Bulletin No. 293 - Buffalograss--Native of the Shortgrass Plains

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Buffalograss--
Native of the Shortgrass Plains

by A. A. Beetle
BUFFALOGRASS. *Buchloe dactyloides* (Nutt.) Engelm., a North American endemic and the most typical of the shortgrasses, although long considered as on the way toward extinction and a difficult grass with which to work, now typifies in its growing importance the conquest of conservation problems by the range workers of the West.
Buffalograss--Native of the Shortgrass Plains

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INTRODUCTION

BUFFALO AND BLUE GRAMA, often linked in reference to the shortgrass plains (98, 151)* are frequently confused both in field identification and in the popular mind (55, 56, 87, 104, 167, 172) because of the abundant basal leaves forming a curly covering close to the ground. Both were formerly called buffalograss (118) and stockmen frequently mistake buffalo for the different varieties of gramagrass (15) or vice versa (87). Actually the gramagrasses and the buffalograss have their own distinct areas of importance, which though they overlap are nevertheless individual. No grass (including blue grama) is more characteristic of or more nearly confined to the shortgrass plains area than buffalo.

Twins they are in fact, for they are linked together both in nature and in the mind of man. Identical twins they are not. Although of the same grass tribe (Chlorideae) and essentially of the same world flora, they have little else in common.

Buffalograss, alone in its monotypic genus, vigorously stoloniferous, and with unisexual flowers must at once be recognized as strongly contrasting with blue grama, member of a moderate-sized genus, a bunch type, with perfect flowers.

Continued and increased recognition of the value of buffalo and blue grama to the agriculture of the shortgrass region will do much to prevent the costly mistakes of the dust bowl days. Too many acres of this productive native sod were destroyed under the plow before its true value in producing livestock was fully appreciated.

HISTORICAL APPRECIATION

No other native grass than buffalograss has entered as extensively into the literature of the West, both folk and scientific—or become, by name if not by sight, better known to the general public.

Probably from failure to understand vegetation fluctuations due to seasonal differences in rainfall, buffalograss was long hailed as a grass on the verge of extinction, the extinction being blamed primarily on overgrazing, secondarily on plowing of the prairie sod to plant row crops, and thirdly on the control of yearly fires.

It is probable that C. E. Bessey of the University of Nebraska, at least in scientific circles, started the myth that buffalograss was on the way out. Whether he was reflecting a widespread popular opinion of the day is difficult to determine. He wrote (18) in the years 1887 to 1893, “This plant is

*Italic numbers in parenthesis refer to “Literature Cited,” p. 25.
fast disappearing. Its hard-awned fruits were especially suited for distribution by the buffalo, and since these have disappeared and the prairie fires are no longer allowed to sweep the plains, the buffalograss is being rapidly choked out by the ranker species.” Also, “It is the most valuable native pasture grass, but is rapidly passing toward extinction,” and “This remarkable grass is disappearing rapidly from the state,* and while it may endure in small isolated patches here and there for perhaps many years, it will ere long cease to have any agricultural interest.”

This battle cry of conservation mixed with a forecast of doom was immediately taken up almost universally and is still heard today (26, 87, 89, 113, 142, 171). The feeling was echoed as late as 1936 (98) except that this dodge was finally introduced to help fit the facts: “the shortgrass type, however, has remarkable recuperative powers. With favorable weather and adequate care, it recovers quickly”—facts supported by research workers (127, 155).

Buffalograss, after more than 50 years of post-buffalo, man-controlled grazing, found the strength in the 1930’s to survive the combined onslaught of the plow, dust, drought, and overgrazing and emerged in the moisture-conservation-conscious 1940’s as a grass of great importance. It seems safe at this time to predict that buffalograss will survive at least the twentieth century.

**TAXONOMY**

*Buchloë* Engelmann, St. Louis Acad. Sci. Trans. 1: 432. 1859. Name a contraction of “Bulachloë”, from two Greek words for buffalo and grass. Not the earliest generic name used, nor for a while more commonly used than *Bulbilis*, but through international agreement conserved over earlier names on the basis of authority and completeness of original description. *Bulbilis* Rafinesque, Amer. Month. Mag. 4: 190. 1819; Kuntze, Rev. Gen. Pl. 2: 763. 1891. Rafinesque gives a review of Nuttall’s genera of North American Plants. The part relating to *Bulbilis* is: “18. Sesleria dactyloides must form a peculiar genus by Mr. N’s own account. It may be called *Bulbilis*.”

*Calanthera* Kunth, in Hook. Kew Jour. 8: 18. 1856. A single species included “C. dactyloides Kth.—Nutt. Sesleria...Buffalo grass,” in a list of Geyer’s plants from the Upper Missouri.

*Casiostega* Benth. Pl. Hartw. 347. 1857, a misprint for *Lasiostega* Rupr., is a nomen nudum.

phora, Texas, collected by Drummond, a pistillate plant.


_Casiostega humilis_ Rupr.; Munro, in Benth. Pl. Hartw. 347. 1857. Name only, an error for _Lasioestega_, Aquas Calientes, Mexico, collected by Hartweg, a staminate plant.


See references: 44, 45, 52, 61, 69, 70, 90, 139, 150, 153, 167.

**DESCRIPTION**

_Habit:_ Low creeping stoloniferous perennial forming a dense grayish-green sod, the curly blades forming a layer commonly 5 to 10 cm. thick; sod turned a light straw by drought, a purplish red by light frosts.

_Culms:_ Commonly 10 to 20 cm. long, those of the pistillate plants usually shorter, in small tufts, or in densely matted small or large patches, or forming a continuous sod, slender, erect or decumbent at the base, with stolons 5 to 60 cm. long (1 to 2 ft.), the nodes glabrous, often with a tuft of small leaves, frequently rooting at the nodes, forming new plants. In the staminate plants the culms exceed the leaves, while in the pistillate plants the leaves exceed the culms.

_Leaves:_ Blades 2 to 10 cm. long, more or less, 1 to 3 mm. wide, sparingly pilose or ciliate on both sides; nerves rather inconspicuous; margins somewhat scabrous and with pilose hairs, these usually papilllose; sheaths split, loose, mostly pilose in the throat, those of the pistillate plant partly enclosing the pistillate inflorescence, round in section, split, glabrous; ligule a ring of hairs, collar-shaped, about 0.5 mm., sometimes to 1.0 mm., auricles absent; collar long-pilose on lower outside edge; vernation clasping, edges not overlapping.

