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Ecological Studies of Blue Grama Grass (Bouteloua gracilis)

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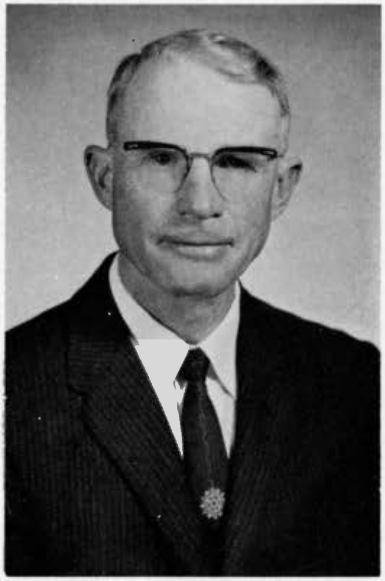
Fred W. Albertson

Fred W. Albertson was born in Hill City, Kansas, in 1892. He received his B. S. degree at Fort Hays Kansas State College in 1918, his M. A. at the University of Missouri in 1930 and his Ph. D. at the University of Nebraska in 1937. He joined the staff at Fort Hays Kansas State College in 1918 and remained there until his death in June, 1961. He was chairman of the Division of Biological Sciences.

Dr. Albertson published many articles on grassland ecology and became recognized as an international authority in that area. He was co-author of a book entitled "Grasslands of the Great Plains." His research was primarily on the effects of drought and overgrazing on grasslands, two of the most important problems of the Central Great Plains. His work has been used widely by technicians and has been important in the establishment of better range management practices in the Great Plains.

From 1956 to 1958 Dr. and Mrs. Albertson spent two years in India helping that country find ways of improving its grasslands.



David Andrew Riegel

David Andrew Riegel was born in Seward, Kansas, in 1901. He received his B. S. in 1927 at Fort Hays Kansas State College and his M. S. from the same institution in 1939. He spent several years teaching in the public schools of Western Kansas before he joined the staff at Fort Hays Kansas State College in 1939.

He has published numerous articles and has done extensive research on autecology of plants, range management of short-grass pastures, seed production with native grasses and bioecology of the mixed prairie.

Gerald W. Tomanek

Gerald W. Tomanek was born in Collyer, Kansas, in 1921. He received his B. S. degree in 1942 at Fort Hays Kansas State College and, after four years in the U. S. Marine Corps, returned to Fort Hays to finish his M. S. in 1947. He joined the staff at Fort Hays Kansas State College in 1947 but took a two-year leave of absence in 1949 to obtain his Ph. D. at the University of Nebraska.

He has published a number of scientific papers on grassland ecology and conducts extensive research on soil-vegetation relationships and effects of drought and grazing on grasslands.

In 1961 he made two trips to Argentina as a consultant for the Agency for International Development. He helped to identify Argentina's range management problems and made suggestions for finding solutions. He is chairman of the Division of Biological Sciences at Fort Hays Kansas State College.

Ecological Studies of Blue Grama Grass (Bouteloua gracilis)

Foreword

"Ecological Studies of Blue Grama Grass" was written in rough draft by Dr. Albertson in 1956 just prior to his trip to India. Upon his return he did not find time to work on the paper before his death in 1961. Much of the research data included in the paper was taken from earlier work by Mr. Riegel. Dr. Tomanek prepared the final manuscript from Dr. Albertson's original rough draft; however, the original paper by Dr. Albertson remains essentially unchanged. Therefore, most of the literature cited and data in the tables and figures terminates in 1955.

Introduction

Blue grama grass (*Bouteloua gracilis*) was selected for detailed description here because of its wide distribution and importance throughout the Great Plains Region in the United States. Shantz (1923) stated that in the Plains Grassland, blue grama was by far the most important plant and that buffalo grass (*Buchloe dactyloides*) ranked second in importance. Aldous and Shantz (1924) further stated that blue grama "is probably the most common and abundant plant type throughout the northern and western Great Plains Region. It also extends westward into the semidesert areas on the high plateaus of New Mexico, Arizona, southern Colorado and southwestern Utah."

The wide distribution of this grass, its value in restoring and preserving productivity of soil, its ability to endure drought and other climatic adversity and its excellence as herbage for livestock, all attest to its importance to profitable living in the Great Plains. The value of this grass is further indicated by the fact that "grama grass" is a household term to almost everyone who resides in this vast grassland area, or writes or reads of life on the Great Plains during pioneer days, and even to this day.

Description

Blue grama (*Bouteloua gracilis*) (H. B. K.) (Lag. ex. Steud.) is a member of the tribe Chlorideae of the grass family (*Gramineae* or *Poaceae*). This short grass has been known by various scientific names during past years, but the one given above seems to have general approval (Hitchcock and Chase, 1950).

The common name "grama" apparently originated with the Spanish conquistadores, because the flaglike spikes were similar to the grama grasses of Spain (Woolfolk, 1944). The bluish green color of leaves is probably responsible for the descriptive part of the name.

This warm-season, densely-tufted, long-lived perennial is a distinct bunch grass especially in drier regions (Phillips Petroleum Company, 1955). Flower stalks range in height from eight to 24 inches depending upon such factors as soil texture, soil moisture and latitude (Fig. 1).

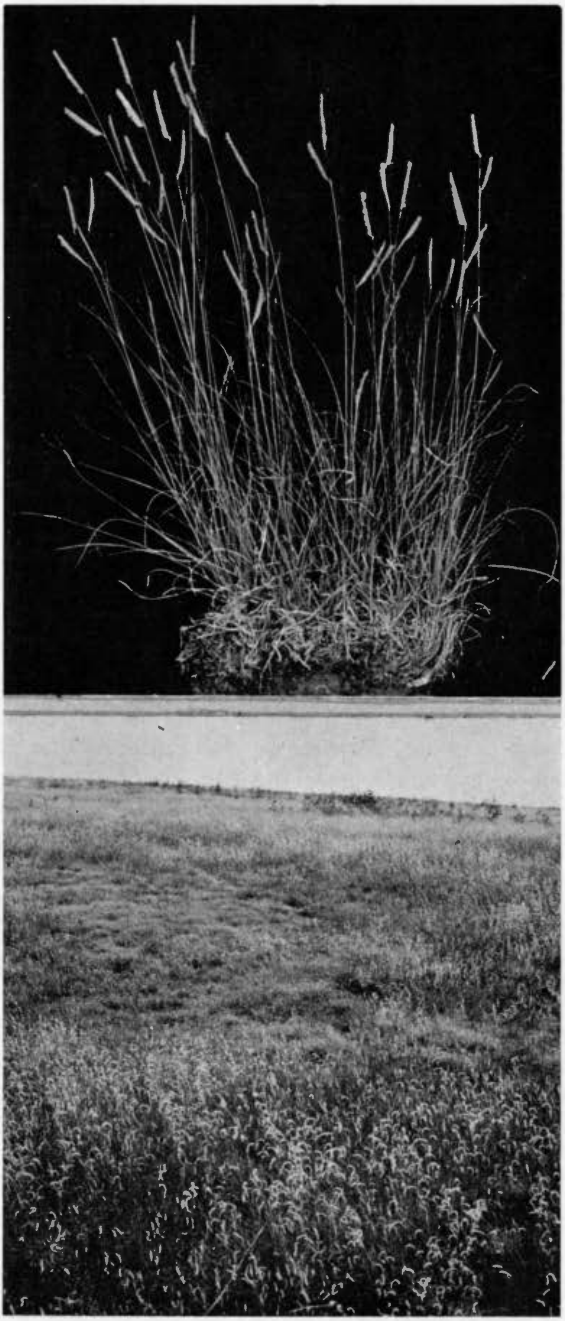


FIGURE 1. (Upper) Blue grama plant in full head. (Lower) Upland prairie near Beardsley, Kansas, with cover of mostly blue grama (shiny curved heads) and buffalo grass. August 21, 1942.

Blades are dark green and narrow, four to eight inches long, prominently veined above and usually with a small tuft of silky hairs at juncture of blade and sheath. Roots are fine, fibrous and minutely branched, thoroughly occupying the upper few feet of soil.

Inflorescence is of several (usually two) racemose spikes. Spikelets are numerous, one-flowered and in two rows on one side of the rachis (Fig. 2). The rachis does not project much beyond spikelets.

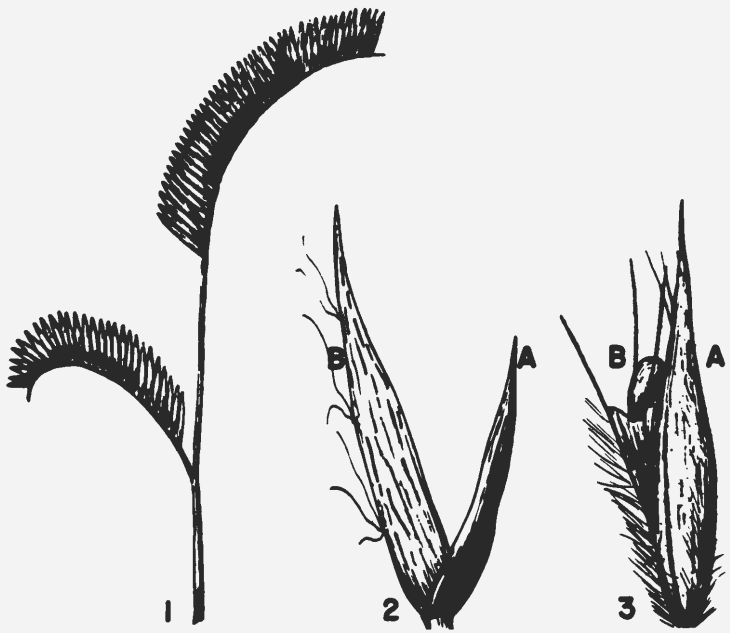


FIGURE 2. (1) Head of blue grama. (2) Glumes of spikelet: (A) first glume and (B) second glume. 3) (A) Lemma of fertile spikelet and (B) rudimentary flower of spikelet.

