Ecotypic Variation in Selected Fourwing Saltbush Populations in Western Texas

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Abstract

Fourwing saltbush [*Atriplex canescens* (Pursh) Nutt.] seedlings from 4 western Texas tetraploid populations were established in uniform nurseries at San Angelo, Barnhart, and Marfa, Texas, in 1981 to determine relative adaptability to these respective environments. Survival and canopy development of the ecotypes were similar at the site with the most favorable growing conditions (San Angelo), but the ecotype originating nearest the planting site tended to have greatest survival and canopy size where site conditions were less favorable. Additional shrub attributes evaluated at the San Angelo site included: leaf, current year's stem, and wood phytomass, seasonal nutrient concentrations, and floral development and phenotype. Prediction equations utilizing plant canopy measurements were used to estimate weights of plant components. Variation in canopy size and yields among individual plants within ecotypes masked detection of significant ($P \leq 0.05$) differences among ecotypes, but ecotypes from arid environments tended to be larger and to have greater yields than those from more mesic environments. Concentrations of crude protein (CP), phosphorus (P), and digestible organic matter (DOM) of leaves and stems were similar among the 4 ecotypes. Floral development of the ecotype from the most mesic environment progressed at a faster rate than that of ecotypes from more xeric environments. Ecotypes from xeric environments tended to have fewer staminate plants, but more plants with no sex expression than ecotypes from more mesic areas.

Key Words: *Atriplex canescens*, phenology, nutritive value, shrub biomass, autecology

Fourwing saltbush [*Atriplex canescens* (Pursh) Nutt.], a native, facultative-evergreen shrub, is widely distributed in western North America and provides browse and cover for livestock and wildlife (Plummer et al. 1966). This nutritious and palatable shrub is often recommended and used for rangeland seeding, surface mine reclamation, and stabilization of critical areas (Springfield 1970, Smit and Jacobs 1978, Shoop et al. 1985). Excellent native stands of fourwing saltbush occur locally in the Trans-Pecos and western Edwards Plateau resource areas, but the species is absent or only occasionally encountered on most rangeland in western Texas. The adaptability of the genetic material from western Texas to other areas has not been researched, but it is currently of great interest among ranchers and resource managers. The success of rangeland seeding projects depends highly upon the availability and use of adapted plant materials.

Ecotypes are local populations of a species that have genetically controlled characteristics which limit the extent of their area of favorable growth (Oosting 1956). Ecotypic variation among populations of fourwing saltbush has been documented (see McArthur et al. 1983 for references, Potter et al. 1986). The objectives of this study were to determine the extent of genetic variation within selected western Texas populations of fourwing saltbush and to determine if some populations are better adapted for seeding and revegetating areas of western Texas.

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Clay Evans provided land for the research plots at Marfa, Texas.

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Materials and Methods

Fourwing saltbush seeds from about 100 plants were hand-harvested in November 1980 from each of 4 native stands. The collection sites included (from east to west): a southern mixed prairie site dominated by fourwing saltbush, buffalograss [*Buchloe dactyloides* (Nutt.) Engelm.], sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.], and honey mesquite *(Prosopis glandulosa* Torr. var. *glandulosa)* near San Angelo (Tom Green County); a saline site dominated by fourwing saltbush, honey mesquite, and belvedere summercypress [*Kochia scoparia* (L.) Schrad.] within a tarbush (*Flourensia cernua* DC.)-honey mesquite-threeawn (*Aristida purpurea* Nutt.) community at Texon (Reagan County); a shrub savannah site dominated by creosotebush [*Larrea tridentata* (DC.) Cav.], mesquite, and burrograss (*Scleropogon brevifolius* Phil.) near Grandfalls (Pecos County); and a desert grassland site dominated by grama grasses (*Bouteloua* Lag. Mut. Lag. spp.), and tobosagrass [*Hilaria mutica* (Buckl.) Benth.] near Valentine (Jeff Davis County (Table 1). Seeds were dewinged in a modified hammermill and stored at room temperature until planted. Seedlings were grown in a greenhouse in 4 by 5 by 18-cm plastic tube packs containing a mixture of soil, peat moss, and vermiculite (1:1:1, v/v/v) from January 1981 until transplanted in uniform gardens at 3 locations. All 4 of the populations were tetraploids (Dunford 1984; Jerry Barrow, USDA-Agric. Res. Serv., Las Cruces, NM, personal communication).

