Nutrients alleviate the deleterious effect of salinity on germination and early seedling growth of the psammophytic grass *Elymus farctus* L.
Title page

Full title of manuscript:

Nutrients alleviate the deleterious effect of salinity on germination and early seedling growth of the psammophytic grass *Elymus farctus* L.

Running title: Nutrient salinity interaction on germination of *Elymus farctus*

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Abstract

*Elymus farctus* is a perennial grass, dominating the Mediterranean coastal sands of Egypt. Germination of *E. farctus* seeds was monitored under the impact of NaCl levels up to 300 mM, either in water or in nutrient solution containing nitrogen in the form of ammonium, nitrate or ammonium nitrate. Seed germination was more salt tolerant than extension of embryonic axis and radicle elongation was more salt tolerant than plumule elongation. NaCl applied in water sharply reduced germinability beyond a threshold of 55 mM, but progressively inhibited embryonic axis elongation. Presence of nutrients alleviated the effect of salinity; particularly if nitrogen was in the form of nitrate. The effect of salinity on speed, uniformity and synchrony of germination was in general modulated by the presence of nutrients.

Salt-treated seeds readily recovered from stress when moved to distilled water, without a lag period, and with high speed, uniformity and synchrony of germination but with a lower recovery percentage compared to the germination of fresh seeds in distilled water; which might point to a combination of osmotic and specific ion effects of salinity on seed germination.

Key words: *Elymus farctus*, germination, nitrogen form, nutrients, salinity, seedling growth
Introduction

Salinity is a major constraint of seed germination and establishment of wild plant species including halophytes (Khan et al. 2004). Therefore, adaptation of plants to salinity during germination and early seedling stages is crucial for the establishment of species in saline habitats. Seeds usually are located near the soil surface where salts accumulate and the concentration of salt changes over time by continuous evapotranspiration or rainfall (Tobe et al. 2000).

The inhibitory effect of salinity on germination and plant growth can be assigned either to an osmotic effect (water stress) imposed by the very negative water potential of saline habitats or to a specific ion effect (that is of Na⁺ or Cl⁻) on metabolism or to a combination of both effects. In support to the first hypothesis, the inhibition of seed germination by NaCl was of similar magnitude to that imposed by iso-osmotic solutions of mannitol (Myers and Morgan 1989) or PEG (Llanes et al. 2005). On the other hand, the inhibitory effect of NaCl on germination and seedling growth was more severe than that of iso-osmotic solutions of polyethylene glycol (Katembe et al. 1998) or of different inorganic salts (Sosa et al. 2005), which suggests a combination of both osmotic and specific ion effects. It is probable that uptake of salt ions during salt stress might lead to alteration of certain enzymatic or hormonal activities of the seeds during germination.

Most studies concerning the effect of salt stress on germination have been performed using single salt solutions; which represents an artificial system rarely encountered in natural habitats. Under natural conditions, emerging seeds were bathed by the soil solution which is a mixture of different inorganic salts. The question is does the behavior of germinating seeds under salinity stress imposed by single salt solutions differ from that in which NaCl was superimposed on a full nutrient solution. If the effect of salinity on germination includes a specific ion effect; then it is probable that the presence of plant nutrients might counteract the adverse effect of salt
ions on seed germination. A variety of inorganic nutrients such as KNO$_3$ as well as organic compounds including growth promoters have been reported to play a significant role in breaking seed dormancy and increasing germinability (Kandari et al. 2011).

*E. farctus* is a perennial grass of widespread occurrence in the psammophere; recorded in the coasts of northern Europe and the British isles, extending through Russia and Asia to Northern America (Clapham et al. 1987). The plant is a perennial rhizomatous herb with erect, rigid 40-50 cm long stems, flat ribbed 0.5 cm wide silver-colored stiff leaves and 5-10 cm long spike. The plant flowers and sets seeds from May to July. *E. farctus* is a facultative halophyte (Rozema et al. 1985) and has the ability to fix sand, and thus furnishes a less hostile habitat for other associated species; therefore, it is considered as the pioneer of the psammophere (El–Ghareeb and Rezk 1989). The plant propagates by seeds and also vegetatively by rhizomes. In the present work, germination of the wild grass *Elymus farctus* was monitored under the interaction of salinity and fertility. NaCl was applied either in water or superimposed on a full nutrient solution, and in the latter case nitrogen was supplied either in the form of ammonium, nitrate or ammonium nitrate.

**Materials and methods**

*Germination conditions*

Seeds of *Elymus farctus* were collected from the coastal sand dunes at New Damietta city, northern Egypt. Fresh seeds were subjected to a preliminary viability test before experimentation. Seeds germinated readily and the percentage of germination exceeded 80% in distilled water. Seeds, selected for homogeneity, were germinated at 25°C in the dark in 12-cm Petri dishes lined with filter paper moistened with the treatment solutions; 50 seeds per dish. At intervals seeds and emerging seedlings were transferred under dim light to new dishes with filter papers.
saturated with the experimental solutions to prevent buildup of salt. Germination was monitored at regular intervals up to 8 days from sowing and seeds were considered germinating when the radical was emerged to a length of 2 mm. After approaching steady germination percentage in the test solutions, the lengths of radicles and plumules of the emerging seedlings were recorded and the non-germinated seeds were transferred from saline solutions to distilled water and the number of seeds germinating after transfer was counted at time intervals up to 7 days.

The experiment is a factorial one with two factors and four replications in a completely randomized design. The first factor was nutrients with 4 levels that is: no nutrients or distilled water (control) and nutrient solutions containing 6 mM N in the form either of ammonium, nitrate or ammonium nitrate. The second factor was salinity with five levels (0, 50, 100, 200 and 300 mM NaCl). In addition to the 6 mM N, the nutrient solutions contained the following macronutrients (mM): K 4.5, P 0.5, Ca 1, Mg 0.5, S 0.5, and the micronutrients (µM): Fe (Fe-EDTA) 25, Mn 5, Cu 0.5, Zn 0.5, B (boric acid) 25, Na 50, Cl 50, Mo 0.25 and Co 0.1.

**Definitions, calculations and statistical analysis**

Final cumulative germination percentage and final percentage recovery of germination from salinity were arcsine transformed before performing statistical analysis to ensure homogeneity of variance. Data were analyzed using SPSS version 22 and the effect of main factors (nutrients and salinity) and their interaction were assessed using two way ANOVA. Mean separation was performed using the Duncan's multiple range test at p < 0.05.

According to **Ranal and Santana (2006)** the germination parameters estimated in this work were grouped into five categories- taking into account the different notations and expressions in the literature. These are the germinability or final germination percentage, rate or speed, times, uniformity and synchrony of germination.
1. Germinability or germination capacity is the final cumulative germination percentage and was calculated as the total number of germinants at the end of germination period as a percentage of the total number of seeds.

2. Rate or speed of germination was estimated by using several calculations as follows:
   a) Mean daily germination (MDG) or Daily germination speed (DGS) was calculated as:

   \[
   MDG = \frac{\text{cumulative germination } \% \text{ at time } t_i}{t_i}. \quad (\% \text{ d}^{-1})
   \]

   The cumulative germination\% is the number of germinants as a percentage of the total number of seeds.

   b) Peak value (PV) is the maximum MDG, or the maximum quotient derived by dividing daily the accumulated number of germinants by the corresponding number of days; i.e., the mean daily germination of the most vigorous component of a seed lot.

   c) Germination value (GV), also called the Czabator index of germination velocity, was calculated as:

   \[
   GV = PV \times \text{final MDG} \quad (\% \text{ d}^{-1})
   \]

   d) Timson index of germination velocity was calculated as:

   \[
   \text{Timson index} = \frac{\sum G_i}{T} = \frac{G_1 + G_2 + G_3 + \cdots + G_n}{T} \quad (\% \text{ d}^{-1})
   \]

   Where \( G_i, G_1, G_2, G_3, G_i \) and \( G_n \) are the cumulative number of germinants at the first, second, third, \( i^{th} \) and final time respectively and \( T \) is the total germination period; that is to sum the cumulative germination\% for certain intervals and divide by the final germination period.

   e) Germination rate index (GRI), also called speed of germination was calculated as:

   \[
   \text{GRI} = \sum \frac{g_i}{t_i} = \frac{g_1}{t_1} + \frac{g_2}{t_2} + \frac{g_3}{t_3} + \cdots + \frac{g_n}{t_n} \quad (\% \text{ d}^{-1})
   \]

   \[
   = \frac{G_1}{t_1} + \frac{(G_2 - G_1)}{t_2} + \frac{(G_3 - G_2)}{t_3} + \cdots + \frac{(G_n - G(n-1))}{t_n}
   \]
f) Mean germination time (MGT or $\bar{t}$), also called mean emergence time (MET) or mean length of incubation time (MLIT) or mean days for germination (Mdays) is a measure of the average length of time required for maximum germination of a seed lot. It is one of the measures of time of germination and can be employed also as an inverse measure of speed of germination and was calculated according to the following equation:

$$MGT = \frac{\sum g_i \times t_i}{\sum g_i} = \frac{\sum g_i \times t_i}{N}$$ (d)

Where $g_i$ is the number of seeds newly germinated or the daily germination percentage at time $t_i$ from sowing, not the cumulative germination%, and $N$ is the total number of germinants or the final cumulative germination percentage.

The variance of germination time ($S_t^2$) was calculated according to the following formula:

$$S_t^2 = \frac{\sum g_i (t_i - \bar{t})^2}{\sum g_i - 1}$$ (d^2)

$S_t^2$ was used in the calculation of the coefficient of variation of germination time (CV$_t$)

3. Germination times

a) The first day of germination (FDG) is the time of first germination or the time of germination of the faster or most vigorous seeds.

b) The last day of germination (LDG) is the time of last germination or the time of germination of the slower or the least vigorous seeds.

c) Time spread of germination (TSG) is the time elapsing between FDG and LDG and was calculated as: $TSG = (LDG - FDG) + 1$

d) Mean germination time (MGT or $\bar{t}$), was mentioned above among the indices of rate of germination.

e) $T_{10}$ or time to 10% germination is a measure of the lag period between imbibition and onset of germination.
4. Uniformity of germination

a) The coefficient of uniformity of germination (CUG) measures the variability among seeds in relation to the mean germination time of the sample and was calculated as:

\[ CUG = \frac{\sum g_i}{\Sigma (t - t_i) \times g_i} \]  

(d²)

Where \( g_i \) is the number of newly seeds germinated on time \( t_i \) from sowing and \( \bar{t} \) is the mean germination time. High values would be associated with concentrated germination in time.

b) The coefficient of variation of the germination time (CVₜ) is another measure of the germination uniformity or variability in relation to the mean germination time and was calculated as:

\[ CV_t = \frac{(S_t) \times 100}{\bar{t}} \% \]

Where \( S_t \) is the standard deviation of the germination time and \( \bar{t} \) the mean germination time.

5. Synchrony of germination was estimated using the synchronization index (\( \bar{E} \)), calculated as:

\[ \bar{E} = - \sum f_i \times \log_2 f_i \]  

bit and \( f_i = \frac{g_i}{\Sigma g_i} \)

where \( f_i \) is the relative frequency of germination and \( g_i \) the number of seeds germinated on day \( i \). Low values of \( \bar{E} \) indicate more synchronized germination.

The recovery from salinity stress was calculated using the following formula of Khan and Ungar (1984):

\[ \text{Percent recovery} = \frac{(a-b) \times 100}{(c-b)} \]

where, \( a \) is the total number of seeds germinated after being transferred to distilled water, \( b \) is the total number of seeds germinated in saline solution and \( c \) is the total number of seeds. In other words, the recovery percentage is the number of newly germinated seeds after transfer to water.
(a-b) as a percentage of the number of seeds transferred (those non-germinated in the saline solution (c-b)).

The threshold and critical salinity levels for a specific process are defined as those levels leading to 5% and 50% reductions respectively.

Results

Germination indices

The preliminary germination test returned a fairly high germinability of 84%. Time course of germination in the different treatments exhibited the same sigmoidal pattern; with an initial lag period followed by a period of rapid rise in germination and ended with leveling off of germination percentage to steady final values which differed according to the treatment (Figure 1). The final germination percentage was comparable in the three nitrogen treatments (an average of 86%) and higher than in case of water (an average of 53%).

The results revealed highly significant effects of the main factors: nutrients and salinity and their interaction on germination parameters of *E. farctus* seeds (Table 1). The response of final germination percentage and final mean daily germination (FMDG) to salinity differed according to the presence of nutrients. The dose-response relationship of figure 2 revealed that in water, the two parameters were sharply reduced by about 91% as salinity exceeded a threshold of 55 mM NaCl and up to 300 mM NaCl, with a critical salinity of 155 mM NaCl. Nutrients greatly modified the salinity response; either making the inhibitory effect of salinity non-significant (in ammonium nitrate) or appreciably improving the final germination percentage and FMDG within the threshold salinity of 50 mM NaCl and leading to a mild reduction of 12% in the two parameters at the high salinity of 300 mM NaCl in case of ammonium and nitrate.
In addition to affecting germinability, the treatments had profound effects on times, speed, uniformity and synchrony of germination. The values of FDG and LDG were comparable in the three nitrogen forms (2.1 and 5.9 d respectively), shorter by 25% and 5% respectively than those of water, and were non-significantly affected by salinity. However, in water, the FDG was doubled whereas the LDG was reduced by 29% as salinity exceeded 100 mM NaCl up to 300 mM NaCl (Table 2). The values of TSG and T_{10} were non-significantly affected by the presence of nutrients and averaged around 4.7 d and 2.2 d, respectively, in the four nutrient treatments, but were variably affected by salinity according to the form of N. Whereas TSG and T_{10} were non-significantly affected by salinity in case of the three nitrogen treatments, TSG was shortened to half but T_{10} was increased to twice their non-salinized control values as salinity exceeded 100 mM and up to 200 mM NaCl. However, at 300 mM NaCl, TSG was further decreased while the germination percentage never attained 10%. MGT was comparable in the four nutrient treatments and averaged around 3.9 d, and the effect of salinity varied according to the nutrient treatment. Increasing NaCl concentration beyond a certain threshold (up to 100 mM in water, 200 mM in ammonium and 50 mM in case of nitrate and ammonium nitrate) up to 300 mM increased MGT by 25%, 10%, 13% respectively.

The PV, the GV of Czabator, Timson index and the GRI were each of comparable magnitude in the three nitrogen treatments and were either higher than those of water over the whole range of salinity (PV, GV and Timson index) or comparable to those of water under moderate salinity (GRI). However, all these indices were markedly higher than those of water at high salinity (> 100 mM NaCl). In water, increasing salinity from 0 to 300 mM NaCl reduced both of PV, Timson index and GRI by 92% and GV by 99%, and the reductions were particularly steep over the range 100-200 mM NaCl. In case of ammonium and nitrate, increasing salinity from 0 to 50 mM NaCl significantly increased PV by 13.5%, GV by 25.5% and both of Timson.
index and GRI by 10%; this was followed by a reduction in PV by 20%, in GV by 30% and in both Timson index and the GRI by 20% with further increase in salinity from 50 to 300 mM NaCl. In ammonium nitrate, increasing salinity from 0 to 300 mM NaCl progressively reduced Timson index and GRI by 24%, but moderate salinity of 100 mM NaCl reduced PV and GV by 22.5%, with non-significant increase at higher salinity (Figures 2 and 3).

Uniformity of germination, either in terms of CUG or CVt, of the three nitrogen treatments was comparable to that of water, with an average of 0.79 d² for CUG and 27.8% for CVt under moderate salinity of up to 100 mM NaCl but was higher (with higher values of CUG and lower values of CVt) than in water at higher salinity. The effect of salinity on CUG was non-significant over the whole range used in the three nitrogen treatments and up to 100 mM NaCl in water, but in water further increase in salinity from 100 to 300 mM NaCl sharply increased CUG by about 14 times. CVt, however, is a more precise measure of germination uniformity and permitted better separation of treatment effects. Increasing salinity from 0 to 100 mM NaCl in water increased CVt by 23%, but further increase up to 300 mM NaCl reduced it by 76%. Whereas salinity led to non-significant reduction in CVt in ammonium and nitrate, the reduction (21%) was significant with the rise in salinity beyond a threshold of 200 mM and up to 300 mM NaCl in ammonium nitrate (Figure 3).

Germination synchrony (E) was comparable in the three nitrogen treatments with an average of 2.1 bit, which was 46% higher than in water. Moderate salinity of 100 mM NaCl non-significantly affected E in water, but increased it by 15% in ammonium nitrate and further increase in salinity up to 300 mM NaCl reduced E by 59% and 20% in water and ammonium nitrate respectively. Increasing salinity from 0 to 300 mM NaCl reduced E by 24% in ammonium but non-significantly affected it in nitrate (Figure 4).
**Elongation of embryonic axis**

At the end of the germination period, radicle length was on average highest in ammonium nitrate, followed by nitrate and ammonium and was least in water. Plumule length was comparable in the three nitrogen treatments and was more than twice that of water. In water increasing salinity progressively inhibited radicle and plumule elongation until complete cessation at 300 mM NaCl; with critical levels of 100 and 75 mM NaCl for radicle and plumule respectively. With the presence of nutrients, increasing salinity from 0 to 300 mM NaCl moderately reduced radicle elongation by 35%, 21% and 29% in ammonium, nitrate and ammonium nitrate respectively. Increasing salinity from 0 to 300 mM NaCl reduced plumule length by 36% and 24% in ammonium and ammonium nitrate respectively; but in nitrate fairly high salinity of 200 mM increased plumule length by 43% and only 300 mM NaCl was inhibitory and reduced it by 32% below the value of 200 mM NaCl (Table 3).

**Recovery from salt stress**

The recovery test was applicable only in water, in which moderate and high salinities (100-300 mM NaCl) led to increasing number of non-germinated seeds; that were subsequently transferred to distilled water to monitor the recovery from salt stress. By contrast, in case of the three nitrogen treatments effect of salinity on germination percentage was mild. The time course of recovery reflected the typical sigmoidal pattern observed in the main germination test, but with no lag periods (Figure 5). Recovery percentage increased exponentially with time with different speed according to the previous salt level and approached an asymptote by the second day of transfer to water. The final recovery percentage increased from 51% for seeds transferred from 100 mM NaCl to 74.5% in case of 200 mM NaCl (a 50% increase) and then non-significantly reduced to 65.6% in case of 300 mM NaCl.
The speed of recovery increased with the increase in the previous salinity treatment from 100 to 200 mM NaCl, but with a non-significant effect at 300 mM NaCl. Increasing germination salinity from 100 to 200 mM NaCl increased PV, FMDG, GV, Timson index and GRI by 88%, 45%, 147%, 64%, and 85% respectively but reduced MGT by 25%. However, increasing germination salinity from 100 to 300 mM NaCl had a non-significant effect on times of germination (FDG, LDG, TSG) and CUG. CV increased by 31% as germination salinity increased from 100 to 200 mM NaCl but was reduced by 42% with a further increase in salinity up to 300 mM NaCl. The value of $\bar{E}$ was progressively reduced by 33% with the increase in germination salinity from 100 to 300 mM (Table 4).

The previous salinity treatment affected growth of the seedlings emerged after recovery. Lengths of radicle and plumule increased by 76% and 58% respectively with the increase in germination salinity from 100 to 200 mM NaCl, with non-significant reduction at 300 mM NaCl (Table 4).

**Discussion**

The fairly high germinability of *E. farctus* seeds points to readiness of seeds of this grass to germinate. Wild species usually exhibit seed dormancy of diverse causes and this represents an efficient strategy to spread germination over time and to avoid occasional germination in un-appropriate environments.

Presence of nutrients in the germination medium seems to alleviate the deleterious effect of salinity on germination and early seedling growth of *E. farctus*. Nevertheless, the comparable values of germinability and most of the germination speed indices as well as seedling growth in the presence and absence of nutrients at zero salinity suggests that the presence of nutrients is not essential for seed germination and seedling growth in non-salinized habitats.
However, the form of nitrogen seems to be of relatively small importance, compared to the mere presence of nutrients, since most of the germination indices exhibited close values irrespective of whether nitrogen was supplied as ammonium, nitrate or ammonium nitrate. Inhibition of seed germination by salinity is common in crop species (Jamil et al. 2005), wild species such as *Acacia* (Reichman et al. 2006) and even in halophytes (Khan and Ungar 1984). Nevertheless, the inhibition of germination parameters of *Oryza sativa* by salinities as high as 14% NaCl reported by Kandil et al. (2012) seems unreliable since this level of salinity is extraordinary, particularly for a crop species such as rice (14% NaCl is 2.4 M, with water potential of -9.4 MPa; for comparison seawater is about 0.5 M NaCl with -2.05 MPa). Katembe et al. (1998) reported that NaCl solution of -1 MPa water potential was strong enough to retard imbibition, germination and root elongation of *Atriplex prostrata*, an obligate halophyte. Most halophytic species can tolerate up to 350 mM NaCl, or even 500 mM NaCl (Khan and Gulzar 2003; Llanes et al. 2005).

Application of nutrients, either in the form of a complete nutrient solution such as Hoagland solution (Kandari et al. 2011) or in the form of only nitrate (Khan and Ungar 2002) can improve seed germination. However, the composition of the nutrient solution and its level of nutrients are important factors. Nitrate at a level of 10 mM promoted seed germination of *Atriplex sagittata* (Mandák and Pyšek 2001); at 20 mM it alleviated the adverse effect of salinity on seed germination of *Salicornia rubra* (Khan et al. 2002), *Atriplex prostrata* (Khan et al. 2003) and *Allenrolfea occidentalis* (Gul and Weber 1998) but higher levels (< 100 mM) of nitrate were inhibitory (Mandák and Pyšek 2001). Application of oxidized (nitrate) and reduced (ammonium) forms of nitrogen at 10 mM promoted seed germination of *Phacelia grandiflora* and *Salvia mellifera* (Thanos and Rundel 1995). Thus, it seems that the beneficial effect of application of the nutrient solution on seed germination is due primarily to
nitrogen rather than to the other accompanying nutrients. In support of this hypothesis, it has been reported that nitrate and ammonium increased germination of *Clematis vitalba* with no effect of the non-nitrogen compounds (*Bungard et al. 1997*), and that Hoagland’s solution without nitrogen completely inhibited seed germination of tropical soda apple (*Solanum viarum*) (*Kandari et al. 2011*). Furthermore, thiourea (a non-nutrient nitrogenous compound) can alleviate the adverse effect of salinity on seed germination to an extent either lower (*Gul and Weber 1998; Atia et al. 2006*), or even greater than that of nitrate (*Khan et al. 2002; Khan et al. 2003*).

The present results suggest that emergence of the embryo of *E. farctus* is a more salt tolerant process than is the subsequent seedling growth and that radicle growth is more salt tolerant than plumule growth. Only in water the adverse effect of salinity on seed germination and seedling growth was strong enough to calculate the threshold and critical levels for both processes. In water, germination exhibited an appreciable threshold salinity of 50-60 mM NaCl and a relatively high critical salinity of 150-160 mM NaCl (Figure 2). This is in comparison with elongation of the embryonic axis which exhibited progressive inhibition with the increase in salinity without a definite threshold until complete cessation at 300 mM NaCl and with lower critical levels of 100 and 75 mM NaCl for radicle and plumule elongation respectively (Table 3). In this respect, *Ungar (1996)* found that germination of *Atriplex patula* seeds was more salt tolerant than vegetative plants and *Llanes et al. (2005)* claimed that for successful establishment of *Prosopis strombulifera* in saline environments, emerging seedlings must exhibit higher salinity tolerance than the vegetative plant. This suggests that salt tolerance of plants might decrease in the following order: embryo emergence, embryonic axis growth and vegetative growth. However, different species exhibit different behavior in this regard and *Zhang et al. (2012)* reported more
salt tolerance of the mature stage than during germination in buffalo grass (*Buchloe dactyloides*), with the reverse being evident in blue grama (*Bouteloua gracilis*).

The form of nitrogen - although being of little influence compared to just the presence of nutrients – differentially affected the salt response of seed germination. The effect of salinity on germinability of *E. farctus* seeds in the presence of nutrients was either non-significant as in ammonium nitrate or promotive in the low range (up to 50 mM NaCl) but slightly inhibitory at higher salinity as in the case of ammonium and nitrate.

In addition, the form of nitrogen improved elongation of the embryonic axis, particularly under salt stress; and nitrate seems to be the best form of nitrogen, for it led to the least inhibition of radicle elongation, concomitant with promotion of plumule elongation under relatively high salinity of 200 mM NaCl. *Yu et al.* (2012) reported promotion of germination of *Phragmites australis* by moderate salinity of 0.5% NaCl (86 mM), with inhibition by high salinity until complete cessation at 3% NaCl (513 mM).

In addition to affecting germinability, nutrients and salinity exerted a profound interaction on germination times of *E. farctus* seeds. It seems that the presence of nutrients in the bathing medium forced seeds to start germination earlier, and the effect was independent on the form of nitrogen. By contrast, salinity delayed the onset of germination (longer FDG and T10) but accelerated its termination (shorter LDG), particularly in absence of nutrients. Thus, salinity results in shorter time spread of germination (TSG), which means concentrated germination in time under salt stress. Increasing salinity delayed the beginning and ending of germination of wheat (*Eskandari and Kazemi 2011*) and rice (*Kazemi and Eskandari 2012*).

Rapidity of germination is an important factor in the establishment of plant species in nature. In the present work, the rate of germination was assessed with various indices, which reflected different behavior. Rate of germination, estimated in terms of MGT, was non-
significantly affected by presence of nutrients but was inhibited as salinity increased beyond a certain threshold, which was higher in case of ammonium (200 mM NaCl) than in the other treatments. When estimated in terms both of PV, GV of Czabator, Timson index and GRI, rate of germination seems to benefit appreciably by application of nutrients, and the effect of salinity ranged from a sharp reduction in water to a mild reduction in ammonium nitrate, or even promotion by low salinity, which was followed by inhibition at high salinity in ammonium and nitrate. Rate of germination in terms of CVG, $\bar{v}$ and GI shared a different pattern, with higher values in water than in the presence of nutrients, particularly at moderate salinity. However, the inhibitory effect of salinity on CVG and $\bar{v}$ was evident beyond a certain threshold which was higher in ammonium than in nitrate; while the inhibition was progressive without a definite threshold in ammonium nitrate. Rate of germination of *Kochia scoparia* (*Khan et al. 2001*), *Atriplex prostrate* and *Atriplex patula* (*Katembe et al. 1998*) and *Atriplex triangularis* (*Khan and Ungar 1984*) was inhibited with increase in salinity.

Germination uniformity, either in terms of CUG or CV$_t$, as well as germination synchrony of *E. farctus* seeds germinated in absence of nutrients was promoted by increasing salinity beyond a threshold of 100 mM NaCl but the addition of nutrients seems to alleviate the effect of salinity. However, the two measures of germination uniformity were of different precision; and CV$_t$ seems to be a more precise index of germination uniformity, for it allowed fine screening of the effect of nutrients in the main germination experiment as well as screening of the effect of salinity level on subsequent recovery. Whereas in terms of CUG, germination uniformity within the threshold salinity was comparable in water and the three nitrogen treatments, the value of CV$_t$ was markedly higher (lower uniformity) in case of water (Figure 4); likewise, during recovery from stress the effect of the highest salinity level was distinguished from lower levels only in terms of CV$_t$ (Table 4). The effect of salinity on germination uniformity seems to be species specific; with a non-significant effect on seeds of soybean (*Rastegar and Kandi 2011*) and *Physalis peruviana* (*de Souza et al. 2014*)
at 60 mM NaCl and 12 dS m\(^{-1}\) (about 120 mM NaCl) respectively, but a reduction in case of *Moringa oleifera* seeds by as low salinity as 40 mM NaCl (*Elhag and Abdalla 2012*). The reports about effect of salinity on germination synchrony are scarce; however, *Jeller and Perez (2001)* reported that increasing NaCl salinity reduced germination synchrony of *Senna spectabilis* seeds.

The pattern of recovery from salt stress (which was applicable only in water) suggests a beneficial effect of the salt pretreatment on germination of a large proportion *E. farctus* seeds upon removal of stress. Salt-treated seeds readily recovered from stress, without a lag period and recovery percentage leveled off at a maximum of 75% within 2 days of transfer to water; this in comparison with a lag period of 3-4 days in the main germination experiment. Thus the previous salt treatment seems to adversely affect a low proportion of the population of seeds, meanwhile exerting a priming effect on the majority of the population (those not injured) and enhance their germination speed. The low recovery percentage compared to the germinability of fresh seeds in water might point to a combination of both osmotic and specific ion effects of salinity on seed germination. Usually, high recovery percentage is an indication of an osmotic effect, whereas low recovery percentage might indicate specific ion toxicity. Seeds of halophytes usually recover completely when saline stress is removed indicating an osmotic effect (*Hardegree and Emmerich 1990; Duan et al. 2004*). Salt pretreatments promoted an increase in the speed of recovery which, in *Arthrocnemum macrostachyum* and *Sarcocornia fruticosa*, doubled their speed of germination compared to that in distilled water controls (*Pujol et al. 2000*).

The increase in the recovery percentage of *E. farctus* seeds with increase in the previous salinity level from 100 to 200 mM NaCl might point to entry of salt ions with water into seeds germinated at moderate salinities (100 mM NaCl) and initiation of the germination process which may cause damage to the embryo whereas at higher salinities the very negative water potential of the germination medium is expected to limit the entry of water and salt ions into the seed which
keep the seed quiescent and able to germinate efficiently later after removal of stress. Othman et al. (2006) reported that increasing duration of seed soaking in hyper-saline medium significantly reduced seed recovery when transferred to distilled water and this was related to uptake of Na$^+$ and release of K$^+$ from seeds under salt stress.

In addition to shortening of germination times, increasing the dose of salt treatment seems to enhance the speed, uniformity and synchrony of recovery as well as elongation of the embryonic axis of the recovered seedlings. Redondo-Gómez et al. (2008) demonstrated that salinity pretreatment had a stimulatory effect on germination of Limonium emarginatum and Farhoudi and Sharifzadeh (2006) reported that salt priming of canola seeds improved seed germination, seedling emergence and growth under saline conditions. This priming effect of salt pretreatment is generally related to promotion of the activity of hydrolytic enzymes such as amylase (Sedghi et al. 2010) and the protective enzymes: superoxide dismutase, peroxidase and catalase as well as increase in the content of compatible solutes such as malondialdehyde, proline, and soluble sugar (Kazemi and Eskandari 2012); which might contribute to enhanced elongation of embryo.

On the basis of germination measurements, the present work suggests that E. farctus, although inhabiting the coastal Mediterranean sands is a facultative halophyte or a salt tolerant grass rather than an obligate halophyte. The effect of salinity on seed germination (germinability, speed, synchrony and uniformity of germination) was more adverse than on embryo growth particularly the plumule. The presence of nutrients in the medium can alleviate the toxic effect of salinity on germination and embryonic growth, with more pronounced effect of nitrogen in the form of nitrate. The salt pretreatment seems to benefit seed germination after release of stress, since salt-treated seeds germinated readily, without a lag period, and with high speed, uniformity and synchrony of germination. Nevertheless, the low recovery percentage compared to
germinability of fresh seeds suggests a combination of osmotic and specific ion effects of salinity on seed germination.
References


Table 1. The two-way ANOVA of the parameters of germination of *E. farctus* seeds under the influence of nutrients and salinity showing the effects of main factors and their interaction.

<table>
<thead>
<tr>
<th>Variable and source of variation</th>
<th>df</th>
<th>F</th>
<th>Sig.</th>
<th>Variable and source of variation</th>
<th>df</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Germinability (deg.)</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>Germination Rate Index (GRI)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nutr.</td>
<td>3</td>
<td>60.611</td>
<td>.000</td>
<td>Nutr.</td>
<td>3</td>
<td>56.613</td>
<td>.000</td>
</tr>
<tr>
<td>Salin.</td>
<td>4</td>
<td>20.380</td>
<td>.000</td>
<td>Salin.</td>
<td>4</td>
<td>93.028</td>
<td>.000</td>
</tr>
<tr>
<td>Nutr. × Salin</td>
<td>12</td>
<td>11.492</td>
<td>.000</td>
<td>Nutr. × Salin</td>
<td>12</td>
<td>37.481</td>
<td>.000</td>
</tr>
<tr>
<td><strong>Final Mean Daily Germination (FMDG)</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>Coefficient of variation of germination time (CV&lt;sub&gt;t&lt;/sub&gt;)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nutr.</td>
<td>3</td>
<td>168.498</td>
<td>.000</td>
<td>Nutr.</td>
<td>3</td>
<td>1.683</td>
<td>.180</td>
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<tr>
<td>Salin.</td>
<td>4</td>
<td>31.994</td>
<td>.000</td>
<td>Salin.</td>
<td>4</td>
<td>19.363</td>
<td>.000</td>
</tr>
<tr>
<td><strong>Peak Value (PV)</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>Coefficient of Uniformity of Germination (CUG)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nutr.</td>
<td>3</td>
<td>44.808</td>
<td>.000</td>
<td>Nutr.</td>
<td>3</td>
<td>14.862</td>
<td>.000</td>
</tr>
<tr>
<td>Salin.</td>
<td>4</td>
<td>44.890</td>
<td>.000</td>
<td>Salin.</td>
<td>4</td>
<td>11.496</td>
<td>.000</td>
</tr>
<tr>
<td>Nutr. × Salin</td>
<td>12</td>
<td>22.579</td>
<td>.000</td>
<td>Nutr. × Salin</td>
<td>12</td>
<td>9.915</td>
<td>.000</td>
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<tr>
<td><strong>Germination Value (GV)</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>Synchronization Index (E)</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Nutr.</td>
<td>3</td>
<td>46.482</td>
<td>.000</td>
<td>Nutr.</td>
<td>3</td>
<td>44.435</td>
<td>.000</td>
</tr>
<tr>
<td>Salin.</td>
<td>4</td>
<td>20.297</td>
<td>.000</td>
<td>Salin.</td>
<td>4</td>
<td>13.038</td>
<td>.000</td>
</tr>
<tr>
<td>Nutr. × Salin</td>
<td>12</td>
<td>7.573</td>
<td>.000</td>
<td>Nutr. × Salin</td>
<td>12</td>
<td>4.234</td>
<td>.000</td>
</tr>
<tr>
<td><strong>Mean Germination Time (MGT)</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>Plumule length</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nutr.</td>
<td>3</td>
<td>5.450</td>
<td>.002</td>
<td>Nutr.</td>
<td>3</td>
<td>63.65328</td>
<td>.000</td>
</tr>
<tr>
<td>Salin.</td>
<td>4</td>
<td>35.440</td>
<td>.000</td>
<td>Salin.</td>
<td>4</td>
<td>18.81001</td>
<td>.000</td>
</tr>
<tr>
<td>Nutr. × Salin</td>
<td>12</td>
<td>6.725</td>
<td>.000</td>
<td>Nutr. × Salin</td>
<td>12</td>
<td>7.105669</td>
<td>.000</td>
</tr>
<tr>
<td><strong>Timson index</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>Radicle length</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nutr.</td>
<td>3</td>
<td>136.653</td>
<td>.000</td>
<td>Nutr.</td>
<td>3</td>
<td>211.3009</td>
<td>.000</td>
</tr>
<tr>
<td>Salin.</td>
<td>4</td>
<td>68.726</td>
<td>.000</td>
<td>Salin.</td>
<td>4</td>
<td>64.89347</td>
<td>.000</td>
</tr>
<tr>
<td>Nutr. × Salin</td>
<td>12</td>
<td>22.235</td>
<td>.000</td>
<td>Nutr. × Salin</td>
<td>12</td>
<td>15.65375</td>
<td>.000</td>
</tr>
</tbody>
</table>
Table 2. Germination times of *E. farctus* seeds (mean of four replicates ± SE) in response to nutrients and salinity.

<table>
<thead>
<tr>
<th>mM NaCl</th>
<th>FDG (d)</th>
<th>LDG (d)</th>
<th>TSG (d)</th>
<th>MGT (d)</th>
<th>T₁₀ (d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>2.00 ± 0.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.50 ± 0.50&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>5.50 ± 0.50&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3.31 ± 0.08&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.38</td>
</tr>
<tr>
<td>0</td>
<td>2.00 ± 0.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.50 ± 0.50&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>5.50 ± 0.50&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>3.41 ± 0.14&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>1.35</td>
</tr>
<tr>
<td>50</td>
<td>2.00 ± 0.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.00 ± 0.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.00 ± 0.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.39 ± 0.07&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>1.35</td>
</tr>
<tr>
<td>100</td>
<td>4.00 ± 0.00&lt;sup&gt;b&lt;/sup&gt;</td>
<td>6.00 ± 0.58&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>3.00 ± 0.58&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.44 ± 0.15&lt;sup&gt;d&lt;/sup&gt;</td>
<td>3.70</td>
</tr>
<tr>
<td>200</td>
<td>4.00 ± 0.00&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.00 ± 0.00&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>2.00 ± 0.00&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>4.23 ± 0.09&lt;sup&gt;de&lt;/sup&gt;</td>
<td>∞</td>
</tr>
<tr>
<td>300</td>
<td>4.00 ± 0.00&lt;sup&gt;b&lt;/sup&gt;</td>
<td>5.00 ± 0.00&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>2.00 ± 0.00&lt;sup&gt;cd&lt;/sup&gt;</td>
<td>4.23 ± 0.09&lt;sup&gt;de&lt;/sup&gt;</td>
<td>∞</td>
</tr>
</tbody>
</table>

**Ammonium**

| 0       | 2.00 ± 0.00<sup>a</sup> | 6.00 ± 0.41<sup>a</sup>  | 5.00 ± 0.41<sup>a</sup>  | 3.78 ± 0.06<sup>a</sup> | 2.12    |
| 50      | 2.00 ± 0.00<sup>a</sup> | 5.75 ± 0.25<sup>ab</sup> | 4.75 ± 0.25<sup>ab</sup> | 3.87 ± 0.05<sup>ab</sup> | 1.92    |
| 100     | 2.00 ± 0.00<sup>a</sup> | 5.75 ± 0.25<sup>ab</sup> | 4.75 ± 0.25<sup>ab</sup> | 3.89 ± 0.10<sup>abc</sup> | 1.95    |
| 200     | 2.25 ± 0.25<sup>ab</sup> | 6.00 ± 0.41<sup>a</sup>  | 4.75 ± 0.63<sup>abc</sup> | 3.92 ± 0.03<sup>abcd</sup> | 2.19    |
| 300     | 2.00 ± 0.00<sup>a</sup> | 6.00 ± 0.41<sup>a</sup>  | 5.00 ± 0.41<sup>a</sup>  | 4.30 ± 0.14<sup>c</sup>  | 2.7     |

**Nitrate**

| 0       | 2.00 ± 0.00<sup>a</sup> | 5.50 ± 0.29<sup>ab</sup> | 4.50 ± 0.29<sup>ab</sup> | 3.74 ± 0.08<sup>a</sup> | 2.06    |
| 50      | 2.00 ± 0.00<sup>a</sup> | 5.25 ± 0.25<sup>a</sup>  | 4.25 ± 0.25<sup>a</sup>  | 3.76 ± 0.12<sup>ab</sup> | 2.15    |
| 100     | 2.00 ± 0.00<sup>a</sup> | 6.50 ± 0.29<sup>ab</sup> | 5.50 ± 0.29<sup>b</sup>  | 4.04 ± 0.08<sup>c</sup>  | 2.11    |
| 200     | 2.13 ± 0.13<sup>ab</sup> | 6.00 ± 0.41<sup>abc</sup> | 4.88 ± 0.43<sup>abc</sup> | 4.05 ± 0.04<sup>cd</sup> | 2.37    |
| 300     | 2.13 ± 0.13<sup>ab</sup> | 6.00 ± 0.00<sup>abc</sup> | 4.88 ± 0.31<sup>abc</sup> | 4.12 ± 0.07<sup>cde</sup> | 2.20    |

**Ammonium nitrate**

| 0       | 2.00 ± 0.00<sup>a</sup> | 5.75 ± 0.25<sup>abc</sup> | 4.75 ± 0.25<sup>abc</sup> | 3.59 ± 0.08<sup>a</sup> | 1.90    |
| 50      | 2.00 ± 0.00<sup>a</sup> | 5.75 ± 0.25<sup>ab</sup> | 4.50 ± 0.25<sup>ab</sup> | 3.77 ± 0.06<sup>ab</sup> | 2.20    |
| 100     | 2.13 ± 0.13<sup>ab</sup> | 6.75 ± 0.25<sup>c</sup>  | 5.63 ± 0.38<sup>c</sup>  | 4.07 ± 0.06<sup>c</sup>  | 2.30    |
| 200     | 2.00 ± 0.00<sup>a</sup> | 5.25 ± 0.25<sup>a</sup>  | 4.25 ± 0.25<sup>a</sup>  | 3.89 ± 0.09<sup>cd</sup> | 2.40    |
| 300     | 2.25 ± 0.25<sup>abc</sup> | 5.75 ± 0.41<sup>abc</sup> | 4.75 ± 0.25<sup>abc</sup> | 4.36 ± 0.08<sup>c</sup>  | 2.80    |

Note: For definition of FDG, LDG, TSG, MGT and T₁₀ see materials and methods. Means with common letters are not significantly different at p ≤ 0.05. Values of T₁₀ were calculated from the time course of germination curves, therefore, neither SE values nor mean separation was available.
Table 3. Lengths of plumule and radicle of *E. farctus* seedlings (mean of four replicates ± SE) in response to nutrients and salinity.

<table>
<thead>
<tr>
<th>mM NaCl</th>
<th>Form of nitrogen</th>
<th>Plumule length (cm)</th>
<th>Radicle length (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Water</td>
<td>Ammonium</td>
<td>Nitrate</td>
</tr>
<tr>
<td>0</td>
<td>1.93 ± 0.16&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.41 ± 0.35&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.51 ± 0.15&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>50</td>
<td>1.28 ± 0.19&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.05 ± 0.21&lt;sup&gt;abc&lt;/sup&gt;</td>
<td>1.83 ± 0.13&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>100</td>
<td>0.58 ± 0.02&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>2.09 ± 0.26&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>1.83 ± 0.13&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>200</td>
<td>0.05 ± 0.03&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.61 ± 0.11&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2.15 ± 0.07&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>300</td>
<td>0.00 ± 0.00&lt;sup&gt;de&lt;/sup&gt;</td>
<td>1.52 ± 0.06&lt;sup&gt;de&lt;/sup&gt;</td>
<td>1.46 ± 0.06&lt;sup&gt;cd&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Means with common letters are not significantly different at p ≤ 0.05.
Table 4. Germination parameters (mean of four replicates ± SE) of *E. farctus* seeds during recovery from salt stress.

<table>
<thead>
<tr>
<th>Germination parameter</th>
<th>mM NaCl</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100</td>
<td>200</td>
<td>300</td>
</tr>
<tr>
<td>Final Germination%</td>
<td>51.1 ± 8.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td>74.5 ± 1.08&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>65.6 ± 7.07&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>MGT (d)</td>
<td>2.45 ± 0.26&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.84 ± 0.09&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.76 ± 0.04&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>PV (% d⁻¹)</td>
<td>18.5 ± 4.60&lt;sup&gt;a&lt;/sup&gt;</td>
<td>34.8 ± 0.72&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>31.8 ± 2.99&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>FMDG (% d⁻¹)</td>
<td>7.30 ± 1.15&lt;sup&gt;a&lt;/sup&gt;</td>
<td>10.6 ± 0.15&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>9.38 ± 1.01&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Germination value (% d⁻¹)</td>
<td>150 ± 62.9&lt;sup&gt;a&lt;/sup&gt;</td>
<td>370 ± 7.23&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>307 ± 57.6&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Timson index (% d⁻¹)</td>
<td>27.4 ± 5.34&lt;sup&gt;a&lt;/sup&gt;</td>
<td>45.0 ± 0.52&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>39.8 ± 4.32&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>GRI (% d⁻¹)</td>
<td>26.8 ± 5.15&lt;sup&gt;a&lt;/sup&gt;</td>
<td>49.7 ± 0.64&lt;sup&gt;bc&lt;/sup&gt;</td>
<td>41.9 ± 5.07&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>FDG (d)</td>
<td>1.00 ± 0.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.00 ± 0.00&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.00 ± 0.00&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>LDG (d)</td>
<td>4.00 ± 0.58&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>4.75 ± 1.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.00 ± 0.71&lt;sup&gt;abc&lt;/sup&gt;</td>
</tr>
<tr>
<td>TSG (d)</td>
<td>4.00 ± 0.58&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>4.75 ± 1.03&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.00 ± 0.71&lt;sup&gt;abc&lt;/sup&gt;</td>
</tr>
<tr>
<td>CUG (d⁻²)</td>
<td>1.73 ± 0.73&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>1.61 ± 0.85&lt;sup&gt;a&lt;/sup&gt;</td>
<td>4.22 ± 1.14&lt;sup&gt;abc&lt;/sup&gt;</td>
</tr>
<tr>
<td>CV&lt;sub&gt;t&lt;/sub&gt; (%)</td>
<td>40.7 ± 6.88&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>53.3 ± 7.82&lt;sup&gt;a&lt;/sup&gt;</td>
<td>30.6 ± 4.40&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>E (bit)</td>
<td>1.50 ± 0.16&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.22 ± 0.09&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>0.99 ± 0.13&lt;sup&gt;bc&lt;/sup&gt;</td>
</tr>
<tr>
<td>T&lt;sub&gt;10&lt;/sub&gt; (d)</td>
<td>1.05</td>
<td>0.36</td>
<td>0.45</td>
</tr>
<tr>
<td>Radicle length (cm)</td>
<td>1.02 ± 0.34&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.80 ± 0.14&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.27 ± 0.07&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
<tr>
<td>Plumule length (cm)</td>
<td>0.26 ± 0.09&lt;sup&gt;a&lt;/sup&gt;</td>
<td>0.41 ± 0.06&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.29 ± 0.02&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Note: Estimation of recovery parameters was possible only in case of salinity applied in water at levels ≥ 100 mM NaCl. Means with common letters are not significantly different at p ≤ 0.05. For definition of the abbreviated germination parameters see materials and methods. Values of T<sub>10</sub> were calculated from the mean values of the four replicates, therefore, they were not followed by SE.
Figure captions

Figure 1. Time course of germination of *E. farctus* seeds under the influence of nutrients and salinity. Seeds were germinated in the dark for 8 days at 25°C under the effect of 0, 50, 100, 200 and 300 mM NaCl either in water (A) or on a full nutrient solution containing 6 mM N either in the form of ammonium (B), nitrate (C) or ammonium nitrate (D). Each value is the mean of four replicate; each was a petri dish containing 50 seeds.

Figure 2. Final germination percentage (A), final mean daily germination (B), peak value (C) and germination value (D) of *E. farctus* seeds under the influence of 0, 50, 100, 200 and 300 mM NaCl either in water or in a full nutrient solution containing 6 mM N in the form of ammonium, nitrate or ammonium nitrate. Each value is the mean of four replicates ± SE.

Figure 3. Timson index (A), germination rate index (GRI, B), coefficient of variation of germination time (C) and coefficient of uniformity of germination (CUG, D) of *E. farctus* seeds under the influence of 0, 50, 100, 200 and 300 mM NaCl either in water or in a full nutrient solution containing 6 mM N in the form of ammonium, nitrate or ammonium nitrate. Each value is the mean of four replicates ± SE.

Figure 4. Synchronization index of germination of *E. farctus* seeds germinated under the influence of 0, 50, 100, 200 and 300 mM NaCl either in water or in a full nutrient solution containing 6 mM N in the form of ammonium, nitrate or ammonium nitrate. Each value is the mean of four replicates ± SE.

Figure 5. Time course of recovery of germination of *E. farctus* seeds from salinity stress. Seeds were germinated in salt solutions prepared in water in the dark for 8 days at 25°C then the non-germinated seeds were transferred to distilled water and the number of germinants was monitored at time intervals up to 7 days. Each value is the mean of four replicates.
Figure 1.
Figure 2.
Figure 3.
Figure 4.
Figure 5