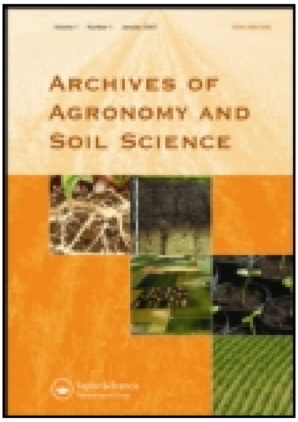

Archives of Agronomy and Soil Science
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/gags20

Influence of seed nitrogen content and biofertilizer priming on wheat germination in salinity stress conditions

Jabbar Fallahi [a b], Parviz Rezvani Moghaddam [a], Mahdi Nassiri Mahallati [a], Mohammad Ali Behdani [b], Mahsa Aghhavani Shajari [a] & Mohammad Behzad Amiri [a]

[a] Department of Agronomy, Faculty of agriculture, Ferdowsi University of Mashhad, Mashhad, Iran

[b] Saffron Research Group, Department of Agronomy, Faculty of agriculture, Birjand University, Birjand, Iran

Accepted author version posted online: 26 Apr 2012.Published online: 08 Jun 2012.

To cite this article: Jabbar Fallahi, Parviz Rezvani Moghaddam, Mahdi Nassiri Mahallati, Mohammad Ali Behdani, Mahsa Aghhavani Shajari & Mohammad Behzad Amiri (2013): Influence of seed nitrogen content and biofertilizer priming on wheat germination in salinity stress conditions, Archives of Agronomy and Soil Science, 59:6, 791-801

To link to this article: http://dx.doi.org/10.1080/03650340.2012.688196

Archives of Agronomy and Soil Science
Vol. 59, No. 6, June 2013, 791–801

Influence of seed nitrogen content and biofertilizer priming on wheat germination in salinity stress conditions

Jabbar Fallahi[a,b]*, Parviz Rezvani Moghaddam[a], Mahdi Nassiri Mahallati[a], Mohammad Ali Behdani[b], Mahsa Aghhavani Shajari[a] and Mohammad Behzad Amiri[a]

[a]*Department of Agronomy, Faculty of agriculture, Ferdowsi University of Mashhad, Mashhad, Iran;* [b]*Saffron Research Group, Department of Agronomy, Faculty of agriculture, Birjand University, Birjand, Iran*

(*Received 9 October 2011; final version received 22 April 2012*)

In order to study the effects of seed nitrogen content and biofertilizer priming on germination indices of wheat seeds under salinity stress, a factorial experiment based on a completely randomized design with four replications was conducted in 2009. Experimental factors consisted of: (1) the application of different nitrogen fertilizer rates (0, 55, 110 and 165 kg ha^{-1} N) on parent plants; (2) priming of achieved seeds by biofertilizers (Nitragin, Biophosphorus and distilled water); and (3) different levels of salinity produced by NaCl (0, −0.4, −0.8 and −1.2 MPa). Germination percentage, germination rate, mean germination time, germination index, radicle and plumule length, radicle and plumule dry weight and radicle number per seedling were measured. Nitrogen application increased seed nitrogen content in parent plants. All germination indices decreased with increasing in salinity levels. Biofertilizer priming, especially Nitragin, had a positive effect on germination percentage, radicle number and radicle and plumule length in most salinity levels. The highest values for germination factors were related to achieved seeds from parent plants that were treated with 110 kg ha^{-1} N. Overall, application of middle levels of N fertilizer (55 and 110 kg ha^{-1} N) on parent plants combined with seed priming with Nitragin biofertilizer improved the germination indices of wheat under salinity stress.

Keywords: wheat; salinity stress; biophosphorus; Nitragin; nitrogen

Introduction

Salinity is a major abiotic stress that limits plant growth and development and reduces the yield of a wide variety of crops all over the world (Lutts et al. 2004; Yagmur and Kaydan 2008). Salinity greatly affects seed germination and consequently induces a reduction in germination rate and a delay in the initiation of seedling growth (Zheng et al. 2009). Nearly half of the irrigated lands and 20% of the world's cultivated lands are currently affected by salinity stress (Zhu 2001; Zheng et al. 2009). Although salinity has adversely affected agriculture for thousands of years, the recognition that salt-affected lands can be used for agriculture is relatively recent (Bennett et al. 2009).