_Inflorescence:_ In the staminate plant 2 to 3 nearly or quite sessile, approximate, one-sided spikes 5 to 15 mm. long, on a slender erect rachis on culms 5 to 20 cm. tall, and well exerted above the leaves, each spike of about 10 spikelets, each spikelet about 4 mm. long; in the pistillate plant 1 to 2 spikes in a sessile head, 3 to 4 mm. thick, somewhat included in the sheaths and partly hidden among the leaves, the parts indurated.

_Staminate spikelets:_ 2-flowered, sessile and closely imbricate, in two rows on one side of a slender rachis, forming a short spike; glumes somewhat unequal, rather broad, 1-nerved, acutish; lemma longer than the glumes, 3-nerved, rather obtuse, whitish; palea as long as its lemma, 2-nerved; stamens three; lodicules
FIG. 2.—Left, Female flowers of buffalograss which develop into seed hidden among the leaves. Right, On separate plants the male flowers are borne well above the leaves.
two, triangular-truncate, undulate or emarginate.

Pistillate spikelets: 1-flowered usually 4 to 5 (rarely up to 17) in a short spike or head, this falling entire, usually two heads to the inflorescence, the common peduncle short and included in the somewhat inflated sheaths of the upper leaves, the thickened indurate rachis and broad outer (second) glumes forming a rigid, white, obliquely globular structure crowned by the green-toothed summits of the glumes; first glume (inside)* narrow, thin mucronate, well developed to obsolete or absent in the same head, second glume firm, thick and rigid, rounded on the back, obscurely nervèd, expanded in the middle with inflected margins, enveloping the floret, abruptly contracted above, the summit with three green rigid acuminate lobes; lemma firm-membranaceous, 3-nerved, dorsally compressed, broad below, narrowed in a 3-lobed green summit, the middle lobe much the larger; palea broad, obtuse, about as long as the body of the lemma, enveloping the Caryopsis.

Lodicules: Two, triangular-truncate, undulate or emarginate. According to Harlan (60) they perform no function in opening the flower. The flower is made receptive by the exsertion of the stigmas through the summit of the enveloping lemma and palea, accomplished by a very rapid growth of the styles.

Seed: The development and morphology is described in detail by Harlan (60). The most striking feature of this development is the green scutellum which forms a broad shield behind the remainder of the embryo and which on maturity covers the entire dorsal surface of the endosperm. Differences between buffalograss and the wheat seed are listed.

SEX DIFFERENTIATION

The species is usually described as dioecious (116) because the staminate and pistillate flowers usually are found on different individuals. Experiments in growing plants from seed show that they are monoecious, the two kinds of flowers arising from distinct branches which propagate vegetatively, each branch producing its own kind, i.e., heteromorphous (18, 22, 44, 46, 54, 66, 69, 120, 149, 150, 152).

Ten percent of seedling plants produce both seed and pollen but on different stems arising from the same node, and continue to produce beyond the second year (60, 128, 166). Although staminate and pistillate plants and inflorescences are normally quite different in appearance, transitional forms, even some with perfect flowers, have been observed (63, 128, 163). Perfect florets are more common in Mexico, rarer northward.

Plants of both sexes are usually well distributed throughout a pasture (100). An early observation (44) seems incorrect, namely that "the male plant seems to throw out more numerous runners than the female, and may often overspread and kill it out, which would account for the greater scarcity of the latter."

The chromosome number has been reported (103) as 56 (108) and 60.

*The first glume, being inserted toward the inside of the glume and the lemma opposite the second glume, i.e., towards the inside of the bur, places the insertion of the palea toward the outside of the bur. Thus the dorsal surface of the ovary is oriented towards the inside of the bur and the ventral surface outward.
The inheritance of sex in the grass is known to be complex. Environment unquestionably plays a role in sex expression since plants thought to be unisexual may produce flowers of one sex only in some years and of both sexes in other years (60).

**VARIATION**

Several thousand individual plants of buffalograss have been isolated and studied at Woodward, Fort Hays, and other stations in the Plains. This material displays highly significant differences in density, length and width of leaves, vigor, production, spread, seeding habits, resistance to nematodes, smut, and other pathological conditions, and ability of foliage to remain green late in the season; all of which indicates possibilities for improvement by intensive selection and hybridization (128, 166). At Fort Hayes “plantings made with southern seed exhibited more vigor, heavier yields, better palatability and tendency toward greater resistance to certain foliage diseases than plantings established with northern seed. Such plantings, however, were more susceptible to winter killing, were usually deficient in seed production, usually produced a thinner turf and the foliage was often frozen down in the fall while growth was yet vigorous. The latter situation is held by some to result in forage of inferior quality for winter grazing.”

There have been developed a number of strains of buffalograss including the “Hays” or “one-eye” (29) developed at the Fort Hays Agricultural Experiment Station, of which at least 5,000 pounds of foundation seed were produced for distribution annually in 1944, 1945, and 1946. The strain is superior to common or field buffalograss in production of seed held high off the ground and of forage. A similar strain is described by Gernert (54) from Arbuckle Mountain in southern Oklahoma.

**MORPHOLOGY**

The ovary is rounded and tapers abruptly at the top, where it gives rise to two terminal style-branches, which have been observed up to one inch long (81, 154). The fibrovascular system is clearly defined. The lateral bundles are large and distinct, extending from the base of the pistil up the side of the ovary into the style-branches. The dorsal bundle is large but short, extending only to the top of the ovule which is attached near the base of the ovary (154).

Jones and Newell (80) observed pollen shedding habits of buffalograss. It was found that by 6:30 a.m. a few anthers were visible, and by 7:00 a.m. a uniform blooming of the plants had occurred. Approximately 30 minutes were required for the anthers to dehisce. Since the spikes were only six to ten inches from the ground, relative humidity was high—a condition which retards dehiscence and pollen shedding. Total shedding period was 6–11 a.m., the peak from 7 to 8:30. A temperature range from 70° to 80° F. appears to be optimum for blooming. Blooming in buffalograss is not retarded as much by low temperatures as it is in other warm-season grasses investigated. Mean diameters of pollen (81) for 1944 were 39.1 plus or minus

(10).
0.6 microns, for 1945, 37.4 plus or minus 0.7 (pollen shed May, June). They were reported of similar size by Engelmann (44): “globular, smoothish, 0.07 line in diameter” from anthers one line long, and by Geisler (53). Geisler gives pictures of buffalograss pollen which may be compared with illustrations of 31 other grass pollens.

