Germination of Fourwing Saltbush Seeds: Interaction of Temperature, Osmotic Potential, and pH

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Abstract

Establishment of shrubs and other forage plants on arid and semiarid rangelands and salt-contaminated sites may be enhanced if ecotypes with ability to germinate and establish under moisture stress and high temperatures can be identified. The interactive effects of temperature, osmotic potential, and pH on germination were evaluated with seed from 4 populations of fourwing saltbush [*Atriplex canescens* (Pursh) Nutt.] from western Texas. Predicted optimum temperature (15 to 18°C) from osmotic potential by temperature response surfaces for germination of 3 populations (Valentine, Grandfalls, and San Angelo) were similar to those reported for populations of fourwing saltbush from other western states. Germination of seed collected near Texon, Texas was significantly ($P<0.01$) affected by media pH range 6 to 9. Seed from the Texon population germinated under lower osmotic potentials compared to the other 3 populations. Total germination of all four populations was enhanced by osmotic potentials lower than 0 MPa. Seed from the Texon population may possess germination characteristics more suitable for arid-land seeding than those from populations near Valentine, Grandfalls, and San Angelo, Texas.

Fourwing saltbush [*Atriplex canescens* (Pursh) Nutt.], a native, evergreen shrub, is absent or rare on most western Texas rangeland, probably because of the prevalence of continuous, yearlong grazing by cattle, sheep, and/or goats. The species has been successfully used for rehabilitation of oilwell reserve pits where high concentrations of soluble salts and sodium prevented acceptable establishment or growth of other species.[1] Our preliminary grazing trials suggest that fourwing saltbush may be valuable for balancing the seasonal deficiencies of protein in native forages (D.N. Ueckert, unpublished data).

Fourwing saltbush frequently grows on relatively dry, saline soils, suggesting that its seed may be adapted for germinating under conditions of limited moisture. Springfield (1966) hypothesized capacity to germinate under dry field conditions may vary among geographic strains or ecotypes of fourwing saltbush. Therefore, ecotype selection should improve potential for revegetating arid and semiarid rangelands.

Fourwing saltbush germinates best at low temperatures (13 to 24°C). Light is not required unless seeds are less than 4 months old or under alternating temperature regimes (Springfield 1970). Fourwing saltbush emergence was adversely affected by high (53°C) compared to low (39°C) temperature regimes (Sosebee and Herbel 1969). Buffered pH in the range 3.0 to 8.0 did not affect germination of 6 Australian saltbush species (Beadle 1952). However, saltbushes are seldom found growing in acidic soils (Foiles 1974). Dewinging fourwing saltbush seed in a hammer mill hastens germination and is a standard practice. The bracts contain about 10% saponin, a germination inhibitor (Nord and Van Atta 1960).

Tolerance of fourwing saltbush seed to low media osmotic potential during germination may be genetically controlled. Springfield (1966) reported fourwing saltbush seed germinated at –1.50 MPa of manitol-induced moisture stress, but total germination and germination rate decreased with increasing moisture stress. However, seeds of 3 of 6 seed accessions exhibited greater total germination at –0.30 MPa than at –0.03 MPa, and total germination of 2 accessions was greater at –0.70 MPa than at –0.03 MPa. Springfield concluded that additional research was needed to confirm whether germination of some fourwing saltbush strains was actually stimulated by low media osmotic potentials.

Fourwing saltbush seed tolerated greater levels of moisture stress during germination at 17°C than at higher or lower temperatures (Springfield 1966). This suggests that moisture stress may be less limiting to germination when temperatures are near optimum. Field germination of seeds can be better understood if the interactive effects of seedbed parameters are known (Kaufman and Ross 1970, Sharma 1976). Objectives of this study were to (1) evaluate the interaction of temperature, osmotic potential, and pH on germination of fourwing saltbush seeds, and (2) determine whether germination characteristics varied among naturally occurring populations of the species in western Texas.

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[1]McFarland, M.L. 1984. Revegetation of oilwell reserve pits in west Texas. MS Thesis, Texas A&M University, College Station.

Methods and Materials

Seed from about 100 native fourwing saltbush plants were hand-harvested in December 1981 at each of 4 sites in the western Edwards Plateau and Trans-Pecos resource areas of Texas, including: 1 km west of San Angelo (Tom Green County); Texon (Reagan County); 10 km south of Grandfalls (Pecos County); and 5 km northwest of Valentine (Jeff Davis County) (Table 1). Fourwing saltbush occurred on loam and clay loam soils of the Tulia and Angelo series (Calciorthidic Paleustalfs and Torrertic Calciustolls) at the San Angelo site (Wiedenfeld and Flores 1976), on Reagan silty clay loam soils (Ustollic Calciorthids) at the Texon site (SCS staff, personal communication), on Reakor silty clay loam soils (Typic Calciorthids) at the Grandfalls site (Rives 1980), and on Verhalen and Dalby clay soils (Mollic and Typic Torrerts) at the Valentine site (Turner 1977).

