become stolons. Likewise the new sets that developed on the stolons eventually became firmly established and in favorable years made sufficient foliage growth to develop the vigor of the new plants and later to increase materially in area. As has been previously shown, drought seriously affects the newly established sets on all areas, but it is very evident that conservative grazing, although it somewhat hinders revegetation by stolons, will, nevertheless, permit the building up of a depleted stand in favorable growing years.

HEAVY OVERGRAZING YEAR AFTER YEAR

The effect of heavy overgrazing year after year upon the stand of black grama was fivefold: (1) The existing stand of black grama rapidly broke down and eventually died; (2) natural revegetation was seriously handicapped and reduced because of the low density and poor vigor of the old plants and excessive trampling of new plants; (3) drought losses were intensified; (4) competition from inferior perennial grasses and weeds increased; and (5) a marked reduction appeared in the annual forage crop. The effects of such a grazing practice on livestock production are evidenced in a reduced grazing capacity of the range and the poor condition of the livestock, which in turn seriously reduce the calf crop, increase

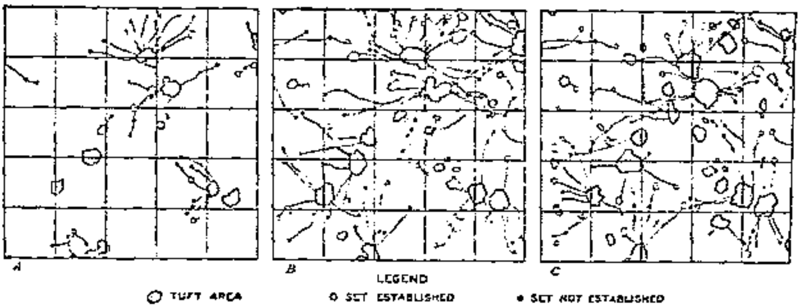

FIGURE 5.—Revegetation of black gama by stolons on a conservatively grazed range on quadrat N 6; *A*, 1925; *B*, 1926; *C*, 1927.

losses from starvation, and allow no provision for reserve feed in critical drought periods.

The average height growth of black grama was very much reduced by continued heavy overgrazing. In dry years it did not exceed 20 percent of the height growth on the ungrazed range, and in more favorable years it was barely 75 percent. Furthermore, in drought years, the forage crop is often completely utilized shortly after the close of the summer growing season.

The effect of heavy overgrazing year after year on the stand of black grama is shown in plate 2, *A* and *B*. In 1915, following several years of favorable growing conditions, black grama on continuously overgrazed range occupied an average of but 154 cm² per square meter, only 28 percent of that on ungrazed range and 30 percent of that on conservatively grazed range in that year. At the end of the severe drought in 1918 the area of black grama had declined to 30 cm² per square meter, 9 percent of that on ungrazed range. As a consequence of the second drought, the greatest influence of which was felt, on the overgrazed range, in 1922, the area again declined to 25 cm², 23 percent of that on the ungrazed range in that year. In the drought period up to 1924 black grama was completely killed out on a large number of range areas and was brought to an extremely low density on others. In favorable climatic years there was not much opportunity for improvement in stand on ranges that were constantly being overgrazed. The small number of tufts that remained after a drought were usually impaired in vigor.

When the range is heavily overgrazed, the improvement of black grama stands by natural revegetation is greatly hindered. The total plant cover becomes so depleted that the loose sandy surface soil is readily exposed and therefore is subjected to wind erosion. It becomes increasingly difficult for black grama to reestablish itself in the presence of this unstable soil condition.

The vigor of the old black grama plants becomes impaired so that increase by lateral spread of the tufts by tillering is hindered even in the more favorable years. The production of stolons is rather limited because of the poor production of flower stalks and their constant grazing by livestock. The establishment of new plants by stolons is slow and uncertain even in the more favorable years because of excessive trampling of the range. In most instances plants newly established in one year are trampled out by livestock later in the same year or in the following year. Once the stand is destroyed, poor seeding habits of black grama make it practically impossible for the species to become reestablished.

The loss in stand from drought is intensified by continued heavy overgrazing. Under conservative grazing the average stand of black grama was reduced by drought to 29 percent of its average maximum. On the overgrazed range, however, the stand was reduced to 5 percent of the average maximum on conservatively grazed range.

The extreme depletion of black grama under overgrazing encouraged the development of a stand of the less palatable perennial sand dropseed grasses because of their more aggressive seeding habits and their ability to increase rapidly in density when more moderately grazed in favorable years after the establishment of the new plants. When heavily grazed in dry years they produce poor seed crops, but in the more favorable growing years yield fair crops of seed which, under favorable conditions, later germinate and become established seedlings. In drought periods the area of these grasses may be severely affected, as in 1918 when it dropped to an average of 18 cm^2 per square meter, 18 percent of the 1915 density. Later, following two favorable growing seasons of 1919 and 1920, it increased to 63 cm^2 but again dropped to 16 cm^2 in 1922. Dropseed grasses are gradually replacing the black grama grass on many overgrazed ranges in southern New Mexico, chiefly because of their reseeding ability.