Distribution

Blue grama is abundantly distributed throughout the Mixed Prairie. It extends northward through Wyoming (Fig. 3) into Alberta and Saskatchewan, and southward into Texas and Arizona (Weaver and Albertson, 1956). It occurs more sparingly from Wisconsin to Manitoba on the north, and southward, both east and west of the Mixed Prairie, in Arkansas, southern California and Mexico. Bews (1929) stated that blue grama extends from Manitoba to South America.

FIGURE 3. (Upper) Ungrazed upland near Carpenter, Wyoming, with lower story of blue grama and thread-leaved sedge, and upper story of needle-and-thread. August 2, 1955. (Lower) Nearly solid cover of blue grama and buffalo grass on moderately grazed range near Stratford, Texas. Red three-awn at left center. Prickly pear cactus was common. July 1, 1955.

Weaver and Bruner (1945) found blue grama to be an important species in succession in the True Prairie near Lincoln, Nebraska.

Blue grama is especially well adapted to fine textured soils, where it occurs in greatest abundance, but it is also found on coarser soils such as sandy loams or thin soil underlaid with rock. Even on more sandy sites, it occurs in considerable amounts (Fig. 4). Buffalo wallows and other shallow depressions with tight impervious soils

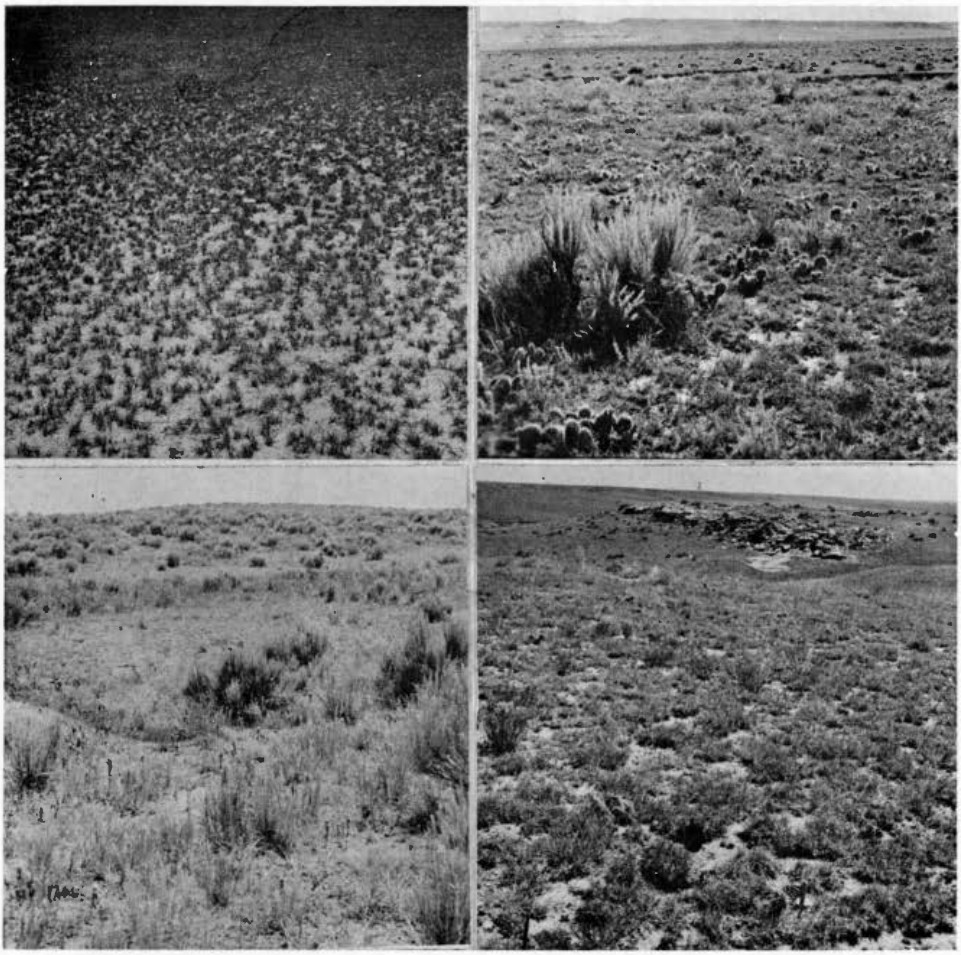


FIGURE 4. Four areas where blue grama forms an important part of the cover: (Upper left) On tight soil near Eads, Colorado. (Lower left) On dune sand at Woodward, Oklahoma, where sand sage forms a discontinuous upper story to the blue grama. (Upper right) On sandy loam north of New Raymer, Colorado. (Lower right) Blue grama on shallow soil above Foxhill Sandstone in Northeast Colorado.

are often occupied by a much greater percentage of buffalo grass than blue grama (Beetle, 1952).

In addition to the general distribution of blue grama grass, a knowledge of variations in density, and percentage composition due to latitude, direction and angle of slope, soil type and other factors is also vital to a more complete understanding of this short grass. Studies on nongrazed or lightly grazed grasslands have revealed great variations in its percentage composition in different locations in the Great Plains.

Regional Abundance

Coupland (1950) has made an extensive study of the Mixed Prairie of Canada. He found that blue grama comprised 61 percent of the grasses on the *Bouteloua-Stipa* faciation and 28.2 percent on the *Stipa-Bouteloua* faciation. Buffalo grass did not occur in either community, but needle-and-thread (*Stipa comata*) made up nearly 20 percent of the grasses on the former site and 34.5 percent on the latter.

Southward from Canada in North Dakota, Hanson and Whitman (1938) have studied the characteristics of major grassland types in the western part of the state. According to their studies, blue grama comprised approximately 36 percent of the grasses. Buffalo grass, as in Canada, did not occur. Chief associates of blue grama were needle-and-thread and certain sedges (*Carex*, spp.).

Heady (1950) found blue grama to comprise 6.1 percent of the basal cover of 6.92 percent at Havre in north-central Montana. Bluebunch wheatgrass (*Agropyron spicatum*) dominated the areas with 82.6 percent of the cover. Other species of less abundance were *Stipa comata* and thread-leaved sedge (*Carex filifolia*). Reitz and Morris (1939) state that blue grama ranks among the best grazing plants in Montana and that the herbage cures well on the ground and is used for late fall or winter grazing. According to these workers, blue grama is most at home in the plains region in Montana but is not found at high altitudes.

In south-central Montana, Wright and Wright (1948) studied the density of grass species on the plains of that section of the state. Vegetation on Pompey's Pillar, a small butte, was used to show composition. The abundance of blue grama (52.1 percent of the grass cover) was intermediate between the two communities given for Canada. Other grass species were needle-and-thread, bluebunch wheatgrass and thread-leaved sedge.

Beetle (1952) found blue grama to comprise 70 percent of the cover in an ungrazed area near Cheyenne, Wyoming. On a small ungrazed area near Carpenter, Wyoming (Fig. 3), blue grama comprised 56 percent of the grasses, needle-and-thread 38 percent and thread-leaved sedge six percent (Albertson, *et al.*, 1957). Eastward from Wyoming in South Dakota, on medium textured soil near Badlands National Monument, blue grama made up 36.1 percent and buffalo grass only 2.4 percent. On a nearby sand site, however, blue grama comprised only five percent of the cover.

Studies in many places in the Great Plains indicate that while density of major species of grasses varies considerably from year to year, percentage composition fluctuates but little. For example, Lang (1945) determined density changes in native vegetation in relation to precipitation from 1936 to 1943 in eastern Wyoming. On a short-grass type, Lang found that blue grama varied from 64.4 to 83.5 in percentage composition of all grasses for the eight-year period. The average was 74.1 percent.

On a mixed-grass type, Lang found the average percentage composition of blue grama to be 60.3, with variations from 53.4 in 1936 to 66 in 1939. Western wheatgrass (*Agropyron smithii*), needle-and-thread and thread-leaved sedge were the most important other species that did not fluctuate greatly from year to year. Sandberg bluegrass (*Poa secunda*) comprised only 3.7 percent composition in 1940 but 16.2 in 1938.

In Nebraska, studies on hardlands, loess hills and sand hills have been made respectively by Brinegar and Keim (1942), Hopkins (1951) and Frolik and Shepherd (1940). Brinegar and Keim found that blue grama composed 50.7 percent and buffalo grass 5.7 percent of the grass cover on the hardlands of the north-central part of the state. Here also were needle-and-thread, western wheatgrass and certain sedges.

On the more open loess soils in Nebraska, Hopkins found that over 90 percent of the grasses was blue grama and less than five percent was buffalo grass. In the dry-valley type of the sand hills, Frolik and Shepherd reported that blue grama was second only to sand dropseed (*Sporobolus cryptandrus*) with 17.3 percent composition. Chief among its associates, in addition to sand dropseed, were prairie sand reed (*Calamovilfa longifolia*), switch grass (*Panicum virgatum*) and hairy grama (*Bouteloua hirsuta*).