*Corresponding author. Email: agroecology86@yahoo.com

ISSN 0365-0340 print/ISSN 1476-3567 online

http://dx.doi.org/10.1080/03650340.2012.688196
http://www.tandfonline.com

Germination is a critical stage for plant establishment and during this period tolerance to salinity can improve the growth of plants (Ungar 1995; Song et al. 2008). It is common knowledge that germination and growth of wheat are negatively affected by salinity stress (Hampson and Simpson 1990; Iqbal et al. 1998; Almansouri et al. 2001). Therefore, it is important to study the ways (such as strengthening and priming wheat seeds) to increase its tolerance to salinity at early seedling growth stage (Yazdani et al. 2010).

The fertility of the maternal growth environment can lead to differences in seed nutrient content (Naegle et al. 2005). It has been well documented that parental conditions, such as nutrient availability during plant growth and seed maturation, can influence seed quality and ability to germinate (Bai et al. 2003). Naegle et al. (2005) reported that germination is heavily dependent upon seed nitrogen content. Some research on wheat revealed that sufficient application of nitrogen to the parent plant can increase salinity- and drought tolerance at the early stage of plant growth (Yazdani et al. 2010; Fallahi and Khajeh Hosseini 2011). However, the effect of nitrogen application on seed vigour was not fully understood (Hanslin and Eggen 2005).

Seed priming by biofertilizers can improve the germination characteristics in many plants. Krishna et al. (2008) reported that seed inoculation by *Azospirillium, Azotobacter,* phosphate-solubilizing bacteria, nitrogen-fixation bacteria and their combinations improved the germination of winter cherry (*Withania somniferum*) and holy basil (*Ocimum sanctum*) seeds. Also, Yazdani et al. (2010) and Fallahi et al. (2011) suggested that application of biofertilizers including Nitragin and Biophosphorus improved the germination rates and stress tolerance in different varieties of wheat. Similar results were obtained for sesame, sunflower and canola using seed inoculation with biofertilizers (Mirshekari and Baser 2010).

Because of the important role of wheat in human nutrition, combined with declining fresh water resources and increasing arable saline lands, it is necessary to improve wheat tolerance to unfavorable environmental conditions. Therefore, the aim of this study was to investigate the effect of nitrogen nutrition of parent wheat plants and priming of achieved wheat seeds by biofertilizers to increase salinity tolerance in wheat.

Materials and methods

This study was conducted in two stages in Ferdowsi University of Mashhad, Iran in 2009. In the first stage, a mono-factorial field experiment as a completely randomized block design with four replications in different nitrogen rates (0, 55, 110 and 165 kg ha^{-1} N) was applied on wheat (*Triticum aestivum* cv. Sayonz). Results of soil analysis of the field experiment site are given in Table 1. Total mineral nitrogen was determined using the macro-Kjeldahl method, plant available phosphorus and exchangeable potassium using an extraction method (1N NH_4OAc), with a spectrophotometer and flame photometer, respectively (Jackson 1967; Abbas et al. 2009).

Table 1. Soil analysis results of the experimental site (Experiment stage 1).

Depth (cm)	Total N (%)	Exchangeable K (mg kg^{-1})	Plant available P (mg kg^{-1})
0–20	0.084	125	9.0
20–40	0.070	100	6.4

In the second stage, a factorial experiment based on a completely randomized design with four replications was conducted under laboratory conditions.

This second stage included following factors:

(1) four nitrogen application rates, analogous to experiment stage 1;
(2) three substances for priming achieved seeds (Nitragin, Biophosphorus and distilled water); and
(3) four salinity levels (0, -0.4, -0.8 and -1.2 MPa).

Nitragin biofertilizer contains different bacteria including *Azotobacter* spp., *Azospirillum* spp. and *Pseudomonas* spp. at a concentration of 10^8 colony forming units (CFU) mL^{-1} and Biophosphorus biofertilizer contains two bacteria, including *Bacillus* spp. and *Pseudomonas* spp., at a concentration of 10^7 CFU mL^{-1}. The mentioned products were manufactured by Mehr Asia Biotechnology Company. Also, the NaCl used was obtained from Merck Company.

For bacterial inoculation, the achieved seeds from parent plants were soaked in biofertilizer treatments for 12 h under laboratory conditions, moreover, distilled water was used for the control treatment. After that, inoculated seeds were placed in the shade for 4 h and then 25 seeds of wheat were placed on filter paper (Whatman paper No. 1) in Petri dishes and soaked with 2.5 mL of each saline solution (see factor 3 of experiment stage 2); all Petri dishes were kept in an incubator at 22°C.

