ISSN 0193-3779

Old World Bluestems and Their Forage Potential for the Southern Great Plains

A Review of Early Studies

U.S. Department of Agriculture
Agricultural Research Service
Agricultural Reviews and Manuals • ARM-S-28/October 1982

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This publication is available from the Southern Plains Range Research Station, 2000 18th St., Woodward, Okla. 73801.

Agricultural Research Service, Agricultural Reviews and Manuals, Southern Series, No. 28, October 1982.

Published by Agricultural Research Service (Southern Region), U.S. Department of Agriculture, P.O. Box 53326, New Orleans, La. 70153.

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By Phillip L. Sims and Chester L. Dewald[1]

ABSTRACT

This paper reviews and summarizes research that has been done to assess the potential of Old World bluestem grasses in the Southern Great Plains of the United States. Much of the information has been culled from unpublished reports of studies done at the U.S. Agricultural Research Service's Southern Plains Range Research Station at Woodward, Okla. These and similar studies have evaluated seed production and germination characteristics, stand persistance and winter hardiness, forage production, and grazing value of several Old World bluestem species, cultivars, strains, and blends. The paper also details the findings of establishment studies with Caucasian bluestem, *Bothriochloa caucasica* (Trin.) C. E. Hubbard, and discusses future research needs and the present usefulness of Old World bluestems in the Southern Great Plains. Index terms: bluestems, *Bothriochloa* spp., forage, grasses, Southern Great Plains.

INTRODUCTION

Old World bluestems can contribute significantly to beef production and soil conservation in the Southern Great Plains. These grasses are mainly intended to reclaim marginal cropland interspersed among the region's rangelands. Used as forages, they can complement native rangeland grasses in forage-livestock production systems; beef production of 150 lb/acre or more has been attained from dryland sites that had minimal fertilizer applications. And recent research indicates that some of the Old World bluestem plant materials also have forage-production potential for the Southeastern United States (Coyne et al., in press). An overview of research on Old World bluestems in the Southern Great Plains should be useful to livestock producers, extension range and livestock specialists, range conservationists, and scientists planning further research. This report reviews all the research, including much information that has previously been available only informally in unpublished reports.

Origin of Plant Materials

Old World bluestems, an array of grasses of the *Bothriochloininae* tribe (*Bothriochloa-Dichanthium-Capillipedium* complex), are mainly European and Asiatic in origin. The taxonomic, cytological, and morphological characteristics have been extensively studied in the collection at Oklahoma State University, Stillwater, Okla. (see

[1]Range scientist and research agronomist, Southern Plains Range Research Station, Agricultural Research Service, U.S. Department of Agriculture, 2000 18th St., Woodward, Okla. 73801.

Celarier and Harlan 1955; Harlan et al. 1958, 1961a, 1961b; Celarier et al. 1961; Dewald and Harlan 1961; de Wet et al. 1963, 1966; Harlan 1963a, 1963b; Harlan and Chheda 1963; Harlan and de Wet 1963; and Harlan, Brooks, et al. 1964). The collection studied by J. R. Harlan and his associates was acquired from more than 25 countries as plant materials that might eventually result in improved forage plants for U.S. pasture and rangeland.

The original evaluations of Old World bluestems (Harlan et al. 1958) found that they react ecologically as plants suited to some stage of secondary succession rather than as climax species. In their original habitat they increase under heavy grazing and other kinds of disturbances. They produce seed freely and are relatively easy to establish.

There are major ecological differences among taxa in the genus *Bothriochloa*. The natural habitat varies from quite restricted to comparatively cosmopolitan (Harlan 1963b). Species with restricted distribution are often confined to only a few hundred hectares while others are restricted ecologically to streambanks, intermittent lakes, or rocky tablelands (Harlan and Chheda 1963). Generally, the restricted ecotypes grow on stable habitats relatively free from human disturbances. Caucasian bluestem, *Bothriochloa caucasica* (Trin.) C. E. Hubbard, is probably endemic to an area in Georgia, U.S.S.R. (Harlan and Chheda 1963). But the natural distribution of this relatively winter-hardy species is not fully known. It was introduced from Tiflis (Tbilisi), U.S.S.R., in 1929, and all known sources in the United States trace to this introduction (Harlan 1952a).

In contrast, Celarier and Harlan (1955) report finding *Bothriochloa ischaemum* (L.) Keng. from the Atlantic coasts of Western Europe to the Pacific coasts of China, Malaya, and Taiwan. Winter-hardy, northern ecotypes occur in southern and western Siberia, Mongolia, northern China, northern Africa, central Asia, Holland, and Germany and in mountainous areas between 2,000 and 10,000 feet elevation in Afghanistan, Pakistan, and India. Taxonomically, *Bothriochloa ischaemum* from the upper plains and lower foothills resembles the more tropical *Bothriochloa intermedia* (R. Br.) A. Camus, and many look like *B. ischaemum* var. *songarica* (Rupr.) Cel. et Harl., a species believed to be related to *B. intermedia*.

According to Harlan and de Wet (1963), *B. intermedia* is a "hodgepodge of germplasm assembled naturally from at least five species belonging to three genera." This hybridization from a diverse genetic background probably contributed to the wide natural geographic range of *B. intermedia*. Populations of *B. intermedia*, generally found at elevations less than 5,000 feet in the more tropical regions of South and East Africa, Pakistan, India, Burma, Indonesia, the Philippines, New Guinea, and Australia, are thought to be markedly less winter hardy than most *B. ischaemum*. Harlan (1963a, 1963b) suggests that introgressive hybridization occurred in isolated locales of regions where these two species are sympatric. Apparently, hybridization occurs only where man's disturbances have increased the range of either species, *B. ischaemum* to lower elevations and *B. intermedia* to higher.