In east-central and northeastern Colorado, Albertson *et al.* (1957) measured composition of grasslands at many stations. Percentage composition of blue grama was found to vary from ap-

proximately 95 percent on the ungrazed hardlands near Eads and Briggsdale to 63.4 percent on sandy loam at Bushnell, Nebraska. Buffalo grass did not occur on the open soils at Bushnell and only sparingly at Eads and Briggsdale.

On a salt meadow site near Brush, Colorado, blue grama formed 41 percent of cover on moderately grazed range. Chief associates of this species were needle-and-thread, prairie sand reed, sand bluestem (*Andropogon hallii*), prairie sedge (*Carex praegracilis*) and sand dropseed. Ramaley (1939) reports its presence as a species of minor importance on the sand hills of northeastern Colorado.

In Kansas the proportion of buffalo grass to blue grama is significantly greater than northward. For example, in 1932, ground or total cover on the uplands at Hays, Kansas, was about 90 percent and was about equally shared by blue grama and buffalo grass (Albertson, 1937).

During a seven-year drought, beginning in 1933, blue grama suffered terrific losses, but these losses were less than those of buffalo grass. Composition of 50 percent for blue grama on an ungrazed upland in 1932 increased to 65 in 1937 and then dropped to 58 percent in 1939 (Table 1).

With return of rainfall, blue grama increased in cover much more slowly than did its codominant buffalo grass, its composition percentage decreasing to only 14 in 1945. Thereafter it increased to almost equal abundance with buffalo grass in 1951. From 1952 to 1955 percentage composition of blue grama rose to 70 in 1954 and then to 78 in 1955.

Adjacent to the ungrazed area, measurements were made on an area moderately used (Table 2). Here blue grama comprised 58 percent of the cover in 1935 but 90 percent in 1936. At the end of the drought in 1939, it had dropped back to 54 percent. After the drought, tremendous gains in cover by buffalo grass caused a significant decrease in percentage composition of blue grama.

During most of the 1940's, blue grama maintained a composition of slightly above or slightly below 20 percent, but during the dry years of 1952-1955 the more drought-resistant blue grama went as high as 51 percent.

On a hillside with open soil underlaid with limestone, and ungrazed since 1932, blue grama was absent at the close of the wet period in 1932 but, with drought, it invaded the hillsides and reached its greatest abundance of 22 percent in 1942. Thereafter, it decreased gradually during good weather to 2.5 percent in 1952. Then, with four years of drought, it increased to 16 percent by 1955.

TABLE I.—Percent composition and basal cover of blue grama and buffalo grass in ungrazed upland from 1932 to 1955 at Hays, Kansas.

Year	'32	'34	'35	'36	'37	'38	'39	'40	'41	'42	'43	'44	'45	'46	'47	'48	'49	'50	'51	'52	'53	'54	'55
Percent composition, blue grama	50	53	60	62	65	49	58	53	31	16	25	18	14	22	23	23	31	38	50	72	56	70	78
Percent composition, buffalo grass	50	47	40	38	35	50	42	47	69	84	75	82	86	78	77	77	69	62	50	28	44	30	22
Basal cover, blue grama	44	44	39	36	16	15	13	10	18	15	23	17	13	20	20	22	29	34	45	67	21	14	25
Basal cover, buffalo grass	44	39	26	22	9	16	9	9	41	80	68	78	80	70	66	72	64	56	45	26	16	6	7
Total cover	88	83	65	58	25	31	22	19	59	95	91	95	93	90	87	94	93	90	90	93	37	20	32

TABLE II.—Percent composition and basal cover of blue grama and buffalo grass in moderately grazed upland from 1935 to 1955 at Hays, Kansas.

Year	'35	'36	'37	'38	'39	'40	'41	'42	'43	'44	'45	'46	'47	'48	'49	'50	'51	'52	'53	'54	'55
Percent composition, blue grama	58	90	81	78	54	60	38	34	19	17	21	22	15	25	25	19	13	17	26	51	44
Percent composition, buffalo grass	42	10	19	22	46	40	62	66	81	83	79	78	85	75	75	81	87	83	74	49	56
Basal cover, blue grama	10	2	7	16	14	16	16	22	14	16	18	17	13	22	19	16	12	10	15	14	19
Basal cover, buffalo grass	7	1	2	5	12	10	26	42	59	75	70	60	72	66	58	71	71	50	42	14	25
Total cover	17	3	9	21	26	26	42	64	73	91	88	77	85	88	77	87	83	60	57	28	44

On hardlands near Norton, in northwest Kansas, following several years of drought, 1952-1955, blue grama was high in composition with 61.7 percent while buffalo grass comprised only 12.7 percent. Western wheatgrass accounted for nearly all remaining grass cover. On ungrazed loessial soils near Atwood, percentage composition of blue grama was only 43.4 and buflalo grass 16 (Tomanek and Albertson, 1957). Side-oats grama (*Bouteloua curtipendula*) and big bluestem (*Andropogon gerardi*) comprised important amounts. Southward in Kansas near Jetmore, blue grama represented nearly 70 percent of the grasses and buffalo grass 24 percent.

In 1954, grass cover on an ungrazed upland at Cedar Bluff Reservoir near Hays, Kansas, contained only 40.1 percent blue grama, but the amount of buffalo grass was 51.7 percent. In southwest Kansas, near Ashland, however, blue grama and buffalo grass comprised only 16.8 and 4.9 percent, respectively, of the grasses on the open Permian red soils. Here side-oats grama made up one-half the grasses (Tomanek and Albertson, 1957).

Across central Kansas, percentage composition for blue grama varied from 72.4 percent on level hardland near Rozel to 14.3 on Dakota Sandstone soil at Geneseo. Percentage composition of buffalo grass was 20.8 and 1.3 percent, respectively, on the same locations. Principal other grasses at Geneseo were big bluestem, tall dropseed (*Sporobolus asper*) and plains muhly (*Muhlenbergia cuspidata*).

On sand-sage prairies near Woodward, Oklahoma, blue grama comprised from 24 to 43 percent of the cover (McIlvain and Savage, 1950). When found on these sandy sites, it occurs in greatest abundance on the heavier soils between the dunes (Fig. 4). Other grass associates in these sandy locations are sand dropseed, sand lovegrass (*Eragrostis trichodes*), sand bluestem, little bluestem (*Andropogon scoparius*) and sand paspalum (*Paspalum stramineum*).

Hitchcock (1919) found both blue grama and hairy grama to be important on the arid portion of the Great Central Plateau of Mexico.

Near Silver City, New Mexico, Gardner (1950) studied an upland prairie that had been protected from grazing for thirty years. He found that total density on the area was 9.6 percent as compared to 4.6 percent on a nearby grazed area. Blue grama comprised 78 percent of the grass cover on the protected area and 72 percent when grazed.

Cottle (1931), who studied the vegetation of southwestern Texas, found blue grama to comprise an important part of the vegetation

in that section of the Great Plains. Hanson (1924) found this short grass between cedars and piñons in the more moist locations on the Desert Plains (*Aristida-Bouteloua*) association of northeastern Arizona. Its associates were black grama (*Bouteloua eriopoda*) and galleta (*Hilaria jamesii*).

Blue grama and galleta are the two most important species of grass on the highland subtype of Arizona (Nichol, 1937). Both species may occur in pure stands.

From the data presented, it is evident that blue grama is widely distributed throughout the Great Plains and, in most places it ranks high in importance among the grasses.

Ecesis

Blue grama is a warm-season grass. Date of beginning of growth in spring is much earlier in the south than in the north. Variation in time of first growth also occurs from season to season due to climate.

Migration

When areas of grassland containing blue grama are destroyed due to cultivation or from drought and overgrazing, blue grama is relatively slow in regaining its former abundance. This characteristic of this short grass is illustrated by data gathered at Hays, Kansas, on an area of formerly cultivated land that had undergone secondary succession for a period of 33 years (Tomanek *et al.*, 1955). On a nearby climax site, blue grama comprised 26.8 percent of total grasses while on the disturbed site, after 23 years of secondary succession without grazing, percentage composition of blue grama was only 6.6 percent. On the same area buffalo grass was 73.3 percent. After 33 years, percentage composition of blue grama had increased to 11.3, but buffalo grass, largely due to increase in number of species of other grasses such as side-oats grama, western wheatgrass and three-awn grasses (*Aristida,* spp.), had been reduced to 21 percent.

Germination and Early Development

Increase from growth of seedlings is common in natural secondary succession on degenerated native rangeland or on cultivated fields that are reseeded either naturally or artificially. Studies from the seedling stage to the end of the first season of growth at Hays, Kansas, have been conducted on side-oats grama (Hopkins,

1941), on buffalo grass (Webb, 1941) and on blue grama (Riegel, 1941).

Riegel found that the seed of blue grama produced in Kansas germinated in three days to two weeks by the root breaking through the wall of the coleorhiza and entering the soil, and by elongation of the coleoptile from the basal node at the juncture of the hypocotyl and epicotyl (Fig. 5A). The plumule emerges within the coleoptile, which forms a protective sheath about it. When exposed to strong light, the coleoptile ceases to grow and the elongating plumule breaks through the tip of the coleoptile to form the first seed leaf for the plant. After about 6 days, the crown node appears just beneath the surface of the soil at the juncture of the stem and basal node (Fig. 5B). It is from the crown node that the first foliage leaf emerges and later the first tiller. The crown node also forms the base from which arise the second internode and the first adventitious roots. At this time the second leaf appears, which indicates that the second node has been formed. With the addition of the third leaf, the first crown root usually starts to elongate (Fig. 5C). The second tiller emerges from the second internode and within the sheath of the second leaf (Fig. 5D). It appears that approximately one root is formed for each tiller. This process of developing roots and tillers continues throughout the season if proper growing conditions prevail. It has been found that on plants in experimental plots, the number of tillers and their roots produced during the first season may run as high as 700 or more (Riegel, 1940). Under conditions that prevail in reseeded cultivated fields or in broken down prairies, the number would probably be considerably less.