All germinated seeds, based on the emergence of 2 mm of radicle, were counted every 12 h for 8 days. On the final day, different indices such as germination percentage (GP), number of radicle per seedling (NR), radicle (LR) and plumule length (PL) were measured. Plumules and radicles were dried in oven at 72°C for 48 h, and their dry weights were determined. The mean germination rate (GR) was calculated by using Equation (1) (Maguire 1962). The mean germination time (MGT) and germination index (GI) were calculated using Equations (2) and (3) (Salehzade et al. 2009). The seed total nitrogen was determined by standard Micro-Kjeldahl method (Bremner and Breitenbeck 1983).

$$RS = \sum\nolimits_{i=1}^{n} \frac{S_i}{D_i} \tag{1}$$

$$MGT = \frac{\sum DN}{\sum N} \tag{2}$$

$$GI = \frac{\text{No of germinated seeds}}{\text{Days of first count}} + \ldots + \frac{\text{No of germinated seeds}}{\text{Days of final count}} \tag{3}$$

Where: Rs = germination rate, S_i = daily seed germination, D_i = number of day to n computation, n = number of days computation, MGT = mean germination time, N = the number of seeds, which were germinated on day D, D = the number of days counted from the beginning of germination and GI = germination index.

The statistical analysis of the experimental results was made by ANOVA and thereafter, if appropriate, by Duncan multiple range test of means at the 5% level, using SAS software, version 9.1.

Results and discussion

Germination percentage, germination rate, germination index and mean germination time

The effect of experimental factors and their interactions were significant on most mentioned criteria (Table 2). The seed nitrogen content was increased by increasing in nitrogen rates (0.95, 1.5, 1.67 and 1.7% for 0, 55, 110 and 165 kg N ha^{-1}, respectively). Interaction results indicated that the germination percentage, germination rate and germination index increased in intermediate levels of nitrogen and seed inoculation by biofertilizers in all levels of salinity (Tables 3 and 4). Moreover, the studied traits decreased by increasing salinity levels except of mean germination time (Tables 3 and 4).

Salinity reduces seed germination by limiting water absorption, reduction of storage substrates decomposition and disturbance in synthesis of storage proteins (Ramagopal 1990; Voigt et al. 2009). Moreover, the toxicity of sodium and chloride ions has an important role in reducing seed germination indices (Lynch and Läuchli 1988; Hara and Toriyama 1998; Zheng et al. 2009). Warraich et al. (2002) reported that seeds obtained from wheat plants nourished by sufficient amounts of nitrogen had a higher germination percentage and lower mean germination time. Similar results were observed by Yazdani et al. (2010) and Fallahi and Khajeh Hosseini (2011) on wheat. These observations are attributed to increasing grain protein content that causes better grain quality and vigour in wheat (Warraich et al. 2002). In our study, seed nitrogen content was increased by nitrogen application on parent plants. Suitable seed nitrogen content increases vigour of produced seedling and enhances their ability to avoid stresses such as drought (Naegle et al. 2005). In monocotyledons like wheat, gibberellic acid stimulates the synthesis of hydrolytic enzymes that are responsible for the hydrolysis of stored substrates for utilizing in seedling tissues synthesis (Soltani et al. 2006). It seems that suitable concentration of nitrogen in seeds induced the germination of wheat, because this element is one of the main components of these enzymes (Yazdani et al. 2010). Moreover, inoculation of seeds by biofertilizers can improve the germination criteria and increase stress tolerance in early seedling growth (Bacilio et al. 2003; Dalla Santa et al. 2004; Krishna et al. 2008; Fallahi et al. 2011). It seems that these functions are related to the production of growth phytohormones such as gibberellin and auxin by *Azotobacter* and *Azospirillum* bacteria (Bacilio et al. 2003; Pallai 2005; Mirshekari and Baser 2010).

Number of radicles per seedling, radicle length, plumule length and radicle to plumule length ratio

The highest values for most early seedling growth indices were obtained at intermediate (55 and 110 kg ha^{-1}) nitrogen rates at all levels of salinity (Table 3). The radicle to plumule length ratio increased with medium N rates at high salinity levels (Table 3). Moreover, seed inoculation by biofertilizers, especially Nitragin, had a positive effect on radicle and plumule length at all levels of salinity stress (Table 4). In general, salinity had a depressive effect on early seedling growth of wheat but its negative effects were decreased by sufficient application of nitrogen on parent plants and inoculation of achieved seeds by biofertilizers.

Harmful ions in the salt environment cause disturbances in plant metabolism and reduce germination indices (Gorham 1996). In our study, the radicle to plumule

Table 2. Results of analysis of variance (mean of squares) for germination indices of wheat.