San Angelo Nursery

The San Angelo nursery was established on an Angelo clay loam (Torrertic Calciustolls) soil at the Texas A&M University Agricultural Research and Extension Center, 8 km northwest (100°30′W, 31°32′N) of San Angelo, Texas. The nursery was disked and planted to oats (*Avena sativa* L.) in the fall of 1980 and disked in spring 1981 prior to transplanting the shrubs.

The nursery experiment was established as a randomized complete block. Twenty-five fourwing saltbush seedlings were transplanted on 1.8-m centers in each of 16 rows [4 rows (replications)-/population] spaced 1.8 m apart on 10 June 1981 with a straight-hinged, rear-frame, tractor-mounted transplanter. Border rows of seedlings were planted to eliminate edge effect. The plant at the end of each row was also considered a border plant and was not evaluated. No supplemental water was applied, but weeds were controlled by hand for the first 2 growing seasons to reduce competition.

Shrub survival, canopy heights, and diameters were measured at the end of the 1982 and 1983 growing seasons. Plant height was measured to the tallest branch. Plant diameter was the average of the crown intercept across the center of the plant parallel with the row and a similar measurement perpendicular to the row. An adaptability index (AI) was calculated to permit ranking performance among the ecotypes using the 1983 mean survival and canopy data, by the equation:

$$AI = [(\text{ecotype \% survival}/\text{maximum \% survival}) + (\text{ecotype height}/\text{maximum height}) + (\text{ecotype diameter}/\text{maximum diameter})]/3.$$

The maximum score an ecotype could receive was 1.00.

Three plants from each row were harvested in late November 1982 and 1 plant from each row was harvested in October 1983 at 15 cm above ground level. Plant material was oven-dried to a constant weight at 45° C, then separated into leaf, current year's

Table 1. Locations, elevation (m), average annual precipitation (cm), and soils where fourwing saltbush seeds were collected in western Texas.

Ecotypes	Location	Elevation	Avg. annual precipitation	Soil classification		
				Series	Texture	Subgroup
		(m)	(cm)			
San Angelo	100°30′W, 31°27′N	580	52	Tulia Angelo	loam clay loam	Calciorthidic Paleustalfs Torrertic Calciustolls
Texon	101°40′W, 31°14′N	790	38	Reagan	silty clay loam	Ustollic Calciorthids
Grandfalls	102°55′W, 31°15′N	800	30	Reakor	silty clay loam	Typic Calciorthids
Valentine	104°35′W, 30°37′N	1430	28	Reagan Hodgins	clay loam clay loam	Ustollic Calciorthids Ustollic Camborthids

stem growth, and woody plant components and weighed. These data and canopy dimension data were used for developing prediction equations to select the best estimate of component and total plant weights for each shrub in the nursery. Growth form of the shrubs was close to cylindrical in 1982 and canopy volume (V) was calculated by the equation:

$$V = \pi r^2 h$$

where: r = radius (average diameter/2)
h = height

Shrub growth form tended to be spherical in 1983 and canopy volume (V) was calculated by the equation:

$$V = 4/3\pi r^3$$

where: $r = [(d/2 + h/2)/2]$
(d = average canopy diameter, h = height)

Nutritive values of leaves and current year's stems of the 4 saltbush populations were estimated on 27 April, 28 July, 24 October, and 19 December 1983. Two to 4 randomly selected leaders of current year's growth (leaves and stem) were collected from each plant and the samples from each row were composited then oven-dried to a constant weight at 55° C. Leaves and stems were ground separately with a Wiley mill to pass a 1-mm screen and stored in plastic vials until laboratory analyses were conducted.

Samples were analyzed for total nitrogen (N) content by the standard Kjeldahl procedure (AOAC 1980), and % N was multiplied by 6.25 to obtain crude protein (CP) estimates. Phosphorus (P) was determined by a colorimetric method (Murphy and Riley 1962), and digestible organic matter (DOM) was estimated in vitro by a 2-stage procedure of incubating the sample in strained rumen fluid for 48 hr, followed by neutral detergent extraction (Van Soest et al. 1966). The in vitro estimates were corrected using a standard forage of known in vivo digestibility. Data are expressed as a percentage of dry matter basis.

