Desert Saltgrass Seed Germination and Seedbed Ecology

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Abstract

Desert saltgrass [*Distichlis spicata* var. *stricta* (Torr.) Beetle] is an important forage species of the saline-alkali basins of the western United States. Revegetation of disturbed sites using saltgrass currently involves the use of rhizomes, but seeding saltgrass with conventional equipment would be much more efficient. The seed and seedbed ecology of desert saltgrass is important to land managers who wish to try new revegetation techniques. The germination of nine collections of saltgrass seed was determined at a wide range of constant and alternating temperatures. The effects of decreasing osmotic potentials on seed germination of one collection was determined using polyethylene glycol and sodium chloride solutions. Seedbed temperatures and moisture potentials were determined during the growing season in two saltgrass stands using thermocouple temperature probes and psychrometers. The temperature regime that produced the highest mean germination (58%) for all nine collections was 10° C for 16 hours alternating with 40° C for 8 hours (10/40° C). Germination response varied significantly (P=0.01) between collections. The best germination was 96% with one collection at the 10/50° C regime, but most collections germinated best with the 10/40° C regime. For all collections, at least a 20° C diurnal fluctuation in temperature was needed for germination above 10%. Seeds did not germinate at temperatures as cold as -5° C or as hot as 60° C. Saltgrass germination was enhanced at osmotic potentials of -1 bar, but inhibited by potentials lower than -1 bar. No significant (P=0.01) germination occurred at -15 bars. Field seedbed temperatures reached optimum levels for germination after moisture potentials were below that required for germination. This suggests that saltgrass seed germination is an episodic event in nature, occurring only when moisture events coincide with optimum seedbed temperatures and can leach sufficient salts to raise moisture potentials above -15 bars.

Desert saltgrass [*Distichlis spicata* var. *stricta* (Torr.) Beetle] is an important forage species that can grow vigorously on wet, saline soils where most others will not survive (Nielson 1956). In many of the salt marsh areas of the interior United States, saltgrass provides the sole forage for cattle during the summer portion of the grazing season. Saltgrass is relatively high in protein (Hansen et al. 1976) and highly resistant to excessive grazing. Desert saltgrass is a potential species for revegetating mine spoils and roadsides in the semiarid west (Pavlicek et al. 1977).

Large, isolated areas of saltgrass occur in many places throughout the western United States, but seed is produced in very few of these areas. This may be because saltgrass is dioecious and mainly reproduces vegetatively through spreading rhizomes. Saltgrass produces seed only where the stands are most dense and vigorous. Consequently, revegetation using saltgrass has entailed the use of rhizomes (Pavlicek et al. 1977). However, seed sources do exist and since revegetation using rhizomes is expensive and labor intensive, seeding desert saltgrass with readily available equipment would be much more efficient than planting rhizomes.

In order for land managers to use saltgrass optimumly for revegetation of rangelands or disturbed sites, it is necessary to understand the seed and seedbed ecology of this species. Important to the ecology of this species are its seed germination characteristics.

Neilson (1956) reported that scarification of saltgrass seeds with sandpaper enhanced germination, but under natural conditions germination of saltgrass seeds is very poor. Nielson's work and our own preliminary investigations on saltgrass seed germination have shown that simple afterripening, cold stratification, and treatment with sulfuric acid, sodium hydroxide, potassium nitrate, sodium chloride, red light, hot water, or hydrogen peroxide does not greatly increase saltgrass seed germination.

The purpose of this study was to determine the moisture and temperature conditions under which saltgrass seed would germinate and the variability in germination characteristics of different collections of saltgrass seed and to relate these data to field measurements of soil moisture potentials and temperature.

Methods

Nine collections of saltgrass seed were obtained in the fall months of 1978, 1979, or 1980 from eight different locations throughout the western United States (Table 1). Pistulate seedheads were hand collected as soon as possible after seeds were ripe and the seeds (caryopses) were cleaned using an air screen and stored in the laboratory at room temperature until tested. The seeds were tested within 6 months of collection.

Germination tests were conducted using methods described by Young and Evans (1979). Seeds were placed on a single thickness of germination paper in petri dishes and kept moist with tap water. Tests were done in dark germinators. The seeds were incubated for 4 weeks, and germination counts were made after 1, 2, and 4 weeks. Seeds were considered germinated when the radicle had emerged 2 mm. Constant germination temperatures were 0, 10, 20, 30, 40, 50, and 60° C. Alternating temperature regimes consisted of 16 hours at each constant temperature and 8 hours at one of each possible higher temperature in each 24-hour period. For example, 0° C alternated with 10, 20, 30, 40, 50, and 60° C, but 50° C with 60° C only. In all, 28 constant and alternating temperature regimes were tested. Seeds of collection 1 (Little Cottonwood Lake, NV, 1978) were also incubated at -5, -2, 2, and 5° C and with each alternating higher temperatures to 60° C. The -2 and -5° C temperatures were produced with a low temperature gradient bar developed by Evans et al. (1970). All experiments included four replications of 25 seeds each.

The effects of reduced osmotic potentials on the germination of desert saltgrass from collection 1 were evaluated using solutions of polyethylene glycol with a molecular weight of 6000 (PEG 6000) and sodium chloride (NaCl). PEG 6000 and NaCl solutions were compared as osmotic adjusting agents because Tiku (1976) showed that desert saltgrass plants are better adapted to osmotic potentials

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This study is a contribution from USDA, Agricultural Research Service, and the Agriculture Experiment Station, University of Nevada, Reno. Journal Series No. 535.
Manuscript received September 22, 1981.

Table 1. Germination of collections of saltgrass seed. Means for 28 constant and alternating temperature regimes.[1]

Collection	Date collected	Location of seed source	Germination	Germinability[2] quotient
1	8/78	39° 36′ N., 118° 36′30″ W.Little Cottonwood Lake, NV	18.8a	1a
1B	8/80	30° 36′ N., 118° 26′30″ W. Little Cottonwood Lake, NV	16.9a	.95a
2	9/79	39° 36′ N., 118° 29′ W., South Lead Lake, NV.	10.6b	.59b
8	10/80	43° 20′ N., 119° W., Burns, OR.	8.7bc	.38bc
7	8/80	41° 20′ N., 112° 20′W. Ogden Bay, UT.	8.3c	.47bc
5	8/80	39° 37′ N., 118° 29′W. Peers Landing, NV.	5.4c	.29c
6	9/80	44°, 116° 30′ W. N. Gem County, ID.	4.6d	.27c
3	10/79	39° 35′ N., 118° 33′W. Dutch Bill Lake, NV.	4.5d	.26c
4	8/80	36° 40′ N., 118° 12′ W. Lone Pine, CA.	3.8d	.24c

[1]Means followed by the same letter are not significantly different at the 0.01 level of probability as determined by Duncan's multiple range test.

[2] $g = \frac{(AG \times \overline{AG}) + (OG \times \overline{OG})}{Q}$ Where: g = germinability quotient, AG = % regimes producing any germination, $\overline{AG}$ = mean % germination of regimes producing any germination, OG = % of regimes producing optimum germination, $\overline{OG}$ = Mean % of germination of regimes producing optimum germination, Q = highest value of the numerator calculated for any collection.

lowered by salts than by long chain macro-molecules like polyethylene glycol. We thought that desert saltgrass seed germination might follow the same pattern. The seed germination was tested at 0, -1, -5, -10, -15, and -20 bars of osmotic potential. The seeds were incubated at an optimum temperature regime of 10° C for 16 hours and 40° C for 8 hours in each 24 hour period in petri dishes sealed with wax laboratory film to prevent moisture loss. There were 25 seeds in each petri dish and four replications per treatment. Because osmotic potential is influenced by temperature, the sodium chloride and polyethylene glycol solutions were adjusted so that the osmotic potential being tested was the weighted average of the cold- and warm-temperature potentials. This fluctuating osmotic potential regime reflected natural seedbed conditions more realistically than a nonfluctuating osmotic regime.

The laboratory temperature regimes were compared with actual seedbed temperatures measured in saltgrass stands using thermocouple temperature probes. Temperature measurements were taken hourly at the soil surface and 5 cm below the soil surface at three locations in two separate saltgrass stands from April through September of 1980. One stand is located at the Gund Research and Demonstrations Ranch in a high (1875 m), desert valley in central Nevada. This area is a dry, salt-affected meadow typified by hot days, cold nights, and highly variable precipitation during the growing season. The second stand is located at Fallon, Nevada in a salt-marsh of lower elevation (1100 m). This area is typified by hot days, mild nights, and little or no precipitation during the growing season. To determine the soil moisture potential, thermocouple psychrometers were buried at 10, 20, and 40 cm in each plot in both saltgrass stands and read at approximately 2-week intervals throughout the 1980 growing season. Electrical conductivity (EC) of the saturation extract was measured at the soil surface and at 5 cm below the soil surface in both saltgrass stands in early and late spring of 1980 to determine the relative salt concentrations.

Table 2. Germination at constant and alternating temperatures of desert saltgrass seeds. Means for all collections.[1]

Cool period °C-16 hr	Germination — Warm period °C - 8 hr: 0	10	20	30	40	50	60
				%			
0	0	0	0	13e	39b	10e	0
10		0	0	11e	58a	24c	0
20			0	2g	37b	26c	0
30				0	4fg	19d	0
40					2gh	7f	0
50						0	0
60							0

[1]Means followed by the same letter are not significantly different at the 0.01 level of probability as determined by Duncan's multiple range test.

A series of germination characteristics were statistically generated for each of the nine collections of saltgrass seed. These characteristics were: percentage of regimes producing any germination, mean percent germination of regimes producing any germination, percentage of regimes producing optimum germination, and the mean percent germination of the regimes producing optimum germination. Optimum germination was defined as that not significantly lower (P=0.01) than the maximum germination. Any germination was defined as that with an average of 1% or higher. A relative germinability quotient was generated for each collection using the following equation:

$$g = \frac{(AG \times \overline{AG}) + (OG \times \overline{OG})}{Q}$$

where g = relative germinability, AG = % of regimes producing any germination, $\overline{AG}$ = mean percent germination of regimes producing any germination, OG = % of regimes producing optimum germination, $\overline{OG}$ = mean percent germination of regimes producing optimum germination and Q = the highest germination value for any collection calculated by the numerator portion of the equation. We developed this equation to account for the range of temperatures at which a collection of seed would germinate coupled with the best germination at certain temperature regimes. Collections were compared only when tested with the same temperature regimes. Values for g rank the collections from 1.0 decreasing toward 0 based on their germination characteristics.

Results

Germination Trials

Mean germination of seeds at all 28 constant and alternating temperature regimes varied greatly with the seed collection (Table 1). Collections 1 and 1B had the highest mean germination with 19 and 17%, respectively. Similarities between collections 1 and 1B were expected since the seeds were collected from the same location in successive years. Collections 3, 4, 5, and 6 all had mean germination near or below 5% and collections 2, 7, and 8 ranged from 8 to 11%.

Seeds of collection 1 were the most germinable when compared with the other collections using the germinability quotient (Table 1). The germinability quotient for seeds of collection 4 was the lowest of all collections at 0.24, meaning that seeds of that collection were only a fourth as germinable as seeds of collection 1. Seeds of collection 3 and 5 were only slightly more germinable with germinability quotients of 0.28 and 0.29, respectively. Collection 1B had the second highest germinability quotient at 0.95 which again was expected since it was a second year collection from location 1.

Highest mean germination for a particular temperature regime (58%) occurred at the 10/40° C (10° C for 16 hours and 40° C for 8 hours daily) temperature regime (Table 2). For all collections, a diurnal temperature fluctuation of at least 20° C was needed for

Table 3. Maximum germination and temperature regime for each collection of saltgrass seeds.

Collection	Temperature Regime (Cold period 16 hr/Warm period 8 hr)	Germination[1]
	-°C	-%-
1	10/40	85 ab
1B	10/50	94 a
2	10/40	86 ab
3	10/40	44 de
4	10/40	35 e
5	0/40	79 bc
6	0/40	52 d
7	10/40	72 c
8	20/50	64 c

[1]Means followed by the same letter are not significantly different at the 0.01 level of probability as determined by Duncan's multiple range test.

greater than 10% germination, with the warm period temperature between 20 and 60° C and the cold period temperature being from below 0 to 40° C.

There was considerable variability in the highest germination responses of the seed collections at a particular temperature regime (Table 3). Maximum germination (94%) was with collection 1B at the 10/50° C regime, although the 10/40° C regime resulted in the highest average germination of all collections as previously noted. Collection 5 germinated significantly (P=0.01) better than the average of the collections at 0/40° C with 79% germination, and collection 8 had its highest germination at 20/50° C with 64%. Many of the collections would not germinate at all if the warm period temperature reached 50° C while other collections, such as collection 8, germinated best when the warm period temperature was 50° C.

Testing of seeds of collection 1 at low temperatures showed no germination at -5° C but some germination at -2/30° C and -2/40° C (Table 4). The 0/30° C regime resulted in significantly better (P=0.01) germination than the 5/30° C regime, indicating that freezing temperatures were not as inhibitory to saltgrass seed germination as was the lack of a 30° C diurnal temperature differential. The regime producing the highest germination was 5/40° C, indicating that this regime may be better for saltgrass seed germination than 10/40° C regime used for testing all the other collections.

Osmotic Trials

No significant differences (P=0.01) were found between the effects of the osmotic potential produced by NaCl and PEG 6000 solutions on saltgrass germination (Table 5). Percentage germination decreased significantly (P=0.01) with decreasing osmotic potentials below -5 bars with both PEG 6000 and NaCl. Germination was significantly (P=0.01) increased at -1 bar of osmotic potential (63%) compared with the control (46%) and germination was near zero at -15 bars with both solutions.

Table 5. Germination of desert saltgrass seeds of collection 1 at 10/40° C with reduced osmotic potentials created with polyethylene glycol or NaCl.[1]

Osmotic potential	Germination: Polyethylene glycol	NaCl
-bars-	-%-	-%-
0	46 b	46 b
-1	58 a	68 a
-5	26 c	29 c
-10	13 d	6 de
-15	0 e	1 de
-20	0 e	0 e

[1]Means followed by the same letter are not significantly different at the 0.01 level of probability as determined by Duncan's multiple range test.

The EC of the saturated paste extract of soils from the Gund Ranch and Fallon saltgrass stands averaged 80 and 150 mmhos/cm on the surface and 40 and 60 mmhos/cm 5 cm below the surface, respectively. Although saltgrass plants grow in soils with very low osmotic potentials and very high salt concentrations, saltgrass seeds cannot germinate in such soils. This is in accordance with Ungar (1978) who cites a long series of studies demonstrating that seeds of many halophytic species germinate best under fresh water conditions. This also substantiates the theory of Hanson et al. (1976) that saltgrass rhizomes are important in the colonization of saline playa soils because they extend from areas that are favorable for growth to aeas that are less favorable. Germination may take place on less saline sites with subsequent colonization of saline areas by spreading rhizomes.

Seedbed Temperatures and Moisture Potentials

Seedbed temperatures measured in the two saltgrass stands indicated that there were large diurnal fluctuations in temperature throughout the growing season (Fig. 1). The soil surface temperatures fluctuated at least 20° C diurnally almost every day during the growing season in both stands. Temperatures consistently reached the mean optimum of 10/40° C for germination of these collections of seed around June 20th in both saltgrass stands. The soil moisture potential of both saltgrass stands was below -15 bars by this date at 10 cm below the surface and visibly drier at the surface. In the Gund Ranch stand, this probably resulted from both a low osmotic potential and a low matric potential. In the Fallon stand, This resulted from a low osmotic potential since, even when the soils were saturated, the total water potential as measured by psychrometers was below -15 bars. These data suggest that optimum temperatures for saltgrass seed germination occur in the field when moisture for germination is unavailable and that, if the soil is

Table 4. Germination of saltgrass seeds of collection 1 at constant and alternating temperatures.[1]

Cool period °C-16 hr	Germination, Warm period °C - 8 hr: -5	-2	0	2	5	10	20	30	40	50	60
						—%—					
-5	0	0	0	0	0	0	0	0	0	0	0
-2		0	0	0	0	0	0	8ef	14ef	0	0
0			0	0	0	0	0	82ab	73bc	0	0
2				0	0	0	0	63c	71bc	0	0
5					0	0	0	63c	92a	0	0
10						0	0	40d	71bc	4ef	0
20							0	1f	34d	35d	0
30								1f	4ef	0	0
40									2f	17e	0
50										0	0
60											0

[1]Means followed by the same letter are not significantly different at the 0.01 level of probability as determined by Duncan's multiple range test.

highly salt affected, moisture may seldom be available even under saturated soil conditions.

Discussion

Considerable variability was found among collections of saltgrass seed in germination responses to different temperature regimes. However, there was not any obvious relationship between optimum temperatures for germination and the environment where the seed was collected. There still may be inherent differences controlling germination response to seedbed temperatures. Plant selection and progeny testing would have to be done in order to determine the heritability of the germination traits.

Of particular importance to saltgrass seedling survival may be the ability to germinate at lower temperatures such as -5/20° C, -2/20° C, and 0/20° C. Unfortunately, most of the variability among collections was in germination response to moderate, not low, temperature regimes. Not one seed germinated if the warm period temperatures was 20° C or lower, or the cold period temperatures as low as -5° C. Average maximum temperatures of the seedbed were not above 20° C until April at either the Gund Ranch or Fallon saltgrass plots. Average minimum temperatures were not above -5° C until mid-May at the Gund Ranch. The probability of receiving substantial rain (1 cm or more) in any given week at Fallon or the Gund Ranch decreases dramatically after May (Gifford et al. 1967), so April and May are critical months for seed germination. Optimum temperatures for germination (10/40° C) are not reached until late June at Fallon and July at the Gund Ranch, long after predictable rainfall. Since saltgrass stands are established in these areas, it is obvious that there are periods when there is enough rain in April and May to raise soil moisture potentials above -10 bars either by leaching of salts, soil wetting, or both. An episodic pattern of establishment of desert plants has been suggested by Went (1955) and discussed by West et al. (1979). Saltgrass establishment from seed may follow this pattern by germinating only rarely, when favorable moisture events coincide with optimum seedbed temperatures for germination.

Why do desert saltgrass seeds have relatively high optimum germination temperatures that rarely coincide with adequate moisture for germination? It may be that saltgrass seedlings have not developed mechanisms for survival at low temperatures. Also, the competitive advantages of cool season grasses such as downy brome (*Bromus tectorum* L.) and crested wheatgrass [*Agropyron desertorum* (Fisch.) Schult.] has been ascribed to the ability of the seedlings to grow deep root systems during the cold, wet, early spring that can follow depleting soil moisture later in the season (Harris and Wilson 1979). We have never observed saltgrass plants with root systems extending below 40 cm in either of the saltgrass stands in this study. It would seem that there would not be any adaptive advantage in germinating during cold weather since, even if the seedlings survived, the shallow root system would not be able to follow receding soil moisture. However, there would be an advantage to early germination if it allowed seedlings to develop in soils which were temporarily leached of high salt concentrations by normal winter precipitation. We have found (unpublished data, Agric. Research Service, U.S. Dept. of Agriculture, Reno, NV) that seedling survival of one collection of saltgrass seed decreased linearly with increasing soil salinity such that no seedlings survived in a saline soil from the stand where the seed was harvested, yet 95% of the seedlings survived in a non-saline soil. Possibly, the advantage of germinating early when the soil would most probably be leached of salts is offset by the inability of saltgrass seedlings to survive cold temperatures. Thus, desert saltgrass is relegated to playa edges and meadows with a shallow water supply where a competitive advantage is derived from the ability of the mature plants to thrive in saline, poorly aerated, inundated soils (Hansen et al. 1976).

In relating the results of this study to land reclamation using saltgrass, three conclusions may be drawn. The first is that saltgrass seed will not germinate under normal greenhouse temperature regimes. This is important to land managers who wish to raise large numbers of saltgrass plants for reclamation purposes and to plant breeders who wish to improve those plants. Second, unless the land to be reclaimed is located in an area of predictable summer precipitation, irrigation will be needed for seed germination. Finally, if irrigation is needed, water should be applied when the seedbed temperature reaches 40° C during the day and 5° C to 10° C at night.

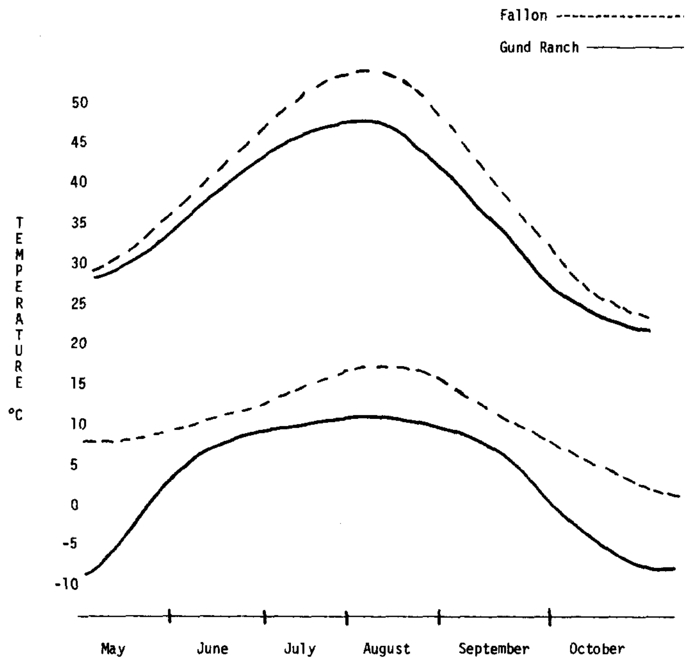

Fig. 1. *Seedbed surface maximum and minimum temperatures in 2 saltgrass stands during the growing season. Temperatures are means from 3 locations in each stand.*

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