Variation in geographic range is just one of the ways *Bothriochloa* species differ among themselves: Harlan et al. (1958) found some types growing in sites with extremely high rainfall (over 215 inches annually) and others in deserts with as little as 4 inches of annual precipitation. Apparent productivity and forage quality varies from very high to extremely low. Some have high levels of aromatic oils and are quite pungent. Others lack winter hardiness even in the Southern Plains, while others are hardy in Canada.

The six yellow bluestems, *B. ischaemum*, described in "Grass Varieties in the United States" (Hanson 1972) are the cultivar 'King Ranch', the blend Plains, and the experimental strains El Kan, Marash, A–1407, and P–15626. The *B. ischaemum* var. *songarica* cv. 'King Ranch' bluestem, also variously called Turkestan bluestem, East Indian bluestem, yellow beardgrass, and yellow bluestem (Harlan 1956), was introduced from Amoy, China, in 1917 (Webster and Foster 1949). Taiwan, an experimental strain of *B. ischaemum* var. *songarica*, has not been released (table 1). Plains, a blend of seed from 30 accessions of *Bothriochloa ischaemum* var. *ischaemum* from the midelevations of Afghanistan, Pakistan, India, Turkey, Iran, Kashmir, Iraq, and the U.S.S.R. (Harlan, Richardson, and de Wet 1964), was released in 1972 (Taliaferro et al. 1972). 'King Ranch' seed were made available to users by the U.S. Soil Conservation Service (SCS) in 1941 and later certified and released by SCS and the Texas Agricultural

Experiment Station in 1949. El Kan was tested at the Kansas Agricultural Experiment Station, Manhattan, Kans.; it has not been released, but it has had limited use from seed harvested from field plantings. Marash, collected in Marash, Turkey, by J. R. Harlan in 1948 and later evaluated at the Oklahoma Agricultural Experiment Station, has not been released nor have seed been distributed for field testing. Seed of P-15626 have been distributed for field testing, but it has not been released. In 1979, New Mexico State University, Colorado State University, University of Arizona, and U.S. Soil Conservation Service (1979) released A-1407 as 'Ganada' yellow bluestem.

Under the *Dichanthium caricosum* A. Camus complex, Hanson (1972) lists three experimental strains: Angleton (Gould 1975 lists it as *Dichanthium aristatun* (Poir) C. E. Hubb.), Gordo, and Medio bluestems. Angleton is a palatable grass with some drought and salt tolerance. It is well adapted to the Texas coastal plains that receive 30 inches or more of annual precipitation. Medio and Gordo are best adapted to southern Texas and coastal prairie areas. None of these grasses has been released.

Evaluation of Collections

Forage production potential and seed characteristics of about 200 Old World bluestem populations from about 1,500 accessions and more than 1,000 hybrids were evaluated by Harlan, Richardson, and de Wet (1964). Seeds from promising lines were bulked by J. R. Harlan and his associates at Oklahoma State University to form blends or mixtures of accessions from different origins (table 1) for further evaluation. Because grasses of the Old World bluestem complex are largely apomictic, it was felt that large acreages of genetically identical plants would be more susceptible than a blend of several accessions from more than one population to the vagaries of climate and diseases (J. R. Harlan, personal communication). Also, a mixture of genetically different plants might be more suitable for the diversity of sites found on most rangelands. The selection of seed lots to form the various blends was based on morphological similarities, including plant stature, growth form, and maturity indexes, of accessions growing in uniform nurseries at Stillwater, Okla. (Harlan, Richardson, and de Wet 1964). (Descriptions of these blends are included in table 1.)

M blend (*Bothriochloa ischaemum* var. *ischaemum*) was released under the name of Plains bluestem (Taliaferro et al. 1972). 'WW Spar' bluestem, one of the accessions found in Plains, was recently released (U.S. Agricultural Research Service and Oklahoma Agricultural Experiment Station 1982) by scientists at the Southern Plains Range Research Station. This grass has greater winter hardiness, earlier spring green-up, increased drought tolerance, and higher forage production than many of the other accessions in Plains. Several other blended strains are still in the evaluation stages and have not been made available for general use.

The blends of *B. intermedia* var. *montana* (table 1) are I blend (30 hybrids of accessions from India and Pakistan), J blend (7 hybrid lots from accessions collected in Afghanistan), and K blend (a composite of three lots from the Kulu Valley, India) (Forage Crops Staff 1960 and Harlan, Richardson, and de Wet 1964).

Seed Production and Germination Characteristics

Old World bluestems reproduce by facultative apomixis, have an indeterminate flowering habit, and have seeds enclosed in chaffy glumes. So special management is required to successfully produce, process, and plant the seeds. Ahring et al. (1978) reported that low seed yields of 'King Ranch', El Kan, Caucasian, and Medio have significantly limited acceptance and use of these grasses. They projected that 20–40 million acres in the Southern Plains could eventually be planted to Old World bluestems if seed were available.

How cultural and management practices affect seed production of Plains has been evaluated by Ahring et al. (1973). With proper management, Plains produces two seed crops annually, one in midsummer and another in the fall. Yields of over 200 lb/acre of pure live seed have been attained. From a survey of producers, Dalrymple (1979b) concluded that Plains is well liked and that most producers are interested in increasing their acreage. Producers expressed concern over difficulties in planting, cost of establishment, seed-harvesting problems, and quality of the hay after-

Table 1.—*Bothriochloa* spp. and blends of accessions evaluated at the Southern Plains Range Research Station, Woodward, Okla.

