Amer. J. Bot. 73(8): 1163–1167. 1986.

FACTORS INFLUENCING SEED GERMINATION IN SALICORNIA PACIFICA VAR. UTAHENSIS[1]

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ABSTRACT

The halophyte, *Salicornia pacifica* var. *utahensis* (Tiderstorm) Munz produces seed under high salinity conditions, and deposits its seed on saline soil. Experiments were conducted to determine the effect of salinity, temperature and growth regulators on germination. Results indicate that the seeds can germinate at very high salt concentration (5% NaCl). Germination was sensitive to the changes in temperature regimes. At higher 30–20 C, light-dark sequence, no germination occurred at 3, 4 and 5% NaCl treatments. On the other hand, 30% germination did occur at 5% NaCl treatment at a temperature regime of 15–5 C. These seeds required light for germination. Only 50% germination occurred in the non-saline control in the dark and the addition of NaCl further reduced germination. The GA_3 partially alleviated the inhibitory effect of NaCl and darkness. Kinetin did not promote germination.

SALICORNIA PACIFICA VAR. *UTAHENSIS* (Tiderstorm) Munz (Chenopodiaceae) is a perennial halophyte that occurs in inland salt playas of central Utah (Hansen and Weber, 1975). *Salicornia pacifica* var. *utahensis* is the principal succession species in the high salt playas and can tolerate 5% salt in the soils (Ungar, 1974). The majority of the salt in the inland playas is NaCl (Hansen and Weber, 1975). The plant produces seed by fall and most of it falls onto the saline soil around the parent plant. The seeds are often dispersed by water upon which they readily float. There is little information available on the seed germination of perennial *Salicornia* ssp. particularly *S. pacifica* var. *utahensis.* Various studies have shown the differential effect of salinity and temperature on the germination of annual species of *Salicornia* (Langlois, 1966; Grouzis, Berger and Hein, 1976; Ungar, 1977; Philipupillai and Ungar, 1984). Ungar (1977) found that *Salicornia europaea* showed a maximum germination in distilled water at 25 C and a minimum level of germination in salt solutions at 10 C. Increased salinity inhibited germination at all temperatures. The growth regulator GA_3 stimulated germination at all temperatures but kinetin did not promote germination. Rivers and Weber (1971) indicated that in *Salicornia bigelovii* maximum germination occurred at sea salt concentrations except at 26.6 C. At 15.5 C, they obtained a relatively high germination percentage in solutions up to 8% NaCl. Langlois (1966) reported that three annual species, *Salicornia stricta, S. disarticulata* and *S. radicans,* had optimal germination percentages at low NaCl concentrations. The rate of germination depended on incubation temperature. Grouzis et al. (1976) reported that seeds of *Salicornia emerici, S. brachystachya,* and *S. patula* require cold stratification to germinate under saline conditions. Philipupillai and Ungar (1984) have shown that in the absence of cold pretreatment, change in day and night temperature did not have any effect on germination of *Salicornia europaea* seeds. However, when seeds were stratified the highest germination values were obtained at the 5–15 C temperature regime.

Our objective was to investigate effects of temperature, salinity, light exposure, and growth regulators on the germination characteristics of *Salicornia pacifica* var. *utahensis.*

MATERIALS AND METHODS—Seeds of *Salicornia pacifica* var. *utahensis* were collected from the salt playas at Goshen, Utah, during October 1984. Seeds were stored dry in small plastic containers in a refrigerator at 5 to 6 C. The seeds were surface sterilized with 10% clorox (0.52% sodium hypochlorite) for 1 min and then washed 2 to 3 times with distilled water. Germination was carried out in 50 × 9-mm Gelman No. 7242 tight-fitting plastic petri dishes with 5 ml of test solution. Each dish was placed in a 9-cm diam glass petri dish to reduce water loss. Four replicates of 25 seeds each were used for each treatment. Seeds were considered to be germinated with the emergence of the radicle.

[1] Received for publication 9 October 1985; revision accepted 4 February 1986.

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This reaearch was supported in part by a grant from the National Science Foundation No. 8403768.

TABLE 1. *Index of germination velocity (G/t) of* Salicornia pacifica *var.* utahensis *seed under various temperature and NaCl solutions (G = germination percentage at 1-day intervals; t = total germination period)*

NaCl (%)	Temperature C (day-night)			
	15–5	25–5	25–15	30–20
0	27.6	33.6	23.5	27.3
1	29.8	26.5	22.3	18.1
2	23.9	16.6	14.2	3.8
3	15.2	0.5	5.6	0
4	6.9	0.25	0.25	0

To determine the effect of temperature on germination, we used alternating regimes of 15–5, 25–5, 25–15 and 30–20 C based on a 24 hr cycle, with the higher temperature (15, 25, and 30 C) during 12 hr light period, and the lower temperature (5, 15, and 20 C) coincided with the 12 hr dark period. We studied the light requirement by comparing germination in petri dishes kept in the dark (covered in a box) with germination in petri dishes in light. Seeds were germinated in distilled water and of NaCl solution 1, 2, 3, 4, 5%. The GA_3 concentrations of 10^{-3} and 10^{-4} M and kinetin concentrations of 10^{-4} and 10^{-5} M were used with or without 1, 2, 3, 4, and 5% NaCl solutions at a temperature of 25–5 C. We recorded germination on alternate days for 20 days. An index of germination velocity was calculated according to Khan and Ungar (1984a) (Table 1).

RESULTS—*NaCl-temperature effects on germination*—Optimal germination of *S. pacifica* var. *utahensis* in 12/12 hr light/dark conditions occurred in distilled water at temperatures of 25–5 and 15–5 C (Fig. 1–2). Germination of *S. pacifica* var. *utahensis* seeds was

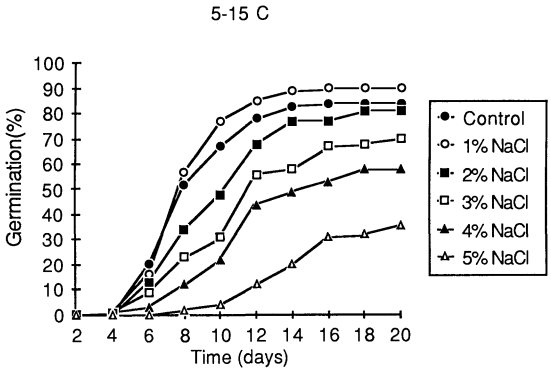

Fig. 2. Germination of seeds of *Salicornia pacifica* var. *utahensis* at the 15–5 C regime in 0 to 5% NaCl with a 12 hr light period.

delayed with an increase in NaCl. This delay was more obvious at 30–20 C (Fig. 4) with other temperature regimes. The final germination percentage was also progressively inhibited with the increase in salinity. Minimum inhibition of final germination occurred at 15–5 C temperature regime and maximum at 30–20 C. No seeds germinated at 3, 4 and 5% NaCl treatment.

The rates of germination in non-saline conditions were highest at the 25–5 C temperature regime (Table 1). The rate of germination decreased with increase in salinity stress at all temperature regimes. This decrease was more substantial at the warmer (30–20 C) temperature regime than at the cooler ones. The germinating seeds were more tolerant of NaCl stress at the 15–5 C temperature regime.

Germination of *S. pacifica* var. *utahensis* was adversely affected by darkness (Fig. 5). Only 50% of the seeds germinated at optimal temperatures in non-saline conditions compared

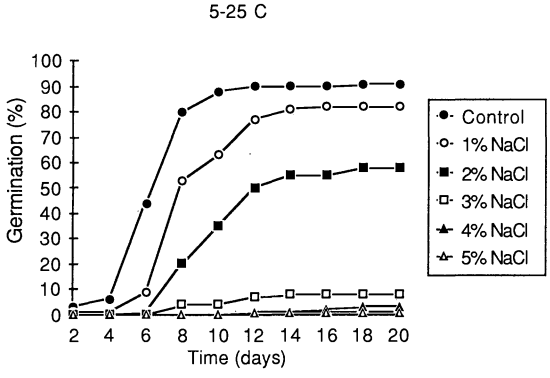

Fig. 1. Germination of seeds of *Salicornia pacifica* var. *utahensis* at the 25–5 C regime in 0 to 5% NaCl with a 12 hr light period.

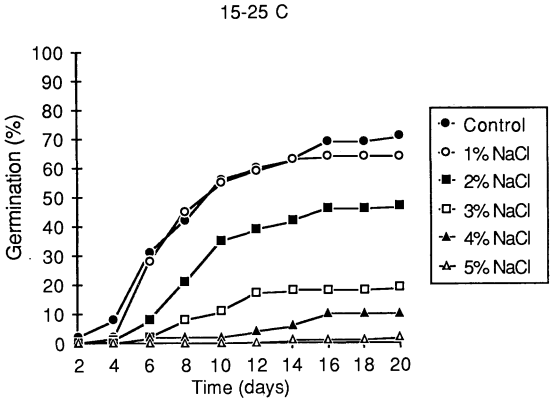

Fig. 3. Germination of seeds of *Salicornia pacifica* var. *utahensis* at the 25–15 C regime in 0 to 5% NaCl with a 12 hr light period.

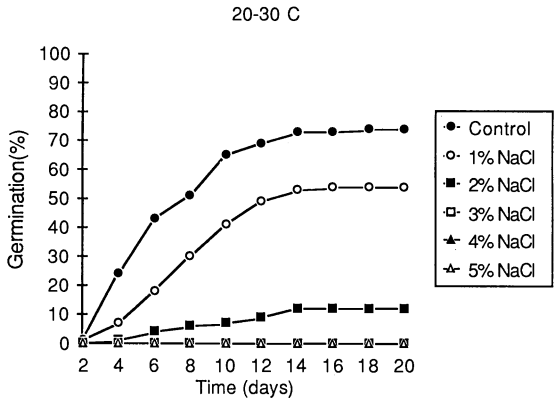

Fig. 4. Germination of seeds of *Salicornia pacifica* var. *utahensis* at the 30–20 C regime in 0 to 5% NaCl with a 12 hr light period.

to almost 100% in the light. No seeds germinated at 3, 4 and 5% NaCl treatments at any temperature regimes in darkness. Temperature regimes of 25–5 and 15–5 showed more germination than 25–15 and 30–20 C.

Salinity and growth regulator effects on germination—Treating the seeds with GA_3 increased the percentage of germination (Fig. 6). Germination in a 2% NaCl treatment increased from 55% in the control treatment to 75% in the GA_3 treated sample. The results presented in Fig. 6 are for 1×10^{-3} M GA_3 because 1×10^{-3} M GA_3 produced less effective results.

When GA_3 was applied to the seed germinated in dark at 25–5 C 12/12 hr light/dark period at salinity regimes of 1–5% NaCl, it significantly enhanced the germination at 0, 1, and 2% NaCl treatments (Fig. 8).

Kinetin solution alone did not stimulate germination of *S. pacifica* seeds at 25–5 C and did not overcome the inhibitory effect of NaCl

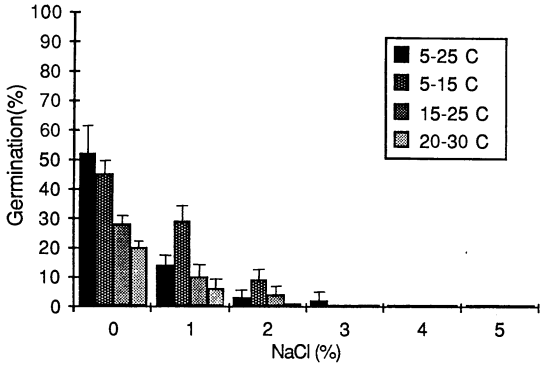

Fig. 5. Final germination (after 20 days) of *Salicornia pacifica* var. *utahensis* at the 25–5 C regime in 0 to 5% NaCl in the dark.

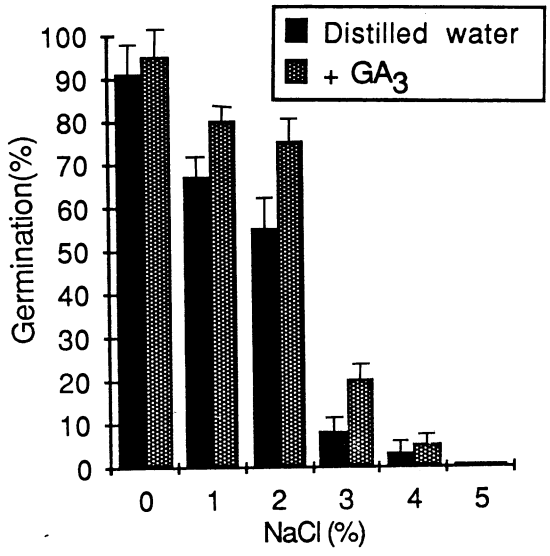

Fig. 6. Effect of GA_3 (1×10^{-3} M) on salinity-induced germination inhibition of *Salicornia pacifica* var. *utahensis* seeds at 25–5 C, 12/12 hr light/dark, for 20 days. The error bars represent the statistical variation in germination in the four replicates of 25 seeds each.

concentration (Fig. 7). Only at 3% NaCl was there a slight stimulation of germination percentage of seeds.

DISCUSSION—*S. pacifica* var. *utahensis* grows in the most saline region of an inland salt playa at Goshen, Utah, but germination of its seeds

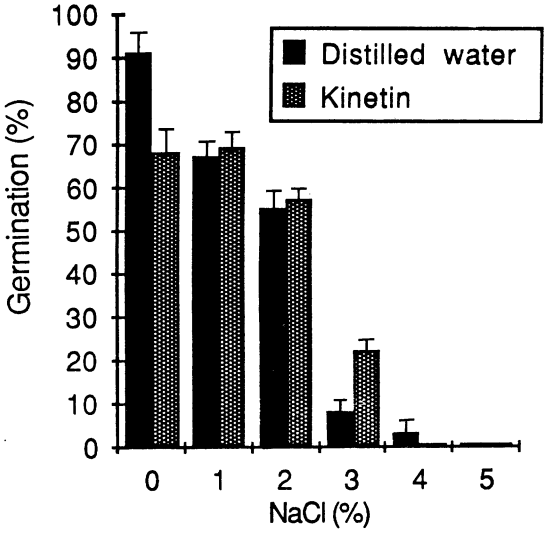

Fig. 7. Effect of kinetin (1×10^{-4}M) on salinity-induced germination inhibition of *Salicornia pacifica* var. *utahensis* seeds at 25–5 C, 12/12 hr light/dark, for 20 days. The error bars represent the statistical variation in germination in the four replicates of 25 seeds each.

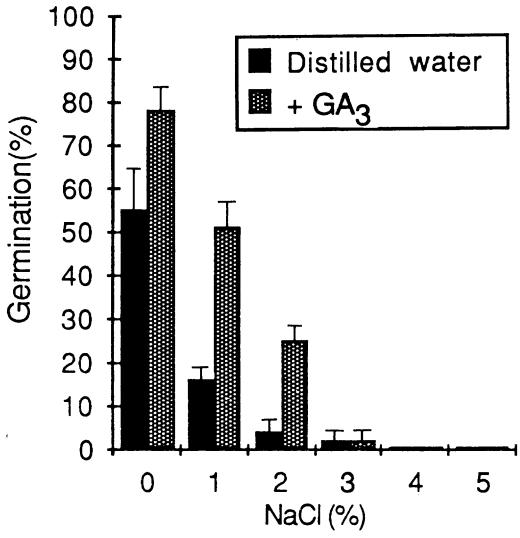

Fig. 8. Effect of (1×10^{-3} M) on dark- and salinity-induced germination inhibition of *Salicornia pacifica* var. *utahensis* seeds at 25–5 C, 12/12 hr light/dark, for 20 days. The error bars represent the statistical variation in germination in the four replicates of 25 seeds each.

was inhibited by increased salinity. Halophyte seed germination has been reported to occur optimally under reduced salinity stress (Ungar, 1962; Binet, 1964; Williams and Ungar, 1972; Ungar, 1977; Khan and Ungar, 1984a, b). An alternating temperature of 15 C for 12 hr (light) and 5 C for 12 hr (dark) stimulated germination of *S. pacifica* var. *utahensis* in salinities ranging from 5–0.0% NaCl at 1% intervals. In comparison, an alternating temperature of 30–20 C completely inhibited the germination at 3, 4 and 5% to NaCl treatment. Mooring, Cooper and Seneca (1971) and Williams and Ungar (1972) reported similar stimulation. This pattern could be of ecological significance since germination of seeds in the playas occurring in early spring, when salinity stress is reduced by high soil moisture levels (rains), and temperatures are cooler. Also the rains and runoff water help disperse the seeds to new areas. Later in summer, salt and temperature stress would be too high for germination to occur on inland salt playas.

If the dormancy induced by salt stress was because of either low growth regulator production or a rapid turnover of gibberellins, exogenous GA_3 application should increase germination. Seed dormancy induced by high salt concentration can be alleviated by GA_3 (Ungar and Binet, 1975; Boucand and Ungar, 1976; Ungar, 1977, 1984; Khan and Ungar, 1985. Ungar and Binet (1976) and Boucand and Ungar (1976), however, could not stimulate seeds of salt stressed halophytes to germinate with kinetin. Kinetin did not promote the rate or total percentage germination of seeds of *S. pacifica* var. *utahensis* in the present study, but treatments with GA_3 proved to be stimulatory to both aspects of germination.

Small seeds of *Salicornia europaea* apparently have a light requirement for germination. Sixty percent of the large seeds but only 4% of seeds germinated when buried in marsh soil (Philipuillai and Ungar, 1984). Present studies with *S. pacifica* var. *utahensis* also show a significant reduction in germination percentage when seeds were germinated in dark. This inhibition could be partially alleviated by GA_3.

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