Source of variation	df	Germination percentage	Germination rate	Germination index	Mean germination time	Radicle number
Nitrogen	3	268.5**	17.5**	1791.7**	4.5*	2.1**
Biofertilizer	2	213.2**	1.5^{ns}	155.2^{ns}	4.3*	1.9**
Salinity	3	2844.4**	67.7**	5995.2**	10.9**	58.4**
Nitrogen × Biofertilizer	6	112.3*	1.8^{ns}	63.3^{ns}	1.5^{ns}	0.5^{ns}
Nitrogen × Salinity	9	268.5**	2.4**	174.1*	3.9**	0.2^{ns}
Biofertilizer × Salinity	6	213.2**	1.2^{ns}	98.9^{ns}	1.6^{ns}	1.0**
Nitrogen × Biofertilizer × Salinity	18	112.3**	2.6**	169.0**	2.7*	0.5^{ns}
Error	96	45.8	0.9	84.7	1.4	0.4

Source of variation	df	Radicle length	Plumule length	Radicle to plumule length ratio	Radicle dry weight	Plumule dry weight	Total dry weight	Radicle to plumule dry weight ratio
Nitrogen	3	15.5**	2.9^{ns}	4.2^{ns}	0.00000473**	0.00000305^{ns}	0.00001408*	0.24^{ns}
Biofertilizer	2	8.7^{ns}	3.7^{ns}	0.2^{ns}	0.00000016^{ns}	0.00000205^{ns}	0.00000327^{ns}	0.37^{ns}
Salinity	3	1572.0**	648.9**	18.2**	0.00019613**	0.00048434**	0.00129373**	4.48**
Nitrogen × Biofertilizer	6	4.1^{ns}	3.6^{ns}	0.7^{ns}	0.00000077^{ns}	0.00000105^{ns}	0.00000278^{ns}	0.16^{ns}
Nitrogen × Salinity	9	6.7*	4.0*	2.7^{ns}	0.00000168*	0.00000213^{ns}	0.00000668^{ns}	0.23^{ns}
Biofertilizer × Salinity	6	12.2**	2.6*	1.0^{ns}	0.00000197**	0.00000449^{ns}	0.00001097*	0.21^{ns}
Nitrogen × Biofertilizer × Salinity	18	3.9^{ns}	2.9^{ns}	1.5^{ns}	0.00000101^{ns}	0.00000237^{ns}	0.00000594^{ns}	0.27^{ns}
Error	96	3.1	2.0	1.6	0.00000073	0.00000228	0.00000474	0.23

Note: Significant at: $^{**}p < 0.01$;$^{*}p < 0.05$; ns, not significant.

Table 3. Effect of different nitrogen rates and salinity levels on some germination indices of wheat seeds averaged over all biofertilizer treatments.

Salinity levels (MPa)	Nitrogen (kg ha^{-1})[1]	Germination percentage	Germination rate (12 h^{-1})	Mean germination time (day)	Germination index (seed day^{-1})	Radicle number	Radicle length (cm)	Plumule length (cm)	Radicle to plumule length ratio	Radicle dry weight (g)	Plumule dry weight (g)	Total dry weight (g)	Radicle to plumule dry weight ratio
0	0	65.5^{b}	2.39^{dc}	3.12^{bc}	30.8c-f	3.39ab	13.4bc	8.0^{b}	1.69c	0.00508^{ab}	0.00777ab	0.01285a	0.65a
	55	74.4^{a}	3.92^{ab}	2.41^{bc}	36.8cd	3.41ab	16.6a	10.4^{a}	1.61c	0.00584^{a}	0.00858a	0.01443a	0.72a
	110	74.7^{a}	3.53^{ab}	2.52^{bc}	39.0bc	3.22ab	14.7b	9.5^{ab}	1.55c	0.00493^{b}	0.00785ab	0.01278a	0.62a
	165	53.3^{c}	1.41^{de}	2.91^{bc}	22.5fgh	2.91b	12.7c	8.5^{b}	1.58c	0.00364^{c}	0.00698b	0.01062b	0.53a
−0.4	0	30^{d}	3.12^{bc}	3.46^{e}	33.0cde	3.68a	5.8d	4.8^{c}	1.26c	0.00312^{c}	0.00449c	0.00761c	0.67a
	55	50^{c}	4.49^{a}	2.24^{c}	51.8a	3.41ab	5.6de	3.6^{cd}	1.66c	0.00320^{c}	0.00322c	0.00633cd	0.82a
	110	52^{c}	3.79^{ab}	2.56^{bc}	46.5ab	3.18ab	5.2de	3.9^{cd}	1.41c	0.00295^{c}	0.00412c	0.00707cd	0.74a
	165	50^{c}	1.96^{d}	2.66^{bc}	26.3efg	2.81b	3.7e	3.0^{d}	1.39c	0.00210^{d}	0.00312c	0.00523d	0.63a
−0.8	0	50^{c}	0.91^{ef}	3.45^{bc}	18.8ghi	1.21cde	0.31f	0.12^{e}	2.15bc	0.00018^{e}	0.00001d	0.00019e	0.61a
	55	51.5^{c}	1.48^{de}	3.46^{b}	27.8d-g	1.65c	0.66f	0.19^{e}	3.05b	0.00018^{e}	0.00000d	0.00011e	0.00b
	110	53^{c}	1.82^{d}	3.21^{bc}	30.8c-f	1.39cd	0.88f	0.19^{e}	4.51a	0.00034^{e}	0.00081d	0.00115e	0.00b
	165	49.5^{c}	0.65^{ef}	3.64^{b}	14.3hij	1.0cde	0.26f	0.11^{e}	2.18bc	0.00000^{e}	0.00000d	0.00000e	0.00b
	0	48^{c}	0.31^{f}	5.33^{a}	9.8ij	1.0cde	0.17f	0.10^{e}	1.77bc	0.00000^{e}	0.00000d	0.00000e	0.00b
	55	50^{c}	0.46^{f}	3.21^{bc}	10.5ij	0.88de	0.17f	0.08^{e}	1.77bc	0.00000^{e}	0.00000d	0.00000e	0.00b
	110	50^{c}	0.51^{f}	3.73^{b}	11.3ij	0.88de	0.22f	0.10^{e}	1.88bc	0.00000^{e}	0.00000d	0.00000e	0.00b
	165	46^{c}	0.28^{f}	2.26^{c}	6.8j	0.55e	0.11f	0.05^{e}	1.11c	0.00000^{e}	0.00000d	0.00000e	0.00b

