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Evaluation of Some Alkali Sacaton Ecotypes Collected in Mexico

Jerry R. Cox
USDA-ARS
Tucson, AZ

Albert K. Dobrenz
University of Arizona
Tucson, AZ

Bartley McGuire
Tucson City Government
Tucson, AZ

Abstract. Nine-week old seedlings of 13 alkali sacaton (*Sporobolus airoides*) ecotypes collected in Mexico were transplanted and irrigated in Summer 1980. Seed from these plantings were collected in Fall 1982, germinated under simulated spring-fall (cool) and summer (warm) temperatures, and forage was harvested in Fall (1983) and spring (1985). Spring regrowth forage production among the 13 ecotypes ranged from 28 to 145 g/plant and total seed production ranged from 0.3 to 3.4 g/plant. Transpiration was significantly different among the ecotypes and average stomate density on the abaxial leaf surface varied from 101 to 174 mm^2. No single ecotype or group of ecotypes exhibited superior traits across all measured *criteria*. Ecotypes which produced more total seed did not display the highest large-seed germination and ecotypes which had the highest forage production did not have good germination or drought tolerance. Transpiration was not lower on ecotypes with lower stomate density. It was concluded that ecotype selection should be based on a single rather than multiple selection criteria.

Introduction

Alkali sacaton (*Sporobolus airoides*), a perennial warm-season bunchgrass is distributed in North America from North Dakota to eastern Washington (United States) and from Zacatecas to southern Sinaloa (Mexico) (Gould, 1975; Hitchcock, 1950). One hundred years ago this grass grew in dense stands on soils that flooded in summer. Today the species grows in soils on playas and flood plains but stands are small islands within large bare areas (Aldon, 1975).

In summer, alkali sacaton produces abundant green forage and the canopy protects surface soil from erosion (Hubbell and Gardner, 1950); hence, extensive seed collections from western United States rangelands and forage production comparisons by USDA, Soil Conservation Service (Cox et al., 1982). Seed from high forage producing ecotypes have been evaluated in alkaline and saline soils but successful field plantings seldom occur without irrigation (Aldon, 1975).

In central Mexico alkali sacaton grows in many diverse habitats and plants are generally more robust than their northern counterparts (Hitchcock, 1950). Thus our selection of 13 southern Mexico ecotypes, and evaluation studies to determine seed production, seed germination, transpiration, stomate densities, and seasonal forage production potentials. Because plant establishment is a function of seed quality and quantity, and plant persistence is a function of growth under less than ideal conditions (Etherington, 1975; Harper, 1978), we evaluated plant productivity in a series of separate tests and designed a composite index to identify superior ecotypes. Similar studies have been used to identify ecotypes in other perennial grasses (Newell and Eberhart, 1961).

Methods

Study Site

Pima (fine-silty, mixed (calcareous), thermic, Typic Torrifluvents) soils at the Tucson Plant Materials Center, USDA-Soil Conservation Service in southeastern Arizona are representative of flood plain soils in southern Arizona and central Mexico (Alba-Avila and Cox, 1988). These soils are recent alluvium, weathered from mixed rocks, moderately alkaline and greater than 2 m (6 ft) in depth. Before farming alkali sacaton was the predominate understory species on the site (Cox et al., 1982).

Plant Propagation

Pima soil, from 0 to 30 cm (0 to 12 in.) depths, collected from outside the study area was mixed with peat moss with a 4:1 ratio by volume and placed in 21 (0.48 gal) plastic pots. Forty to 50 seed of an alkali sacaton ecotype

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Address reprint requests to: Albert K. Dobrenz, Plant Sciences Department, University of Arizona, Tucson, AZ 85721, USA.

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were placed on the medium surface. Seed were covered with 3.3-mm (No. 6) silica sand and subirrigated in trays on a greenhouse bench. Twenty-five percent Hoagland's solution was added to trays and paper placed over pots to reduce evaporation.

Paper was removed after 7 days and trays drained after 14 days. Tap water was applied to the medium surface daily and trays were filled with 25% Hoagland's solution on days 21, 27, 34, and 41. Trays were drained and top growth harvested at 10 cm (4 in.) above the medium surface on day 48. After harvesting we surface watered twice daily for 3 days, once daily for 6 days, and every other day until transplanting at 9 weeks of age. Top growth was harvested at 10 cm above the medium surface 48 h before transplanting.

Summer-day length was approximately 16 h and plants were grown under natural light. Greenhouse temperatures were maintained between 25 and 35°C from weeks 1 to 7 and allowed to vary between 20 and 40°C from weeks 8 to 9. Relative humidity varied from 58 to 80%.