Mueller and Weaver (1942) measured the relative drought resistance of 14 species of grass seedlings. "Only a few plants, all of which were short grass, survived where drought was most critical." Seedlings of blue grama proved to be the most drought resistant of all species studied. In fact, over three times as many seedlings of this species survived in comparison to those of either hairy grama or buffalo grass.

Riegel (1940) also studied variations in growth of blue grama plants that were grown from seed produced in various sections of the Great Plains. Little variation in growth occurred during the first month, but thereafter, plants from the southern group grew significantly faster and also later into the fall than did those of the central or northern groups. For example, height of plants from the Arizona plots averaged 60 cm. at end of first season but only 24 cm.

from the Montana plot. This difference in growth of tops prevailed also in the second season, when height ranged from 52.9 cm. in the Arizona plants to 29.9 cm. in the Montana plants.

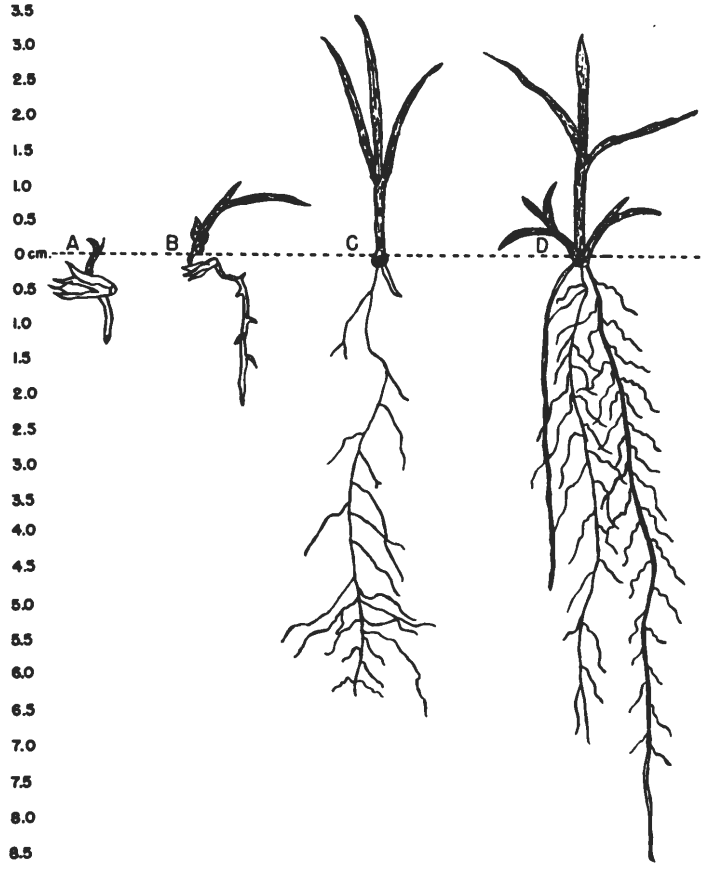


FIGURE 5. Stages in growth of blue grama seedling after emergence: (A) 24 hours. (B) One week. (C) Two weeks. (D) Three weeks.

Depth of roots at the end of the first season ranged from 240 cm. in New Mexico plants to 65 cm. in Wyoming plants (Fig. 6). This difference in root growth was maintained in general during the second season.

Number of tillers per plant at the end of the first season averaged 756 for the Arizona group to 238 for the Kansas source. Number of roots averaged 709 and 299, respectively, on Arizona and Kansas plants.

Spread of roots was also greatest on the southern plants and

least on those from the north. For example, roots on the Arizona plants had a spread of 96 cm. and those of North Dakota only 26

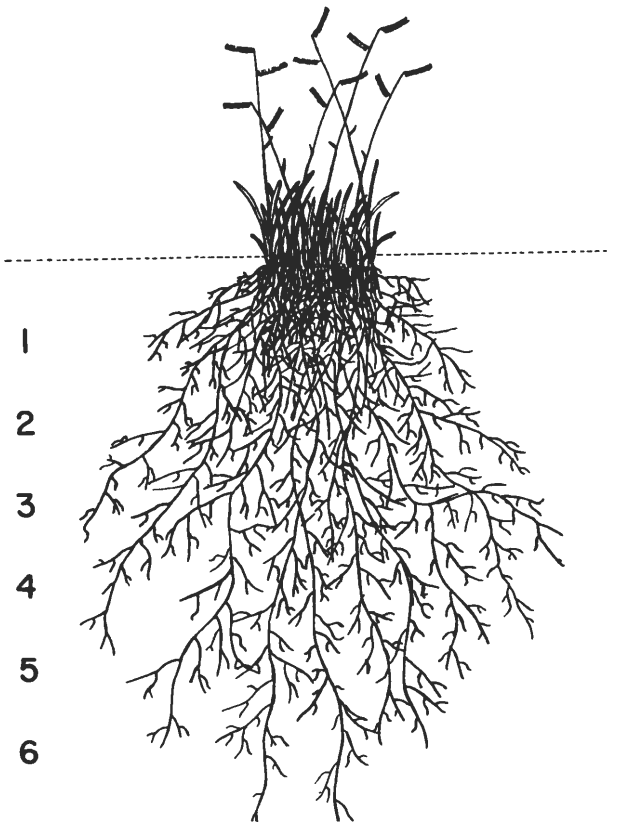


FIGURE 6. Blue grama plant at end of first season of growth from seed. Depth of roots in feet.

cm. at the end of the second growing season.

The main fibrous roots were branched many times to form a network of roots that thoroughly permeated the soil to a depth of several feet. At the close of the first season of growth, Riegel found as many as 24 secondary roots per cm. of primary roots on North Dakota plants.

Reproduction

For several weeks following renewal of growth in spring, activity of blue grama tops is limited to leaf development. Then flower stalks emerge and continue to elongate to a height of usually 8-24 inches,

near the top of which are produced raceme-type inflorescences. Two rows of nearly sessile spikelets are borne on the under side of the rachis which extends nearly laterally from the axis (Sampson and Chase, 1927). The rachis does not extend beyond the spikelets. Stamens mature one to two weeks after the spike emerges from the sheath. When pollen is mature the filaments elongate, causing the anthers to emerge from the lemma and palea. The two stigmas appear above the lemma and palea shortly after emergence of the anthers. The anthers dehisce soon after emerging and pollination frequently is accomplished (Fig. 7). After fertilization the stigmas wither and disappear, and the fruit develops and ripens over a

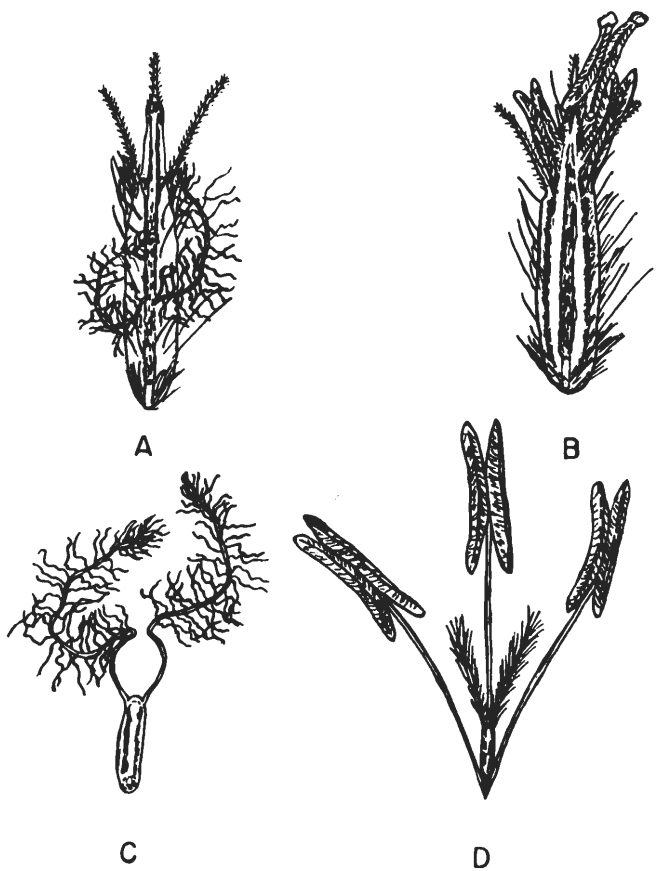


FIGURE 7. Parts of blue grama floret: (A) Floret showing branched stigmas after their emergence. (B) Floret showing anthers of three stamens emerged, the upper anthers dehiscing. (C) Pistil with ovary and stigmas. (D) Stamens with undeveloped ovary and stigmas.

period of several weeks. When mature, disarticulation occurs above the glumes, and the caryopsis enclosed in lemma and palea is shaken to the ground by wind or other forces. The "seed" is light, and barbs on the awns aid in a limited amount of dissemination.