Note: Means follwed by the same letters in each column are not significantly different at the 0.05 level of probability. [1]Seed nitrogen content for 0, 55, 110 and 165 kgN ha^{-1} was 0.95, 1.5, 1.67 and 1.7%, respectively.

Table 4. Effect of biofertilizer seed priming and different salinity levels on some germination indices of wheat seeds averaged over all N fertilization levels of parent plants.

Salinity levels (MPa)	Biofertilizer	Germination percentage	Germination rate ($12\ h^{-1}$)	Mean germination time (day)	Germination index (seed day^{-1})	Radicle number	Radicle length (cm)	Plumule length (cm)	Radicle to plumule length ratio	Radicle dry weight (g)	Plumule dry weight (g)	Total dry weight (g)	Radicle to plumule dry weight ratio
0	Nitragin	78^{a}	3.51a	2.44c	38.9ab	3.3^{b}	14.7^{a}	9.4^{a}	1.54bcd	0.0046^{b}	0.00814a	0.01274ab	0.56a
	Biophosphorus	72^{b}	2.60ab	2.47c	29.3bc	3.2^{b}	16.0^{a}	9.8^{a}	1.67bcd	0.0054^{a}	0.00837a	0.01386a	0.69a
	Control	62^{b}	2.32bc	3.31abc	28.7bc	3.1^{b}	12.5^{b}	8.0^{b}	1.60bcd	0.0045^{b}	0.00687b	0.01141b	0.65a
−0.4	Nitragin	52^{c}	3.28ab	2.32c	38.9ab	4.0^{a}	5.9^{c}	4.6^{c}	1.35d	0.0032^{c}	0.00453c	0.00777c	0.60a
	Biophosphorus	50^{c}	3.22ab	2.63bc	40.6a	2.8^{b}	4.2^{cd}	3.1^{d}	1.47cd	0.0023^{d}	0.00310d	0.00542d	0.73a
	Control	49^{c}	3.51a	2.49c	38.9ab	3.0^{b}	5.0^{cd}	3.7^{cd}	1.48cd	0.0029^{cd}	0.00359cd	0.00650cd	0.82a
−0.8	Nitragin	52^{c}	1.32cd	2.94abc	23.1c	1.4^{c}	0.7^{e}	0.20^{e}	3.54a	0.00021^{e}	0.00000e	0.00021e	0.00b
	Biophosphorus	50^{c}	1.25cd	3.35ab	22.5c	1.2^{c}	0.4^{e}	0.10^{e}	2.75ab	0.00009^{e}	0.00001e	0.00011e	0.05b
	Control	49^{c}	1.07d	4.03a	23.1c	1.2^{c}	0.4^{e}	0.10^{e}	2.62abc	0.00013^{e}	0.00060e	0.00076e	0.02b
−1.2	Nitragin	47^{c}	0.44d	3.93a	11.2d	0.9^{c}	0.1^{e}	0.08^{e}	1.50cd	0.00000^{e}	0.00000e	0.00000e	0.00b
	Biophosphorus	46^{c}	0.46d	3.12abc	10.1d	0.8^{c}	0.2^{e}	0.09^{e}	1.75bcd	0.00000^{e}	0.00000e	0.00000e	0.00b
	Control	42^{c}	0.28d	3.90a	07.3d	0.8^{c}	0.1^{e}	0.08^{e}	1.66bcd	0.00000^{e}	0.00000e	0.00000e	0.00b