Site Preparation and Field Planting

Two weeks before transplanting forty-three 6-m (20-ft.) rows, spaced at 60-cm (2-ft.) intervals were delineated into three groups of 13 rows; with guard rows designated as 1, 15, 29, and 43. Twelve 15 × 30-cm (6 × 12-in.) holes, equally spaced along each row, were prepared with an auger when soil was dry. Loose, dry soil reentered the hole after the auger was removed.

Ecotypes were randomly assigned one row in the three plots and guard rows were transplanted to alkali sacaton "Saltalk." A hand spade was used to remove soil from the hole and the transplant, extracted from the plastic pot, was placed in a hole. Soil was packed around the transplant so that the transplant medium surface was equal to the soil surface. Transplants were irrigated weekly in June and monthly in July and August 1980, and supplemental water was not applied before June 1983. Approximately 10 cm (4 in.) of water were applied during each irrigation.

Seed Germination

In September 1982, seedheads from 10 interior plants in a row were composited, air dried, hammer-milled, and separated from chaff in an air-baffel chamber. Seed were weighed, separated on 600 to 850 μm (No. 20 to No. 30) screens and reweighed. Large alkali sacaton seed were selected because they germinate faster and produce larger seedlings than small seed (Alba-Avila and Cox, 1988; Knipe, 1970).

Fifty caryopses of each ecotype were placed on filter paper in separate petri dishes and germinated in the dark at alternating temperatures of 15 to 20°C (60 to 70°F) and 25 to 30°C (77 to 86°F). Approximately 10 mL of distilled water was initially added to each dish and additional amounts were added daily to replace evaporative losses. Seed were subjected to 12 h at the higher temperature and 12 h at the lower temperature, and germination was considered complete when the seed radicle exceeded 0.5 cm (0.25 in.). Light delays the germination of alkali sacaton seed (Knipe, 1971; Toole et al., 1957) and seed are known to germinate when surface soil temperatures range between 15 and 20°C in spring and fall, and 25 and 30°C in summer (Hubbell and Gardner, 1950; Knipe and Springfield, 1972).

The study was a randomized complete block design and the two temperature regimes were considered separate studies. Blocks contained one dish of each ecotype and there were six blocks.

Stomate Density and Transpiration

In the Chihuahuan and Sonoran Deserts, summer rainfall amount and distribution is variable, summer temperatures are extreme, and perennial grasses are subjected to multiple droughts in a growing season (Cox et al., 1982). When water is limiting, alkali sacaton transpiration rates decline and photosynthetic rates increase (El-Sharkawi and Miehel, 1975) and low transpiration rates are frequently correlated with fewer stomates (Miskin et al., 1972). We were therefore interested in ecotypes with low transpiration rates and few stomates.

Two culms, in full flower and approximately the same size, were subjectively selected from each ecotype. Transpiration was measured on the abaxial surface of one main culm leaf, the first leaf below the flag leaf, with a steady state Li-Cor 1600 Porometer between 1000 and 1300 h. Stomate densities were determined on the second main culm leaf (Cooper and Qualls, 1967) in five 0.132-mm^2 fields, but corrugated abaxil surfaces (Fig. 1) limited our ability to accurately determine stomate density; therefore, only abaxial densities are presented.

Forage Production

In the southwestern United States and northern Mexico, alkali sacaton and other perennial grasses are semiactive or inactive in spring and fall when lactating cows require a source of green feed (Alba-Avila and Cox, 1988). Ecotype selection should therefore be based on early spring and late fall growth.

In June 1983 and 1984, alkali sacaton ecotypes were mowed to 15 cm (6 in.) and blocks were flood irrigated. In fall 1983 (September) and spring 1985 (February) plants were harvested 2.5 cm (1 in.) above the soil surface at biweekly intervals for 16 weeks; forage from the first harvest, in both seasons, was discarded.

Dry weights from 10 plants in a row were averaged and the mean considered a replication. Regrowth was highly variable among ecotypes and harvest dates; therefore, plot means were summed across harvest dates within a season.