Bluestem	Origin	Description
Bothriochloa caucasica:		
Caucasian	U.S.S.R.	One species.
Bothriochloa intermedia var. indica:		
B blend	Pakistan	Blend of 3 accessions from Pakistan and 3 hybrids of *B. intermedia* × *B. ischaemum.*
H blend	India, Pakistan	Blend of 4 lots of accessions from the hills (H=hill type).
L blend	Pakistan	Blend of 8 accessions (L=large stature).
LL blend	Pakistan	Blend of 4 accessions and 1 hybrid (LL=large stature, late maturity).
T blend	India, Pakistan	Blend of perhaps duplicate lots from the Tarnab Experiment Station, Pakistan.
Bothriochloa intermedia var. *montana:*		
I blend	India	Blend of 30 hybrids apparently responsive to irrigation.
J blend	Afghanistan	Blend of 7 hybrids with A-6573b.
K blend	India	Blend of 3 accessions from Kulu Valley, India.
Bothriochloa ischaemum var. *ischaemum:*		
'Ganada'	Turkestan	Released in 1979.
Plains (M blend)	Afghanistan, India, Iran, Iraq, Kashmir, Pakistan, Turkey, U.S.S.R.	Blend of 30 accessions from the mideleva-tions (M=medium plant stature); released in 1972.
S blend	Afghanistan, China, Czechoslovakia, France, Hungary, Iran, Iraq, Italy, Kashmir, Morocco, U.S.S.R., Yugoslavia.	Blend of 30 accessions (S=smaller plant stature).
'WW Spar'	Pakistan	Accession also found in Plains released in 1982.
Bothriochloa ischaemum var. *songarica:*		
'King Ranch'	China	Single accessions introduced in 1917.
Taiwan	Taiwan	One accession.

math following seed harvest. From this survey, he estimated that more than 14,000 acres of Plains had been planted by 1979 from seed produced in southern Oklahoma.

Ahring and Harlan (1961) reported that the germination response of different varieties of *B. ischaemum* and different years of harvest of the same variety varied with environmental conditions. The degree of seed dormancy was influenced by the microclimatic conditions occurring during seed development and by the stage of maturity at harvest. Germination of fresh seed was increased by removing the caryopses from the glumes.

In 1967, R. L. Dalrymple (unpublished data) found that nitrogen fertilizer applied as a top-dressing increased stem size, seed yields, and the number and weight of seedheads of 'King Ranch'. These responses were most pronounced when nitrogen fertilizer was accompanied by phosphorus and potassium fertilizers, particularly at rates of 75 and 100 lb of nitrogen fertilizer per acre. Although these results are based on limited data, they confirm that seed-production practices should include soil analyses to determine proper fertilizer requirements.

Ahring et al. (1964) evaluated how processing grass seed affects seed quality and subsequent stand establishment. Their study included Marash. They concluded that seed growers should be careful not to overprocess range grass seeds. Excessive hammermilling and other cleaning procedures damaged caryopses and reduced the longevity of seed. Although processing bulk seed increased the laboratory germination percentages and facilitated planting, the best stands in field plantings were obtained with either unprocessed or slightly processed seed. According to Ahring et al. (1964), Marash was less susceptible to processing damage than were the native species studied: indiangrass, *Sorghastrun nutans* (L.) Nash; sand bluestem, *Andropogon hallii* Hack.; and buffalograss, *Buchloe dactyloides* (Nutt.) Engelm. They concluded that the oval caryopses of Marash were more able than the slender and brittle native plant caryopses to withstand hammermilling. Because of the small seed size and large number of seeds per pound, a certain amount of pulverized inert material is helpful in obtaining desired field-seeding rates. So, thorough cleaning is not necessary for most planting operations.

Ahring et al. (1975) demonstrated that the appendages surrounding the caryopses inhibited the germination of freshly harvested *B. ischaemum* var. *ischaemum* and *B. intermedia* seed. Heat drying appeared to degrade the inhibitors found in the bracts surrounding the caryopses. But excessive heat during the drying process hindered germination.

Dalrymple (1979a) reviewed several seed harvesting and handling procedures for Plains. Harvesting equipment ranged from specially built grass-seed harvesters and commercial combines to a pickup-mounted grass-seed stripper. In describing the general procedure for setting combines for harvesting this type of seed, Dalrymple pointed out that, although most modern combines could be used, the harvested material would still appear trashy. He reported that home-built pickup-mounted strippers are least costly to build and maintain but are not efficient for harvesting large acreages rapidly. Rapid and efficient harvesting procedures are necessary since the appropriate time to harvest is often brief, and even moderate wind or rain or excessively hot temperatures may cause mature seeds to shatter.

Whitney et al. (1979) developed the OSU Grass-Seed Stripper and evaluated it for harvesting Old World bluestems. They found that the pure-seed content of the material harvested with the stripper was higher than that of chaffy-seeded grasses harvested by most conventional methods. In these evaluations, yields of pure live seed ranged from 29% to 45%. According to Dalrymple (1979a), this commercial stripper is cleaner and easier to operate than a combine and requires less time per acre harvested. He found, however, that the stripper material contains more stems and leaves and requires more cleaning time than material harvested with a combine.

Recently, the Woodward Flail-Vac Seed Stripper was developed (Dewald and Beisel 1982). This machine combines the flail action by a nylon-bristle brush rotating upward on the front edge with a vacuum developed in a curved shroud over the brush. This stripper effectively harvests the chaffy-seeded Old World bluestems with a minimum of stems and other debris.

STAND ESTABLISHMENT

A series of plantings of Caucasian was made in 1957 and 1958 to evaluate establishment practices and the persistence of seedlings on several types of seedbeds (E. H. McIlvain and M. C. Shoop, unpublished data). These plantings were made on a Pratt loamy fine sand (sandy, mixed thermic Psammentic Haplustalfs) at the Southern Plains Experimental Range near Woodward, Okla. Seeding rates were about 10, 20, and 40 pure live seeds per linear foot of row with rows 12 inches apart.

Seeding techniques used in this study simulated actual field-level revegetation operations. Seed were obtained from commercial sources. Purity and germination were determined by the Oklahoma Seed Testing laboratory at Stillwater, Okla. Caucasian was planted with a grassland drill, suitable for rough, chaffy seed. The grassland drill developed in the early 1940's at the U.S. Agricultural Research Service's Southern Plains Range Research Station at Woodward, Okla., in cooperation with SCS, uses seed-planter boxes like those used for planting cotton. These have agitators circulating over rotating plates containing 20 to 36 holes/plate. These plates rotate on a horizontal plane, with the chaffy seed being constantly agitated on the vertical plane to prevent bridging. Rate of rotation and holes per plate regulate the bulk-seed flow or planting rate. Planting depth is maintained at one-half inch by depth bands on single-disk openers. Drill-row spacings from 7 to 12 inches wide are suitable for establishing stands for grazing; wider rows (24, 36, and 42 inches) are more appropriate for seed production.

Seeding Date

In 1957, McIlvain (unpublished data), summarizing the 1-year results of a seeding of Caucasian and several other grasses, found that the most successful stand establishment was obtained from seedings made between late March and mid-April. Peak emergence of seedlings occurred in late June. Evidently, plantings in late April, May, and early June were plagued by competition from weedy plants and by wind and water erosion. But our experience from more recent planting indicates that later planting dates are appropriate. Planting in late April to early June coincides more closely with soil temperatures adequate for germination (60° F).

Plantings in May when soil temperatures are adequate for germination can give faster emergence and faster growth of emerged seedlings if soil moisture is sufficient. Competing weeds should be controlled by proper tillage in years before planting, by very shallow tillage just before planting, or by careful use of appropriate herbicides. Launchbaugh (1976) has shown that "flash" grazing with livestock can remove weed competition before grass seedlings have emerged or before they have grown to a height grazable by cattle.

We need to know how well phosphorus fertilizer enhances seedling establishment, particularly during droughty conditions. Phosphorus deficiencies can restrict grass seedling survival by limiting root growth into moist soils. In 1959, Shoop (unpublished data) found that seedling establishment was improved by phosphorus fertilizer at the Southern Plains Experimental Range. No data were given on phosphorus levels in the soil on the study site. Welch et al. (1962), however, found no seedling-density response to nitrogen and phosphorus fertilizer placed either 1 inch below or 1 inch to the side and 1 inch below the grass seed. This 3-year study included Caucasian and several other warm-season grasses and was conducted on an Amarillo fine sandy loam at Big Spring, Tex. Again, no information was presented on the amount of plant-available phosphorus in the soil. Banding of fertilizer below or below and to the side of grass seeds might result in a less-firm seedbed, which would reduce seedling establishment, according to McIlvain (personal communication). His observations indicate that phosphorus should be applied in the furrow with the seed. Perhaps banding the fertilizer below the seed and refirming the soil before seed placement would help.

Seeding Rate

In 1957 and 1958, McIlvain and Shoop (unpublished data), concluded that seeding rates from 1 to 2 lb of pure live seed per acre gave dense stands of Caucasian. Increases in stand density were not always proportional to increases in seeding rate. With 10 pure live seeds per foot of drill row (0.5 lb of pure live seed per acre), adequate stands of grass were obtained when conditions were optimum. Seeding rates of 20 and 40 pure live seeds per foot of row (1.0 and 2.0 lb of pure live seed per acre) were needed for satisfactory stands under less favorable conditions. Many subsequent plantings throughout the years have demonstrated that 2.0 lb of pure live seed per acre will result in more reliable stand establishment than lower rates under the highly variable climatic conditions that exist in the Southern Plains. If conditions are not optimum (as, for example, with steep slopes, shallow soil, and poor seedbed), rates higher than 2.0 lb pure live seed per acre may be advisable. Ahring et al. (1978) showed that seeding rates of 0.5, 1, and 2 lb of pure live seed per acre planted on June 15 and July 15 in a sandy loam soil in north-central Oklahoma, where precipitation is somewhat higher than at Woodward, resulted in excellent stands.

STAND PERSISTENCE AND WINTER HARDINESS

The early adaptation trials for Old World bluestems were often not well documented. Many were conducted in the late 1930's and early 1940's in response to drought and soil-conservation needs, but the results of these trials are not readily accessible. To help compensate for this lack of available information, P. W. Voigt (unpublished data), in cooperation with J. C. Murray at Oklahoma State University, made several plantings of Caucasian and several of the Old World bluestem blends between 1967 and 1970 on

Table 2.—Survival of some Old World bluestems planted in 1975 and 1976 near Woodward, Okla.