Seed Production

Seed production of native grasses has been of much interest since the drought of the 1930's. Blue grama seed usually matures in August and is often harvested soon thereafter. Yields of 100 to 180 pounds of seed per acre have been harvested from good natural stands (Hoover *et al.*, 1948). Often the yield of seed is much less. It is estimated that a pound of seed contains about 800,000 units. Under average conditions only 5-15 percent of the florets contain caryopses. In Kansas, Branson (1941) found that blue grama yielded an average of 3.5 caryopses per 100 florets in 1939 when drought was extreme. He stated that the average in samples collected before 1939 was 20 percent. Viability of 95 percent, however, is not uncommon in the caryopses produced. Wilson (1931) reported an average of 40.3 percent germination from samples collected over a period of seven years.

Seed that is deposited in open spaces in prairie sod will germinate and grow under proper moisture conditions. As stated earlier in this paper, increase in size of plants depends largely upon addition of new tillers to the crowns formed after the seed has germinated. Number of tillers produced in one season from seed will depend upon the amount of soil moisture. Even under ideal conditions, increase in cover is relatively slow (Savage, 1939).

During the past 20 years vast areas of cultivated land have been reseeded to blue grama and other grasses. If planted in a pure stand in rows, blue grama will form a dense cover in the rows, but between rows the soil tends to remain open for several years (Fig. 8). It is best, therefore, to include other species, such as buffalo grass, to assure a more complete covering of the soil in the shortest time possible.

Drought Resistance

Blue grama is one of the most drought-resistant grasses that occur in the Great Plains, as illustrated by the fact that it usually dominates dry ridges and exposed uplands. It is also common on lowlands during drought cycles or when grazing pressure is fairly heavy. The blue grama leaf consists mostly of a series of parallel bundles composed of mechanical and conducting tissue. Between the larger veins on the ventral surface are large motor or "bulliform"

cells that aid in the process of rolling to decrease the amount of transpiring leaf surface during times of deficient soil moisture (Weaver and Clements, 1938). It enters a period of dormancy when drought is of sufficient duration and, under prolonged adversity, its density is sufficiently decreased through death or reduction in size of individuals to come into equilibrium with the available soil moisture.

Where drought and dusting are severe the cover of blue grama is often greater than that of buffalo grass (Albertson and Weaver,

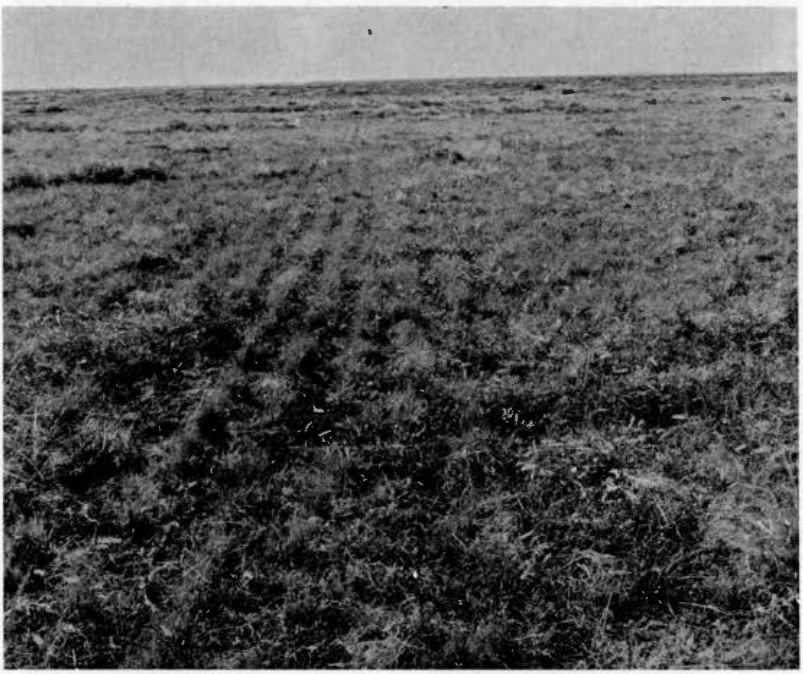


FIGURE 8. Rows of blue grama as they appeared at end of first season from seed planted in field formerly cultivated.

1944). Near Phillipsburg, Kansas, drought and dust had reduced a mixed prairie to a disclimax of blue grama and buffalo grass (Albertson and Weaver, 1946).

Often in Mixed Prairie, blue grama occupies the most exposed sites where mid-grasses are unable to survive. Here, however, severe losses occur during drought. Whitman, Hanson and Peterson (1943) found that blue grama was reduced 74 percent in abundance in western North Dakota due to drought and heavy grazing between 1932 and 1937.

Blue grama grows most efficiently in full sunlight. Therefore, its vigor is greatly reduced when it is shaded by a dense upper story of mid- or tall grasses. It has been found that heavy, early spring growth of little barley (*Hordeum pusillum*) has greatly retarded growth of blue grama until the little barley was matured and shading was thus decreased.

Growth in mature plants occurs by elongation of tillers scattered over the live crowns. When blue grama grows in pure stands, its development is greatly different than when it is associated with buffalo grass. It seems desirable, therefore, to follow growth of this short grass over a period of years in a location with a pure grama stand and in another location where it is mixed with buffalo grass.

Increase in cover of mature blue grama plants depends largely upon extension of crowns around the periphery (Weaver and Albertson, 1944). Buffalo grass, however, is capable of rapid extension of cover through growth of stolons. For example, these runners have been found to elongate at an average rate of one inch per day during periods of optimum growing conditions near Hays, Kansas. This method of asexual reproduction makes it possible for very rapid extension of cover, especially during times of warm, moist weather.

Effectiveness of these methods for increasing cover can be well illustrated by following the development in specific locations over a period of years. Near Tribune, Kansas, a meter quadrat of pure blue grama was staked out and charted in 1937. This area has been charted and photographed each year since the study was begun, thus making it possible to trace rather accurately the change in cover that occurred yearly through wet and dry cycles (Table III). As indicated in this table, cover of blue grama was two percent in 1937 after five years of severe drought. A maximum cover of 56 percent occurred in this quadrat in the fall of 1952, 16 years after the area was first studied. Increased density depended mostly upon enlargements of the small crowns that were present in 1937.

These changes can be more satisfactorily followed by referring to the pantograph records made at intervals from 1937 to 1955 (Fig. 9). In 1937, the cover of two percent was composed of less than two dozen small tufts of blue grama. Six years later the cover of 21 percent was made possible by increase in diameter of the small bunches that existed in 1937. Sand dropseed and other short-lived grasses occupied some of the open spaces.

In 1946, cover had been extended to only 26 percent and one year later to only 32 percent. It should be noted that as the crowns

TABLE III.—Basal cover (percent) of a pure stand of blue grama in meter quadrat from 1937 to 1955 on upland soil in western Kansas.

Year	'37	'38	'39	'40	'41	'42	'43	'44	'45	'46	'47	'48	'49	'50	'51	'52	'53	'54	'55
Blue grama	2	2	6	5	13	18	21	29	29	26	32	34	44	41	46	56	39	17	22

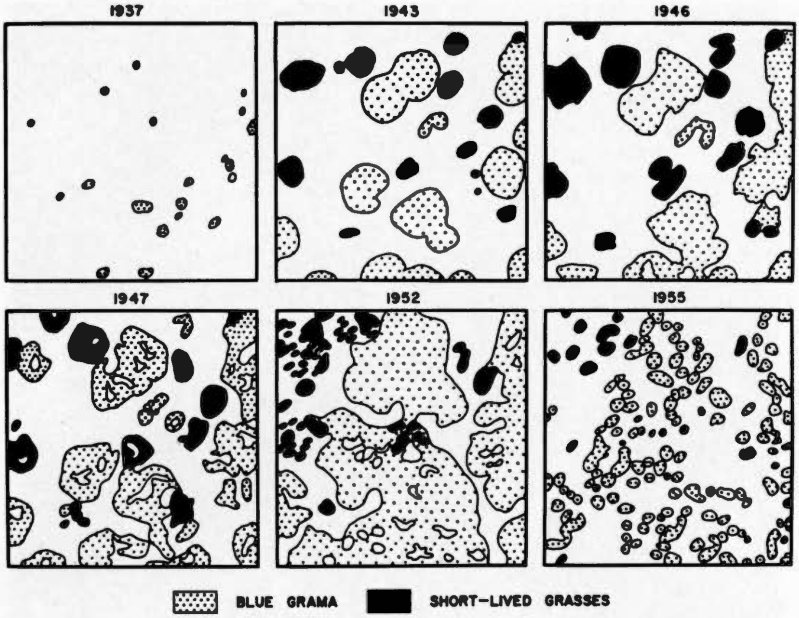


FIGURE 9. Changes in basal cover of blue grama in meter quadrat on upland soil in western Kansas in various years from 1937 to 1955. See, also, Table III.

of blue grama became larger and older, open spaces appeared in the interior of the crowns (Fig. 10). These open spaces were caused by periods of deficient soil moisture during the summers of 1946 and 1947.

After 1947, increase in density was gradual and reached its maximum in 1952. The drought that began in 1952 increased significantly the size of the open spaces in the blue grama crowns, and this grass again appeared as isolated bunches only a few inches in diameter (Fig. 11).