Statistical Evaluation

Analysis of variance and corresponding F-tests were used to determine differences among ecotypes for each of the eight studies. The Scott–Knott (1974) cluster analysis

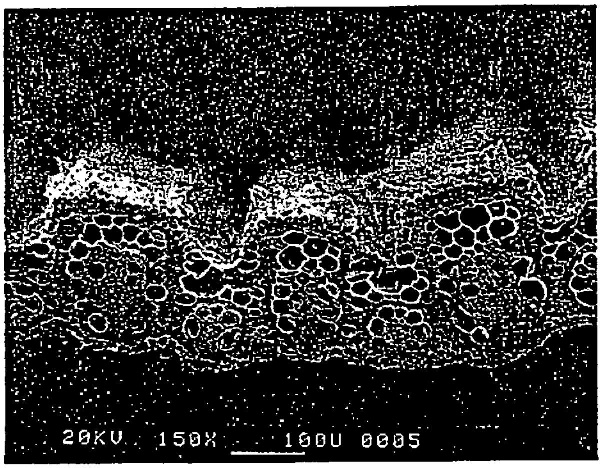

Fig. 1. Cross-section of an Alkali Sacaton SLP-190 leaf showing the corrugated adaxial surface.

technique, which identifies non-overlapping homogeneous mean clusters and simplifies statistical interpretation (Gates and Bilbro, 1978) was used to rank means.

Mean clusters for each study were assigned whole numbers and whole numbers summed across the eight studies. The Scott–Knott technique was used to rank overall means.

Results and Discussion

Seed Production and Germination

In summer 1982, thunderstorms began in July, August was dry, and storms returned in September when seed were collected. Because summer rainfall was 30% below the long-term mean (Climatography of the United States (Arizona), 1982; Sellers and Hill, 1974), potential ecotype seed production was probably underestimated (Table 1).

Large alkali sacaton seed germinate more frequently than small seed (Knipe, 1970) and United States ecotypes were selected for total and large seed production (personal communications, USDA, Soil Conservation Service). Alba-Avila and Cox (1988) have shown that large seed from ecotypes that produce abundant seed germinate more often than large seed from low-producing ecotypes. Therefore, greater large-seed germination was expected for ecotypes that produce more total seed. Such trends were not evident (Table 1) suggesting that alkali sacaton ecotypes from southern latitudes either do not benefit from additional seed reserves, or seed from cultivated plants respond differently than seed from non-cultivated plants.

Ecotypes responded differently to warm- and cool-temperature regimes. Germination of Coahuila 40 and Zacatecas 90 seed began before day 7 when temperatures range from 25 to 30°C (Table 1), while germination of other ecotypes occurred between days 7 and 14. Germination of both Nuevo Leon 150 and Coahuila 40 began after day 7 when temperatures ranged from 15 to 20°C, but germination of other ecotypes occurred after day 14.

Cool temperatures slowed germination, but on day 21 mean ecotype germination was 27% for warm temperatures and 29% for cool temperatures (Table 1). The relatively large numbers of Zacatecas 90 seed germinating at warm temperatures and Nuevo Leon 150 seed germinating at cool temperatures suggests that Zacatecas 90 can be expected to germinate following warm-season moisture in the Chihuahuan and Sonoran Deserts, and Nuevo Leon 150 can be expected to germinate following spring and fall moisture in the Southern Plains. The consistently high germination of Coahuila 40 seeds across both temperature regimes suggests that this ecotype is adapted over a greater climatic gradient and can be expected to germinate following both warm- and cool-season moisture.

Stomate Density and Transpiration

Dobrenz et al. (1969) and Miskin et al. (1972) reported that grasses with fewer stomates had lower transpiration rates. These data (Table 1) do not support the commonly accepted belief that transpiration rates decrease as stomate densities decline. Inconsistencies, in this instance, may occur because stomate densities were measured only on one leaf surface.

Forage Production

Leaves on all ecotypes began to appear within 7 days on plants defoliated in fall and within 28 days on plants defoliated in spring. Defoliation in both fall and spring stimulated green leaf production, and a lush carpet of green leaves was present from September to October in fall, and from April to May in spring. However, green leaves turned yellow in June when daily temperatures exceeded 40°C and in November when nighttime temperatures approached 10°C. The exceptions were Aguascalientes 13 that greened in March rather than April, and Aguascalientes 13 and San Luis Potosi 190 and 244 that remained green until mid-December when nighttime temperatures averaged 5°C.

Index Values

Initially it was expected that a few ecotypes would predominate in 50% or more of the measured char-

Table 1. Seed production, germination (at 21 days), transpiration rates, stomate densities, forage production and a selection index for 13 alkali sacaton ecotypes collected in Central Mexico

	Seed production			Germination				Forage production		
State	Ecotype No.	Total[a]	Large	Warm temperature	Cool temperature	Transpiration	Abaxial stomate density	Fall regrowth	Spring regrowth	Index value[b]
		(g/10 plants)		(%)		($\mu g\ cm^{-2}s^{-1}$)	(mm^2)	(g/plant)		
Aguascalientes	13	2.0b	0.8b	33b	27c	12b	137b	64a	131b	16
	15	2.8b	2.3a	17d	14d	11b	119a	47b	110c	19
	73	0.8c	0.2c	36b	34c	7a	149c	32c	55e	23
Chihuahua	90	3.4a	2.3a	29c	24d	9b	104a	26c	51e	20
Coahuila	40	0.8c	0.3c	40a	44b	12b	160c	27c	52e	22
Durango	132	2.4b	1.2b	23c	19d	7a	140b	46b	103c	19
	236	1.9b	1.1b	17d	20d	11b	157c	40b	66e	24
Nuevo Leon	150	0.3c	0.1c	19d	55a	12b	104a	14d	23f	24
San Luis Potosi	67	0.7c	0.2c	26c	23d	9b	126b	41b	90d	23
	190	1.7b	0.9b	20c	30c	13b	111a	49b	122b	17
	244	1.4b	0.6b	17d	19d	10b	134b	43b	145a	19
Zacatecas	15	0.3c	0.1c	32b	36c	15c	172d	32c	28f	27
	90	0.4c	0.1c	42a	29c	9b	101a	27c	48e	21

[a] Means in rows followed by the same letters are not significantly different according to Scott and Knott (1974).

[b] Index Values are the sum of numbers assigned to Scott-Knott letters (a = 1, b = 2, c = 3, d = 4, e = 5, and f = 6). Ecotypes with lowest Index Values exhibit positive selection traits; there were no differences among ecotypes.

acters (Table 1) and superior plants would be identified easily. Since none of the ecotypes predominated in four or more characters, this assumption is incorrect. Hence the need to develop a general index that values equally the eight characters.

Superior ecotypes, those with the lowest Index Values, are Aguascalientes 13 and San Luis Potosi 190 (Table 1). Aguascalientes 13 has superior fall regrowth but moderate stomate densities and transpiration rates. San Luis Potosi 190 has few stomates but moderate transpiration rates and forage production. Both ecotypes produce average total and large seed quantities and germinate poorly under warm- and cool-temperature regimes.

When forage quantity is related to either forage quality, seed production, seed germination, mineral accumulation, stomate density, or water-use efficiency, plant breeders use an index to identify productive annual or perennial grass breeding lines (Assay et al., 1986; Buckner et al., 1981; Burton and DeVane, 1953; Dobrenz et al., 1969). Index evaluation may not be a useful tool for selecting alkali sacaton ecotypes from Mexico because none of the eight characters (Table 1) appear to be related. Quinones (1975) concluded that 22 alkali sacaton ecotypes collected in the United States were adapted to localized environments because forage production and climate were unrelated.

Implications

Before 1880, alkali sacaton existed in pure stands along alluvial flood plains or in alkaline playas within the North American semidesert grasslands (Griffiths, 1901). These grasslands acted as a continuous dam which naturally spread flood waters from nearby uplands and more distant mountains (Cox, 1988), trapped sediments which leveled valley floors (Hubbell and Gardner, 1950), and contributed to the formation of shallow water tables and perennial streams (Cooke and Reeves, 1976). The species currently occupies a small portion of its original area of distribution because the processes which supplied additional soil moisture were disrupted by channel formation. Rapid water drainage reduced soil moisture and prevented species reestablishment.

In high precipitation areas of the United States, agronomists have for 100 years selected perennial grasses for forage quality and quantity, and frequently the same selection criteria were applied in arid and semiarid areas. Hence the unrealistic expectation that in dry environments seeded grasses would easily establish and disappointment when either seedlings failed to emerge or dense stands disappeared in 2 or 3 years (Cox et al., 1982).

If prevailing agronomic selection criteria are used, Aguascalientes 13 and San Luis Potosi 244 would be selected because they produce either more fall or spring growth. Logically, however, we would conclude that neither ecotype would establish because seed germination is poor and plants are not drought tolerant (Table 1, Alba-Avila and Cox, 1988; Quinones, 1975).

A more sensible approach is to realize that less soil moisture is available where alkali sacaton previously grew, and currently it may not be possible to establish or maintain productive ecotypes. Hence the selection of less productive ecotypes that exhibit either superior seed production (Chihuahua 90), germination (Coahuila 40, Nuevo Leon 150, Zacatecas 90), or drought tolerance (Aguascalientes 15 and 73, Chihuahua 90, Durango 132, Nuevo Leon 150, San Luis Potosi 190, and Zacatecas 90). Under current selection criteria these ecotypes would not be considered in a breeding trial (Quinones, 1975). It should be realized that a "waving sea" of high quality grass cannot be maintained where annual precipitation ranges from 15 to 40 cm (6 to 16 in.).

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