Buffalograss pollen stored in the spike under a temperature of 40° F. and a relative humidity of 90 percent effected fertilization for seven days. Free pollen stored in a beaker under the same temperature and humidity remained viable for six to eight days. Receptivity of buffalograss stigmas remained fairly high for 13 days, after which time it decreased rapidly until no seed was produced on the twenty-first day (80).

Cross and longitudinal sections of buffalograss seed showing the copious endosperm are given by Martin (97) and Harlan (60).

**DISTRIBUTION**

A map showing geographically the distribution of buffalograss has been published by Hitchcock (70) but this one is lacking in detail. Four other maps, although more detailed, do not either fit the facts or agree with each other (126, 75, 166, 77). The correct range of the species was already known in general form by Engelmann in 1859 (44): “Our western prairies from the British possessions throughout the Missouri Territory, Nebraska, Kansas and New Mexico, down to Texas and northern Mexico.” This need only be altered to include southern Mexico. The area of major importance has been estimated to embrace approximately 190,000 square miles (166). This area is surrounded by a second of 234,000 square miles where buffalo is still a desirable component of grass mixtures, especially on heavy soils.

Detailed records for the various states show a stabilized range for the species which seems not to have changed greatly or at all since the settlement of its area by “white man” except where directly disturbed by building or plowing. The common name “buffalograss” (44) was used by hunters and trappers before the invasion of livestock producers and was known to them as “one of the most nutritious grasses, on which, for part of the year, subsist and fatten the immense herds of buffalo.” Rarely has any other common name than buffalograss been used for this grass, though “running mesquite grass” and “vining mesquite” have been used in Texas (73). The upper altitudinal limit is very close to 6,000 feet and the optimum rainfall belt is 15 to 25 inches.

**ORIGIN**

The knowledge that arid climates sufficient to develop highly specialized xerophytes as early as Eocene time (28) casts doubt on any attempt to place the exact point of origin of such individual and phylogenetically isolated plants as *Buchloë dactyloides*. Probably it is true that buffalograss weathered the ice ages of the Pleistocene in Mexico and in post-glacial time has extended its range northward (7), but these late Tertiary migrations are no indication of the point of origin, which was probably very early in the Cenozoic.
ILLUSTRATIONS

Most commonly published illustration of buffalograss is a lithograph made in the United States Department of Agriculture, Division of Agrostology, either by or under direction of F. Lamson-Scribner (15, 16, 71, 88, 90, 111, 112, 114). Other line drawings of plants are common (50, 52, 69, 70, 153, 167, 171; identical plates by Nichols, 143, 152; of spikelets only, 45, 170; portion of leaf and ligule, 61, 72, 80; plants and dissected spikelets, 44).

Photographs of buffalograss are also common (of seedlings, 161, 166; of pure stands, 128, 155; of mixed stands, 1, 3, 75, 156, 159; of resodding, 75, 128, 166; of native range of buffalo and blue grama grasses in the Southern Great Plains, 129; of individual plants, 75, 76, 122, 166; of seed harvest with combine, 77; of smutted spikelets, 166; detail of burs and seeds, 76; bagged pistillate flowers, 81; identical pictures comparing bromegrass sod with buffalograss, 105, 106, 107).

PALATABILITY

Somewhat at variance with the usually high regard for the palatability of buffalograss (32, 122, 145), is the report of Rogier (123), wherein the buffalograss was the last species to be eaten of the warm-season group in the Dakotas. However, this lack of palatability of buffalograss is confirmed by the observations made in Wyoming (14, 177), where, in a mixture of blue grama and buffalograss, the buffalo proved objectionable. Although the mixture produces a large yield of grass, the animal gains are below those on other seeded grasses because the sheep refuse to eat the buffalograss until they have taken the blue grama about to the ground. The number of sheep on this pasture was reduced in 1945, but the lower grazing rate meant that almost none of the buffalograss was used, even though it made up almost half of the cover. In Texas (27) cattle graze buffalograss more closely than adjacent blue grama.

DROUGHT RESISTANCE

The high degree of drought resistance of buffalograss, especially on heavy, fertile soils, has long been noted (cf. 16, 17, 96, 104, 109, 167, 140). During prolonged drought buffalograss is stimulated both during the initial dry years and during the first years of recovery (78). This is because western wheatgrass, blue grama, and other less drought-resistant species are both discouraged more easily, and are slower to recover. In both cases competition for buffalograss is lessened.

Buffalograss, besides being drought-resistant, suffers little from either heat or cold but cannot survive in dense shade (160). Buffalograss may respond quickly and markedly to midsummer precipitation when tall and mid-grasses do not (42).
CHEMICAL COMPOSITION

Very early in the grazing history of the shortgrass plains it was understood through experience that cattle could carry through the winter on short grass without supplemental feed. Long before the first chemical analysis the foliage curing nutritiously on the ground was empirically understood to be buffalograss (67, 96, 140, 167).

Seasonal conditions play an important part in determining the quality of forage whether it is utilized in summer or winter (166). Abnormally heavy rainfall during the growing season will produce forage abundant but of inferior quality. Wet periods following all curing will cause excessive leaching of nutritious elements.

Buffalograss was early reported on the basis of chemical analysis as “one of the most nutritious of the prairie grasses, being equal in feeding value to the gramas, though not producing so large a quantity of forage” (15, 104, 167). A typical analysis is given by Knight, Hepner, and Nelson (87), sample gathered August 18, 1906, at Wheatland, Wyoming, “Rather ripe. It has a very pleasant odor even when dry.” (cf. 38, 47, 48, 56, 74; Canada Central Experiment Farm Bul. 19, pp. 28-29; Colorado Bul. 12, p. 130; N. Dakota Rept., 1904, p. 35; South Dakota Bul. 40, p. 102; Wyoming Bul. 76, p. 28, and Bul. 87, p. 36).

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The moisture, carotene, crude protein, crude ash, calcium, and phosphorus content of buffalograss and blue grama were determined (79, 92) at intervals during the period from May 1939 to November 1941. Moisture, crude protein, carotene, and carotene and phosphorus were high in both grasses during the early stages but decreased rapidly as the plants approached maturity. As shown by the Rocky Mountain Forest and Range Experiment Station Seventh Annual Report (page 9) this drop is slight in buffalograss as compared with that in other plants of the shortgrass region. Calcium was quite variable in both buffalo and blue grama throughout the growing season. Carotene content of buffalograss was determined (85) for Texas: fresh samples varied from 99 to 254 p.p.m., dry samples from 4 to 94. Chromatographic analyses gave 86.6 and 87.6 beta carotene as a percentage of crude carotene.

The average analyses of all samples taken after frost showed buffalograss to be much higher in crude protein, crude ash, calcium, and phosphorus than was blue grama. This has been interpreted as indicating that buffalograss makes better winter pasture and suffers less loss of nutrient material as a result of winter or leaching than does blue grama (92). Buffalograss averages more pounds of crude protein per acre than other warm-season grasses (105).
The chemical composition of buffalograss seems to be affected less by previous clipping than that of blue grama. As a factor in pasture management for the Southern Great Plains area, the effect of frequency or intensity of grazing on chemical composition may be significant in comparison with the effect of the variability of weather conditions and grazing on total yield of grass (92). Some work has been done on the value of native pasture (11) for producing finished cattle as compared with finishing on corn. Native pasture produced cheaper gain but the cattle were not as well finished.

**SEED PRODUCTION**

Buffalograss seed is enclosed in hard burs often called a caryocyst but renamed an indupulvispathe by Gernert (54) one or several grains to a bur. Cutting tests indicate an approximate average of 11\(\frac{1}{2}\) seeds per bur (75). Two is considered high and if less than one per bur then harvest is unprofitable. The stems of the burs are no taller than the leaf growth. When moisture is abundant the burs are produced continuously from midsummer until frost. No seed is produced when soil moisture is low. Few, if any, grasses have as long a period for seed harvest, estimated up to 330 days (77). Pistillate spikelets are shed as soon as they are mature.

For combine or thresher: cylinder speed 1,400, cylinder concave clearance 3/8; for fanning mill: upper screen size 3/16, lower screen size 1/25 (77).

Purity: thresher run, 65, recleaned, 85, average germination 50: i.e., number of treated burs per 100 that produce one or more sprouts each (77). Germination of unscarified seed is reported as 67 percent (83). For good quality 50 percent of burs should show immediate germination even though pretreating is necessary (166).

**SEED COLLECTION**

Not only does buffalograss set comparatively light seed crops (134) but its peculiar seeding habit has made the collection of seed very tedious and costly. Seeds are born in short-stalked burs that shatter readily, and once these have fallen to the ground they become entangled in the vegetative mass in such manner as to make their separation and collection very difficult (75, 134); early prediction often said impossible (16, 94) and as late as 1939 (128) it was reported that "practical methods of harvesting the seed in commercial quantities have not been perfected, and many years may be required to develop seed-producing strains suitable for harvesting easily."

However, recognition of the value of this grass for conservation use has led to extra effort to obtain the seed. Special hand methods have proved satisfactory (75). Heavy street brooms and ordinary flat-bottomed shovels and dust-pan have been used in sweeping up the seed. The shattered seed burs are concentrated in low areas in ripples and hog wallows as the result of heavy rains (73). These depressions are sought out during the dry weather
and the seed swept up in convenient piles and then recleaned with a clipper mill.

Another small-scale method of collecting the seed is to use converted lawn mowers (*cf.* 64) with pan attachments on which bristle brushes have been substituted for the conventional rotating blades. Two pounds of burs per man-hour were collected in this way (75).

Small-grain combines, altered so that the sickle can be seen very close to the ground, have generally proved satisfactory in harvesting buffalograss seed from ungrazed stands. Several special types of motorized equipment to facilitate collection of buffalograss seed in quantity have been developed and tested by the Soil Conservation Service. The most successful of these machines was designed on the principle of a commercial vacuum cleaner. The suction developed from a rotating fan is used to pick up the seed burs from the mass of vegetation. Best success was had with a small portable machine of this same design having a small flexible nozzle that permitted collection of seed from concentrated accumulations. Weather conditions play a part in the successful use of this equipment. Heavy rains either carry away large amounts of seed or bury it in the soil in such a manner that its removal by suction is sometimes difficult (75, 77).

Natural stands have yielded as much as 100 pounds of clean burs to the acre. When plants are grown under cultivation primarily for seed production, it is customary to grow ten seed-producing (female) plants to one pollen (male) plant. This proportion of female to male plants greatly increases the amount of seed produced under cultivation on a given acreage over that which is possible under natural conditions (77).

**SEED PROCESSING**

Smith (137) described a drill hopper whereby burs of buffalograss are broken and the yield is about seven times more seedlings per pound of seed (see also 102) so that high prices for buffalograss seed need no longer stand in the way of more widespread use of this excellent grass. Natural stands have yielded 20 to 100 pounds of clean burs per acre. After being cleaned in an ordinary fanning mill, the burs should have a purity of 95 percent or better (85 percent is a minimum for good-quality seed). Clean burs average 40,000 to 55,000 seeds per pound of pure seed (77); 30,240 to 46,286 (166). Some seed is injured in processing, and cleaned grain cannot be stored as long as unprocessed seed of the same species. Hulled seed is harder to establish and is frequently of poor germination; its use is not recommended (166).

A regular commercial supply of buffalograss seed has been available since 1941. This means that a native soil may be established successfully and economically on cultivated land within a short time and places a responsibility to society squarely upon those who would otherwise abandon cultivated land to natural succession.
Early workers reported that buffalograss seeded freely (11) and that the seed was quite fertile (96). Recent workers have found the viable percentage of buffalograss seeds (162) and burs (77) low, due to dormancy (166) although the seed will remain in good condition a long time after shattering. Usually burs must be treated to ensure good stands at moderate rates (77) unless the seed is old and the dormancy has been broken by weathering (75). This, together with poor equipment of the species for dissemination of seeds, accounts in part for few natural seedlings on the range, and for their limited distribution. Livestock may be helpful in disseminating the seeds of buffalograss (128) and the seeds may be lifted by running water and deposited at bases of slopes or in streams (57). However, seedlings are not found in greater numbers in ravines than elsewhere (161). Many seeds will remain viable ten years or longer under normal conditions (100). Twenty-five-year-old seed found in the walls of old sod houses were found to germinate (95). Germination will not take place until the days are warm; first seedling emergence usually coincides with the last killing frost in spring (166).

Probably 40 percent or more of new seed is hard and will not germinate the first year after planting. Because of this dormancy, success or failure of seedings with untreated seed may not be apparent for a number of years. Studies show strain differences in extent of dormancy. Germination tests will show need for treatment. Whenever a sample of good-quality seed has less than 40 percent germination in the laboratory, it usually may be assumed that treatment is necessary (166).

Seed germination may be increased by soaking in water before planting (164). For results of treatments of seed with water, 0.2 percent solution of potassium nitrate, with sulphuric acid, and with Ceresan (166). Recommended treatment: “soaking the seed for 24 hours in a 0.5 percent solution of salt peter. Following soaking the seed is chilled wet for six weeks at 41 degrees F., and then dried immediately at a temperature below 120 degrees F. This treatment will raise the germination of the usual run of seed from approximately 10 percent to better than 70 percent.” Germination as high as 60 percent is not uncommon (75).

**ESTABLISHMENT BY SEEDING**

Fults (51) working in part with buffalograss, found that when moisture and temperature are favorable, plantings of 1/2 inch or less are more successful than deeper plantings (cf. 166). Although depth of planting is often a deciding factor in emergence, it becomes less and less important as time goes on and a stand is established. It was also found that planting grass seed, especially of warm temperature grasses like buffalograss, when moisture conditions were favorable, was of greater significance than whether plantings were made in the spring or in fall. In New Mexico (115) recommenda-
tions indicate that buffalograss should be sown at one to two pounds per acre on loams and flood flats where the rainfall is above 15 inches and the elevation below 6000 feet; plant to a depth of one inch before summer rains. April and May are the best planting months (166).

Buffalograss normally occurs in mixtures and should be reseeded in mixtures with other shortgrasses such as blue grama (166). A standard mixture (129) consists of blue grama as the basic species with the side-oats grama for the sandy, caliche spots, and buffalograss for the heavier soils. A mixture consisting of about 60 percent blue grama, 30 percent side-oats grama, and 10 percent buffalograss is usually drilled at the rate of about 12 pounds per acre. For sandy soils the proportion of side-oats grama is increased and that of buffalograss is reduced or eliminated (cf. 166).

In Kansas range, stands of pure buffalo are seeded at a maximum of eight pounds per acre. When the price of seed permits and pasturage is desired in a shorter time, fairly heavy seeding rates in 7-inch drill rows will insure a thicker stand; these stands suppress the weeds sooner, especially if the weeds are mowed two or three times during the season to reduce the competition for light and moisture (166). Wenger (166) describes the establishment and management of buffalo pastures in detail.

Trial plantings at the North Platte, Nebraska, nursery of the Soil Conservation Service indicate that the ordinary corn planter can be used successfully in seeding this grass. Spot planting the buffalograss burrs with small grain, which serves as a row marker until the grass has become established, permits early cultivation of the grass seedlings (75). Nurse crops, however, are not recommended, since the shading and competition for moisture do more harm than good (166).

Tillering begins 10 to 14 days after emergence, and stolons appear when plants are only a month old (161).

BUFFALOGRASS SOD

Buffalograss forms a close, even, dense turf of very fine leaves (134) which is effective for erosion control (75) and ranks first among the native grasses for wind-erosion control. Roots are numerous but do not penetrate far into the soil. The first four inches of soil are completely filled, and the roots are thread-like and almost white in color (140). For photographs of plants showing root development see Ten Eyck (140, page 374), Savage (128, page 20), and Weaver and Darland (156, page 153). The roots as observed on specimens excavated in Texas County, Oklahoma (100), are predominantly in the upper two to four feet of soil, but occasional roots were found at a depth of ten feet or greater.

On fine-textured eastern Nebraska soil buffalograss was found to maintain a high organic matter content in the 0-6-inch depth (99). On clay in North Dakota (59) the surface layer of dark soil was found to be seven inches deep, the soil reaction mildly alkaline, the carbonate content low, colloids and total soluble salts high, calcium low to medium high, and potassium, phos-
phorus, sodium, and chlorine negligible to low.

Weaver and Harmon (160) using large numbers of one-half square meter samples, determined that where long-continued grazing had caused replacement of the native and midgrasses by other types, underground yield also decreased. Samples from shortgrass pasture containing buffalo and blue grama yielded 42 and 27 percent less, respectively, than the original upland prairie vegetation which they replaced (cf. 157, 161).

**VEGETATIVE ESTABLISHMENT**

Vegetative establishment may, when seed is scarce, be cheaper and more practical than seeding methods.

Sod in good condition should be cut into small pieces and planted upon prepared soil. The pieces can be dropped by hand upon the surface of the soil and forced into the ground by stepping upon them (96). In resodding large areas a practical method of transplanting consists of the use of sheet-iron chutes in which pieces of sod are dropped in front of a wagon wheel. The pressure from the wheel pushes the pieces of sod firmly into the previously prepared seedbed (75). Pieces of sod may be broadcast with a manure spreader or some similar implement on recently cultivated land which is packed or rolled immediately afterward (126, 166). Vegetative plantings, though very effective in establishing a stand, are costly on account of the large amount of hand labor required (75, 166). May is the best month for transplanting (50), but April and June, when evaporation is low and rains are frequent, may also be good months (166). Successful plantings during other months or plantings, and establishment by runners, depend on artificial watering and should be attempted only when the land is free from weeds which might be encouraged at the expense of buffalograss.

Transplanting of stolons is not recommended, not only because the adventitious rooting at their nodes is dependent upon special conditions not frequently obtained, but also because suitable sources of runners are rare, and their handling is both laborious and expensive (166).

The distance apart depends upon the desirability of obtaining a thick stand at once. If the pieces of sod are placed two feet apart each way, they will spread fairly well in one season (96) and provide a good cover in two years (167). Sod pieces four inches square and spaced at four-foot intervals ordinarily give complete cover within two seasons (75). Cubes of sod about three inches square, set one to three feet apart, will cover the ground in one or two years if some effort is made to control weeds (50). A well-established plant of buffalograss under competition with weeds and with regulated grazing can be expected to make at least a foot of spread each season (162, 166).

Sod planting requires that the soil be thoroughly worked to a depth of about four inches. Transplanting material should be obtained first from long-established areas containing practically pure stands; second, when growth has been vigorous; and third, when the soil is not too dry. Espec-
ially adapted sod cutters have been developed (166). Sods obtained in strips on the contour give maximum opportunity for revegetation of the furrows.

Resodding of buffalograss may be combined with reseeding of blue grama and other adapted grasses. The sods of buffalograss may be scattered on the surface of deeply cultivated land and pressed in, the other grasses being seeded on the packed surface, or in strips between sodded contour furrows (128).

ECOLOGY

Effect of soil

Buffalograss grows on a fairly wide range of soil types (166) but grows more abundantly on heavy soils (77, 127, 128, 129), becoming rare on sandy soils. In North Dakota (59) it occurs on gentle slopes or flats where the soil has a high clay content. In places it plays a part in the succession following solonization and solodization (58, 84), wherein it characterizes the third stage in succession but not the fourth or climax.

Although preferring heavy soils, where it sometimes represents 90 percent of the total grass cover (32, 129), it has been found to adapt itself to poorer soil conditions in moister climates (134). In Kansas, buffalograss clothes the nearly level uplands and recurs on the impervious clay of lower slopes (1). Despite its high degree of drought resistance, it is very scarce on the plateaus and upland areas of western North Dakota but is frequently found on the scabby areas of alkali soils which may occur there over considerable area. It exhibits a high alkali tolerance (167, 174) and seems to be capable of making better growth on the hard clay soils of these areas than blue grama (167).

Effect of burning

Soil moisture loss of three to six percent was found on burned range in North Dakota (59). Moisture content of burned-over land in Wyoming was reduced nearly one-half (12). This severe reduction in moisture has a direct adverse reaction on the amount of forage produced. This is confirmed by Wenger (166), who states, “Burning shortgrass pastures is always accompanied by a temporary reduction in yield and vigor of grass.”

Effect of fertilizing

Little work has been done on fertilization of native shortgrass pastures. In preliminary trials at Hays (166) fertilizing irrigated seed blocks gave no response in either seed or forage production.

Effect of irrigation

Greatly increased yield of pasturage are possible by irrigation. Irrigated buffalograss pastures are relatively short-lived and soon sod-bound. If the forage is not grazed throughout the season it becomes woody and unpalatable and is not as nutritious as dryland forage.
Effect of competition

Buffalograss is a warm-season grass, sometimes called the bermuda grass of the north. The work at the Cotton Branch Experiment Station shows that in the South, buffalograss is eliminated when placed in competition with bermuda grass (109), but in Texas, where their natural ranges overlap (65), a bermuda-buffalo mixture may be present in permanent pasture.

According to Weaver and Fitzpatrick (158), a good growth of little bluestem, interspersed with big bluestem and Indian grass, gives way abruptly, as the soil becomes thinner, to a very open, dwarfed, and distinctly bunched type. This may be replaced almost completely by areas of grama grasses and buffalograss.

Effect of drought

Buffalograss grows especially on level places where there is some accumulation of run-off water (167). Although it is uninjured by drought, it ceases growth sooner when a drought approaches than do the deeper-rooting grasses (140) but will green up with the coming of the first good rain. During years when rains are timely and well distributed, the grass remains green all season (166). For effect of drought years upon buffalograss see Weaver and Albertson (156); Weaver and Hansen (159); for role in recovery of prairie from drought years see Weaver (155); Albertson and Weaver (3). According to Albertson (1), “Among the many changes in plant populations resulting from the series of dry years none was more outstanding than the rapid reclaiming of the bared soil by buffalograss.”

On abandoned fields

Judd and Jackson (83) charted the appearance of buffalograss on abandoned farm lands from a trace in three to six years, to five percent in ten or more years. Buffalograss repossesses abandoned fields much more rapidly and more completely than blue grama (33, 128); abandoned fields fully covered with buffalograss withstood the drought much better than adjacent virgin pasture (128). Costello (34) found that buffalo and other perennial grasses entered abandoned fields (ant mounds provide a substratum for the entrance of shortgrasses into the succession) in three to six years but did not become dominant for 10 to 20 years, depending on the drought cycles and wet years which retard or accelerate the rate of succession. Such land seldom becomes fully revegetated with the more desirable grasses in less than 25 years and often more than 40 years are required (132, 133). Natural revegetation is so slow that it is not recommended, since practical methods of reestablishing this grass in a relatively short period of time have been perfected (166).

Problem of the climax

Certain plant ecologists refuse to give the shortgrass plains the status of a true plant climax, holding that this plant community is a disturbance or dis-climax brought out by the coming of man and of domesticated grazing animals and that the true climax is the mixed grass prairie, which would re-
appear if pristine conditions were restored. Larsen (93) attempted to show that the Great Plains was formerly grazed heavily by bison and other wild animals and that this primitive grazing held the western plains in a shortgrass stage which cannot be called a disturbance climax because this animal life was natural to the biome.

**FACTOR IN RANGE-CONDITION CLASSES**

Long before range-condition classes were an accepted form of range judging, it was known that buffalograss was affected differently from many other perennial grasses by heavy utilization. According to Bentley (16), “Buffalograss will survive almost any degree of drying, trampling, and ill usage, making it one of the finest and most desirable kinds.” Again, according to Shear (134), “it will survive the greatest hardships, and is about the last species to succumb under excessive grazing” (cf. 75, 77, 140, 167).

In 1911 Hogan (73) reported that this grass spread rapidly over the black land when the various other native grasses have been eaten or tramped out by overpasturing. Gernert (54) observed that under permanent grazing the taller bluestem bunchgrass is eliminated, and buffalograss replaces it on the drier tight lands, while on sandy land and in moist ravines less desirable grasses and weeds may occupy the region. These observations are not in full accord with the report of Weaver and Fitzpatrick (158, see page 183) that “Although buffalograss is often abundant in overgrazed pastures throughout the drier area, this species requires more water than the short grama grasses and is found sparingly in draws.” This repeated observation that buffalograss withstands heavy grazing indicates the practicability of special plantings of pure buffalograss for small farm lots and corral pastures. Especially where irrigation is available, buffalograss has the best chance of survival.

In 1938 Hanson and Whitman (58) reported that “in places its occurrence appears to be due to overgrazing, erosion, or other disturbance.” This appears to be the normal behavior of buffalograss on the outer limits of its range (cf. 138) provided neither elevation nor moisture are limiting factors. Shortgrasses do not withstand the shading (31) and competition of weeds occurring under conditions of greater rainfall. They survive under such conditions only when top growth is removed by close clipping or grazing (4).

The percentage of the composition and the percentage of its utilization on Nebraska hardland pasture have been worked out for varying distances from water (24). During prolonged wet years the more mesic mid- and tall-grasses advance for a considerable distance from their original habitat into the more xeric locations occupied by the shortgrass, buffalo, and blue grama (2, 166).

Methods of quadrating shortgrass vegetation have been compared and described in detail by Ellison (43) and Anderson (9). The percentage composition of buffalograss in various shortgrass-plains vegetation types has been
detailed by Costello (32). The Soil Conservation Service (148) recommends quadrats one or two meters square. For actual sample quadrats of the pantograph-chart method see Savage, 1937 (127).

Buffalograss occurs in pure stands only in pastures that have been continuously overgrazed for some time (129, 166). According to Dykes (41), buffalograss is a normal component of mixed prairie in "excellent" condition, increases to dominance in the "good" condition, remains in scattered patches in "fair" condition, and is further reduced in a "poor" condition (cf. 146, 147). This increase of buffalograss following the first stage in the depletion of excellent mixed prairie is confirmed by Allred (5, 6) and illustrated by Costello (34, fig. 4, page 318) as a shortgrass disclimax induced by grazing animals. Barnes and Nelson (13) have demonstrated that mechanical treatment of range in the fair or good conditions will aid its return to a mixture of mid- and shortgrasses typical of a range in excellent condition.

For the Panhandle of Oklahoma, McMillen and Williams (100) found that for the more productive heavy upland soils at their highest state of productivity, blue grama and buffalograss will make up at least 90 to 95 percent of the total vegetation with only a small amount of weeds and the less desirable grasses (cf. 127, 166).

FORAGE VALUE

Probably no other grass of such small stature and limited adaptation as buffalograss has received so wide and universally favorable acclaim. When still not fully described by botanists the grass was already known to laymen of the West as "buffalograss" and recognized as fine feed (44). In agricultural circles and in agricultural literature the long line of grade-A reports seems to have been started by Vasey (150, 152) who called it "perhaps the most valuable plant in support of the cattle of the plains." From then on, this grass was usually hailed as either "the most" or "one of the most" valuable grasses of the Great Plains (cf. 26, 45, 52, 69, 140, 144), and hailed as attractive to all classes of livestock (73, 77, 90, 98, 167). It has long been reported as unsurpassed for winter pasture (16, 73, 100, 111, 144, 170, 171).

Both at the northern and at the southern ends of its range, buffalograss has trouble maintaining its uneclled reputation in the face of strong competition from its natural associate, blue grama. Thus in New Mexico (176) it is not equal to the gramagrasses (cf. 100, 150).

CARRYING CAPACITY

An early estimate (151) of the carrying capacity of shortgrass range seems to have been high as to acreage, low as to number of stock: "over the entire region the average amount required would be 15 acres to the head of stock." In the Panhandle of Oklahoma blue grama and buffalograss (100) should not be grazed to a height of less than two inches. Here the blades of
buffalograss are commonly two to five inches high.

In Texas (65) a nine-acre buffalograss pasture on good land kept six steers for eleven months (Nov. 1946 to Oct. 1947) with a production of 139 pounds of beef. These cattle were fed hay while there was no green grazing. At the Southern Great Plains Experimental Range (131) a pasture of re-seeded buffalograss, not yet fully established, produced less gain per head than native range but supported over twice as many cattle and yielded nearly twice as much gain per acre.

In Kansas (8) buffalograss increased under systems of year-long grazing, a practice which is not recommended, since a deferred pasture has a higher carrying capacity (cf. 20). Reduced height (27) was found to be detrimental to the best use of buffalograss, whether the shortness was due to site or to overgrazing (less than four inches considered short).

For western Oklahoma (40) Durham said, "This grass brings more net cash to many farms than any other plant," and "It will easily produce 100 pounds of meat or 1000 pounds of milk to the acre annually." McCarty judged yield on basis of their calculated values for the second year of treatment, thus attempting to eliminate seasonal variation from year to year. Quadrats of buffalograss, clipped four times, were reduced to 71 percent of their calculated values for the second year of treatment (124). Biswell and Weaver (21) reported the total dry weight of tops from the clipped sods, where the stolons were permitted to grow was 63.1 percent of that of the same species unclipped after transplanting. Plants weakened by repeated clipping renewed growth slowly if at all after being frozen. No new roots were produced during the period of the experiment of those that survived (21). These reports are at variance with all other results obtained for the species under natural grazing conditions, for grazing, when not extreme, has been found beneficial to buffalograss (127). In the same year it was reported that buffalograss and blue grama were found to be affected to only a small extent by frequent clipping (20).

Lang and Barnes (91) found that shortgrass (buffalo and blue grama) will yield considerably more dry weight when harvested frequently than when protected to the end of the season before clipping. It has also been observed that reseeded areas (i.e., areas not yet sod-bound) have a higher carrying capacity than native range (166). However, the same stimulatory effect is obtained on native-shortgrass range by mechanical treatments (152), the best being the eccentric one-way disc (13).

Blue grama and buffalograss showed no consistent variations in yields from the Lincoln, Nebraska, area, where they occurred sparingly, to the shortgrass-plains climax, where they are dominant. Yields varied between 2 and 2.35 tons per acre (135). Work done by the Wyoming Agricultural Experiment Station (177) showed buffalograss stimulated by being clipped at intervals during a dry summer, the clipped plants producing 48
percent more than the unclipped. Loss of stand also occurred in Nebraska (107) on plots of this grass cut only once a year. Fults (51) found that mowing improved pure-stand plantings of buffalograss. Bromegrass, otherwise the highest yielder in Nebraska, was outyielded by buffalograss on the average when compared under frequent clipping (105). Further in Nebraska the shortgrasses—buffalo and blue grama—gave the highest yields of all the grasses during the dry years, even though these particular strains are known to be less productive than other grasses (105).

Wenger (166) uses clipping-yields results to recommend rotation grazing for buffalograss pastures. He also cites Dickson et al. (39), who found that clipping at intervals of eight weeks gave greater yields than more frequent clippings. Grazing too early in the spring and overstocking are the most common abuses of shortgrass pastures. Providing supplemental grazing during the early spring season and conservative stocking throughout the year are practices that will do much toward maintaining the vigor of the grass and providing maximum returns.

BUFFALOGRASS FOR LAWNS

Within its area buffalograss is the only plant that can withstand all combinations of cold, heat, and drought yet maintain an attractive turf under maximum usage with a minimum of care (166). Buffalograss has been repeatedly mentioned as meriting consideration for dryland lawn and landscaping uses for which it appears well suited (40, 109, 128, 167). Perhaps the first suggestion of using buffalograss for this purpose was made by Williams in 1898 (172). In reporting on grasses near Rapid City, South Dakota, he mentioned “full sods of blue grama, black grama, and buffalograss arranged in natural lawns, as it were, according to nature’s own fantastic designs. It made a very pretty sight. No artificial lawn could be more desirable. The color of the grasses, so similar and yet so delicately different that each species growing in separate patches could be recognized at a considerable distance, the splendid sod, and the pleasing general effect suggested the possible use that might be made of these grasses for lawns, borders, and designs about dwellings, public buildings, and cemeteries.”

Solid blocks of either sex may be removed for transplanting, and in this way lawns have been set entirely with the very short plants, which do not require mowing.” (54)*

MISCELLANEOUS USES

The sod houses of the early settlers were made mostly from building blocks of buffalograss (54, 69, 70, 166). Buffalograss can be used to line terrace channels and outlets, to strip sod gullies, and to protect earth fills around ponds and reservoirs (75). It is ideally suited to erosion control (77) and soil-moisture conservation work throughout the Great Plains from

*For photos of lawns of buffalograss (128, p. 21). For detailed description of the maintenance and establishment of lawns see Wenger (166).
central Texas to North Dakota (136). Hanson and Whitman (58) reported the water-holding capacity of soils supporting buffalograss to be high, usually 57 to 60 percent. As an erosion-resistant serviceable turf requiring a minimum of care, buffalograss has many other uses for such purposes as landscape development, strips for airfields, and reduction of weeds and erosion on highways, rights-of-way, athletic fields, golf courses, parks, and cemeteries (166).

Diseases

As high as 86 percent of the caryopses have been found ruined by fungi such as Cercospora, Helminthosporium, and Ustilago (54). Cercospora seminalis causes false smut of the fruiting structure, reducing viability of the kernel. Helminthosporium inconspicuum var. buchloes causes leaf blotch, which prematurely dries the leaves. Puccinia kansensis causes leaf rust and is generally considered less serious than leaf blotch. A condition referred to as witches’ broom, apparently caused by the presence of Eriophyes mites, often occurs in newly established areas of buffalograss, particularly nursery plantings (166).

The nematodes affecting buffalograss have been studied by Miss Gertrude Tennyson of the Plant Pathology Division of the Oklahoma Experiment Station. She reports that the nematode is probably Anguillulina agrostis Steinbuch (54).

A condition called “yellows,” thought to be the result of an iron deficiency (166), is reported by Wenger (1943). The “Nema” strain, named by Gernert in 1937 (54), was found by Powers, and produces pistillate spikes on prostrate surface runners, while the glumes are elongated, thin, and chaffy, resembling somewhat the glumes of a brome. This appears to be due entirely to the action of nematodes, since the growth form is similar to that of other crops affected by nematodes.

MISCELLANEOUS PLANTINGS

There have been a number of trials of buffalograss that are not reported in the preceding paragraphs but for the record may be summarized as follows:

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<td>(19)</td>
<td>recommended “for arid zones”</td>
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<tr>
<td>Arizona</td>
<td>(141)</td>
<td>“25% lived for two years, albeit it was a matter largely of existence”</td>
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<tr>
<td>Arkansas</td>
<td>(109)</td>
<td>“merits consideration”</td>
</tr>
<tr>
<td>California</td>
<td>(Hilgard, 1898)</td>
<td>“has shown very promising growth”</td>
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<tr>
<td>Iowa</td>
<td>(36)</td>
<td>“barely crosses our border, having been collected so far as is known to be the author in but one locality in Lyon County”</td>
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<tr>
<td>Location</td>
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<td>Comments</td>
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<td>---------------</td>
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<tr>
<td>Hawaii</td>
<td>(168)</td>
<td>&quot;growing at experimental gardens and not yet established&quot;</td>
</tr>
<tr>
<td>Kansas</td>
<td>(31)</td>
<td>&quot;does not withstand the shading and competition of weeds occurring under conditions of greater rainfall&quot;</td>
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<tr>
<td>Kansas</td>
<td>(152, 166)</td>
<td>by Sewell at Garden City, probably first demonstration of sodding native grass in Kansas</td>
</tr>
<tr>
<td>New Mexico</td>
<td>(23)</td>
<td>&quot;failed to produce results that have been at all promising&quot;</td>
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<tr>
<td>Texas</td>
<td>(118)</td>
<td>&quot;germinated April 15 to poor stand, disappearing after having grown to a height of one inch&quot;</td>
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<tr>
<td>Texas</td>
<td>(17)</td>
<td>&quot;gave very satisfactory results&quot;</td>
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<tr>
<td>Washington, D. C.</td>
<td>(89, 134)</td>
<td>&quot;live roots transplanted from Nebraska have grown with remarkable vigor&quot;</td>
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LITERATURE CITED

Because in most cases these articles deal only indirectly with buffalo-grass and blue grama, the paging used does not always indicate the full scope of the article but only the pages directly concerned with the two grasses. Obviously it has been impossible to cite all incidental references, but an attempt has been made to include any reference which added (at time of its publication) new and pertinent information.

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<td>GEORGE DUKE HUMPHREY, Ph.D., President of the University</td>
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- **CLARENCE M. RINCKER, M.S., Asst. in Agronomy and Seed Certification.**
- **W. McN. MILLER, M.S., Asst. in Agricultural Engineering.**
- **BYRON TOMLINSON, B.S., Irrigation Engineer (Assoc.).**
- **R. D. LEWIS, M.S., Soil Scientist.**

### Animal Production

- **NEAL HILSTON, Ph.D., Animal Husbandman, Beef Cattle.**
- **H. S. WOOG, Ph.D., Animal Husbandman, Dairy Cattle.**
- **J. A. GORMAN, M. S., Asst. Animal Husbandman, Horses. (On leave).**
- **E. KENNETH FAULKNER, M.S., Asst. Animal Husbandman, Beef Cattle and Sheep.**
- **DONALD C. BROWN, B.S., Asst. Animal Husbandman, Dairy Cattle.**
- **GEORGE T. DAVIS, M.S., Assoc. Animal Husbandman, Poultry.**

### Apiculture and Entomology

- **ROBERT E. PFADT, Ph.D., Assoc. Research Entomologist.**
- **DONALD C. DENNING, Ph.D., Asst. Research Entomologist.**

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*In cooperation with U. S. Department of Agriculture.*