When blue grama grows in pure isolated stands, the yearly increase or decrease in diameter of crowns can be ascertained each year by measuring the cross section of various crowns (Table IV). Diameters of plants 1 and 2 were one inch and three inches, respectively, in 1937. After 1937, increases in diameter occurred nearly every year until the maximum of about 15 inches was reached in 1952. During the drought of 1952-1955, the cover broke and blue grama existed as small isolated bunches with diameters from two to three inches, much as occurred in 1939. With return to favorable growing conditions, the process of increasing cover by crown growth should begin again. It might well be said that occasional drought is not all bad, for during these dry periods,

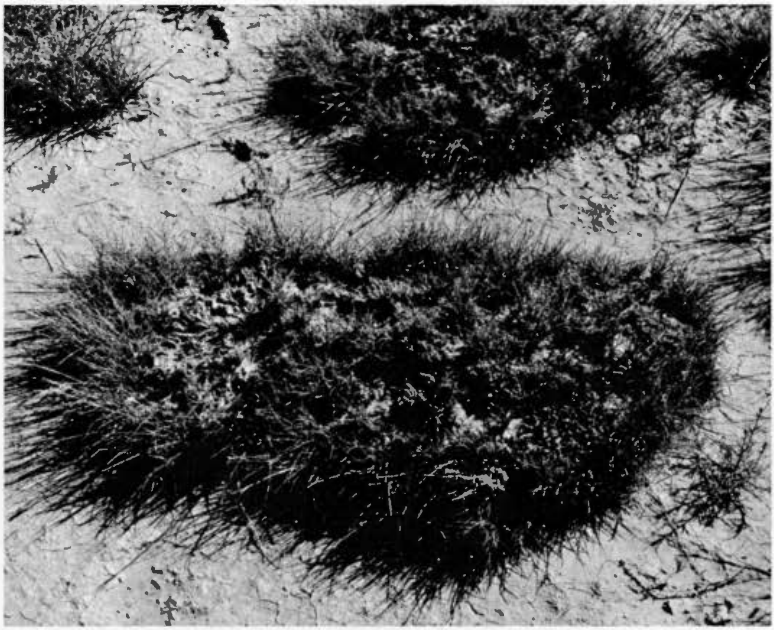


FIGURE 10. Old bunches of blue grama that are dead in the centers but have live growth around the periphery. Typical method of growth of this grass in pure stands. July 1, 1955. Lamar, Colorado.

bunches of grass are broken up, making it possible for crown replacement with increased rainfall.

Plants of blue grama 24 inches in diameter have been found recently in eastern Colorado. These crowns were relatively small in 1939; therefore, uninterrupted crown expansion must have occurred during the past 16 years. In another pasture where both blue grama and buffalo grass remained at the close of drought in 1939, total cover was 30 percent (Table V). Percentage cover of blue grama was 24 and buffalo grass was six. Changes in cover of blue grama were relatively small when compared to that of buffalo grass. At first, blue grama bunches increased in diameter but later, when in close competition with buffalo grass, the relatively large bunches were broken up by the invading buffalo grass. However, cover of both grasses fluctuated considerably in response to wet and dry seasons. This reaction to wet and dry seasons often appeared a year or more after the precipitation change. For example, total cover in 1943 was 75 percent. Rainfall was very low in 1943 but high during 1941 and 1942. Therefore, the high cover in 1943 was due to rainfall of two preceding years. Furthermore, the re-

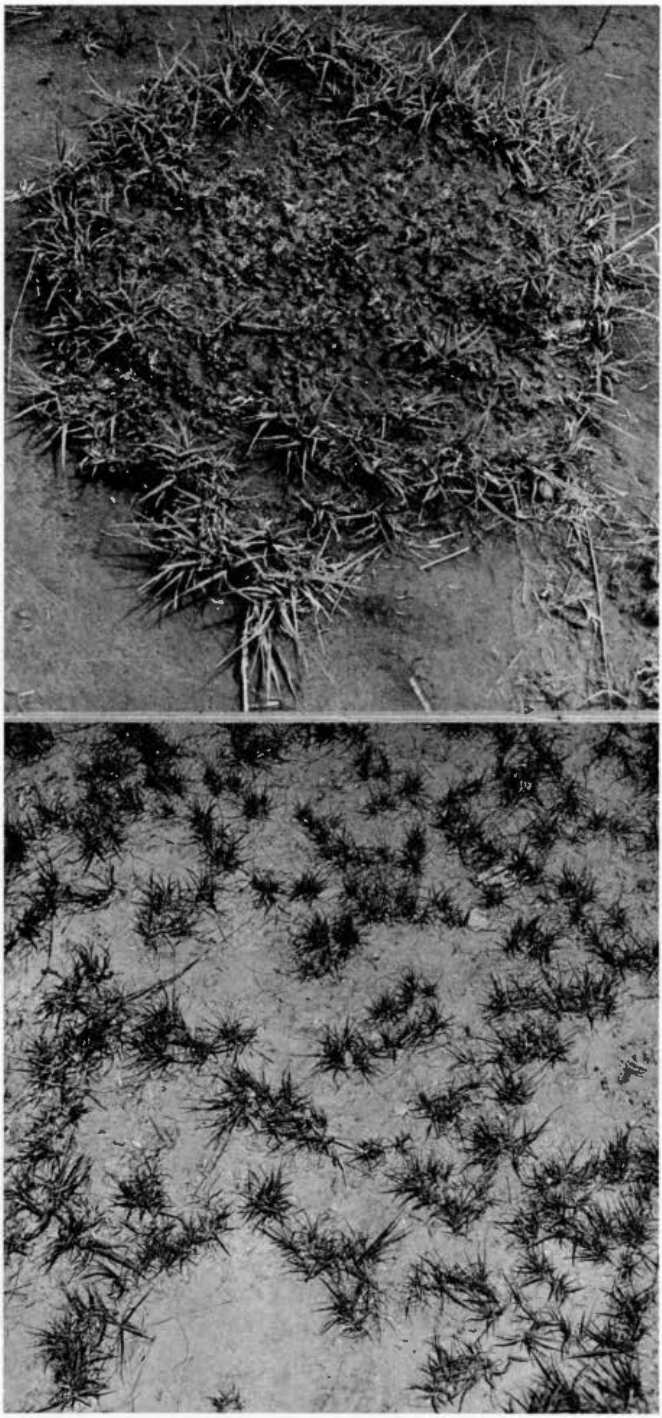


FIGURE 11. (Upper) Old blue grama crown 16 inches across with live tillers mostly on outside border. Loss was due mostly to drought. May 27, 1955. Agate, Colorado. (Lower) Close-up of small tufts of blue grama and buffalo grass. May 28, 1955. Eads, Colorado.

TABLE IV.—Change in basal diameter (inches) of two blue grama bunches through a period of 19 years on an upland soil in western Kansas.

Plants	'37	'38	'39	'40	'41	'42	'43	'44	'45	'46	'47	'48	'49	'50	'51	'52	'53	'54	'55
1	1	1	2	3	5	6	7	7	8	8	8	12	13	13	12	15	2*	3	2
2	3	2	5	6	8	9	9	10	8	10	10	12	12	13	13	15	2	2	2

* Average size of several remnants of old blue grama plant.

duced cover of 52 percent in 1947 resulted from the drought of 1946.

High cover was maintained from 1942 to 1953 except during the dry summers of 1946 and 1947. Deficient soil moisture during 1952-1955 caused a significant drop in cover from 89 percent in 1952 to only 29 percent in 1955. Just how the fluctuations in cover occurred is shown in Table V and Figure 12. In 1939, blue grama appeared in medium-sized bunches over much of the quadrat. Buffalo grass, however, was restricted mostly to two corners of the area. By 1941, no significant change in total cover had occurred, but stolons of buffalo grass were extending into the open spaces from both sides. Results of this stolon growth are shown in 1943. Consolidation of crowns of blue grama had also occurred. In 1947, the crowns had become more open as a result of drought, but most of the loss had been restored in 1948 when blue grama had

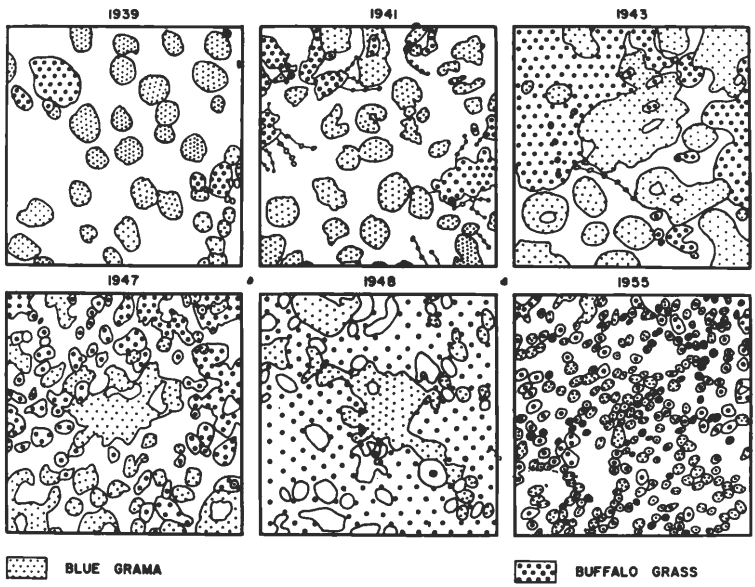


FIGURE 12. Changes in basal cover of blue grama and buffalo grass in meter quadrat on upland soil in western Kansas during certain years from 1939 to 1955. See, also, Table V.

a density of 18 percent and buffalo grass 69 percent. In 1955, the cover of 29 percent was an open stand of isolated bunches.

TABLE V.—Basal cover (percent) of blue grama and buffalo grass in a meter quadrat from 1939 to 1955 on upland soil in western Kansas.

Year	'39	'40	'41	'42	'43	'44	'45	'46	'47	'48	'49	'50	'51	'52	'53	'54	'55
Blue grama	24	15	25	32	40	41	40	37	26	18	34	57	59	46	23	21	15
Buffalo grass	6	6	7	33	35	48	51	39	26	69	59	38	31	43	20	16	14
Total	30	21	32	65	75	89	91	76	52	87	93	95	90	89	43	37	29

Extent of Roots on Mature Plants

Total extent of roots on mature plants depends largely upon soil texture and amount of available soil moisture. Studies on hardland soils at Hays, Kansas, indicated that blue grama roots thoroughly permeated the soil to a depth of nearly five feet (Fig. 13) before the drought of the 1930's (Albertson, 1937). But after several years of deficient soil moisture, roots of this grass penetrated the soil to scarcely more than half this depth (Weaver and Albertson, 1943). With a return of soil moisture, vigorous growth of crown roots quickly restored the underground plant parts to the predrought depth.

When soils are underlaid with layers of rock, root development is often limited to the thickness of the soil above the rock, except where soil-filled crevices extend through rock strata. At Hays, for example, roots of blue grama were found with other plant roots in perpendicular clay pockets in the Fort Hays limestone. However, in the Permian Soils near Ashland, Kansas, blue grama roots on ungrazed upland extended to solid rock at a depth of 5.5 feet (Tomanek and Albertson, 1957). Near Atwood in northwestern Kansas, roots of this grass extended to a depth of over six feet in porous loessial soil. On the hardlands of Colorado, Shantz (1911) found much of the root systems of short grasses limited in the top 18 inches of soil.

Weaver (1920) has made extensive studies of roots of various plants of the Great Plains. He found that near Sterling, Colorado, blue grama roots thoroughly filled the soil to a depth of 2.5 feet, were abundant at 3.2 feet and extended to a maximum depth of 4.2 feet. At Ardmore, South Dakota, they were traced to 4.3 feet.

Forage Production and Utilization

PRODUCTION

Blue grama contributes largely to total yield of grasslands over much of the Great Plains.

In southeastern Alberta, studies on yield of prairie vegetation have been conducted on the Manyberries Range Experimental Farm for many years (Smoliak, 1956). Production on shortgrass prairies dominated by blue grama averaged 317 pounds per acre. It ranged from 90 pounds per acre in 1949 to 825 in 1942. Clark *et al.* (1943) found that blue grama produced an average of 148 pounds per acre from 1934 to 1939, when clipped at end of season.

In southern Saskatchewan, Clark *et al.* (1942) conducted eco-

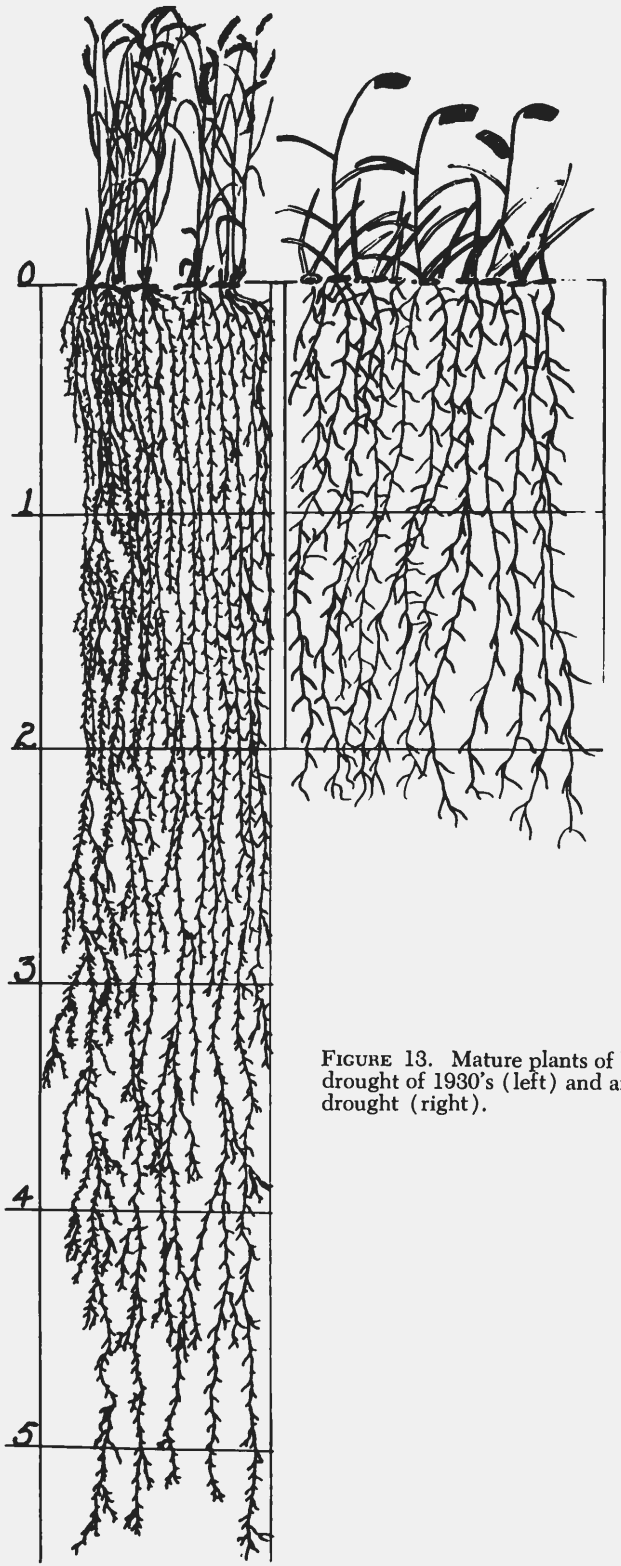


FIGURE 13. Mature plants of blue grama before drought of 1930's (left) and after seven years of drought (right).

logical and grazing capacity studies on native grass pastures from 1937 to 1939. On a short-grass prairie where conditions were favorable to blue grama and where percentage composition of this shortgrass was 54 percent of the total of 13.5 percent cover, yield was 121 pounds of air-dry forage per acre. This amount was 37.7 percent of total production of 321 pounds per acre. These data indicate that blue grama yield per unit area of land is less than for other grasses growing on this prairie.

Coupland (1950) has also reported on yields of short-grass prairies of Canada. At Swift Current, blue grama yielded an average of 191 pounds per acre from 1944 to 1948, where it formed 61 percent of the grass cover. It varied from 140.6 pounds per acre in 1947 to 309.6 in 1944.

Sarvis (1923) working near Mandan, North Dakota, determined the yield of blue grama from 1917 to 1921. He found that when blue grama was clipped every 30 days, the yield was nearly 150 pounds of the total grass yield of about 280 pounds per acre.

Southward from Mandan, in northeastern Colorado, Turner and Klipple (1952) studied growth characteristics of blue grama. They found that yield reached its maximum in early summer in dry years, but later during wet seasons. Also, during seasons of good rainfall, yield was considerably greater than during dry years. For example, in 1941, a wet year, production of 1,485 pounds per acre was reached by mid-August; thereafter, the amount harvested became less and was only 870 pounds per acre the following spring (April 9, 1942). Amount of loss during fall, winter and spring would vary with amount of rain or snow. During the dry year of 1946, a maximum yield of only 794 pounds per acre was reached on August 1. This yield was only slightly more than half the amount produced during 1941. Costello (1944) found that on well-managed pastures in Colorado, blue grama is the dominant species and produces from 50 to 95 percent of total forage.

Much interest has been shown in yield per unit area of different prairie grasses. At Hays, Kansas, clippings of several intensities were made on blue grama and buffalo grass for a five-year period from 1942 to 1946. Results of this study are found in Table VI. Given in this table are percent cover, yield per acre and yield per one percent of cover when clipped to simulate moderate grazing. It should be noted that buffalo grass yielded from 41 to nine pounds per acre for one percent cover, while for blue grama the range was 26 to seven.

In another study on uplands at Cedar Bluff near Hays, Kansas,

Franks (1953) found that blue grama, with 50.6 percent basal cover, produced 1,336 pounds per acre in 1952 and 1,217 pounds the following season. This gave 26.4 pounds for each percent of cover in 1952 and slightly less in 1953. Buffalo grass, with 75.4 percent cover, yielded 1,252 pounds per acre or 16.6 pounds per one percent in 1952 and only 13.5 pounds in 1953.

Riegel (1947) determined the forage yield of various pasture grasses when seeded artificially in cultivated ground. These yields were compared with those of native prairies. Several species of grass were planted in the spring of 1941, and clippings were started in 1945 to determine yields. Clippings on the same areas were made in June, July, August and September. Yield of blue grama was determined for plants from southern-source seed, central-source seed and from northern-source seed. Total production for the season for southern, central and northern-sources was, respectively, 1,808, 1,843 and 1,332 pounds per acre. Approximately one-third total production was harvested by June 15 on all seed sources, but yield from the northern-source plants was considerably less than on other sources for the September harvest.

UTILIZATION

One of the most serious problems confronting the ranch operator today is the amount of current growth that can safely be removed

TABLE VI.—Average percent cover, yield in pounds per acre and pounds of forage per one percent cover on uplands at Hays, Kansas, dominated by blue grama (Bgr) and buffalo grass (Bda).

