Gulzar, S. Khan, M.A. and Ungar, I.A. (2001), *Seed Sci. & Technol.*, **29**, 21-29

Effect of salinity and temperature on the germination of *Urochondra setulosa* (Trin.) C. E. Hubbard

S. GULZAR[1], M.A. KHAN[1] AND I.A. UNGAR[2]*

[1] Department of Botany, University of Karachi, Karachi-75270, Pakistan
[2] Department of Environmental and Plant Biology, Ohio University, Athens, Ohio 45701, USA
(E-mail: ungar@ohio.edu)

(Accepted May 2000)

Summary

Urochondra setulosa (Trin.) C.E. Hubbard) is a halophytic grass occurring in coastal areas of Sind Province and in a pure stand at the upper end of Manora creek at Hawkes Bay, Karachi, Pakistan. Seeds were collected from a salt flat situated at the Hawkes Bay location and germinated under a range of salinity and temperature regimes. Highest germination percentages were obtained under non-saline conditions and increases in salinity inhibited seed germination, with less than 10% of the seeds germinating at 500 mM NaCl. Germination was inhibited by either an increase or decrease in temperature from the optimal temperature regime of 20-30°C. The rate of germination, percent recovery germination and rate of recovery were greatest at 20-30°C, with the lowest germination and recovery occurring at the 10-20°C temperature regime. An interaction between salinity and the 10-20°C temperature regime yielded no germination at salinities of 300 mM and higher, whereas, some seeds germinated in up to 500 mM NaCl under the optimal temperature treatment (20-30°C).

Introduction

Urochondra setulosa (Trin.) C.E. Hubbard (Poaceace) is distributed in the coastal regions of Sudan, Ethiopia, Somalia, Arabia, Pakistan and Northwest India (Cope, 1982). It is a dominant species in the sand dunes, saline flats and saltwater creeks in the Indus delta and Hawkes Bay near Karachi. Little precipitation is available to the Hawkes Bay population, with the only possible sources of moisture being monsoon rains and oceanic seepage (Khan and Shaukat, 1997). *Urochondra setulosa* has erect and stout culms attaining a height of 15-90 cm, produces a large number of caryopses and also has vegetative reproduction by short rhizomes. While it usually grows in pure stands, it can also be found in communities associated with other halophytes such as *Limonium stocksii*, *Atriplex griffithii, Cyperus arenarius* and *Arthrocnemum macrostachyum*. Populations at Hawkes Bay were grazed by cattle, indicating that this species could be used as a forage crop on saline soils.

Seeds of halophytes often germinate best under non-saline conditions and their germination decreases with increases in salinity (Ungar, 1995; Khan and Gul, 1998; Khan and Ungar, 1998a); germination is substantially inhibited at 342 mM NaCl (*Puccinellia nuttaliana*; Macke and Ungar, 1971), 430 mM NaCl (*Diplachne fusca*; Myers and Morgan,

* Author for correspondence

1989), 300 mM NaCl (*Halopyrum mucronatum*; Noor and Khan, 1995 and *Briza maxima*; Lombardi *et al*., 1998), but one species, *Spartina alterniflora,* has up to 8% germination at 1027 mM NaCl (Mooring *et al*., 1971). Salinity and temperature are two important factors in the salt marsh and salt desert environment (Khan and Ungar, 1996) and they interact to affect halophyte seed germination (Ungar 1978, 1982; Khan and Weber, 1986; Badger and Ungar, 1989; DeVilliers *et al*., 1994; Khan and Ungar, 1998b). Some halophytic species like *Suaeda fruticosa* show little effect of change in temperature on germination (Khan and Ungar, 1998a) while other species like *Triglochin maritima* are highly sensitive to temperature regimes (Khan and Ungar, 1999).

Seeds of some halophytes have been found to retain their ability to germinate even after prolonged exposure to hypersaline conditions (Macke and Ungar, 1971; Woodell, 1985; Keiffer and Ungar, 1997) and variation in their capacity to germinate upon transfer to distilled water could be affected by the temperature regime to which they are exposed (Khan and Ungar, 1996, 1997). Some species remain dormant under high salinities and germinate when soil salinity levels are reduced. Macke and Ungar (1971) reported 88% recovery germination of *Puccinellia nutalliana* seeds in distilled water after a 25 day exposure to 900 mM NaCl. Khan and Ungar (1999) reported 72% recovery of germination of *Triglochin maritima* seeds after a 20 day exposure to 500 mM NaCl.