Bluestem	Stand survival (%)			
	Planted May 24, 1975, in Harper County on Pratt loamy fine sand and assessed on Dec. 17, 1975	Planted June 17, 1976, in Woodward County on Woodward-Quinlan loam and assessed on—		
		Oct. 15, 1976	May 3, 1977	Apr. 18, 1978
B Blend		91	74	77
Caucasian	74	94	90	91
H blend		92	79	79
I blend		90	70	70
K blend	43	75	54	55
'King Ranch'		83	55	51
L blend	69	94	85	84
LL blend	74	94	74	77
Plains	67	94	82	84
S blend		92	77	77
T blend		89	54	54

four sites near Woodward (lat. 36°27′ N., long. 99°23′ W.). Plantings were made on sites varying from Pratt loamy fine sands to a Mansker-Potter sandy loam complex. Seed quality was undefined, and results by the first fall after planting were generally poor stands on all entries. But Voigt evaluated these plantings in later years and found that most of the Old World bluestems had increased in stand density. Recent observations of these stands indicate that Caucasian, Plains, and L blend have been the most persistent. When rated in 1974, plants of Plains had the largest crowns; the next largest were L, B, and S blends. Voigt made more extensive plantings of Old World bluestems in 1969 at the Woodward station. In 1970, Voigt (unpublished data) concluded that Plains, LL, S, and Caucasian were the most hardy, then L, H, B, and K. Blends J, I, and T were not considered to be hardy in these tests. Apparently, H blend was susceptible to winter damage but recovered rapidly and has persisted in this area.

Additional plantings of these blends and several other Old World bluestems were made in 1975 and 1976 at the Woodward field station (tables 2, 3). Again the data indicate that excellent stands of Old World bluestems can be obtained if soil moisture is adequate. After a dry winter, precipitation during April 1976 was 5.17 inches; during May it was 2.85 inches; and during June it was 2.77 inches. Late summer, fall, and winter were markedly dry. Initial stand ratings of all entries were 75% to 94%. The dry weather after establishment, however, probably increased the winter injury on the more susceptible grasses. 'King Ranch' and T, LL, B, I, and K blends were severely injured after their first winter. Caucasian had the least winter injury, and Plains and H and S blends had moderate winter injury.

Stand ratings 1 year after planting generally reflect the magnitude of winter injury. Those plants that had the least winter damage in years after planting had the highest stand ratings. The grasses with severe winter injury in 1 or more years were 'King Ranch' and LL, B, T, I, and K blends. So these plant materials may be less than desirable for planting in northwest Oklahoma, since recovery time after winter injury may interfere with normal utilization strategies and result in lowered productivity. Faix et al. (1980) found that Caucasian growing at a site in southern Illinois made good recovery after the severe winter of 1977–78. Recovery of Plains was slow at this site, and the *B. intermedia* blends (B, L, LL, and T) winterkilled.

These plant materials vary from 1 (Caucasian, 'King Ranch', and Taiwan) to 30 (Plains and S blend) accessions (table 1). Therefore, certain accessions within the multiple-accession blends are, perhaps, more winter hardy than others. Successional changes through time should eliminate those accessions more susceptible to winter injury, and a stand of the more winter-hardy plants would result.

Table 3.—Winter hardiness of some Old World bluestems planted in 1975 and 1976 near Woodward, Okla.

Bluestem	Winter injury: Planted May 24, 1975, in Harper County on Pratt loamy fine sand and assessed on Dec. 17, 1975	Planted June 17, 1976, in Woodward County on Woodward-Quinlan loam and assessed on— Oct. 15, 1976	May 3, 1977	Apr. 18, 1978
B blend		Severe	None to slight	Moderate.
Caucasian	None to slight	None to slight	None to slight	None to slight.
H blend		Moderate	None to slight	None to slight.
I blend		Severe	Moderate	Severe.
K blend	Severe	Severe	None to slight	None to slight.
'King Ranch'	Severe	Severe	Severe	Severe.
L Blend	Moderate to severe	Moderate	None to slight	None to slight.
LL Blend	Moderate to severe	Severe	None to slight	Moderate.
Plains	None to moderate	Moderate	None to slight	None to slight.
S blend		Moderate	None to slight	None to slight.
T blend		Severe	None to slight	Severe.

These data seem to substantiate the belief that *B. ischaemum* var. *ischaemum* is generally the most winter hardy (tables 2, 3). These grasses, along with Caucasian, appear to be best suited to survive the winters in the northern part of the Southern Plains. There are, however, some *B. intermedia* var. *indica* plants that are considered to be relatively winter hardy; namely H, L, and perhaps LL blends. I, J, and K blends, all *B. intermedia* var. *montana* accessions, are not considered to be winter hardy at Woodward. T blend, *B. intermedia* var. *indica*, and 'King Ranch' are not winter hardy at this location.

Limited evaluations of Old World bluestems have been made on arid southwest U.S. rangelands. Herbel et al. (1973) reported 'Ganada' to have better stand establishment than El Kan or Caucasian on harsh sites dominated by tarbush, *Flourensia cernua* DC., near McGregor, N. Mex.

FORAGE PRODUCTION

Although some Old World bluestems, such as Caucasian and 'King Ranch', have been available to livestock producers for over 60 years, detailed forage-production data remain scarce. In a study by Oklahoma Agricultural Experiment Station and U.S. Agricultural Research Service scientists at Perkins and Woodward, Okla., and Fayetteville, Ark., Caucasian produced more forage than 'King Ranch' (Harlan et al. 1961a, 1962, 1963). Yields under these dryland conditions were about 6,400 lb/acre for Caucasian and about 4,900 lb/acre for 'King Ranch'. Caucasian was apparently better able than 'King Ranch' to withstand repeated clippings during the growing season. In this region (about lat. 36° N.), 'King Ranch' is not considered winter hardy, so it is more susceptible to damage by grazing. Adding about 60 lb of nitrogen per acre enhanced the production of Caucasian subjected to repeated clipping. 'King Ranch' was not as responsive to nitrogen fertilizer as Caucasian, and forage production declined as clipping frequency increased.

In fertilization trials with 'King Ranch' in south-central Oklahoma in 1966 and 1967, R. L. Dalrymple (unpublished data) used all combinations of 0, 50, 75, and 100 lb of nitrogen per acre and 0 and 60 lb of phosphorus and potassium per acre. 'King Ranch' responded well to moderate applications of nitrogen fertilization up to about 50 lb/acre without phosphorus and potassium fertilization. Phosphorus and potassium alone did not enhance the production of 'King Ranch'. But combined with nitrogen they increased yields of 'King Ranch' markedly at all application rates. In this 2-year study, each 25-lb increment of nitrogen fertilizer from 50 to 100 lb/acre, with no phosphorus and potassium, resulted in successively less forage. Forage production declined from 32 to 18 lb dry matter per pound of nitrogen applied. Similar rates of nitrogen with 60 lb each of phosphorus and potassium maintained forage yield of 36 lb dry matter per pound of nitrogen ap-

Table 4.—Average forage production (1960–65) of Caucasian and 'King Ranch' bluestems grown on the Southern Plains Experimental Range near Woodward, Okla.

Year	Forage production (pounds per acre)							
	Caucasian pastures				'King Ranch' pastures			
	Caucasian	Other grasses	Forbs	Total	'King Ranch'	Other grasses	Forbs	Total
	Unfertilized							
1960	2,895	0	226	3,121	2,732	0	241	2,973
1961	2,690	94	1	2,785	2,606	76	4	2,685
1962	3,092	152	36	3,280	4,213	117	16	4,346
1963	3,764	82	10	3,856	1,242	934	49	2,225
1964	2,189	21	1	2,211	1,130	698	53	1,881
1965	3,007	38	18	3,036	990	597	169	1,756
Average:								
1960–65	2,940	64	49	3,053	2,152	404	89	2,645
1963–65	2,986	47	10	3,043	1,121	743	90	1,954
	Fertilized with 33 lb of nitrogen per acre							
1963	4,088	128	19	4,325	1,442	1,686	182	3,310
1964	3,575	60	0	3,635	1,293	916	253	2,462
1965	3,404	200	307	3,911	1,272	1,022	259	2,553
Average	3,689	129	109	3,927	1,336	1,208	231	2,775

Source: E. H. McIlvain and M. C. Shoop (unpublished data compiled in 1960, 1962, 1963, and 1965).

plied. A superficial economic analysis of these data suggests that either the 50-lb nitrogen fertilizer treatment or the 100-60-60 lb/acre of nitrogen, phosphorus, and potassium were the most economical in these south-central Oklahoma trials.

Taliaferro et al. (1972) evaluated Plains, Caucasian, and 'King Ranch' at various locations in Oklahoma. In these trials, Plains was more productive and persistent than 'King Ranch' but less productive than Caucasian. In the studies at Perkins, Okla., Plains was found to be 83% as productive as Caucasian, and 'King Ranch' 54% as productive. At Mangum, Okla., 2-year (1969–70) average production for Plains was 4,130 lb dry forage per acre, and for 'King Ranch' 2,655 lb/acre. Also, the production of Plains was almost doubled by applying 60 lb nitrogen per acre. These studies indicated that for each pound of nitrogen applied, about 102 lb of additional forage dry matter was produced. Adding phosphorus fertilizer did not markedly increase this response. At these north-central and southwestern Oklahoma locations, about 60 lb of nitrogen was the best rate of fertilization for Plains during a normal precipitation year.

McIlvain and Shoop (unpublished data) conducted a fertilizer study on Caucasian and 'King Ranch' pastures at the Southern Plains Experimental Range between 1960 and 1965. During the last 3 years of this study (1963–65), part of each pasture was fertilized with nitrogen at about 33 lb/acre. On the unfertilized pastures, average annual production of Caucasian exceeded that of 'King Ranch' by about 750 lb/acre (table 4). Over the period of study, production of unfertilized 'King Ranch' declined because of winterkill and because the plant community was invaded by other grasses and forbs.

Although both Caucasian and 'King Ranch' responded to nitrogen fertilization, increased yield per pound of nitrogen applied was only 21 lb for Caucasian and less than 7 lb for 'King Ranch'. The less palatable plants that invaded the stands of 'King Ranch' responded to fertilization with a 70% increase in yield. Caucasian maintained a relatively closed stand over several years even when subjected to grazing pressure.

Faix et al. (1980) reported no significant differences in yields of the six Old World bluestems evaluated in southern Illinois. During each of the 3 years of the study, average yields for Caucasian, Plains, B, L, LL, and T exceeded 13 tons of air-dry forage per acre when nitrogen was broadcast at 200 lb/acre before planting and applied at 133 lb/acre in July. But only Caucasian survived the winters with no observable winter injury. Plains recovered very slowly in this humid climate with its relatively high rainfall, and the other Old World bluestems winterkilled.

Dalrymple et al. (1980) reported preliminary results of establishment and yield tests of commercially available Old World bluestems and some promising experimental selections obtained from the Southern Plains Range Research Station. Yields ranged from 3,163 to 5,483 lb/acre. Of the commercially available materials, Caucasian and Plains had the highest yields (about 5,100 lb/acre) and 'Ganada' the lowest (about 4,313 lb/acre). These plants, grown in south-central Oklahoma, were irrigated during the hot summer of 1980 and fertilized with 102-204-102 lb/acre of N-P_2O_5-K_2O at planting time in early May.

In southwest Missouri, Matches and Mowery (1980) established two varieties of trefoil, *Lotus corniculetus* L., in Caucasian and switchgrass, *Panicum virgatum* L., pastures. Yields, in some cases, were markedly increased by the legumes. Matches and Mowery stated that the legumes should be harvested often to prevent shading of the grasses. Legumes increased the digestibility of forage from 2% to 12% over that of grass alone.

Table 5.—Weight gains and stocking rates (1949–62) for yearling steers grazing 'King Ranch' bluestem at the Southern Plains Experimental Range near Woodward, Okla.

Variable	Average (1949–62)	Range	
		Low	High
Steer weights (lb/head):			
Initial	466	437	506
End of winter	562	504	618
End of summer	851	788	913
Monthly gains (lb/head):			
November[1]	10	−21	31
December	20	−10	55
January	21	6	42
February	20	−2	45
March	12	−6	40
April	20	−8	50
May	66	26	93
June	66	46	90
July	58	19	92
August	45	3	73
September	40	9	68
October[1]	6	−5	24
Seasonal gain (lb/head):			
Winter	96	38	152
Summer	289	231	380
Year	385	322	447
Seasonal gain (lb/acre):			
Winter	21	11	36
Summer	63	33	80
Year	85	52	113
Seasonal stocking rates (acres/steer):			
Winter	4.5	10.0	3.1
Summer	4.6	8.1	3.6
Year	4.6	7.7	3.6

[1]These gains may be for less than a full month.

Source: E. H. McIlvain and M. C. Shoop (unpublished data compiled in 1961).

GRAZING VALUE

The final criterion for evaluating forage is the production of red meat per animal and per unit of land area. Factors such as palatability, nutritional quality, and forage production are integral to the beef-production potential of plant materials. The beef-producing value of 'King Ranch' and Caucasian has been studied extensively at the Southern Plains Range Research Station since about 1949.

In a 13-year study (table 5), yearling steers gained 385 lb during an 11-month grazing period on 'King Ranch' (McIlvain and Shoop, unpublished data). About three-fourths of the gain came during the summer and the remaining one-fourth during the winter when the steers were given a supplement of 1.5 lb of cottonseed cake per head per day. Because 'King Ranch' winterkilled, much of the gain by steers came from invader plants during the latter part of the study.

Comparative winter gains of yearling steers on summer-deferred Caucasian and 'King Ranch' were measured between 1959 and 1962 (table 6) with yearling steers weighing between 473 and 493 lb at the beginning of the winter grazing period. Steers grazing Caucasian gained an average of 52 lb/head; steers grazing 'King Ranch' gained an average of 74 lb/head (Shoop and McIlvain, unpublished data). The stocking rate for Caucasian was 1.6 acres/steer and for 'King Ranch' 1.7 acres/steer. Average gain per acre during the winter for Caucasian and 'King Ranch' grazed only in the winter was 33 and 44 lb.

Table 6.—Winter gains of yearling steers on summer-deferred Caucasian and 'King Ranch' pastures (1959–62) at the Southern Plains Experimental Range near Woodward, Okla.

Variable	Summer-deferred, winter-grazed pastures							
	Caucasian				'King Ranch'			
	1959–60	1960–61	1961–62	Avg.	1959–60	1960–61	1961–62	Avg.
Steer weights (lb/head):								
Initial	485	490	473	483	483	482	474	480
Final	561	519	523	535	584	531	548	554
Monthly gains (lb/head):								
November	11	11	−1	7	15	19	0	12
December	14	3	−4	4	37	6	8	17
January	11	−7	16	7	12	9	27	16
February	25	2	3	10	13	4	−1	5
March	15	6	8	10	16	4	11	10
April	0	14	28	14	8	7	29	14
Total	76	29	50	52	101	49	74	74
Gain/acre (lb)	32	19	42	33	28	43	46	44
Stocking rate (Acres/steer)	2.3	1.6	1.2	1.6	3.6	1.1	1.6	1.7

Source: M. C. Shoop and E. H. McIlvain (unpublished data compiled in 1962).

Table 7.—Stocking rates and weight gains for steers on fertilized (30 lb of nitrogen per acre) and unfertilized Caucasian and 'King Ranch' pastures during summer 1963

Bluestem, pasture size, and treatment	Stocking rates		Gain in previous winter (lb.)	Summer weight gain							
				Monthly (lb/head)						Total	
	Steers per pasture (No.)	Acres per steer (No.)		Apr.	May	June	July	Aug.	Sept.	lb/head	lb/acre
Caucasian, 6 acres:											
Fertilized	3.2	1.9	74	21	92	55	90	57	1	316	166
Unfertilized	2.6	2.3	83	27	44	68	74	69	21	303	132
'King Ranch', 12.5 acres:											
Fertilized	2.2	5.4	76	32	80	52	85	70	47	366	68
Unfertilized	2.3	5.3	75	32	80	48	82	55	28	325	61

Source: E. H. McIlvain and M. C. Shoop (unpublished data compiled in 1960, 1963, and 1965).

In 1962, Shoop and McIlvain (unpublished data) stated that these winter-deferred pastures had twice the carrying capacity of native range during the nongrowing season. They concluded that Caucasian could satisfactorily be used for winter grazing after summer deferment if a management scheme found it useful.

Between 1960 and 1965, McIlvain and Shoop (unpublished data), reporting on a summer grazing study of fertilized and unfertilized Caucasian and 'King Ranch', found that 30 lb of fertilizer nitrogen per acre increased carrying capacity of Caucasian 17%, gain per acre 30%, and gain per steer 8% (table 7). During the first year, in-

Table 8.—Average stocking rates and weight gains for steers on fertilized[1,2] and unfertilized Caucasian and 'King Ranch' pastures from November 12, 1964, to September 20, 1965

Variable	Caucasian bluestem		'King Ranch'	
	Fertilized	Unfertilized	Fertilized	Unfertilized
Steer weights (lb):				
Initial	473	473	473	473
End of winter	497	497	510	534
End of summer	833	751	881	899
Gain/steer (lb):				
Winter:				
November	7	3	13	17
December	4	−3	−17	2
January	−5	−4	10	1
February	10	16	13	7
March	12	25	11	30
April	−4	−13	70	4
Summer:				
April	42	24	47	47
May	100	88	98	70
June	70	48	75	80
July	66	57	56	68
August	4	2	27	39
September	54	35	68	61
Seasonal gain (lb/head):				
Winter	24	24	37	61
Summer	336	254	371	365
Year	360	278	408	426
Seasonal gain (lb/acre):				
Winter	12	11	10	16
Summer	177	98	93	70
Year	189	109	103	86
Seasonal stocking rates (acres/steer):				
Winter	2.0	2.2	3.8	3.9
Summer	1.9	2.6	4.0	5.2
Year	2.0	2.4	3.9	4.4

[1]Fertilized with 36 lb of nitrogen per acre between April 29 and May 5.

[2]The fertilized 'King Ranch' pasture was grazed only in midsummer 1964. The unfertilized pasture was ungrazed in summer 1964.

Source: E. H. McIlvain and M. C. Shoop (unpublished data compiled in 1965).

dividual animal gains on fertilized 'King Ranch' were increased 13% and gain per acre 10% over gains on unfertilized pastures. There was no apparent difference in carrying capacity. McIlvain and Shoop observed that significantly more forage was available for winter grazing on the fertilized pastures.

Beef production was also measured on fertilized and unfertilized Caucasian and 'King Ranch' (tables 7 and 8). Beef production per acre of Caucasian was increased by adding about 30 lb of nitrogen per acre to the system. This increase was partly the result of an increase in the stocking rate on the fertilized Caucasian pastures. With 36 lb of nitrogen per acre, individual animal gains increased from 303 to 326 lb/steer in 1963 (table 7) and from 278 to 360 lb/steer in 1964–65 (table 8). Although forage quality was not measured in these studies, the data indicate that the added nitrogen increased both forage production and nutritional quality. With 36 lb of nitrogen per acre, beef production of 'King Ranch' pastures increased from 86 to 103 lb/acre (table 8). This increase was not observed during the first year (table 7). The stocking rate in the 1964–65 study was increased about 13% from 4.4 to 3.9 acres/steer. Average gain on unfertilized 'King Ranch' was 426 lb/steer and 408 lb/steer on the fertilized pastures. Differences in gain per steer were not evident during the summer. Gains on unfertilized 'King Ranch' during the winter averaged 61 lb/steer and 37 lb for the fertilized grass. These results were unexpected, since fertilized forages are usually higher in crude protein, which increases animal gains.

Horn and Taliaferro (1979) evaluated the seasonal changes in the nutritive value of five Old World bluestem grasses. In vitro dry-matter digestibility (IVDMD) for these forages ranged from 58% to 65%. These values were similar during the early growth stages before August; but, during the later part of the growing season, some differentation occurred: L and B blends had the highest IVDMD, Plains and T were intermediate, and Caucasian had the lowest. Crude-protein values followed the same general pattern. For both IVDMD and crude protein, Caucasian had consistently lower values than the other materials tested. No measures of statistical differences were reported. Horn and Jackson (1979) evaluated the hay from these same Old World bluestems. The hay was harvested three times during each of the 2 years of their study. They found few differences between the hays in dry-matter digestibility, hay consumption, and nitrogen retention. They concluded that the "high yields of Caucasian bluestem hay probably offset the slight disadvantage of lower quality."

IMPLICATIONS FOR MANAGEMENT AND FUTURE RESEARCH

Livestock producers need an array of plant materials to revegetate severely depleted rangeland and marginal cropland in the Southern Great Plains. These plants should be relatively palatable, nutritious, reasonably easy to establish, drought resistant, and persistent under reasonable grazing. The research reviewed in this paper indicates that the Old World bluestems can meet, to some degree, many of these requirements. Perhaps the Old World bluestems available now and those released in the future can contribute significantly to rangeland management and beef production in the Southern Plains. Their broad genetic diversity indicates a potential range of adaptability to many sites outside their original area of distribution.

Presently, 'King Ranch', Caucasian, Plains, Angleton, Media, Gordo, 'Ganada', and 'WW Spar' Old World bluestems are available to producers. Only Caucasian, Plains, 'Ganada', and 'WW Spar' have adequate winter hardiness for the northern part of the Southern Plains. Seed availability for these grasses has been extremely limited. Additional releases of Old World bluestems, suitable for the different range sites needing revegetation, should occur in the near future.

Much work on seed production and processing technology is required to assure an adequate supply of quality seed. Newer releases that have a more predictable flowering and seed-maturation period would be helpful. Nondestructive methods of seed harvesting that would permit multiple harvests of the same stand within a growing year would assist in attaining maximum seed crop.

Apparently, Old World bluestems are quite tolerant to grazing by cattle. Most reports on grazing studies have been of either continuous grazing or simple two-pasture rotations. More research on grazing strategies is needed to optimize beef production from these plants. If beef production can approach or exceed 150 lb/acre and 300 lb/yearling steer during a grazing season, these grasses can be practical alternatives to crop production on marginal lands. Also, more information is needed on the primary productivity of these plants when grazed by cattle. Little information is presently available on the nutritional value and beef-producing potential of the Old World bluestems. Furthermore, basic data about physiological responses of potential releases is needed to determine how they will adapt to various environments and how they will respond to different kinds of stress.

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