A phenological index was used to score individual plants and monitor the growth process during the 1983 growing season. Phenology was recorded at 7- to 44-day intervals, depending upon the rate of development of the plants, from 21 March to 12 December 1983. Observations were more frequent during periods of rapid growth. Plant phenophases were modified from those developed for shadscale [*Atriplex confertifolia* (Torr. and Frem.) S. Wats.] (West and Gasto 1978). Each plant was given a numerical rating corresponding to its growth stage. A phenophase was determined when approximately 50% of the plant parts had developed that stage. Floral phenotype of each shrub was also recorded: staminate, pistillate, monoecious, or no flowering.

Barnhart Nursery

The Barnhart nursery site was established on 12 June 1981 on a Tobosa clay (Typic Chromusterts) soil in abandoned cropland at

Table 2. Mean survival (%), canopy heights (cm), and canopy diameters (cm) of 4 western Texas ecotypes of fourwing saltbush evaluated at the end of the second (1982) and third (1983) growing seasons in uniform nurseries near San Angelo, Barnhart, and Marfa, Texas. Adaptability indices (AI) were calculated from 1983 survival and growth data for each nursery site.[1]

Ecotypes	Survival 1982	Survival 1983	Height 1982	Height 1983	Diameter 1982	Diameter 1983	AI
	(%)	(%)	(cm)	(cm)	(cm)	(cm)	
San Angelo							
Grandfalls	99	99	70 a	121	111	182	1.00
Valentine	99	99	66 ab	117	107	180	.98
Texon	100	100	66 ab	118	106	176	.98
San Angelo	99	96	62 b	114	97	166	.94
Barnhart							
Texon	80	78	37 a	54	24	39 a	1.00
Valentine	67	64	36 ab	52	23	38 a	.92
San Angelo	76	70	31 b	46	23	37 a	.90
Grandfalls	70	70	32 b	47	19	29 b	.84
Marfa							
Valentine	72	69	18	27 a	15	25 a	.98
Grandfalls	65	61	17	29 a	10	19 b	.88
Texon	68	63	15	25 ab	11	19 b	.85
San Angelo	49	49	15	18 b	10	16 b	.66

[1]Means within percent survival, canopy height, and canopy diameter columns for each nursery, without lower case letters or followed by the same letter are not significantly ($P \leq 0.05$) different according to Duncan's new multiple range test.

the Texas Range Station (Crockett Co.), 20 km south (100° 11'W, 30° 58'N) of Barnhart, Texas. Elevation and average annual rainfall were 790 m and 49 cm, respectively. The nursery was disked prior to transplanting fourwing saltbush seedlings. Nursery design was as described for the San Angelo nursery. Seedlings were watered (11 liters) on 12 and 22 June to facilitate establishment. Weeds were controlled by hand at the start of the 1982 growing season but no subsequent weed control was utilized. The nursery was fenced to exclude livestock and white-tailed deer *(Odocoileus virginianus).*

Marfa Nursery

The Marfa nursery was established on 11 August 1981 on a Musquiz clay loam (Aridic Argiustolls) soil 25 km west (104° 22'W, 30° 22'N) of Marfa, Texas. Elevation and average annual rainfall were 1,420 m and 31 cm. Seedlings were moved out of the greenhouse 2 months prior to transplanting. The experiment was established as described for the San Angelo nursery, except that the site was not disked and no border rows were planted. Seedlings were transplanted into the native shortgrass vegetation with the tractor-mounted transplanter which temporarily suppressed competing vegetation in a 10-cm-wide strip.

Survival and canopy heights and diameters of live shrubs were measured at the Barnhart and Marfa nurseries at the end of the 1982 and 1983 growing seasons. Adaptability indices were calculated as described for the San Angelo nursery. Precipitation records were obtained from rain gauges maintained near the study sites at San Angelo and Barnhart and from the National Weather Station at El Paso, Texas, for the Marfa study site.

Statistical Analyses

All data except AI and phenological development were subjected to analyses of variance and means were separated ($P \leq 0.05$), where appropriate, by Duncan's new multiple range test. Percentage data were transformed by $\sin^{-1} \sqrt{x}$ prior to statistical analyses. Phenological development data were tested for significant ($P \leq 0.05$) differences by a nonparametric procedure developed by Estabrook et al. (1982). The number of plants of each ecotype expressing a specified phenophase on each date were recorded and expressed as a percentage of the total number of plants from that ecotype that eventually expressed the respective phenophase. The difference (D) between the percentages for 2 ecotypes was significant ($P \leq 0.05$) if:

$$D > 1.36 \sqrt{(m+n)/(m)(n)},$$

where m and n represent the numbers of plants from the 2 ecotypes that eventually exhibited the phenophase (Estabrook et al. 1982).

Results and Discussion

Annual precipitation received at each nursery site exceeded the long-term average each year of the study except for Barnhart in 1983. The 3-year average precipitation at San Angelo, Barnhart, and Marfa was 23, 13, and 26% greater, respectively, than the long-term averages.

Survival and growth of the saltbush plants varied greatly among the 3 study sites (Table 2), but differences in planting dates, soils, seedbed preparation, and weed control practices precluded any statistical comparisons among sites. Greatest survival and canopy growth occurred at the San Angelo nursery. Shrubs at the Barnhart and Marfa nurseries were subjected to competition from associated grasses and forbs while the San Angelo nursery was maintained weed-free the first 2 growing seasons. The San Angelo site also received 16 and 64% more rainfall than the Barnhart and Marfa nurseries, respectively, during the 3-year study. Heavy clay soil and indurate caliche underlying the solum possibly restricted root development and shrub growth at Barnhart.

Survival and canopy growth data provided evidence of ecotypic differentation at 2 of the 3 nurseries (Table 2). Differences among the 4 ecotypes at San Angelo were not significant after 3 growing seasons although plants of the Grandfalls ecotype tended to be larger. The ecotypes with origins closest to the planting site tended to have greater survival, to be larger, and have the highest AI ratings at the Barnhart and Marfa nurseries. Texon seedlings (seeds collected about 60 km west of the Barnhart nursery) averaged 8 to 14% greater survival than the other ecotypes at Barnhart. Texon shrubs were about 16% taller than the San Angelo and Grandfalls ecotypes and 34% greater in canopy diameter than the Grandfalls ecotype after 3 growing seasons. Seeds of the Valentine ecotype were collected about 37 km northwest of the Marfa nursery. The average survival of Valentine shrubs after 3 growing seasons was 6 to 20% greater than that of the other ecotypes at the Marfa nursery. Canopy height and diameter of the Valentine ecotype in the Marfa nursery were 50 and 56% greater, respectively, than those of the San Angelo ecotype.

Differences in survival and growth among the 4 western Texas ecotypes of fourwing saltbush generally supported earlier research[1] (Springfield 1970, Van Epps 1975) which suggested that germplasm originating nearest to the planting site is better adapted to the edaphic and climatic conditions of a particular site. Evidence was greatest at the Marfa nursery (AI rating for the Valentine ecotype was .98 compared to .66 for the San Angelo ecotyope) (Table 2). The desert grassland climate, low precipitation, high elevation, and plant competition at the Marfa site (Table 1) provided an environment more harsh than that at other nursery sites, particularly for the San Angelo ecotype. Genetic material from an environment more favorable than that at the planting site is usually poorly adapted (Van Epps 1975). Ecotypes of fourwing saltbush originating in environments less favorable than that at the planting site can perform well even if moved to distant places (McArthur et al. 1983). This may partially account for similar survival and growth among the ecotypes at the San Angelo nursery.

The best fit prediction equations for estimating component and total weights of fourwing saltbush in the San Angelo nursery were: natural logarithm oven-dry weight = $a + b$ [natural logarithm($\pi r^2 h$)] for 1982; and natural logarithm oven-dry weight = $a + b$ [natural logarithm($4/3 \pi r^3$)] for 1983, where a and b are the Y intercept and slope, respectively, weight is expressed in g, and canopy volume in cm^3 (Table 3). These equations accounted for 86 to 98% of the variability in weights of the various components.

Table 3. Prediction equations used to estimate oven-dry weight *(W)* of leaves, current year's stem, wood, and total biomass of 4 western Texas ecotypes of fourwing saltbush grown in a uniform nursery near San Angelo, Texas. Coefficients of determination (r^2) for each equation are included.

Plant component	Prediction equation[1]	r^2
	1982	
Leaf	$\log W = -5.989 + 0.866 [\log (\pi r^2 h)]$	.86
Current year's stem	$\log W = -8.727 + 1.014 [\log (\pi r^2 h)]$	.93
Wood	$\log W = -10.650 + 1.207 [\log (\pi r^2 h)]$	.86
Total	$\log W = -6.795 + 0.993 [\log (\pi r^2 h)]$	.92
	1983	
Leaf	$\log W = -9.002 + 1.128 [\log (4/3 \pi r^3)]$	.93
Current year's stem	$\log W = -11.685 + 1.277 [\log (4/3 \pi r^3)]$	.96
Wood	$\log W = -13.332 + 1.434 [\log (4/3 \pi r^3)]$	.98
Total	$\log W = -10.235 + 1.283 [\log (4/3 \pi r^3)]$	.97

[1]Equations for 1982 were derived from data from 48 plants and those for 1983 were derived from data from 16 plants.

Fourwing saltbush from Grandfalls tended to have greater yields while the San Angelo ecotype tended to have the lowest yields in both years at the San Angelo nursery (Table 4). Mean total weights of Grandfalls shrubs were 28 and 20% greater than that of San

[1]Ward, R.T., W.L. Slauson, and C.W. Welden. 1982. Ecogenetic variability in native shrubs related to the reestablishment of vegetation on disturbed arid shrublands. p. 57-65. *In:* E.F. Redente and C.W. Cook (Comp.). Revegetation studies on oil shale related disturbances in Colorado. Colorado State Univ. Fort Collins.

Table 4. Estimated mean oven-dry leaf, current year's stem, wood, and total weight (g/plant) (± SE) of 4 western Texas ecotypes of fourwing saltbush at the end of the second (1982) and third (1983) growing seasons in a uniform nursery near San Angelo, Texas. Estimated weights were calculated using the prediction equations from Table 3.

	Estimated oven dry weight			
Ecotypes	Leaf	Current year's stem	Wood	Total
	(g/plant)			
	1982			
Grandfalls	310 ± 21	154 ± 12	324 ± 29	795 ± 60
Valentine	291 ± 22	145 ± 13	305 ± 31	747 ± 64
Texon	284 ± 20	139 ± 11	288 ± 26	720 ± 56
San Angelo	246 ± 21	120 ± 12	246 ± 28	619 ± 60
	1983			
Grandfalls	1569 ± 91	949 ± 61	1824 ± 130	4415 ± 287
Valentine	1496 ± 88	900 ± 58	1722 ± 122	4190 ± 272
Texon	1411 ± 76	840 ± 50	1587 ± 104	3906 ± 234
San Angelo	1317 ± 102	788 ± 68	1501 ± 144	3667 ± 318

Angelo shrubs in 1982 and 1983, respectively. The estimated weights of the various plant components increased 5 to 6-fold over the 1-year period. Wood constituted about 40% of the plant weight both years. Leaves and current year's stem growth accounted for 40 and 19% of the phytomass in 1982, respectively, and 36 and 21% in 1983, respectively. The estimated weight of total browse (leaves + current year's stems) for the 4 ecotypes ranged from 2,100 to 2,500 g/plant (6,300 to 7,500 kg/ha).

Differences among the 4 ecotypes in CP, P, and DOM were too small to be considered biologically or nutritionally significant to herbivores (Table 5). Seasonal trends were similar among the ecotypes studied, probably because of similar phenologies (Table 6) and seasonal leaf retention. Nutrient content of the browse was highest in early spring and declined as the new growth matured and as the plants produced seeds. Leaf and stem CP and leaf P and DOM values stablized by late October, whereas stem P and DOM values continued to decline into December. Crude protein contents and in vitro digestibility of winter-sampled current year's growth varied significantly among fourwing saltbush ecotypes grown in a uniform garden in Idaho (Welch and Monsen 1984). Differences in nutritive values may be associated with differential retention of winter leaves among individual plants and ecotypes (Welch et al. 1983).