FULL USE OF FORAGE IN GOOD YEARS AND SLIGHT OVERGRAZING IN DRY YEARS

The combination of full use of forage in good years and slight overgrazing in years of poor forage growth did not permit the full recovery of black grama from the losses suffered in drought years. The average area of black grama under such grazing during the

13-year period was approximately 71 percent of that under both conservative grazing and no grazing. Starting in with an average area of 335 cm^2 per square meter there was a decline to 152 cm^2 by 1919, a recovery to 322 cm^2 in 1921, and a new decline to 112 and 105 cm^2, respectively, in 1922 and 1923. Then after a recovery to 152 cm^2 in 1924 it declined again to 115 cm^2 in 1925. Thus the slight overgrazing in each drought period caused an important decline, giving an area of 50 to 75 percent of that under conservative grazing in the same years, although greater than that which prevailed without grazing in the general drought period from 1922 to 1925. The stand on the average remained fairly vigorous and in a condition to respond quickly to lighter grazing in the more favorable years. This is especially noticeable in the recovery under light grazing between 1925 and 1927 when the quadrats used to represent full use of forage in good years and slight overgrazing in dry years up to 1925 reached an average area of 391 cm^2. The lateral spread of the tufts by tillering in the favorable growing years, however, was not as effective as on the ungrazed or conservatively grazed ranges.

Average height growth of black grama in favorable growing years was only slightly under that of the ungrazed range, but in dry years it was much less than that on ungrazed range, as for example in 1922 when it was only 53 percent.

The stands of the sand dropseed and three-awn grasses on the average under full use in good years and slight overgrazing in dry years were generally very low in density, only in a few instances exceeding black grama and at no time attaining a sufficient density to hinder the growth of black grama. The stands of these grasses decreased greatly in drought periods and in fact on some areas went out completely. They came back in a very small degree in 1919 to 1921, but in many instances only to succumb again in the following drought period. They were given a good opportunity, however, following the depletion of the black grama stand in that drought period, to increase in density by natural reseeding. For example, on range near the headquarters and West Well, the sand dropseed grasses had declined to their low average of 16 cm^2 per square meter by 1922. The black grama stand was at its low of 105 cm^2 in 1923. By 1927 the sand dropseed grasses occurred in some abundance, an average of 152 cm^2 per square meter. This did not, however, prevent a material increase in black grama by lateral spread and stolons, under light grazing from 1925 to 1927, and therefore black grama with an average of 391 cm^2 still remained the dominant grass in 1927 on all of the quadrats except one. Where a stand of black grama was maintained at a moderate density in drought periods it increased in favorable years to such an extent that the sand dropseed grasses were not able to develop materially. This was especially evident on the South Well area where the stand of black grama, even though greatly depleted by the drought that started in 1922, built up so rapidly by lateral spread and stolons when rainfall improved that the stand of sand dropseed grasses in this area, not producing good crops of seed, became established much slower and in less density than on any of the other range areas.

Slight overgrazing in years of short feed production is detrimental to stands of black grama because it hinders this species from attaining its optimum condition. The uncertain rainfall in southern New Mexico further complicates the situation under such utilization.

OVERGRAZING DURING THE SUMMER GROWING SEASON

The study of the effects of overgrazing in summer only was made (1919–25) on range consisting principally of summer forage grasses on which there were small isolated black grama areas. Because of the high palatability and low density of the black grama, the abundance of summer grasses did not prevent the overgrazing and rapid breaking down of the stand of black grama.

Summer overgrazing reduced the height growth of black grama even in favorable growing seasons, but not so severely as did heavy year-long overgrazing. The maximum height growth attained in such a favorable growing season as that of 1920 was 66 percent of that on conservatively grazed range. In the drought year of 1922, local showers in the summer growing season were responsible for a better average height growth on the summer-overgrazed quadrats than on the other grazed areas.

The average area of black grama in 1919 on the quadrats subsequently overgrazed each summer was 225 cm^2, practically the same as that of the ungrazed range and 16 percent better than that on the quadrats representative of the range conservatively grazed throughout the entire period of the study. The total increase in density in 1920 and 1921 was 28 percent as compared to 124 percent on conservatively grazed range and 135 percent on ungrazed range. In the drought that followed, the stand of black grama on the summer-grazed range dropped in 1923 to 44 cm^2 or 15.4 percent of its 1921 density. A slight improvement occurred in 1924 and 1925 when the overgrazing in summer was not quite so severe.

The opportunities for natural revegetation of the stand of black grama in the favorable growing seasons were greatly impaired by the constant close cropping which the species suffered, which largely prevented both the lateral spread of the tufts by tillering and the establishment of new plants by stolons. Furthermore, the vigor of the individual plants was seriously depleted by the severe grazing, especially during drought.

The stand of sand dropseed grasses which occurred with the black grama on the isolated sandy areas was extremely low throughout the period under study and consequently was not considered a serious factor in competition with the black grama.

Summer overgrazing was chiefly responsible for the breakdown in the stand of black grama during drought periods and interfered materially with its improvement by natural revegetation in favorable growing seasons. While such overgrazing cannot entirely be avoided on the isolated black grama areas in the summer when the bulk of the feed can best be utilized, it is well to discourage use of the black grama as much as possible by judicious salting of those large areas supporting the other vegetation best suited for summer use.

SUMMARY

Black grama, the subject of this 13-year study on the Jornada Experimental Range in southern New Mexico, owes its great value in this region of low, uneven rainfall, high temperatures, high evaporation, and relatively severe winds, to its characteristically drought-resistant quality and its high palatability and forage value both in summer and winter. The main growth of black grama is made during the summer rainy season, ordinarily July, August, and September. Only under the most favorable precipitation is growth made in the spring. Black grama seldom reproduces from seed but, after drought or overgrazing, revegetates rapidly from residual plants by tillering and by stolons.

The period of study included two droughts, one of which continued through 1916, 1917, and 1918, and a second which began in the late summer of 1921 and continued almost 5 years until the spring of 1926. In addition to observation of the effects of variations in seasonal and annual precipitation, the areas studied were submitted to several intensities of grazing use.

The area of black grama on ungrazed range, both in pure stands and in association with other perennial grasses, gradually declined during the first drought, following a marked and consistent lag, to a point 41.5 percent of the original stand at the beginning of the study; practically recovered to the original area again as the result of 2 favorable growing years; then dropped very suddenly in the following 2 years of drought to the extremely low point of 10.9 percent of the original area and 19.3 percent of the 13-year average; remained low for the rest of the drought period; and finally increased markedly during the succeeding favorable years. The increase or decrease in the area of black grama from one fall to the next is influenced mainly by the vigor of the plants at the start of the current growing season, as reflected by the previous year's or even by the previous summer's precipitation. Current summer-seasonal rainfall has no significant effect on the current change in plant density. Ordinarily one favorable growing season appeared to be necessary to restore the vigor of weakened plants before marked improvement in the stand began. On the other hand, it is the rainfall during the current summer season which largely determines the height growth during that season on the existing black grama stands.

The average density of black grama over the 13-year period was practically the same under conservative grazing as under no grazing. The decline during drought was rather similar under both conditions, but the return of favorable rainfall brought more rapid recovery under conservative grazing. Conservative grazing appears to break up the large, separated tufts formed under freedom from use into smaller tufts better adapted to make efficient use of the available soil moisture. Under conservative grazing, other things being equal, natural revegetation of black grama tufts by tillering is far superior to that by stolons, since many of the stolons are removed by grazing; but the latter method is an important means of reestablishing a stand after drought on conservatively grazed range. By means of these methods of revegetation, black grama remains dominant after drought in spite of the rapid inroads of associated grass and weed species.

A grazing practice which involves the full use of black grama range in good years and slight overgrazing in years of short feed gives results considerably below those of consistently conservative grazing. It prevents the maximum development of the black grama stand and permits the inferior associated grasses and other species to secure a foothold on the more depleted black grama areas.

The system of overgrazing in the summer growing season only, year after year, decreases the density of black grama rapidly in dry years and greatly handicaps recovery through natural revegetation in favorable growing periods.

Under heavy overgrazing year after year the density of black grama is apt to decline in drought years to almost a negligible quantity. Such grazing results in unstable soil conditions, greatly weakens individual black grama plants, hampers the recovery of black grama by natural revegetation in favorable years, permits inferior plants to encroach and establish themselves, intensifies the influence of drought, greatly reduces the grazing capacity, and, finally, adds greatly to the instability of production of livestock on the range.

The results of all tests made bring out especially the amazing ability of black grama to survive drought, to recover after a drought period, to compete successfully with associated species, and to remain as the dominant plant on conservatively grazed range in spite of encroachment of sand dropseed and three-awn grasses and other species following depletion of stand by drought. The ability of black grama to withstand conservative utilization by livestock, without a reduction in stand except the variations due to vicissitudes of climate suggests conservative grazing as the most stable and productive system of grazing. Heavier grazing use, in the degree of its intensity, results in gradual or extreme deterioration, a subordinate stand of black grama, reduced grazing capacity, and unsatisfactory conditions for permanent livestock production.

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