Table 1. Collection sites of fourwing saltbush seeds used in evaluation of the interaction of temperature, osmotic potential and pH upon germination.

Location	°N Lat	°W Long	Elevation (m)	Avg annual precipitation (cm)
San Angelo	31°30′	100°25′	564	48
Texon	31°15′	101°40′	792	38
Grandfalls	31°15′	103°00′	792	30
Valentine	30°35′	104°40′	1433	28

Soils at all sites except Texon were nonsaline, but characterized by some degree of disturbance. The Texon site was at the edge of an oilfield characterized by heavily eroded, barren soil and a shallow, saline water table with electrical conductivities of 100 to 200 dSm^{-1}. Fourwing saltbush seeds were collected from plants growing on the edge of this saline area. All seeds were oven-dried at 49°C for 24 hr, then dewinged in a modified hammer mill. Soil surface temperatures frequently exceed 49°C during summer in western Texas, thus we feel that there was no biologically significant effect caused by oven drying the seeds. The seeds were stored at room temperature in paper sacks until July 1982 when germination studies were initiated.

Germination trials were conducted in a factorial design with 3 replications. Constant temperature regimes were 12, 17, and 22°C. Polyethylene glycol (PEG) 6,000 was used to simulate low (-0.3 to -0.4 MPa), moderate (-0.6 to -0.8 MPa), and high (-1.3 to -2.2 MPa) osmotic potentials using the empirical formula and gravimetric procedures developed by Michel and Kaufmann (1973). Approximate concentrations (kg PEG/kg water) of PEG needed to achieve desired osmotic potentials at each temperature were calculated from the empirical formula. Exact concentrations of PEG were determined by drying 20 ml of buffered solution in a vacuum oven. Exact PEG concentrations were entered into the empirical formula to provide approximate values for media osmotic potentials. A 0 MPa treatment (distilled water plus buffer) was included in all experiments. Buffered pH levels were 6, 7, 8, and 9. Sorensen's phosphate buffers were used at pH 6 and 7 and tris(hydroxymethyl)aminomethane buffers were used at pH 8 and 9 (Henry 1979). Buffer solutions were added at 40 ml per liter of germination media. These buffers cause slightly lower osmotic potentials than those estimated from gravimetric determinations of PEG concentrations. Effects of the buffers on osmotic potentials were not determined.

A replication consisted of 50 seeds placed on 2 layers of filter paper in a petri dish and subjected to each combination of temperature, osmotic potential, and pH. Eight ml of the appropriate germination media was added to each dish. The dishes were randomly placed on several layers of blotter paper in covered glass boxes. The blotter paper was kept saturated with distilled water throughout the 4-week trials. This procedure minimizes changes in media osmotic potentials through time (Berkat and Briske 1982). Seeds were germinated in controlled environment chambers in darkness but were exposed to light when germination was evaluated weekly. Seeds were considered germinated when the length of the radicle exceeded the length of the seed (3.5 to 7.0 mm). Surplus PEG solutions were placed in bottles and stored with the seeds throughout the trials. The change in pH of the PEG solutions averaged ±0.1 units at the end of the 4-week trials. The experiment was repeated in 2 controlled environment chambers (Puffer-Hubbard Model GL-10CT, Grand Haven, Mich., and Sherer Environmental Model RI-25LTP, Asheville, N. Carolina) and the data pooled for statistical analysis.

Germination was modeled by quadratic response surfaces or regression analysis (Evans et al. 1982). Quadratic response surfaces based on osmotic potential by pH were estimated for each fourwing saltbush population, temperature, and week on cumulative germination transformed by $\sin^{-1}\sqrt{p}$, where p = proportion of seeds germinated. Regression analysis was used to model germination responses where appropriate. All tests for significant main effects and interactions were at the $P \leq .01$ probability level.

Results and Discussion

Effect of pH in the quadratic response surfaces based on osmotic potential by pH treatments was significant only within the Texon fourwing saltbush seeds at 22°C. Linear and quadratic effects of osmotic potential and pH were generally significant each week for the Texon seeds at 22°C. Since varying pH did not affect germination of the Texon seeds at 12 or 17°C, quadratic regression equations based on osmotic potential within temperatures were used to model weekly germination responses. Data were pooled over pH levels for the Valentine, Grandfalls, and San Angelo populations and quadratic response surfaces based on osmotic potential by temperature were used to model weekly germination responses.

Germination of seed from the Texon population at 22°C increased toward extremes in pH. Critical values were pH 7.6 to 7.7 and -0.3 to -0.4 MPa for each week. Total germination (week 4) was 22% in the saddlepoint at pH 7.7 and -0.4 MPa, and increased to 30 and 27% at pH 6 and 9, respectively.

Rapid germination is important for successful establishment of range seedings (Jordan 1983). The most rapid germination (week 1) at 12°C occurred at 0 MPa for the Texon seeds (Table 2). Greatest predicted germination of the Texon seeds after 1 week (27%) occurred at 17°C and -0.4 MPa. Discrete sets of temperature and media osmotic potentials produced maximum germination of seeds from the Valentine, Grandfalls, and San Angelo populations. Linear effects of temperature and quadratic effects of temperature and osmotic potential were statistically significant for each week. Linear effects of osmotic potential were present during weeks 3 and 4 in the Valentine population, week 2 in the Grandfalls population, and weeks 1 and 2 in the San Angelo population. More seeds from these populations germinated at 0 MPa than at lower osmotic potential during the first 2 weeks (Table 3).

Germination of the Texon seeds was significantly greater at media osmotic potentials less than 0 MPa than at 0 MPa for weeks 2, 3, and 4 at 12°C and each week at 17°C (Table 2). Maximum germination at 17°C occurred at -0.6 to -0.8 MPa, but the greatest total germination occurred at 12°C and -0.4 MPa. However, Texon seed germinated at considerably lower osmotic potentials at 17°C than at 12°C. Maximum germination after 4 weeks occurred at -0.1 MPa for the Grandfalls and San Angelo populations, compared to -0.3 MPa for the Valentine seeds (Table 3). Maximum germination after 1 week occurred at higher temperatures (16.7 to 17.9°C) than maximum germination after 2 weeks (15.1 to 16.4°C). Predicted optimum temperatures for maximum germination after 3 or 4 weeks were about 15 to 16°C for these 3 populations.

Wildland species can vary greatly in germination characteristics,

Table 2. Predicted germination (%) of fourwing saltbush seeds collected from a saline area near Texon, Texas at 12 and 17° C constant temperatures and selected media osmotic potentials (MPa).[1]

Temperature	Week	Osmotic Potential (MPa) 0.0	-0.2	-0.4	-0.6	-0.8	-1.4	-1.8	SEE[2]
(°C)		(Germination %)							
12	1	17	15	13	10	6	0	0	1
	2	24	33	36	34	27	0	0	1
	3	26	34	37	37	32	3	0	1
	4	27	34	38	37	33	6	0	1
17	1	24	26	27	26	24	13	4	1
	2	26	30	33	34	33	21	8	1
	3	27	31	34	35	34	24	11	1
	4	27	31	34	35	35	25	13	1

[1]Germination values estimated from quadratic regression equations based on media osmotic potential.
[2]SEE = Standard error of the estimate.

Table 3. Predicted optimum germination (%) of fourwing saltbush seeds collected near Valentine, Grandfalls, and San Angelo, Texas and associated critical values of media osmotic potential (MPa) and temperature (° C) for each week of a 4-week trial.[1]

Population	Week	Critical values: Osmotic potential (MPa)	Temperature (°C)	Predicted optimum response (% germination)
Valentine	1	0.0	17.9	37
	2	0.0	16.4	44
	3	-0.2	16.2	45
	4	-0.3	16.0	46
Grandfalls	1	0.0	17.3	23
	2	0.0	15.3	31
	3	0.0	15.5	31
	4	-0.1	15.5	31
San Angelo	1	0.0	16.7	33
	2	0.0	15.1	45
	3	0.0	15.2	45
	4	-0.1	15.2	45

[1]Germination and critical values estimated from quadratic response surfaces based on media osmotic potential by temperature. Critical values, in these cases, where those at which germination responses were maximum. The significant effect of media pH on germination of seed of the Texon ecotype prohibited estimation of a response surface based on these factors for this ecotype.

even within populations (Westoby 1981). Fourwing saltbush and other woody chenopods have the ability to evolve new ecotypes adapted to harsh site conditions (Stutz 1983). Adaptation to a saline environment may explain the unique germination characteristics of seed from the Texon ecotype in relation to pH and osmotic potential of the germination medium. However, the increased germination of seeds from the Texon ecotype at lower media osmotic potentials compared to the other 3 ecotypes might have been caused by the environment in which these seeds matured. Seeds that developed on plants growing on the saline soils at Texon may have taken up more salts (osmoticum) which allowed them to germinate at lower osmotic potentials.

A significant interaction between temperature and osmotic potential occurred with the Valentine population during the third and fourth weeks, whereas this interaction was generally absent from the Grandfalls and San Angelo populations. The interaction indicates that the nonadditivity for total germination occurs at lower (more negative) osmotic potentials and higher temperatures (Fig. 1).

A temperature by osmotic potential interaction exists for some species but not for all (Kaufmann and Ross 1970, Sharma 1976). Results of this study suggest that this interaction exists in some ecotypes of fourwing saltbush but not others. This interaction implies that when seeds are subjected to high temperatures (e.g., summer) the effect of limited moisture is more inhibitory to germination than when temperatures are near or below optimum (e.g., spring or fall), whereas if moisture is not limited, these seeds germinate well over a broader range of temperatures. Fourwing saltbush from the Valentine population apparently has undergone selection resulting in plants that produce seed that do not germinate at high temperatures and low soil moisture contents. Conversely, the absence of this interaction from the San Angelo and Grandfalls populations suggests high and low temperatures inhibit germination equally as soil water contents vary.

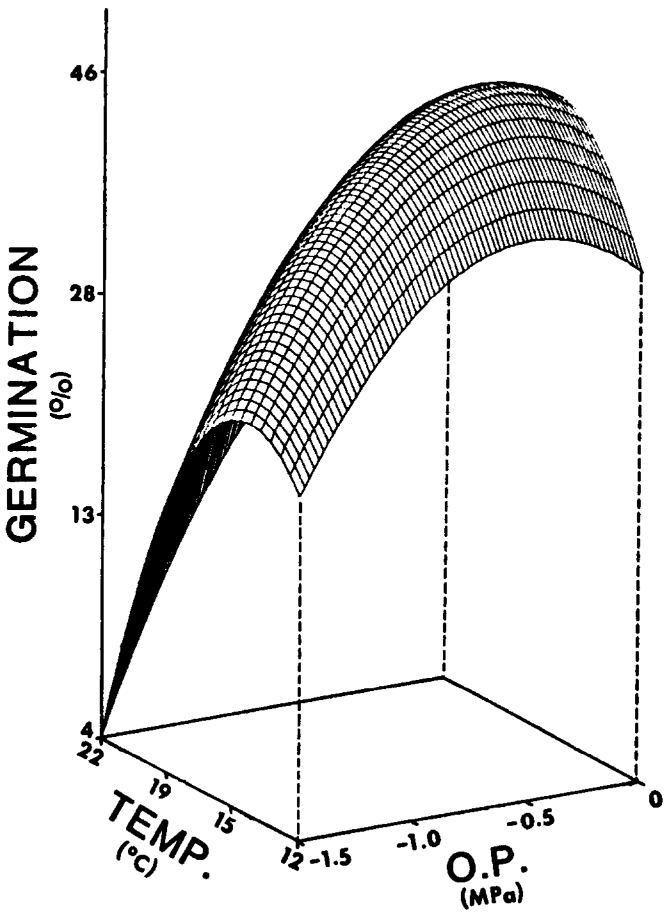

Fig. 1. *Illustration of the significant (P≤0.01) interaction between temperature (TEMP) and media osmotic potential (O.P.) for total germination of fourwing saltbush seeds collected from plants growing in a high elevation, desert grassland near Valentine, Texas. Maximum germination after 4 weeks occurred at 16.0° C and -0.3 MPa. Data generated from a quadratic equation were used for plotting by SAS/GRAPH.*

Conclusions

Interactive effects of seedbed parameters upon germination varied considerably among ecotypes of fourwing saltbush. Optimum temperatures for germination varied among the populations, but were generally 15 to 18°C, which agrees with studies on other saltbush populations (Springfield 1966, 1970). The relative tolerance of the 4 populations of fourwing saltbush to moisture stress during germination was Texon > Valentine > Grandfalls = San Angelo. The effect of pH was relatively minor though it cannot be ignored as a factor affecting germination of seeds from the Texon population at 22°C.

Low media osmotic potential was less detrimental to germination at optimum germination temperature than at higher or lower temperatures. Increasing moisture stress delayed germination of 3 populations similar to the findings of Springfield (1966) and Sharma (1976). Total germination of seeds from the Texon site was significantly greater at osmotic potentials of −0.4 to −0.8 MPa than at 0 MPa, which suggests results observed by Springfield (1966) were not attributable simply to random variation. This result suggests seed from the Texon population might have more potential for arid land seedings compared to seed of the other populations.

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