

## Alleviation of innate and salinity-induced dormancy in *Atriplex griffithii* Moq. var. *stocksii* Boiss.

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(Accepted August 1999)

### Summary

*Atriplex griffithii* var. *stocksii* is a perennial salt-secreting halophyte that grows in the coastal and inland salt deserts of Karachi, Pakistan. Seeds are surrounded by bracts at maturity, and were inhibited from germinating when they were enclosed by bracts or when naked seeds were germinated in the presence of their excised bracts but had 60% germination in the absence of bracts. The effect of dormancy relieving compounds (ethephon, fusicoccin, nitrate, thiourea, proline and betaine) in alleviating the effects of innate or salt-induced dormancy on seed germination of *A. griffithii* was investigated. Ethephon and fusicoccin failed to stimulate germination, whereas proline, betaine, nitrogen, and thiourea partially alleviated the innate dormancy in seeds. Salinity-induced dormancy was partially alleviated by fusicoccin, proline, betaine, thiourea, and nitrate. The rate of germination in non-saline controls increased significantly when seeds were treated with proline, betaine, and thiourea. Proline, betaine, thiourea, and nitrate also were found to increase the rate of germination under saline conditions.

### Introduction

*Atriplex griffithii* Moq. var. *stocksii* Boiss. (Chenopodiaceae) is a short, robust perennial shrub that occurs in Mediterranean, South Asian, and Southeast Asian regions. In Pakistan, this species commonly is found growing both in coastal and inland saline areas, with salinities ranging from 300 to 400 mM NaCl. We collected our seeds from a population of *A. griffithii* that occurs on an inland salt flat located on the University of Karachi campus, Karachi, Pakistan. Flowering and seed set of *A. griffithii* occurred after monsoon rains in July and August, and this was followed by the germination of seeds produced in the current year as well as those stored in the soil seed bank from previous years. *Atriplex griffithii* reproduces predominantly through seeds in a habitat where vegetative reproduction is most common among shrubs and recruitment through seeds is a rare event (Khan et al. 1998). Seeds were capable of germinating in salinities ranging up to 345 mM NaCl at cooler temperature regimes (10–25 °C) (Khan and Rizvi 1994).

Presence of bracts around seeds is reported to affect the germination of *Atriplex halimus* and other *Atriplex* spp., and inhibition of germination was substantially alleviated by the removal of bracts (Beadle, 1952; Osman and Ghassali, 1997). Bracts may be

inhibitory to germination because they contain inorganic salts and organic inhibitor substances such as saponins (Beadle, 1952; Fernandez et al., 1985; Osman and Ghasali, 1997).

Ethephon – an ethylene releasing compound – stimulates germination of dormant and non-dormant seeds, although in some case it may inhibit or have no affect on germination (Kepczynski and Kepczynska, 1997). Ethephon or ethylene alleviates primary dormancy (Kepczynski et al., 1996), secondary dormancy (Corbineau et al., 1988), and light induced dormancy (Esashi 1991). The inhibitory effects of salinity, high temperature, and osmotica can be reduced by ethylene (Braun and Khan, 1976; Dunlap and Morgan, 1977; Kepczynski, 1986). The ability of ethephon to reduce the inhibitory effect of salt stress on seeds of halophytes varies with the species investigated (Gul and Weber, 1998). Germination inhibition caused by salinity was partially alleviated by ethephon in *Zygophyllum simplex* and *Sporobolus arabicus* (Khan and Ungar, unpublished data) and completely alleviated in *Allenrolfea occidentalis* (Gul and Weber, 1998).

Fusicoccin (FC), a diterpene glucoside, was shown to affect seed germination both by accelerating the normal process of development and by replacing light and phytohormones in breaking dormancy (Lado et al., 1974, 1975). A treatment of FC was as effective as kinetin, ethylene and gibberellic acid in alleviating stress, suggesting that FC might affect processes common to both cytokinins and gibberellins (Braun and Khan, 1976). FC alleviated innate dormancy in *Zygophyllum qatarensis* but had no affect on salinity-enforced dormancy (Ismail, 1990). FC completely alleviated innate dormancy in *Zygophyllum simplex*, *S. alterniflora*, and *Sporobolus arabicus* (Plyler and Proseus, 1996; Khan and Ungar, unpublished data), partially reduced the salinity effect in *Sporobolus arabicus*, and completely alleviated salinity effects on *Zygophyllum simplex* and *Allenrolfea occidentalis* seeds (Khan and Ungar, unpublished data; Gul and Weber, 1998).