Concentrations of CP and DOM in fourwing saltbush leaves (Table 5) exceeded minimum requirements of cattle, sheep, goats (NRC 1981, 1984, 1985), and deer (Dietz 1965) in all seasons. Phosphorus was adequate at the spring sampling date but marginal to slightly deficient in other seasons. The stems were moderately high in CP and marginal in DOM and P during April but contained deficient levels of all 3 nutrients in summer, autumn, and winter. Protein content of 'Rincon' fourwing saltbush leaves and stems were 17.9 and 6.9%, respectively, in November (McArthur et al. 1984), and mature leaves collected from fourwing saltbush grown in Saudi Arabia averaged 17.4 and .19% for CP and P, respectively (Khalil et al. 1986). Our data indicate that ruminant animals can be kept at a good level of nutrition for body maintenance on saltbush diets alone. Whether satisfactory productivity can be supported or enhanced by saltbush requires additional investigation. Preliminary observations (unpublished data) indicate that the CP in fourwing saltbush foliage may not be totally available for digestion.

Fourwing saltbush plants in the nursery at San Angelo were rated for both vegetative and floral development, but significant differences were observed only for floral development. Considerable variation in initiation and duration of a phenophase occurred both within and among the 4 ecotypes of fourwing saltbush (Table 6). The San Angelo ecotype generally progressed through each floral phenophase faster than did the Valentine and Grandfalls ecotypes, while floral development of Texon plants was usually intermediate. Utricle maturation was observed for all ecotypes on 7 December 1983. Observations were not frequent enough late in the season to detect significant ($P \leq 0.05$) differences.

The sex ratios of the 4 western Texas ecotypes were similar to those of other tetraploid populations (McArthur 1977, McArthur and Freeman 1982), indicating there were monoecious plants and a bias towards pistillate floral phenotypes (Table 7). The proportions of pistillate and monoecious individuals were similar among the 4 ecotypes. Significantly ($P \leq 0.05$) fewer staminate plants occurred within the Grandfalls ecotype compared to San Angelo or Texon ecotypes. Significantly ($P \leq 0.05$) more plants with no floral expression occurred in the Valentine and Grandfalls ecotypes compared to the Texon ecotype. This may account for the trends for Grandfalls and Valentine ecotypes to be larger and have greater yields in the San Angelo nursery. Plants without sex

Table 5. Mean percent (%) crude protein (CP), phosphorus (P), and digestible organic matter (DOM) of leaves and current year's stems of 4 western Texas ecotypes of fourwing saltbush in a uniform nursery near San Angelo, Texas during spring, summer, autumn and winter 1983.[1]

	Leaves				Current year's stem			
Ecotypes	Apr. 27	July 28	Oct. 24	Dec. 19	Apr. 27	July 28	Oct. 24	Dec. 19
	(%)							
	CP							
San Angelo	25.4 a	18.4	16.3	17.9	15.8	7.8	5.8	6.5 b
Texon	23.6 b	18.8	16.2	17.6	15.5	7.8	6.3	7.1 a
Grandfalls	22.4 c	19.2	16.9	18.1	14.9	7.9	6.0	6.7 ab
Valentine	23.2 bc	19.2	16.7	17.9	15.2	8.0	6.3	7.0 ab
	P							
San Angelo	.25 a	.14	.12	.14	.17	.15	.10	.05
Texon	.23 ab	.13	.13	.13	.18	.15	.10	.06
Grandfalls	.21 b	.14	.12	.14	.17	.15	.10	.06
Valentine	.22 b	.13	.12	.13	.16	.14	.10	.06
	DOM							
San Angelo	62.3 ab	62.0	60.8 a	58.6	50.5 a	25.6	12.5	9.5
Texon	62.8 a	61.5	61.3 a	58.5	49.7 ab	24.2	12.3	11.5
Grandfalls	61.2 b	61.3	59.0 b	59.5	47.9 b	23.9	10.6	9.4
Valentine	61.5 ab	62.1	61.0 a	59.2	47.8 b	24.2	12.9	9.3

[1]Means within a column for each nutrient component without lower case letters or followed by the same letter are not significantly ($P \leq 0.05$) different according to Duncan's new multiple range test.