Note: Means followed by the same letters in each column are not significantly different at the 0.05 level of probability.

length ratio was increased by increasing the salinity levels. Many crops when exposed to osmotic stress expand their underground organs and reduce their aerial organs. Therefore, lowering of shoot to root ratios is thought to be a fundamental strategy among plant species to promote root exploration of soil and subsequent acquisition of water and nutrients, reducing stress impacts (Naegle et al. 2005; Fallahi et al. 2009). In the present study, seed nitrogen content was increased by nitrogen application on the parent plant. It has been reported that phytohormones, modulated by nitrogen nutrition, may affect the plant response to saline environments (Mansour 2000) and the positive effects of nitrogen on germination characteristics could be partly explained from this point of view. It is well documented that seedling vigour is strongly influenced by seed nutrition resources and application of nitrogen can improve seed resources (Naegle et al. 2005).

In the present study, radicle to plumule length ratio was increased by sufficient nitrogen application on parent plants. Another study has shown that shoot to root ratios is lowered soon after a nitrogen stress is imposed (Naegle et al. 2005). The negative effects of 165 kg N ha^{-1} on germination indices is probably caused by inducing an increasing number of tillers in wheat plants, thousand kernel weight of wheat seed was therefore reduced (18%), which corresponds with decreasing germination vigour. In a similar study on wheat, the findings were attributed to the toxic effects of high rates of nitrogen which could be induced by an imbalance in the germination hormones (Yazdani et al. 2010). But the seed nitrogen content at high nitrogen rate in the present study was not unusual (1.7%).

Some microorganisms, particularly beneficial bacteria and fungi, can improve plant performance in stressful environments (Kapoor et al. 2008). The beneficial effects of inoculation with *Azospirillum* are caused by better absorption of water and nutrients, based on a more developed root system (Dalla et al. 2004; Mirshekari and Baser 2010). Moreover, seed inoculation by biofertilizers has a positive effect on the production of plant growth hormones (Remus et al. 2000; Kizilkaya 2008). In similar studies, it has been reported that seed inoculation by Nitragin, Biophosphorus and *Azotobacter chroococcum* increased the number of root hairs, root and seedling length, root projection area, specific root area and dry matter concentration of wheat, sesame, canola and bean (German et al. 2000; Kizilkaya 2008; Mirshekari and Baser 2010).

Radicle dry weight, plumule dry weight, total dry weight and radicle to plumule dry weight ratio

Salinity stress had a negative effect on all mentioned indices (Table 3 and 4). Interaction results revealed that root dry weight was increased by application of 55 kg ha^{-1} N at low salinity levels (Table 3). Moreover, Nitragin seed priming improved partial radicle and plumule dry weight at all salinity levels (Table 4).

The inhibitory effect of salinity stress on seed germination is due to an osmotic effect and ion toxicity (Song et al. 2008; Zheng et al. 2009). Moreover, salt stress causes reactive oxygen species stress, leading to gradual peroxidation of lipid and antioxidant enzyme inactivation (Zheng et al. 2009) and finally reduces germination and plant growth. Osmotic adjustment is a strategy in many crops for salinity tolerance at the seedling growth stage; this strategy is energy consuming and therefore reduces plant growth (Penuelas et al. 1997; Karimi et al. 2004; Fallahi et al. 2009). Nitrogen is one of the main components of plant growth enzymes.

Therefore, sufficient application of this element induces these enzymes and reduces the negative effects of salinity (Yazdani et al. 2010). Parent plant conditions, such as nutrient availability, affect the seed quality and ability to germinate (Bai et al. 2003). In our study, seed nitrogen content and, therefore, seed protein and quality were increased at suitable nitrogen rates. Sufficient nitrogen application increases the vigour and nutrient reserves of achieved seeds and, as a result, seedlings produced from these seeds are more successful in germinating under environmental stress conditions (Hanslin and Eggen 2005; Yazdani et al. 2010). In another study, it was shown that lower seed nitrogen content resulted in lower seedling vigour and growth (Naegle et al. 2005). Nitragin biofertilizer increased root and seedling growth by producing growth phytohormones, natural enzymes and antibiotics (Mirshekari and Baser 2010). Therefore, seed priming by Nitragin had a positive effect on root dry weight under salinity conditions. In similar studies, it was reported that inoculation of wheat and bean seeds with *Azosprillum brasilense* and two biofertilizers (Phosphorein and Microbein) significantly increased shoot and root dry weight over control plants (Bacilio et al. 2003; El-Zeiny 2007).

Conclusion

The results revealed that sufficient application of nitrogen fertilizer on parent plants (up to 110 kg ha^{-1}) combined with achieved seeds priming by Nitragin, improved the salinity tolerance of wheat during germination and the early seedling growth stages, particularly at low salinity levels. The highest values for germination percentage and germination rate were obtained using 55 and 110 kg ha^{-1} nitrogen, respectively, whereas the lowest values of these indices were observed at 165 kg ha^{-1} N at all salinity levels. In addition, the highest and the lowest number of radicles per seedling, radicle length and radicle/plumule length ratio were obtained at mid (55 and 110 kg ha^{-1}) and high nitrogen rates (165 kg ha^{-1}), respectively. Root dry weight increased by application of 55 kg ha^{-1} N and Nitragin seed priming. In addition, the numbers of radicle per seedling, radicle and plumule length were increased $\sim$15% by Nitragin seed inoculation at all salinity levels.

References

Abbas G, Khan MQ, Jamil M, Tahir M, Hussain F. 2009. Nutrient uptake, growth and yield of wheat (*Triticum aestivum*) as affected by zinc application rates. Int J Agr Biol. 11:389–396.

Almansouri M, Kinet JM, Lutt S. 2001. Effect of salt and osmotic stresses on germination in durum wheat (*Triticum durum* Desf.). Plant Soil. 231:243–254.

Bacilio M, Vazquez P, Bashan Y. 2003. Alleviation of noxious effects of cattle ranch composts on wheat seed germination by inoculation with *Azospirillum* spp. Biol Fertil Soil. 38:261–266.

Bai Y, Tischler CR, Booth DT, Taylor EM. 2003. Variations in germination and grain quality within a rust resistant common wheat germplasm as affected by parental CO_2 conditions. Environ Exp Bot. 50:159–168.

Bennett SJ, Barrett-Lennard EG, Colmer TD. 2009. Salinity and water logging as constraints to salt land pasture production: a review. Agric Ecosyst Environ. 129:349–360.

Bremner JM, Breitenbeck GA. 1983. A simple method for determining ammonium in semi-micro Kjeldahl analysis of soils and plant materials using block digester. Comm Soil Sci Plant Anal. 14:905–913.

Dalla Santa OR, Hernandez RF, Alvarez GLM, Junior PR, Soccol CR. 2004. Azospirillum spp. inoculation in wheat, barley and oats seeds greenhouse experiments. Braz Arch Biol Technol. 47:843–850.

El-Zeiny OAH. 2007. Effect of biofertilizers and root exudates of two weed as a source of natural growth regulators on growth and productivity of bean plants (*Phaseolus vulgaris* L.). J Agr Biol Sci. 3:440–446.

Fallahi J, Ebadi MT, Ghorbani R. 2009. The effects of salinity and drought stresses on germination and seedling growth of clary (*Salvia sclarea*). Environ Str Agric Sci. 1:57–67.

Fallahi J, Khajeh Hosseini M. 2011. Effects of applying various levels of nitrogen on parent plants on the resistance to salinity stress in achieved seeds in *Triticum aestivum* L. cv. Gaskojen at germination period. J Agr Tech. 7(6):1743–1754.

Fallahi J, Rezvani Moghaddam P, Ghorbani R, Amiri MB, Fallah Pour F. 2011. Effects of seed priming by biofertilizers on the growth characteristics of three wheat cultivars at the germination period under greenhouse condition. In: Proceedings of the 10th Conference of the International Society for Seed Science. Brazilian Association of Seeds Technology, Salvador, Brazil. p. 286.

German MA, Burdman S, Okon Y, Kigel J. 2000. Effects of *Azospirillum brasilense* on root morphology of common bean (*Phaseolus vulgaris* L.) under different water regimes. Biol Fertil Soil. 32:259–264.

Gorham J. 1996. Mechanisms of salt tolerance of halophytes: halophytes ecologic agriculture. New York: Marcel Dekker. p. 30–35.

Hampson CR, Simpson GM. 1990. Effects of temperature, salt and osmotic pressure on early growth of wheat (*Triticum aestivum*). 1. Germination. Can J Bot. 68:524–528.

Hanslin HM, Eggen T. 2005. Salinity tolerance during germination of seashore halophytes and salt-tolerant grass cultivars. Seed Sci Res. 15:43–50.

Hara Y, Toriyama K. 1998. Seed nitrogen accelerates the rates of germination, emergence, and establishment of rice plants. Soil Sci Plant Nutr. 44:395–366.

Iqbal N, Ashraf HY, Javed F, Iqbal Z, Shah GH. 1998. Effect of salinity on germination and seedling growth of wheat (*Triticum aestivum* L.). Pak J Biol Sci. 3:226–227.

Jackson ML. 1967. Soil chemical analysis. New Delhi: Prentice Hall of India.

Kapoor R, Sharma S, Bhatnagar AK. 2008. Arbuscular mycorrhizae in micropropagation systems and their potential applications. Sci Hortic. 116:227–239.

Karimi G, Haydari-Sharifabad H, Asareh MH. 2004. Effects of salinity on germination, seedling establishment and proline content in pasture species of *Atriplex verrucifera*. Iran J Range Plant Breed Gen Res. 12:419–433.

Kizilkaya R. 2008. Yield response and nitrogen concentrations of springwheat (*Triticum aestivum*) inoculated with *Azotobacter chroococcum* strains. Ecol Eng. 33:150–156.

Krishna A, Patil CR, Raghavendra SM, Jakati MD. 2008. Effect of bio-fertilizers on seed germination and seedling quality of medicinal plants. Kar J Agr Sci. 21:588–590.

Lutts S, Almansouri M, Kinet JM. 2004. Salinity and water stress have contrasting effects on the relationship between growth and cell viability during and after stress exposure in durum wheat callus. Plant Sci. 167:9–18.

Lynch J, Läuchli A. 1988. Salinity affects intercellular calcium in corn root protoplasts. Plant Physiol. 87:351–356.

Maguire JD. 1962. Speed of germination-aid in selection and evaluation for seedling emergence and vigor. Crop Sci. 2:176–177.

Mansour MMF. 2000. Nitrogen containing compound and adaptation of plants to salinity stress. Plant Biol. 43:491–500.

Mirshekari B, Baser S. 2010. Effect of seed inoculation with Nitragin biofertilizer on germination and primary growth of rapeseed (*Brassica napus*), sesame (*Sesamum indicum*) and sunflower (*Helianthus annus* L.). J New Agr Sci. 5:91–100.

Naegle ER, Burton JW, Carter TE, Rufty TW. 2005. Influence of seed nitrogen content on seedling growth and recovery from nitrogen stress. Plant Soil. 271:329–340.

Pallai R. 2005. Effect of plant growth promoting rhizobacteria on canola (*Brassica napus*. L) and lentil (*Lens culinaris*. Medik) plants [MSc thesis]. University of Saskatchewan, Saskatoon, Canada. pp. 157.

Penuelas J, Isla R, Filella I, Araus JL. 1997. Visible and near-infrared reflectance assessment of salinity effects on barley. Crop Sci. 37:198–202.

Ramagopal S. 1990. Inhibition of seed germination by salt and its subsequent effect on embryonic protein synthesis in barley. J Plant Physiol. 136:621–625.

Remus R, Ruppel S, Jacob HJ, Hecht-Buchholz C, Merbach W. 2000. Colonization behavior of two entero-bacterial strains on cereals. Biol Fertil Soil. 30:550–557.

Salehzade H, Izadkhah Shishvan M, Ggiyasi M, Forouzani F, Abbasi Siyahjani A. 2009. Effects of seed priming on germination and seedling growth of wheat (*Triticum aestivum* L.). Res J Biol Sci. 4:629–631.

Soltani A, Gholipoor M, Zeinali E. 2006. Seed reserve utilization and seedling growth of wheat as affected by drought and salinity. Environ Exp Bot. 55:195–200.

Song J, Fan H, Zhao Y, Jia Y, Wang B. 2008. Effect of salinity on germination, seedling emergence, seedling growth and ion accumulation of a euhalophyte *Suaeda salsa* in an intertidal zone and on saline inland. Aquat Bot. 88:331–337.

Ungar IA. 1995. Seed germination and seed-bank ecology of halophytes: seed development and germination. New York: Marcel Dekker. p. 599–629.

Voigt EL, Almeida TD, Chagas RM, Ponte LFA, Viégas RA, Silveira JAG. 2009. Source–sink regulation of cotyledonary reserve mobilization during cashew (*Anacardium occidentale*) seedling establishment under NaCl salinity. J Plant Physiol. 166:80–89.

Warraich EA, Basra SMA, Ahmad N, Ahmed R, Aftab M. 2002. Effect of nitrogen on grain quality and vigour in wheat (*Triticum aestivum* L.). Int J Agr Biol. 4:517–520.

Yagmur M, Kaydan D. 2008. Alleviation of osmotic stress of water and salt in germination and seedling growth of triticale with seed priming treatments. