Cultural Practices for Establishing Fourwing Saltbush within Perennial Grass Stands

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Abstract

Establishment of fourwing saltbush [*Atriplex canescens* (Pursh) Nutt.] on rangelands in western Texas could improve forage production and quality. Three experiments were conducted to evaluate establishment and growth of fourwing saltbush in grass stands as affected by width of tilled seedbed, fertilization, and competition from various grasses. Four-month-old seedlings were transplanted on 1.8-m centers and seeds were planted in 10-cm-wide, ripped areas and in 46- or 91-cm-wide, tilled strips within a dense stand of sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.]. Transplanted seedlings were fertilized with nitrogen (N) (50 kg/ha), phosphorus (P) (50 kg/ha), or N+P (50+50 kg/ha). Survival and size of transplanted seedlings were significantly ($P \leq 0.01$) greater after 17 months in tilled than in ripped strips. Standing crops of competing vegetation were about 50% greater in ripped than in tilled areas. Fertilizer did not affect survival of fourwing saltbush seedlings or standing crops of competing vegetation. However, P increased ($P \leq 0.05$) mean canopy height and diameter of 17-month-old fourwing saltbush seedlings 50 and 67%, respectively, compared to those of plants receiving no fertilizer or N. Very few seedlings established following direct seeding. Survival and growth of transplanted fourwing saltbush seedlings were significantly ($P \leq 0.05$) greater in competition-free plots than in interspaces between rows of various species or short-, mid-, and tall grasses, and survival decreased as height of grasses increased.

Desirable shrubs are an important, but often neglected, component of rangeland plant communities in western Texas, and technology for establishing and utilizing shrubs as a forage resource has not been researched for this region. Fourwing saltbush [*Atriplex canescens* (Pursh) Nutt.], a native, facultative-evergreen shrub, has been recommended for improvement of depleted rangeland, surface mine reclamation, and stabilization of critical areas. The species furnishes browse and cover for livestock and wildlife, is adapted to diverse soil and climatic conditions, and is drought tolerant (Springfield 1970). It is relatively palatable and maintains high levels of crude protein and phosphorus throughout most of the year (Smit and Jacobs 1978).

Success in attempts to revegetate western rangelands with fourwing saltbush and other shrubs has been variable. Shrubs may be established within grass stands by interseeding and transplanting (Stevens et al. 1981). Under harsh environments, transplanting of saltbushes is more successful than direct seeding (Plummer et al. 1966). Controlling plant competition improves survival, establishment, and growth of fourwing saltbush (Giunta et al. 1975; Van Epps and McKell 1977, 1983; Geist and Edgerton 1984). Adequate soil water contents and temperatures favorable for seed germination are also critical for shrub establishment (Springfield 1970, Nord et al. 1971, Aldon 1972). Fourwing saltbush seeds should be harvested near the planting site to insure adaptation to the site (Springfield 1970, Nord et al. 1971). Yields of seedlings of fourwing saltbush and other species of *Atriplex* growing in soil, processed oil shale, and topsoiled coal mine spoil have responded favorably to fertilization, but most studies have been conducted under greenhouse conditions (Williams and O'Connor 1973, Richardson and McKell 1981, Holechek 1982). The influence of fertilization under field conditions has not been thoroughly researched.

Three experiments were conducted to evaluate the feasibility of establishing fourwing saltbush within established grass stands. The objective of the first 2 experiments was to determine the effects of fertilization and width of tilled seedbed strips on establishment and growth of fourwing saltbush direct seeded or transplanted into a stand of 'El Reno' sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.]. The objective of the third experiment was to compare establishment and growth of fourwing saltbush seedlings transplanted between rows of various short-, mid-, and tall grasses and into adjacent competition-free areas.

Materials and Methods

The study sites were on Angelo clay loam soils (fine, mixed, thermic Torrertic Calciustolls) at the Texas A&M University Agricultural Research and Extension Center, 8 km northwest of San Angelo in the southern Rolling Plains resource area. Elevation is about 580 m and mean annual precipitation is 52 cm. About 75% of the precipitation occurs during April through October with the peak month, May, receiving an average of about 8 cm.

Fourwing saltbush seeds were hand-harvested in the fall of 1980 from native stands near the study site and at Texon and Grandfalls, Texas. Texon (Reagan County) is about 135 km southwest of San Angelo in the western Edwards Plateau resource area. Average rainfall is 38 cm and elevation is about 790 m. Grandfalls (Ward County) is about 240 km west of San Angelo in the Trans-Pecos resource area. Average rainfall is 30 cm and the elevation is about 900 m. The true seeds of fourwing saltbush are enclosed within the utricle (fruit), which is slightly compressed, united to the apex, and conspicuously 4-winged (4–12 mm) (Wagner and Aldon 1978). Utricles are referred to as seed in this report. The seeds were dewinged in a modified hammermill for ease of handling, reduction in bulk, and better coverage with soil (Springfield 1970).

Two experiments were conducted in a 2-ha field seeded to 'El Reno' sideoats grama in spring 1980. A uniform, dense stand of sideoats grama occupied the site. The field was fenced to exclude white-tailed deer *(Odocoileus virginianus)* and livestock. Ten bulk soil samples were taken from 0 to 30- and 30 to 60-cm depths and analyzed for nitrate-nitrogen (NO_3-N) by acid extraction and colorimetry; for phosphorus (P) by ammonium acetate extraction and colorimetry; for potassium (K) by ammonium acetate extraction and flame photometry; for calcium (Ca) and magnesium (Mg) by ammonium acetate extraction and atomic absorption; and for pH at the Texas A&M Soil Testing Laboratory, Lubbock (Welch et al. 1980).

Direct Seeding

Percent germination of the fourwing saltbush seeds harvested at San Angelo was determined from 5 replications of 50 seeds. The seeds were treated with a fungicide (50% manganese ethylenevisdithiocarbamate and 10% hexachlorobenzene), placed on filter papers in 10-cm petri dishes, then 8 ml of distilled water was added to each dish. The petri dishes were placed in a dark, controlled environmental chamber for 21 days at 20° C. Seeds were considered germinated when the length of the radicle equalled or exceeded the length of the utricle.

Twelve rows of each of 3 tillage treatments were prepared in the stand of sideoats grama on 23 April 1982 using a tractor-drawn

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Approved by the Director, Texas Agricultural Experiment Station, as TA No. 21028.
Manuscript accepted 17 February 1986.

Table 1. Mean survival (%), canopy heights (cm), and canopy diameters (cm) of fourwing saltbush plants and standing crops (kg/ha) of competing vegetation after transplanting into a dense stand of sideoats grama as affected by width of tilled area.[1]

	Survival				Canopy height			Canopy diameter			Competing vegetation
	Months after transplanting										
Treatment comparisons	2	5	17	38	5	17	38	5	17	38	17
	(%)				(cm)						(kg/ha)
ripping 10 cm vs.	81	56	31	29	8	17	58	4	9	46	2260
			**	**		**	**		**	**	**
tillage 46 and 91 cm	86	65	49	46	9	27	74	5	19	76	1485
tillage 46 cm vs.	86	61	44	41	8	25	73	5	18	78	1450
tillage 91 cm	86	68	53	51	9	28	74	5	20	74	1520

[1]Pairs of mean separated by asterisks are significantly ($P\leq0.01$) different according to individual degree of freedom contrasts.

Table 2. Mean survival (%), canopy heights (cm), and canopy diameters (cm) of fourwing saltbush plants and standing crops (kg/ha) of competing vegetation after transplanting into a dense stand of sideoats grama as affected by fertilization treatments.[1]

		Survival				Canopy height			Canopy diameter			Competing vegetation
		Months after transplanting										
Fertilizer(s)	Rate	2	5	17	38	5	17	38	5	17	38	17
	(kg/ha)	(%)				(cm)						(kg/ha)
none		88	62	45	41	8	20 b	63 b	4	12 b	56 b	1840
nitrogen (N)	50	83	62	42	37	8	19 b	61 b	4	12 b	57 b	1500
phosphorus (P)	50	80	54	39	38	8	30 a	78 a	5	20 a	82 a	1980
N+P	50+50	88	68	46	44	9	26 ab	70 ab	5	18 a	68 ab	1670

[1]Means within a column without lower case letters or those followed by the same letter are not significantly ($P\leq0.05$) different according to Duncan's multiple range test.

cultivator with sweep tines (46- and 91-cm-wide strips) or a ripping chisel point (10-cm-wide strip) set to plow to a 15-cm depth. The tillage treatments were spaced 3 m apart and the rows were 30 m long. Fungicide-treated fourwing saltbush seed from the San Angelo population were hand-planted at a depth of 1 cm on 30 April 1982 into the center of the tilled strips at 0.7 kg pure live seed/ha (31 viable seed/m of row). The experiment was arranged as a completely randomized design with 12 replications of each treatment. Emergence and establishment of seedlings were evaluated 2, 5, and 17 months after planting by counting the number of live seedlings in each row.

Transplanting

Seedlings from the San Angelo and Grandfalls seed sources were grown in a greenhouse from January to mid-April 1982 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). The seedlings were moved outdoors 2 weeks prior to transplanting. Twelve rows of each of 3 tillage treatments were prepared on 23 April 1982 in the sideoats grama stand as described above. Thirty-one San Angelo and 17 Grandfalls seedlings were transplanted on 1.8-m centers over a 56- and 30-m segment of each row, respectively, on 7 and 10 May 1982 with a straight-hinged, rear frame, tractor-mounted transplanter. Three rows of each tillage treatment received no fertilizer, or 50 kg N/ha, 50 kg P/ha, or N+P (50+50 kg/ha) which was surface applied on 18 May 1982. Nitrogen as ammonium nitrate (NH_4NO_3) and P as concentrated superphosphate (P_2O_5) were evenly distributed within a 0.25-m^2 area around each transplanted seedling. The factorial experiment was arranged as a completely randomized design with treatments replicated 3 times.

Survival of transplanted shrubs was evaluated after 2, 5, 17, and 38 months, and canopy heights and diameters of live shrubs were measured after 5, 17, and 38 months. Standing crops of associated herbaceous plants were estimated by harvesting at ground level from 0.25-m^2 quadrats placed over 5 randomly selected fourwing saltbush transplants in each row (15 quadrats/treatment) in August 1983. Samples were oven dried at 50° C to a constant weight and weighed. Data for the 2 populations were pooled and subjected to analyses of variance. Interactions were not significant. Means for seedling survival and canopy dimensions, as affected by the 3 tillage treatments, were separated by an orthogonal set of individual degree of freedom contrasts. Means for these variables, as affected by fertilizer treatments, were separated ($P\leq0.05$) by Duncan's multiple range test. Survival data were transformed by $\sin^{-1}\sqrt{X}$ prior to statistical analyses.

Competition Study

The third experiment was established in a grass nursery on 1 June 1983. Grasses had been planted in 7-m-long rows spaced 1 m apart in the spring and fall of 1973. Grasses used in the experiment were: shortgrasses-buffalograss [*Buchloe dactyloides* (Nutt.) Engelm.] and blue grama [*Bouteloua gracilis* (H.B.K.) Lag. ex Griffiths]; mid-grasses-sideoats grama, green sprangletop [*Leptochloa dubia* H.B.K.) Nees.], plains bristlegrass [*Setaria leucopila* (Scribn. & Merr.) K. Schum.], alkali sacaton [*Sporobolus airoides* (Torr.) Torr.], wilman lovegrass [*Eragrostis superba* Peyritsch], and western wheatgrass [*Agropyron smithii* Rydb.]; and tall grasses-caucasian bluestem [*Bothriochloa caucasica* (Trin.) Hubb.], blue panicum (*Panicum antidotale* Retz.), kleingrass (*Panicum coloratum* L.), switchgrass (*Panicum virgatum* L.), and false switchgrass (*Panicum plenum* Hitchc. & Chase).

Seedlings produced from the Texon seed source were grown in the greenhouse from February to May 1983 as described above. Seedlings were moved outdoors for 1 month for environmental conditioning prior to transplanting. The experiment was arranged as a completely randomized design with 4 competition treatments: (1) tilled areas where competition was initially eliminated by rototilling then controlled by hand for 2 growing seasons; (2) between rows of shortgrasses; (3) between rows of midgrasses; and (4) between rows of tall grasses tilled only at time of planting. A 66-cm-wide garden tiller set to plow 13 cm deep was used to eliminate grass tillers and weeds between rows of grass prior to transplanting. A replication consisted of 3 fourwing saltbush seedlings hand transplanted on 1-m centers. Treatment replications were 14, 10, 17, and 19 for the competition-free, short-, mid-, and tall grass treatments, respectively. The number of rows of each grass species was too small to permit comparison of responses of the shrubs among grass species. Survival and canopy heights and diameters of live plants were evaluated 6, 16, and 26 months after transplanting. Data were subjected to analyses of variance and means were separated ($P \leq 0.05$) by Duncan's multiple range test. Survival data were transformed by $\sin^{-1}\sqrt{X}$ prior to statistical analyses.

Results and Discussion

About 37 cm of rainfall were received during May through July 1982 (long-term average = 16 cm), but only 4 cm were received the next 90 days. Common broomweed [*Xanthocephalum dracunculoides* (DC.) Shinners], western ragweed (*Ambrosia psilostachya* DC.), and common sandbur (*Cenchrus incertus* M.A. Curtis) rapidly invaded the tilled strips within the sideoats grama stand. Plowing with sweeps did not totally control sideoats grama within the tilled strips. The grass root systems were effectively severed by plowing, but many plants survived within the strips.

Direct Seeding

Only 34 fourwing saltbush seedlings were found 2 months after seeding (data not shown). Seedlings were not counted prior to the 2-month evaluation, but very few seedlings emerged during this period. The laboratory germination test indicated 24% germination for seeds from the San Angelo population, thus failure of the seeding was not attributed to low seed viability. Only 13 live seedlings were found after 2 growing seasons. Seedlings were found only in the strips tilled 46 or 91 cm wide. Failure of the direct seeding may have been caused by plant competition or possibly by allelopathic effects of associated vegetation. Soil water contents were not determined. Bokhari (1978) found that extracts of blue grama and western wheatgrass inhibited germination of blue grama, western wheatgrass, and buffalograss seeds. Several investigators have reported poor stand establishment and growth of direct-seeded fourwing saltbush and other shrubs due to plant competition (Holmgren 1956, Hubbard 1957, Nord et al. 1971, Giunta et al. 1975, Van Epps and McKell 1977). Rabbits and rodents often clip new seedlings to ground level and kill whole stands (Plummer et al. 1966).

Results from this single experiment should not be construed to imply that fourwing saltbush cannot be successfully interseeded in tilled strips within established grass stands in western Texas. However, rainfall was more than twice the long-term average during the 3-month period after our seeding, thus the probability of attaining establishment of acceptable stands by interseeding in tilled strips ≤91 cm wide appears to be relatively low.

Transplanting

Survival and canopy development of fourwing saltbush plants in the tillage treatments were significantly ($P \leq 0.01$) greater than that of those in the ripping treatment after 17 and 38 months (Table 1). Seedling survival was over 1.5 times greater while canopy heights and diameters were 27% and 65% greater, respectively, in the tilled strips compared to the ripped areas after 38 months. This response was attributed to greater competition, primarily from the sideoats grama, in the ripped areas (2,260 kg/ha) than in the tilled areas (1,485 kg/ha) (Table 1). Increasing the width of the tillage treatment from 46 to 91 cm neither increased survival nor size of the shrubs, apparently because standing crops of competing vegetation were not affected (Table 1). Perennial grasses were the dominant competing vegetation within all treatments after 2 growing seasons.

Plant competition also adversely affected establishment of fourwing saltbush transplants in Utah and Oregon studies (Van Epps and McKell 1977, 1983, Geist and Edgerton 1984). Acceptable growth of shrubs was achieved by providing 76-cm-diameter zones free from competition within cheatgrass (*Bromus tectorum* L.) stands (Holmgren 1956, Giunta et al. 1975). Optimum growth of transplanted fourwing saltbush within crested wheatgrass [*Agropyron cristatum* (L.)] in Utah required grass row spacings of about 210 cm (Van Epps and McKell 1977). About 80% of the bareroot shrub seedlings transplanted into 64-cm-wide by 23-cm-deep scalps in intermediate wheatgrass [*A. intermedium* (Host) Beauv] sod survived, compared to only 5% or less when transplanted into unscalped sod (Stevens et al. 1981).

Table 3. Average nutrient availability (ppm) and pH of the Angelo clay loam soil at the study site near San Angelo, Texas.

Soil depth (cm)	pH	NO_3-N	P	K	Ca	Mg
		Nutrient availability[1]				
		(ppm)				
0–30	8.0	2 (VL)	34 (H)	398 (VH)	8998 (VH)	440 (H)
30–60	8.0	2 (VL)	31 (H)	225 (VH)	8998 (VH)	529 (H)

[1]VL=very low, H=high, and VH=very high, based on expected grain sorghum (*Sorghum vulgare* Pers.) yield as percent of maximum (Texas High Plains soil).

Variation in growth habit within ecotypes of fourwing saltbush has been documented (Blauer et al. 1976). We also observed extreme variation in seedling vigor and apparent ability of fourwing saltbush seedlings within the Grandfalls and San Angelo ecotypes to tolerate competition. This variability suggests seedling vigor is a genotypic trait that might be selected for in cultivar improvement programs.

Survival of transplanted fourwing saltbush seedlings had stabilized after 17 months, but survival was not influenced by the fertilizer treatments evaluated (Table 2). Survival averaged 40% after 38 months. However, shrub growth was significantly ($P \leq 0.05$) improved by applications of P at 50 kg/ha. Shrubs fertilized with P were 50 and 67% greater in mean canopy height and mean canopy diameter, respectively, than unfertilized or N-fertilized shrubs 17 months after planting (Table 2). Shrubs fertilized with N+P tended to be somewhat smaller than those fertilized with P alone.

The response to P fertilizer was not expected based on the soil analysis (Table 3). However, available phosphates in alkaline soils with readily exchangeable Ca will react with Ca and its carbonates

Table 4. Mean survival (%), canopy heights (cm), and canopy diameters (cm) of fourwing saltbush as affected by height of associated grasses 6, 16, and 26 months after transplanting in a grass nursery near San Angelo, Texas.[1]

Treatments	Plant survival			Canopy height			Canopy diameter		
	Months after transplanting								
	6	16	26	6	16	26	6	16	26
	(%)			(cm)					
no competition	91 a	88 a	88 a	17 a	83 a	104 a	22 a	86 a	111 a
shortgrass	70 b	64 b	64 b	9 b	18 b	40 b	6 b	8 b	24 b
mid-grass	64 bc	58 b	52 b	9 b	16 b	43 b	5 b	9 b	24 b
tall grass	40 c	25 c	23 c	8 b	18 b	38 b	5 b	9 b	19 b

[1]Means within a column followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's multiple range test.

and become relatively insoluble (Buckman and Brady 1962). Calcium and Mg ions cause precipitation of P and a decline in its availability in soils with pH about 7 (Tisdale and Nelson 1975). Fertilizer P, however, is quite soluble and its availability to plants is greatest shortly after application (Black 1968). Fourwing saltbush may also have a high demand for P.

The rate of fertilizer N used in this study did not affect growth of fourwing saltbush seedlings (Table 2) even though the soil contained very low levels of NO_3-N (Table 3). Fertilizer N applied at 56 kg/ha increased plant competition and negated the effect of herbicidal weed control in a grass establishment study (Evans and Young 1977). Fertilizer N applied in our experiment may have been utilized by the sideoats grama, which has roots that may spread laterally 30 to 46 cm (Weaver 1958), and by weeds that established in the tilled areas. Our tillage treatments removed the vegetation at the surface but rhizomes and root systems of undisturbed plants may have regrown into the tilled areas and the N fertilizer may have been utilized by the competing vegetation before fourwing saltbush seedlings could respond to it. However, there was no evidence that fertilizer N, P, or N+P influenced standing crops of competing vegetation 17 months after treatment (Table 2). Application of N+P (37+94 kg/ha) fertilizer to topsoiled coal mine spoil increased belowground biomass, but had no effect on aboveground biomass or survival of fourwing saltbush seedlings in a field study in Montana (Holechek 1981, 1982).

Competition Study

About 8 cm of rainfall was received within 21 days prior to initiation of the competition experiment and about 60 cm were received during the following 16 months. Survival and canopy development of transplanted fourwing saltbush seedlings were significantly ($P\leq0.05$) reduced in interspaces between rows of short-, mid-, and tall grasses compared to that in adjacent, competition-free plots (Table 4). Plant survival decreased rapidly during the first growing season but had generally stabilized within all treatments after about 16 months. Tall grasses were significantly ($P\leq0.05$) more detrimental to shrub survival than were short- or mid-grasses, but growth of shrubs that established was not affected by height of adjacent grasses. Survival of saltbush seedlings after 26 months in competition-free plots averaged 88% compared to 64, 52, and 23% in shortgrass, mid-grass, and tall grass plots, respectively. Grass competition reduced the average heights and diameters of 26-month-old fourwing saltbush seedlings 61 and 80%, respectively.

Conclusion

Our data support those of other studies indicating fourwing saltbush seedlings have a relatively low tolerance for plant competition. Controlling plant competition after the initial seedbed preparation probably can not be justified for shrub interseeding or transplanting on rangelands. Initial control of plant competition in strips wider than 91 cm appeared essential for achieving acceptable establishment and canopy development of fourwing saltbush in western Texas. Row spacings >158 cm were recommended for planting fourwing saltbush within crested wheatgrass in Utah (Van Epps and McKell 1977). A well-prepared seedbed and substantial or complete elimination of competition appears to be critical for successful direct seeding in western Texas.

Our data suggest that the effect of competition from sideoats grama masked any potential response to fertilizer N or P relative to survival of transplanted fourwing saltbush seedlings, although fertilizer P increased the growth rate of seedlings that established.

Characteristics of associated grasses such as canopy height, rooting patterns, season(s) of growth, and allelopathy may influence survival of shrub seedlings. However, our data indicate that canopy height of associated grasses may not be an important factor regulating growth of shrub seedlings that establish within grass stands. Our observation that some fourwing saltbush seedlings have greater tolerance to competition than others suggests that seedling vigor might be a genotypic trait that could be selected for in cultivar improvement programs.

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