Table 6. Percentages (%) of plants within 4 western Texas ecotypes of fourwing saltbush in a uniform nursery near San Angelo, Texas exhibiting floral phenophases on selected dates during 1983.[1]

	Evaluation dates															
Ecotypes	3/21	4/4	4/19	4/28	5/9	5/17	5/24	6/11	6/24	7/8	7/22	8/12	9/2	9/21	10/25	12/7
	(%)															
	Floral bud development															
San Angelo	9	33 a	53 a	78 a	95 a	96 a	99 a	100 a	100	100	100	100				
Texon	0	13 ab	44 a	59 ab	77 ab	83 ab	86 ab	86 ab	89	89	92	100				
Grandfalls	1	6 b	22 b	46 b	67 b	75 ab	83 ab	84 ab	87	88	97	100				
Valentine	0	15 ab	38 ab	56 ab	70 b	71 b	76 b	79 b	79	82	94	100				
	Flowers opening															
San Angelo				3	41 a	47 a	63 a	99	100	100	100	100	100			
Texon				0	20 ab	38 ab	58 ab	85	87	87	90	99	100			
Grandfalls				1	15 b	19 b	38 b	80	87	88	93	100	100			
Valentine				1	27 ab	36 ab	47 ab	79	79	80	94	100	100			
	Male flowers dying															
San Angelo						0	62 a	95 a	95	97	97	100	100	100		
Texon						0	10 c	70 ab	88	88	90	90	93	100		
Grandfalls						4	13 bc	57 b	65	78	78	87	96	100		
falls																
Valentine						0	50 ab	85 ab	89	89	89	92	100	100		
	Utricle fill															
San Angelo							0	68 a	97 a	100	100	100	100	100		
Texon							6	48 ab	78 ab	82	83	93	100	100		
Grandfalls							2	39 b	70 ab	79	86	90	100	100		
Valentine							5	45 ab	67 b	74	74	91	98	100		
	Utricles ripe															
San Angelo									5	44	71 a	90 a	93 a	98 a	100	100
Texon									2	36	60 ab	74 ab	79 ab	81 ab	100	100
Grandfalls									2	30	43 ab	50 b	63 b	75 ab	100	100
Valentine									0	29	38 b	52 b	52 b	64 b	93	100

[1]Means within a column for each phenology stage without lower case letters or followed by the same letter are not significantly ($P \leq 0.05$) different according to a nonparametric procedure. The number of plants within each ecotype expressing a specific phenophase are presented as a percentage of the total number of plants within the same ecotype eventually expressing the respective phenophase.

Table 7. Mean percentages (%) of floral phenotypes expressed during the third growing season by 4 western Texas ecotypes of fourwing saltbush in a uniform nursery near San Angelo, Texas.[1]

	Floral phenotypes			
Ecotypes	Staminate	Pistillate	Monoecious	None
	(%)			
San Angelo	36 a	40	4	17 bc
Texon	26 a	48	13	9 c
Grandfalls	12 b	48	11	27 ab
Valentine	22 ab	41	7	31 a

[1]Means within a column without lower case letters or followed by the same letter are not significantly ($P \leq 0.05$) different according to Duncan's new multiple range test.

expression may allocate more resources to growth and biomass production than plants with reproduction functions. Fourwing saltbush is a species that includes some sexually labile genotypes sensitive to environmental changes (McArthur 1977, McArthur and Freeman 1982, Freeman et al. 1984). Ecotypic differences in floral phenotypes observed in the Grandfalls and Valentine ecotypes at the San Angelo site may in part be due to a change in environmental conditions.

Conclusion

Evidence of genetic variation among the 4 western Texas tetraploid populations of fourwing saltbush in common nurseries supports our earlier observations on differential seed germination characteristics among these 4 populations (Potter et al. 1986). Evidence of ecotype differentation, based on seedling survival and growth, was more apparent at planting sites with less favorable growing conditions. Our data support those of others that suggest genetic material orginating in harsh environments has a wider range of adaptation than that originating in favorable environments (Van Epps 1975, McArthur et al. 1983). High laboratory-determined CP and DOM values and forage yields (6,300 to 7,500 kg/ha) suggest that the fourwing saltbush germplasm in western Texas has considerable potential for improving rangelands and marginal cropland for livestock and wildlife production.

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