Little work has been done on the germination strategies of sub-tropical maritime grasses exposed to high temperature and salinity. The present research describes the ability of *Urochondra setulosa* caryopses to germinate under various temperature and salinity conditions. Based on the distribution of *Urochloa setulosa,* we hypothesize that optimal germination would be maintained at moderate salinities and high temperature regimes.

Materials and methods

Caryopses of *Urochondra setulosa* were collected in December 1997 from a coastal population at Hawkes Bay, Karachi (24°45’-25°N and 66°45’-67°E). Seeds were separated from the hull and stored in a refrigerator at 4°C. Germination experiments were initiated in August 1998. Seeds were surface sterilized in 0.58% Clorox (sodium hypochlorite) solution for one minute, subsequently washed with distilled water and air-dried before being used in the germination experiments. Six salinity concentrations (0, 100, 200, 300, 400 and 500 mM NaCl) were used based on a preliminary test to determine the salt tolerance limits of the species. Germination was tested at (dark-light) 10-20°C, 15-25°C, 20-30°C and 25-35°C temperature regimes with a twelve-hour photoperiod (25 µmol $m^{-2} s^{-1}$, 400-700 nm Sylvania cool white fluorescent lamps). Four replicates of 25 seeds each were germinated in two folds of Whatman filter paper #1 placed in 2.5cm × 18cm glass test tubes with 5 ml of test solution. A seed was considered to have germinated when the radicle emerged. Germination was noted on alternate days for 20 d. After 20 d, all ungerminated seeds were placed in distilled water and under the initial temperature regimes for another 20 d to determine their ability to recover from salt pretreatments. Rate of germination was calculated using a modified Timson’s germination velocity index = $\sum G/t$, where G = percentage of seed germinated after 20 days and t = total time of germination (Khan and Ungar, 1984). Rate of recovery germination was calculated by using the relation = $(a-b)/(c-b) \times 100$, where a = total number of seeds germinated after being transferred to distilled water, b = total number of seeds germinated in saline solution and c = total number of seeds. Data were subjected to two-way analysis of variance (ANOVA) using SPSS ver. 9.0 (SPSS, 1999).

Results

Salinity, temperature and their interaction significantly (P<0.05) affected the germination of *Urochondra setulosa* seeds (table 1). Seed germination decreased with an increase in salinity and was maximal at the 20-30°C temperature regime (figure1, 2), while both the highest and

Table 1. Results of two-way analysis of variance of characteristics by salinity (S) and Temperature (T). Data represent F-values significant at P<0.05.

	Independent variable		
Dependent variable	S	T	S × T
Germination (%)	96.9	70.4	9.8
Rate of germination	121.4	65.4	14.5
Recovery	48.7	71.2	10.6
Rate of recovery	23.1	150.1	5.2

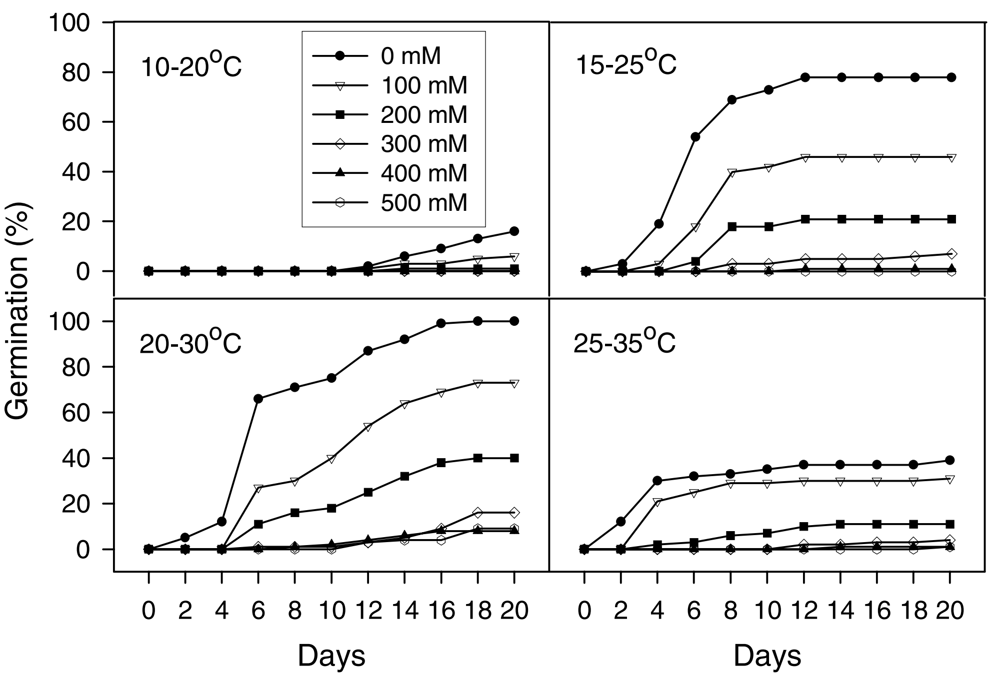

Figure 1. Rate of germination of *Urochondra setulosa* seeds in 0, 100, 200, 300, 400 and 500 mol m^{-3} NaCl at thermoperiods of 10-20°C, 15-25°C, 20-30°C and 25-35°C.

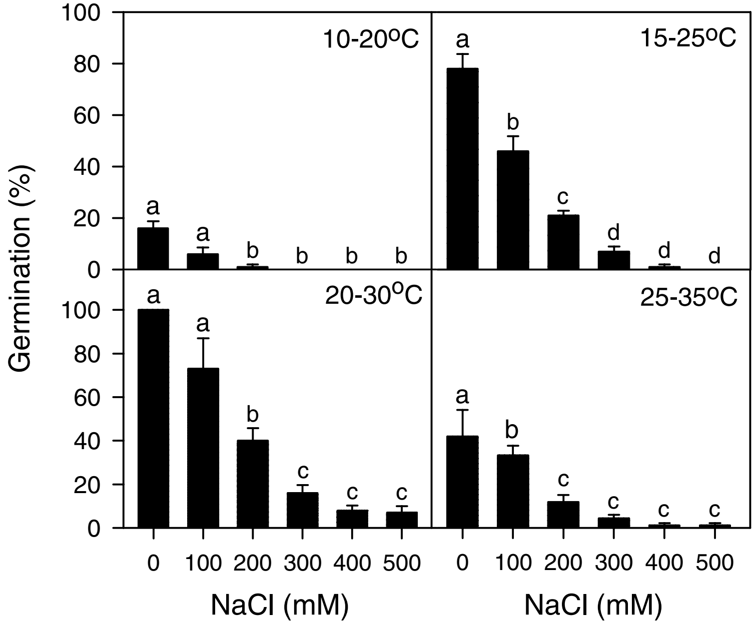

Figure 2. Final germination percentages of *Urochondra setulosa* seeds in 0, 100, 200, 300, 400 and 500 mol m-3 NaCl at thermoperiods of 10-20°C, 15-25°C, 20-30°C and 25-35°C.

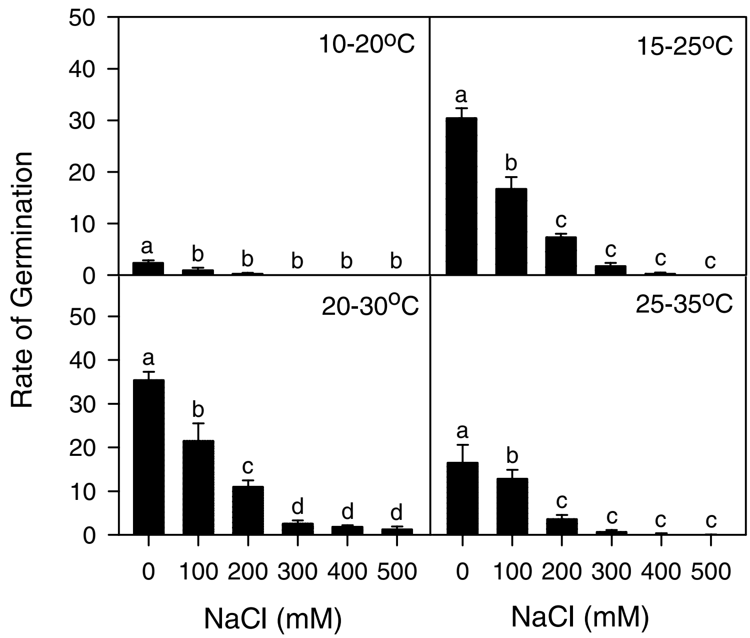

Figure 3. Rate of germination of *Urochondra setulosa* seeds after they are transferred from 0, 100, 200, 300, 400 and 500 mol m^{-3} NaCl at thermoperiods of 10-20°C, 15-2°C, 20-30°C and 25-35°C.

lowest temperatures inhibited germination. However, greatest inhibition of germination occurred at the lower temperature regime (10-20°C), where no seeds germinated at a salinity above 200 mM NaCl. Lower temperatures also delayed germination for 12 days in the non-saline control (figure 1).

A two-way ANOVA of rate of germination showed significant ($P<0.05$) main effects of salinity, temperature and their interaction (table 1). The rate of germination was lowest at 10-20°C followed by 25-35°C and 15-25°C and the highest germination rate was recorded at 20-30°C (figure 3). There was a decrease in the rate of germination with an increase in salinity at all temperature regimes.

When seeds were transferred to distilled water after a twenty day exposure to salinity, a differential in the recovery of germination was obtained for all salinity and temperature regimes tested (figure 4). A two-way ANOVA for recovery of germination and rate of recovery showed significant ($P<0.05$) effects of salinity, temperature and their interaction (table 1). There was little recovery at the lower temperature treatment (10-20°C), but there was up to 80% recovery germination at 20-30°C. Our data indicates that change in ambient temperature significantly affects the recovery from salt stress. There was a decrease in the rate of recovery germination with an increase in salinity at all temperatures except for 25-35°C (figure 5).

Discussion

Vegetation present at the Manora Creek on the Arabian coast near Karachi is exposed to various stresses including high salinity, drought and high temperatures. The climate of the area can be characterized as a sub-tropical maritime desert. It has an irregular rainfall of less than 220 mm per year in which potential evapotranspiration exceeds precipitation. Inundation of vegetation with seawater in Manora creek depends upon the proximity to the open sea. The area near Hawkes Bay, where *U. setulosa* was located, occurs at the upper end of the creek and it is rarely inundated by seawater. Due to a high water table, saline water is available to the roots and the upper surface of the soil is usually dry. Halophytic grasses like *Halopyrum mucronatum*, *Aeluropus lagopoides* and *U. setulosa* are commonly found growing in the coastal areas near Karachi; however, sporadic small populations of seven other halophytic grasses have also been reported (Jafri, 1966). *Urochondra setulosa* appears to be preferred for grazing by animals, indicating that it would be a potential forage crop that could be grown with seawater irrigation.

Seeds of most halophytes germinate better in distilled water than in saline solutions, but they differ from glycophytes in their ability to germinate at higher salinities (Khan and Ungar, 1999). Halophytic grasses have been reported to have different levels of salt tolerance, ranging from 300 mM to 430 mM (Macke and Ungar, 1971; Myers and Morgan, 1989; Lombardi *et al.,* 1998; Khan and Ungar, 1999). Germination of *Spartina alterniflora* seeds is not inhibited by up to 430 mM NaCl (Wijte and Gallagher, 1996) and up to 8% germinate at 1027 mM NaCl (Mooring *et al*., 1971). A small percentage of the seeds of *U. setulosa* could germinate in 500 mM NaCl at an appropriate temperature regime, indicating that this grass species is more salt tolerant than most other grass species.

The role of temperature in regulating seed dormancy of halophytes is known for some

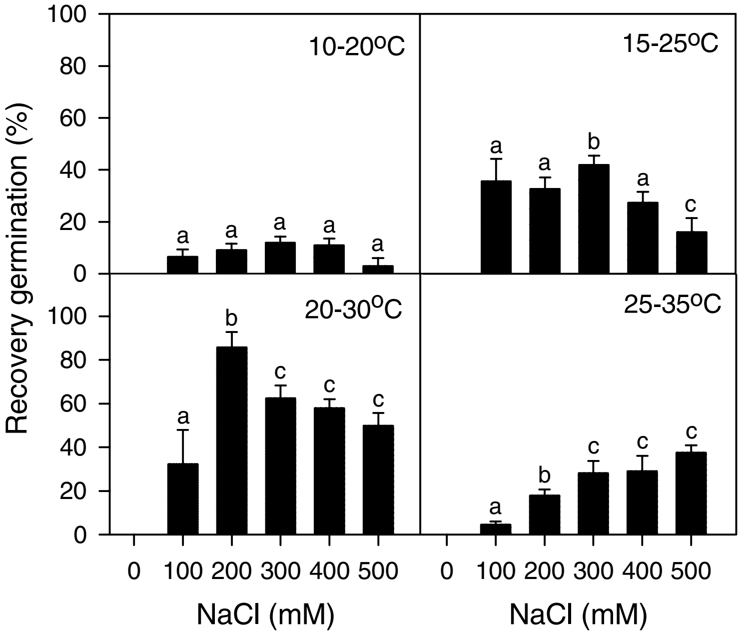

Figure 4. Percent recovery of *Urochondra setulosa* seeds in 0, 100, 200, 300, 400 and 500 mol m^{-3} NaCl at thermoperiods of 10-20°C, 15-25°C, 20-30°C and 25-35°C.

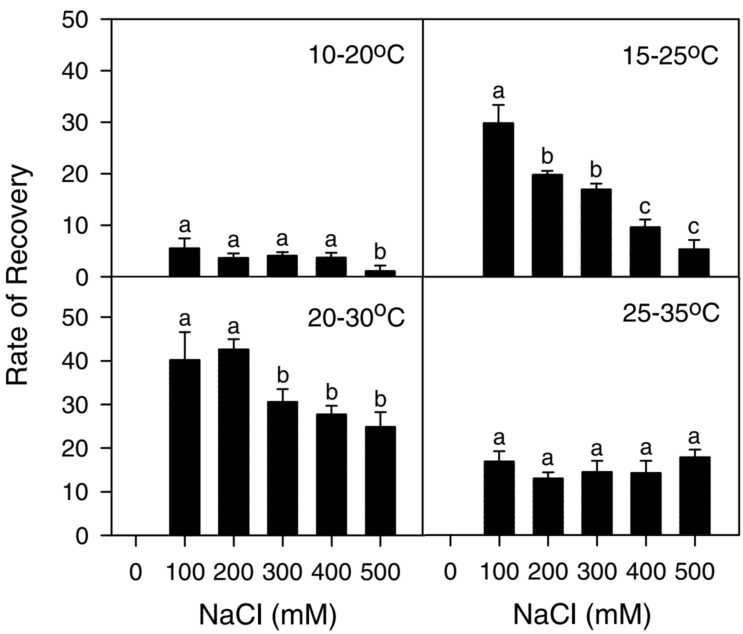

Figure 5. Rate of recovery of *Urochondra setulosa* seeds in 0, 100, 200, 300, 400 and 500 mol m^{-3} NaCl at thermoperiods of 10-20°C, 15-25°C, 20-30°C and 25-35°C.

species (Khan, 1999) and halophytic grasses have also shown similar patterns e.g., *H. mucronatum* (Noor and Khan, 1995); *Hordeum maritimum* (Onnis *et al.*, 1993); *Puccinellia festucaeformis* (Onnis and Miceli, 1975); *P. nuttalliana* (Macke and Ungar, 1971); *Diplache fusca* (Morgan and Myers, 1989); and *Briza maxima* (Lombardi *et al.*, 1998). *Urochondra setulosa* seeds are sensitive to change in temperature. Few seeds germinated in the non-saline control at the lower temperature regime (10-20°C) while germination was also inhibited at the higher temperatures, with the greatest germination occurring at 20-30°C. *Halopyrum mucronatum* is a coastal grass found growing on the sand dunes with *U. setulosa a*nd it seeds varied in their level of sensitivity to temperature. Both winter and summer seeds showed no effect of temperature under non-saline conditions (Noor and Khan, 1995). Introduction of salinity decreased germination and this decrease was similar at all temperatures in winter seeds, but higher temperatures substantially alleviated the inhibitory effects of high salinity in summer seeds. The two subtropical halophytic grasses *U. setulosa* and *H. mucronatum*, growing in similar environmental conditions, appear to have different requirements for germination.

Seeds of some halophytes are reported to tolerate high salinity during the period when they are dormant in the soil and subsequently germinate when soil salinities are reduced (Khan and Ungar, 1997). Variation in recovery germination responses have been demonstrated in a few halophytic species (Ungar, 1962, 1967; Ungar and Capilupo, 1969; Clarke and Hannon, 1970; Woodell, 1985). The recovery germination of seeds that were previously exposed to hypersaline conditions is affected by the temperature regime to which seeds are exposed (Khan and Ungar, 1996, 1998ab; Khan and Gul, 1998). Temperature regime had a substantial effect on the recovery of *U. setulosa* seeds. Recovery was inhibited at the low and high temperature regimes, while at the moderate temperature regime a substantial recovery of germination was obtained. Khan and Ungar (1997) reported that species vary greatly in their germination recovery responses when exposed to various salinity and temperature regimes. They found that the annual *Zygophyllum simplex* had little recovery after exposure to salt stress. However, other species like *Suaeda fruticosa, Haloxylon recurvum* and *Triglochin maritima* did demonstrate recovery of germination. Change in the temperature regime had little effect on the recovery germination response of *S. fruticosa* in the low salinity treatment, but at the higher temperature regime there was an interaction with the high salt concentration that inhibited recovery (Khan and Ungar, 1997).

Urochondra setulosa is one of the common grasses found on the Karachi coast and is present in the upper portion of the creek that is rarely exposed to direct seawater inundation but is exposed to underground seepage of seawater. This grass appears to be highly salt tolerant and has optimal germination at temperatures that are prevalent in the environment around Karachi. Its seeds have the ability to tolerate high salinity while in the soil and if the soil salinity is reduced when a suitable temperature regime is present, they should be able to germinate under natural conditions. However, in contrast to our hypothesis, the highest temperature regime and increases in salinity proved to be inhibitory to germination of seeds of this coastal halophyte. *Urochloa setulosa* had a high degree of salt tolerance at later stages of development (Gulzar *et al.*, unpublished data). It was also found to be selectively grazed by cattle at Hawkes Bay. Based on the above-mentioned characteristics, *U. setulosa* has a high potential to be utilized as a forage crop that could be grown under seawater irrigation.

Acknowledgements

M.A.K. thanks the University of Karachi for the provision of a research grant. M.A.K. and I.A.U. would like to thank the National Science Foundation for supporting this collaborative research project with NSF research grant INT-9730882.

References

Badger, K.S. and Ungar, I.A. (1989). The effects of salinity and temperature on the germination of the inland halophyte *Hordeum jubatum*. *Canadian Journal of Botany*, **67**, 1420–1425.

Clarke, L.D. and Hannon, N.J. (1970). The mangrove swamp and salt marsh communities of the Sydney district. III. Plant growth in relation to salinity and water-logging. *Journal of Ecology,* **58**, 351–369.

Cope, T.A. 1982. Poaceae (No. 143). In: *Flora of Pakistan*, (ed. E. Nasir and S.I. Ali.), pp. 680, Department of Botany, University of Karachi, Karachi.

Devilliers, A.J., Van Rooyen, M.W., Theron, G.K., Van De Venter, H.A. (1994). Germination of three Namaqualand pioneer species as influenced by salinity, temperature and light. *Seed Science and Technology,* **22**, 427–433.

Jafri, S.M.H. (1966). *The Flora of Karachi (Coastal West Pakistan).* The Book Corporation, Karachi.

Keiffer, C.W. and Ungar, I.A. (1997). The effect of extended exposure to hypersaline conditions on the germination of five inland halophyte species. *American Journal of Botany*, **84**, 104–111.

Khan, M.A. (1999). Comparative influence of salinity and temperature on the germination of subtropical halophytes. Halophyte Uses in different climates I: Ecological and Ecophysiological Studies. *Progress in Biometeriology*, (ed. H. Lieth, M. Moschenko, M. Lohman, H.–W. Koyro and A. Hamdy), Vol. 13. pp. 77–88, Backhuys Publishers, Leiden.

Khan, M.A. and Gul, B. (1998). High salt tolerance in the germinating dimorphic seeds of *Arhrocnemum macrostachyum*. *International Journal of Plant Sciences*, **159**, 826–832.

Khan, D. and Shaukat, S.S. (1997). Population structure, intraspecific competition and phasic development of *Urochondra setulosa* (Trin.) C.E. Hubb., A coastal halophytic grass of Pakistan. *Pakistan Journal of Botany,* **29,** 271–288.

Khan, M. A. and Ungar, I.A. (1984). Effects of salinity and temperature on the germination and growth of *Atriplex triangularis* Willd. *American Journal of Botany*, **71**, 481–489.

Khan, M.A. and Ungar, I.A. (1996). Influence of salinity and temperature on the germination of *Haloxylon recurvum*. *Annals of Botany*, **78**, 547–551.

Khan, M.A. and Ungar, I.A. (1997). Effect of thermoperiod on recovery of seed germination of halophytes from saline conditions. *American Journal of Botany*, **84**, 279-283.

Khan, M.A. and Ungar, I.A. (1998a). Seed germination and dormancy of *Polygonum aviculare* L. as influenced by salinity, temperature and gibberellic acid. *Seed Science and Technology*, **26**, 107–117.

Khan, M.A. and I.A. Ungar. (1998b). Germination of salt tolerant shrub *Suaeda fruticosa* from Pakistan: Salinity and temperature responses. *Seed Science & Technology,* **26**, 657–667.

Khan, M.A. and I.A. Ungar. (1999). Seed germination and recovery of *Triglochin maritima* from salt stress under different thermoperiods. *Great Basin Naturalist,* **59**, 144–150.

Khan, M.A. and Weber, D.J. (1986). Factors influencing seed germination in *Salicornia pacifica* var. *utahensis*. *American Journal of Botany*, **73**, 1163–1167.

Lombardi, T., Fochetti, T. and Onnis, A. (1998). Germination of *Briza maxima* L. seeds: effects of temperature, light, salinity and seed harvesting time. *Seed Science and technology,* **26**, 463–470.

Macke, A. and Ungar, I.A. (1971). The effect of salinity on germination of *Puccinellia nuttalliana*. *Canadian Journal of Botany*, **49**, 515–520.

Mooring, M.T., Cooper, A.W. and Seneca, E. D. (1971). Seed germination response and evidence for height of ecophenes in *Spartina alterniflora* from North Carolina. *American Journal of Botany*, **58**, 48–56.

Morgan, W.C. and Myers, B.A. (1989). Germination characteristics of the salt tolerant grass *Diplachne fusca*. I. Dormancy and temperature responses. *Australian Journal of Botany*, **37**, 225–237.

Myers, B.A. and Morgan, W.C. (1989). Germination characteristics of the salt tolerant grass *Diplachne fusca.* II. Salinity responses. *Australian Journal of Botany,* **37**, 239–251.

Noor, M. and Khan, M.A. (1995). Factors affecting germination of summer and winter seeds of *Halopyrum mucronatum* under salt stress. In: *Biology of Salt Tolerant Plants*, (ed. M. A. Khan and I.A. Ungar), pp. 51–58, Department of Botany, University of Karachi, Karachi.

Onnis, A. and Miceli, P. (1975). *Puccinellia festucaeformis* (Host) Parl.: Dormienza e influenza della salinita sulla germinazione. *Giornale Botanico Italiano*, **109**, 27–37.

Onnis, A., Lombardi, T. and Bertacchi, A. (1993). Ecological significance of rhythmical phenomenon in the germination of some Mediterranean halophytes. *2nd Europaean Meeting of Societies of Chronobiology,* Paris.

SPSS Inc. (1999). *SPSS: SPSS 9.0 for Windows Update*. SPSS Inc., Chicago.

Ungar, I.A. (1962). Influence of salinity on seed germination in succulent halophytes. *Ecology*, **43**, 763–764.

Ungar, I.A. (1967). Influence of salinity and temperature on seed germination. *Ohio Journal of Science*, **67**, 120–123.

Ungar, I.A. (1978). Halophyte seed germination. *Botanical Review*, **44**, 233–260.

Ungar, I.A. (1982). Germination ecology of halophytes. In: *Contributions to the Ecology of Halophytes*, (ed. D.N. Sen and K. Rajpurohit), pp. 143–154. Junk, The Hague.

Ungar, I.A. (1995). Seed germination and seed-bank ecology in halophytes. In: *Seed Development and Seed Germination*, (ed. J. Kigel and G. Galili), pp. 599–628, Marcel Dekker, New York.

Ungar, I.A. and Capilupo. F. (1969). An ecological life history study of *Suaeda depressa* (Pursh) Wats. *Advance Frontiers of Plant Science,* **23**, 137–158.

Wijte, A.H.B.M. and Gallagher, J.L. 1996. Effect of oxygen availability and salinity on early life history stages of salt marsh plants. I. Different germination strategies of *Spartina alternifora* and *Phragmites australis* (Poaceae). *American Journal of Botany,* **83**, 1337–1342.

Woodell, S.R.J. (1985). Salinity and seed germination patterns in coastal plants. *Vegetatio*, **61,** 223-230.