Compatible osmotica such as proline and glycinebetaine, which increase the tolerance level of plant tissues to salinity by acting as osmoregulators in the cytoplasm or as osmoprotectants of proteins, may also act as compatible solutes in seeds (Schobert, 1977; Gorham, 1995, Khan and Ungar, 1997). Application of proline and betaine to halophytic seeds did not stimulate germination of *Arthrocnemum indicum*, *Halopyrum mucronatum*, and *Kostelytzkyia virginica* (Poljakoff-Mayber et al., 1994; Khan unpublished data; Khan et al., 1998), however, in *Zygophyllum simplex* both compatible solutes alleviated innate dormancy but neither was effective at high salinities (Khan and Ungar, 1997). Both proline and betaine were found to substantially alleviate the salinity-enforced dormancy in *Allenrolfea occidentalis* (Gul and Weber, 1998).

Nitrate and thiourea both have been considered as possible regulators of seed germination in soils (Egely, 1995; Esashi et al., 1979). Thiourea and nitrate significantly alleviated the innate dormancy in halophytes such as *Zygophyllum simplex* and *Sporobolus arabicus* (Khan and Ungar, unpublished data). Salinity-enforced germination inhibition was completely alleviated by nitrate and thiourea in *Allenrolfea occidentalis* and partially stimulated germination in summer seeds of *Halopyrum mucronatum* (Khan, unpublished data; Gul and Weber, 1998). Nitrate was more effective in alleviating salinity-enforced dormancy at lower salinities in *Sporobolus arabicus*, and thiourea was

more effective in the case of *Zygophyllum simplex* (Khan and Ungar, unpublished data).

The influence of seed bracts on the germination of *A. griffithii* seeds was determined. This study was undertaken to determine if the application of compatible osmotica such as proline and betaine, growth regulators such as ethylene and fusicoccin, and nitrogenous compounds such as nitrate and thiourea could alleviate the remaining innate dormancy and dormancy enforced by high salinity when bracts were removed.

### Materials and methods

Seeds of *Atriplex griffithii* were collected during the fall of 1994 from salt flats situated on the University of Karachi campus, Karachi, Pakistan. Seeds were separated from the inflorescence and stored at 4°C. These seeds were brought to Ohio University, USA and germination studies were started in May 1995. Seeds were surface sterilized using the fungicide Phygon (active ingredient is dichlone; 2,3-dichloro-1,4-naphthoquinone). Germination was carried out in 50 × 9-mm (Gelman No. 7232) tight-fitting plastic petri dishes with 5 ml of test solution and each dish was placed in a 10-cm-diameter plastic petri dish as an added precaution against loss of water by evaporation. Four replicates of 25 seeds each were used for each treatment and seeds were considered to be germinated with the emergence of the radicle.

Seeds (brown and black) were germinated in a growth chamber at an alternating temperature regime of 15–25°C, where the higher temperature coincided with the 12-h light period (Sylvania cool white fluorescent lamps, 25  $\mu\text{M}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ , 400–750 nm) and the lower temperature coincided with the 12-h dark period. Concentrations of germination regulator substances used were 3 mM ethephon, 0.5 mM fusicoccin, 20.0 mM nitrate, 10.0 mM thiourea, 1.0 mM proline, 1.0 mM betaine, and salinity concentrations of 0, 100, 200, and 300 mM NaCl. These growth regulator concentrations stimulated germination in other species (Khan, unpublished data). Percent germination was recorded every alternate day for 20 days. The rate of germination was estimated by using a modified Timson index of germination velocity =  $\sum G/t$ , where G is percentage of seed germination at 2-days intervals, and t is total germination period (Khan and Ungar, 1984). The maximum value possible using this index with our data was 50 (i.e., 1000/20). The higher the value, the more rapid the rate of germination.

Germination data were arcsine transformed before statistical analysis. An ANOVA analysis was used to determine if significant differences were present among means and a Bonferroni test was carried out to determine if significant ( $P < 0.05$ ) differences occurred between individual treatments (SPSS 1996).

### Results

Germination of *A. griffithii* seeds was completely inhibited by either the enclosure of seeds by bracts or when the naked seeds were germinated in the presence of their bracts. Sixty-percent germination of *A. griffithii* seeds occurred when bracts were removed from seeds.

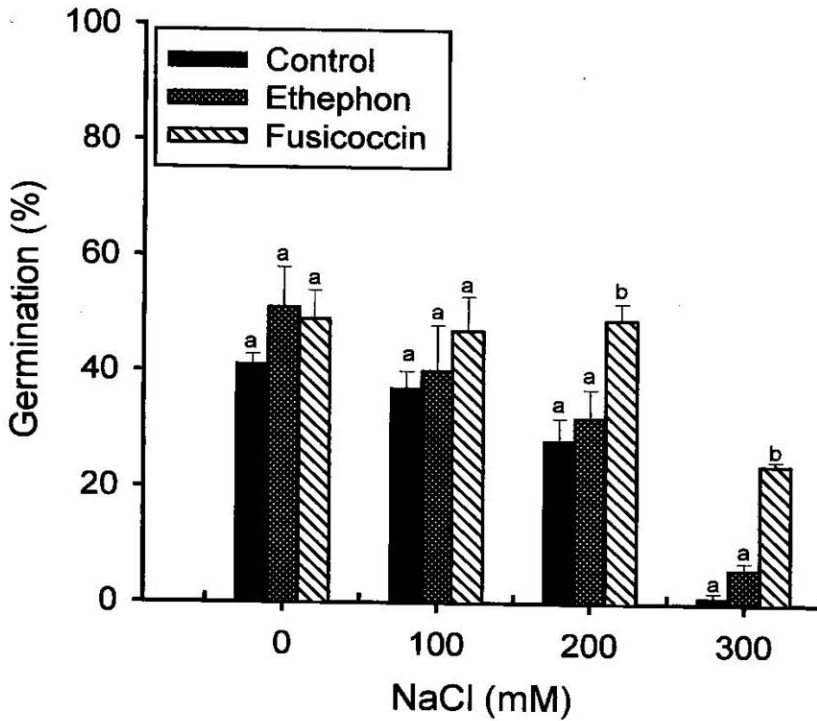


Figure 1. Mean ( $\pm$  SE) final germination percentages of *Atriplex griffithii* seeds in 0, 100, 200, and 300 mM NaCl, 3.0 mM ethephon, and 0.5 mM fusicoccin. Values at each NaCl concentration having the same letter are not significantly different ( $P > 0.05$ ).

Ethephon failed to alleviate the innate or salinity-enforced dormancy in seeds of *A. griffithii* (Figure 1). Fusicoccin partially alleviated the salinity-enforced germination inhibition (Figure 1), while proline and betaine both partially alleviated the innate and salinity-enforced dormancy (Figure 2). These compatible osmotica were more effective at the high salinity (300 mM NaCl) than any other regulator treatment. Thiourea and

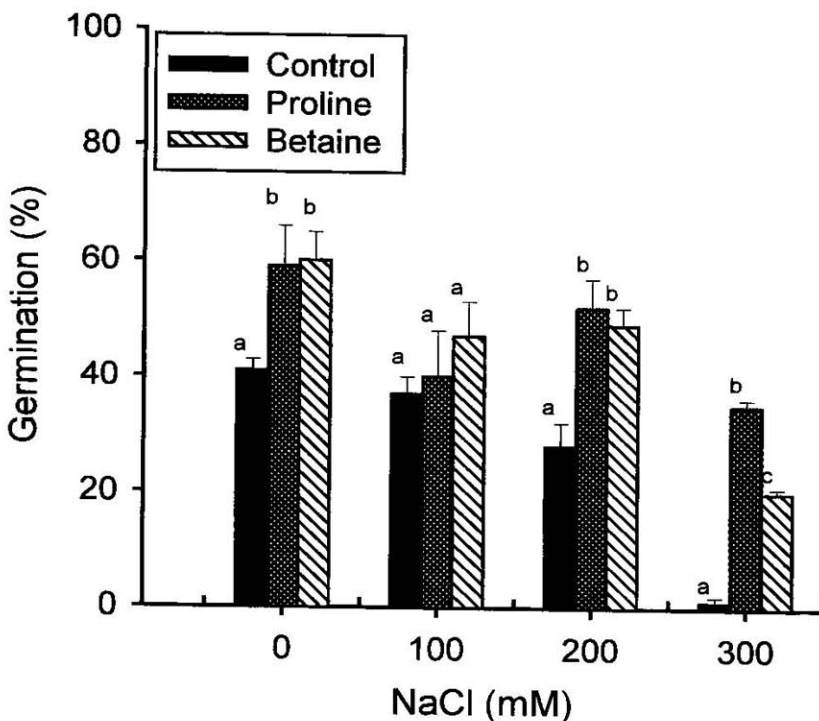


Figure 2. Mean ( $\pm$  SE) final germination percentages of *Atriplex griffithii* seeds in 0, 100, 200, and 300 mM NaCl, 1.0 mM proline, and 1.0 mM betaine. Values at each NaCl concentration having the same letter are not significantly different ( $P > 0.05$ ).

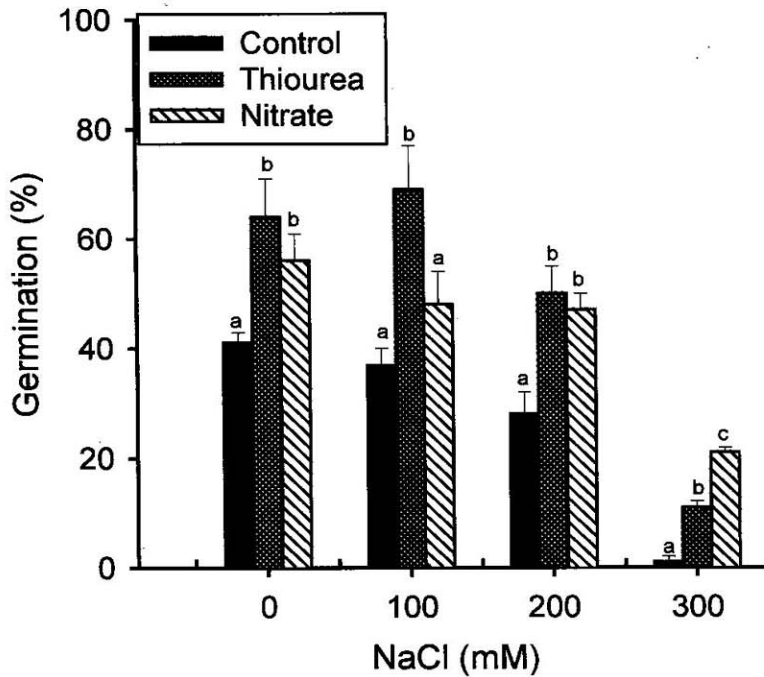


Figure 3. Mean ( $\pm$  SE) final germination percentages of *Atriplex griffithii* seeds in 0, 100, 200, and 300 mM NaCl, 10.0 mM thiourea, and 20.0 mM nitrate. Values at each NaCl concentration having the same letter are not significantly different ( $P > 0.05$ ).

nitrate both were effective in alleviating both innate and salinity-enforced dormancy (Figure 3). Thiourea was more effective at low salinity (100 mM NaCl) and nitrate was more effective at the higher salinity (300 mM NaCl). A one-way ANOVA for each dormancy relieving compound revealed that seed germination was significantly increased at different NaCl concentrations by ethephon,  $F = 1.25$ ,  $P > 0.05$ ; fusicoccin,  $F = 7.6$ ,  $P < 0.004$ ; proline,  $F = 13.5$ ,  $P < 0.0001$ ; betaine,  $F = 19.3$ ,  $P < 0.0001$ ; thiourea,  $F = 126.6$ ,  $P < 0.0001$ ; nitrate,  $F = 13.0$ ,  $P < 0.0001$ .

Rate of germination in the non-saline control increased significantly in proline, betaine, and thiourea treatments (Table 1). Proline, betaine, thiourea and nitrate promoted the rate of germination under saline conditions (Table 1). A one-way ANOVA for each dormancy relieving compound revealed that rate of germination significantly increased at different NaCl concentrations when seeds were treated with ethephon,  $F = 9.9$ ,  $P < 0.001$ ; fusicoccin,  $F = 7.4$ ,  $P < 0.005$ ; proline,  $F = 4.9$ ,  $P < 0.02$ ; betaine,  $F = 14.3$ ,  $P < 0.0001$ ; thiourea,  $F = 88.6$ ,  $P < 0.0001$ ; nitrate,  $F = 11.0$ ,  $P < 0.0001$ .

Table 1. Effect of growth regulators, osmotica, nitrogenous compounds, and salinity on the rate of germination (Timson Index ( $\pm$ SE), Max = 50) of *Atriplex griffithii* seeds.

NaCl	Water	Proline	Betaine	Thiourea	Nitrate	Ethephon	Fusicoccin
0	14 $\pm$ 0.8 <sup>a</sup>	19 $\pm$ 2.1 <sup>b</sup>	20 $\pm$ 2.2 <sup>b</sup>	24 $\pm$ 0.9 <sup>b</sup>	16 $\pm$ 1.4 <sup>ab</sup>	17 $\pm$ 2.3 <sup>ab</sup>	17 $\pm$ 2.0 <sup>ab</sup>
100	11 $\pm$ 1.6 <sup>a</sup>	14 $\pm$ 0.9 <sup>b</sup>	15 $\pm$ 1.7 <sup>b</sup>	21 $\pm$ 1.4 <sup>b</sup>	16 $\pm$ 1.8 <sup>b</sup>	14 $\pm$ 2.6 <sup>b</sup>	18 $\pm$ 2.4 <sup>b</sup>
200	7 $\pm$ 1.4 <sup>a</sup>	13 $\pm$ 1.5 <sup>b</sup>	11 $\pm$ 1.6 <sup>b</sup>	22 $\pm$ 3.2 <sup>c</sup>	14 $\pm$ 2.6 <sup>b</sup>	9 $\pm$ 1.3 <sup>a</sup>	16 $\pm$ 1.4 <sup>bc</sup>
300	0.2 $\pm$ 0.2 <sup>a</sup>	5 $\pm$ 1.0 <sup>b</sup>	3 $\pm$ 0.8 <sup>b</sup>	2 $\pm$ 0.3 <sup>b</sup>	3 $\pm$ 1.3 <sup>b</sup>	2 $\pm$ 0.3 <sup>b</sup>	7 $\pm$ 1.1 <sup>b</sup>

Values in each row with the same letter are not significantly different  $P > 0.05$ , Bonferroni test.

## Discussion

Perennial halophytes in a subtropical maritime desert at Karachi, Pakistan are usually recruited through rhizomes and stolons, whereas recruitment through seeds is not common (Khan et al., 1998). *Atriplex griffithii* is one of the few halophytic perennial species that is primarily recruited through seeds (Khan and Rizvi, 1994). The ability of seeds to respond to high salinity and temperature stress is crucial to the success of this species. Khan and Rizvi (1994) reported that *A. griffithii* did not germinate at high salinities (516 mM NaCl), with greatest germination occurring in light, cooler temperature regimes, and non-saline treatments. Both GA<sub>3</sub> and kinetin alleviated salinity-enforced inhibition of germination in this species.

*Atriplex griffithii* seeds are enclosed in a bract, which was found to be inhibitory to seed germination in our investigation. Seeds that were either enclosed in the bract or the naked seeds exposed to their bracts in the medium were completely inhibited from germinating, whereas in comparison seeds without bracts had 60% germination. This indicates that bracts contain some kind of potent germination inhibitor that completely suppressed seed germination. Osman and Ghassali (1997) reported that bract removal significantly improved germination of *A. halimus* seeds and a leachate from bracts produced a slight but non-significant reduction in germination. Inhibitors are reported in the pods and bracts of a wide range of shrub and tree species (Al-Charahafchi and Clor, 1989; Hashim, 1990) and presoaking of pods and fruits was effective in reducing the effect of inhibitors (Young et al., 1980; Hashim, 1990).

Ethephon failed to alleviate the salinity-enforced dormancy in *A. griffithii*. Ethylene is known to stimulate the germination of dormant and non-dormant seeds, although in some cases it inhibits or does not affect germination (Kepczynski, 1985; Esashi, 1991; Corbineau and Come, 1995). Germination inhibition caused by salinity is partially alleviated by ethephon in *Zygophyllum simplex* and *Sporobolus arabicus* (Khan and Ungar, unpublished data), and completely alleviated in *Allenrolfea occidentalis* (Gul and Weber, 1998).

Fusicoccin (FC) partially alleviated germination in all treatments, however, FC was more effective in higher salinity treatments. It is known to stimulate germination of halophyte seeds under salinity conditions but FC failed to alleviate the inhibitory effect of salinity on germination of *Zygophyllum qatarensis* seeds (Ismail, 1990), partially alleviated germination in *Sporobolus arabicus* (Khan and Ungar, unpublished data) or completely alleviated the salinity effect (*Allenrolfea occidentalis*, Gul and Weber 1998). FC has the ability to remove the inhibitory effect of ABA on germination of seed and on embryo growth of decoated seeds (Lado et al., 1975). It is likely that ABA production caused by salinity stress could be counteracted by FC, alleviating the inhibition of germination by salinity.

Proline and betaine partially alleviated both innate and salinity-enforced dormancy in *Atriplex griffithii* seeds, which may be because of a general germination enhancing effect rather than acting on two distinct mechanisms. External application of compatible osmotica (proline and betaine) did not stimulate germination of *Arthrocnemum in-*

*dicum*, *Halopyrum mucronatum* and *Kosteletzkya virginica* seeds (Poljakoff-Mayber et al., 1994; Khan et al., 1998), but alleviated both innate and salinity-enforced dormancy in seeds of *Zygophyllum simplex* and *Allenrolfea occidentalis* (Khan and Ungar, 1997; Gul and Weber, 1998). Compatible osmotica are known to alleviate salt stress in growing plants and may in some cases have the same function in seeds (Volkmar et al., 1998).

Nitrate and thiourea both were able to reduce innate and salinity-enforced dormancy in *A. griffithii*. Thiourea and nitrate alleviated innate dormancy in halophytes such as *Z. simplex* and *S. arabicus* (Khan and Ungar, unpublished data). Inhibition of germination caused by salinity was partially alleviated by nitrate and thiourea in summer seeds of *Halopyrum mucronatum* (Khan, unpublished data) and completely in *A. occidentalis* (Gul and Weber, 1998). Nitrate was more effective in stimulating germination at low salinity in *S. arabicus* seeds and thiourea was more effective in *Z. simplex* (Khan and Ungar, unpublished data).

*Atriplex griffithii* Moq. var. *stocksii* is distributed both in inland and coastal marshes and deserts around Karachi, Pakistan. Coastal species receive seasonal inundation while inland populations either tap underground water sources or rely on monsoon rains that occur during July and August. After monsoon rains, seeds germinate and a significant recruitment of seedlings was observed (Khan, unpublished data). It is interesting to note that most of the other perennial halophytes rarely are recruited through seeds but are able to expand their distribution by vegetative growth. Our data indicate that the inhibitory effect of salinity on germination can be mediated through growth regulator substances. Bracts are inhibitory to germination and may contain inhibitory substances that induce seed dormancy. Further investigations are necessary to determine if germination regulators can overcome the inhibitory effects of bracts on *A. griffithii* seeds.

## Acknowledgements

M. A. Khan would like to thank the CIES for providing a Fulbright Scholar Research Grant, Ohio University for a Postdoctoral Fellowship, and the University of Karachi for granting a foreign service leave. This research was supported in part by National Science Foundation research Grant INT-9730882.

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