Year	Percent cover		Yield in pounds per acre		Yield in pounds per acre per 1% cover	
	Bgr	Bda	Bgr	Bda	Bgr	Bda
1942	16	53	394	2158	24	41
1943	19	78	136	1100	7	14
1944	18	79	476	2211	26	28
1945	17	81	379	1548	23	19
1946	13	81	137	766	10	9
Average	16	74	304	1557	18	22

without seriously reducing yield. It has become generally recognized that approximately one-half the herbage by weight should be left on the plant if maximum production is to be maintained (Fig. 14). On southwestern ranges, this would mean grazing to approximately two inches (Crafts and Glendening, 1942). Northward, this height could probably be reduced slightly.

On the loess uplands of west-central Nebraska, Branson and Weaver (1953) determined percentage composition of various grasses in relation to range condition. They found that blue grama composed 75 percent of the grasses on ranges in excellent condition with a density of 36 percent. It was decreased to 65 percent on a good range with 49 percent cover. On the fair range with 49 percent basal cover, blue grama comprised 28 percent composition.

Today there are vast areas of grassland throughout the Great Plains that have suffered from heavy grazing. The yield of both tops and roots is reduced as much as 50 percent when excessively grazed (Albertson *et al.*, 1953).

Studies by Lantow and Flory (1943) on southwestern ranges also indicated that plant root production was greatly influenced by degree of grazing intensity. For example, roots of blue grama plants with full vigor penetrated to a depth of 30 to 45 inches. Roots of

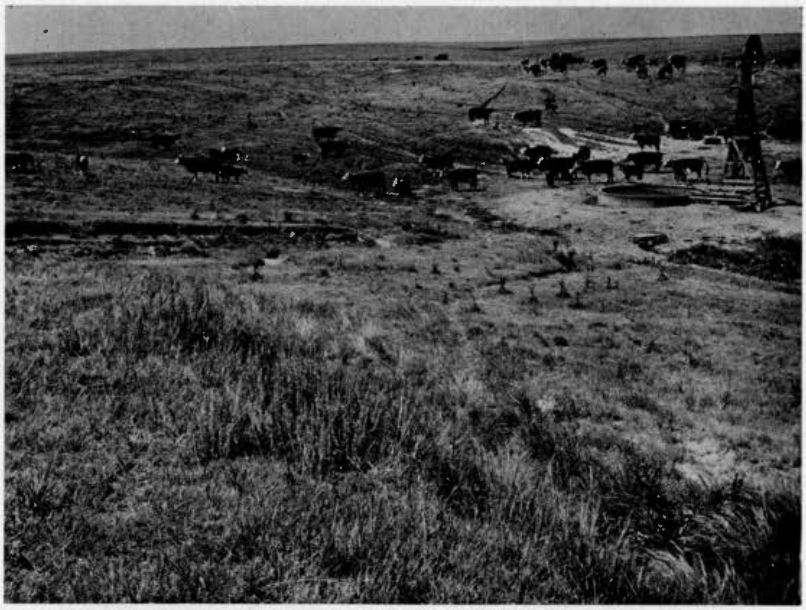


FIGURE 14. Well-managed pasture near Jetmore, Kansas. Good cover of blue grama and buffalo grass except around the windmill. July 2, 1955.

low vigor reached a depth of 12 to 30 inches and with one-third the volume of full-vigor roots. Plants with depleted vigor had roots extending to only six to nine inches and one-tenth the volume of full-vigor roots.

Plants gradually become weaker due to insufficient food reserves to support full growth. When drought strikes, plants in this weakened condition succumb quickly to deficient soil moisture and the result is little short of disaster.

NUTRITIVE VALUE

Yield in pounds per acre is an important criterion in determining value of range forage. It has been found, however, that nutritive value is equally as important. For example, great variations in protein content occur among different species of prairie plants. Also, amount of protein in early spring growth is often several times as much as in late fall or winter. Clarke and Tisdale (1945) studied the chemical composition of prairie plants in southern Alberta and Saskatchewan. They found blue grama to contain 14.85 percent protein in leaf stage. In flower stage it had 9.52 percent. In the medium-seed stage, cured stage and winter-exposure stage, it was, respectively, 7.46, 5.22 and 5.00 percent. In general, protein content in this warm-season short grass was lower in spring growth and higher in fall growth than it was in certain cool-season species such as western wheatgrass, needle-and-thread or June grass (*Koeleria cristata*).

At Hays, Kansas, considerable work has been conducted on nutritive value of both grasses and forbs (Runyon, 1943). Young growth of blue grama was found to contain 13.3 percent protein. In medium growth the amount was 6.6 percent, then rose to 9.5 percent in the bloom stage. When mature, protein content was 5.2 percent and only 2.4 when exposed to severe winter weather. Newell and Keim (1947), working in Nebraska, found 10.5 percent protein in blue grama pasture and 8.2 percent in blue grama hay.

In Oklahoma, Savage and Heller (1947) obtained approximately 10.5 percent protein in the first half of summer growth of blue grama, 3.5 in the last half, 3.0 percent in early winter and only 2.5 during late winter. In northwest Texas, Fudge and Fraps (1945) found 9.76 percent protein in comparatively young growth of blue grama. It was only 4.46 percent in medium stage of growth but, in bloom, it had increased to 7.21 percent. When mature, it had 6.40 percent protein.

Other Ecological Relationships

Blue grama seldom occurs in pure stands except in small areas. Buffalo grass is usually a codominant, especially on uplands in the central Great Plains where the two short grasses comprise the most important species of the lower story of the Mixed Prairie and short-grass plains (Clements, 1928). Northward, however, buffalo grass is usually absent, and in its place is a mixture of needle-and-thread and western wheatgrass or other wheat grasses to form an upper story or layer. Associated with blue grama as a part of the lower story of grasses are various sedges, especially thread-leaved sedge.

There also are certain tall and short forbs that form a part of the upper and lower stories or layers. These forbs blossom at different times in the season—some early, some medium and some in late summer or fall. They form the vernal, aestival and autumnal aspects, respectively. Some are yellow in color, some are blue and some are white. Together they add much beauty to the prairies.

Southward from the central Great Plains, needle-and-thread generally gives way to a variety of other grama grasses, curly mesquite (*Hilaria belangeri*) and galleta grass.

All through the Great Plains on rolling topography, certain mid-grasses such as big and little blue stem and side-oats grama grow in fairly pure stands to form alternes with areas dominated by short grasses. Investigation indicates that the mid-grasses usually occur most abundantly on areas with shallow soil underlaid with partially disintegrated rock, or on open loessial or sandy soils, whereas the short grasses are more at home on the heavier type soils.

Layering is common below ground as well as above ground. Some plant roots are limited to the top 18 to 24 inches. Others are intermediate in depth, while some penetrate the soil to a depth of 8-16 feet, depending upon species of plant and type of soil. Layering both above and below ground provides for growth of plants with the least amount of competition.

When grasslands are ungrazed or lightly grazed, there is an accumulation of mulch on the surface of the soil. If this accumulation continues indefinitely, the layer of mulch may become so thick that grass species which are incapable of adequate height growth are shaded out, at least in occasional small areas.

There is evidence to indicate that grasslands dominated by blue grama will maintain better health when moderately utilized. This being true, it behooves the rancher to give careful thought to proper stocking rates in order to produce a maximum of good forage and also to maintain a healthy range for posterity.

Burning pastures with blue grama as a part of the cover has proved to be unprofitable (Hopkins *et al.*, 1948). In this study, greatest damage occurred to such plants as blue grama where the growing point of the grass is maintained above ground. Cover and yield were reduced 70 and 76 percent, respectively, on short-grass pasture at Hays, Kansas, as a result of burning.

During drought when prickly pear cactus (*Opuntia*) increased greatly, remnants of the prairie grasses (mostly blue grama) frequently survived because of the protection from grazing given them by the cactus plants, which were often several feet in diameter.

In these cactus plants, partially covered with dust, there were usually several kinds of rodents. Moisture conditions were often much better in the cactus plants than outside because of snow collecting around the plant in winter and because of less run-off of rain water. Thus, myriads of the small mesic islands dotted the prairies and furnished a place of refuge for important plants and small animals during drought, and from these they could migrate with return of sufficient rainfall.

Best development of vegetation in the Mixed Prairie occurs when an area is occupied by both mid- and short grasses. Most satisfactory cover of short grasses is maintained when blue grama grows, not in pure stands, but rather in close association with other prairie plants. Northward in Canada the blue grama associate in the lower story is usually thread-leaved sedge. Southward in the central Great Plains, this low-growing sedge is replaced by buffalo grass.

In the southern Great Plains, the other short grasses, in addition to buffalo grass, are black and hairy grama and several species of the genus *Hilaria*.

Important mid-grasses in Canada are needle-and-thread, various wheat grasses and June grass. Farther south, needle-and-thread gives way to other mid-grasses, such as side-oats grama, little bluestem and western wheatgrass. In the southern Great Plains, there is a large number of important mid-grasses. Scattered among the grasses are numerous species of forbs—some tall, some medium and some short. Some of the root layers extend 12 to 20 feet in depth, depending upon species and type of soil. Some penetrate three to six feet, while others are limited to the top 12 to 18 inches.

This plan of wide variation in height of tops above ground, and in depth of penetration of roots, makes it possible for plants to grow side by side with a minimum of competition and to utilize almost completely the available moisture in the soil. Blue grama is a definite part of this complex relationship among plants.

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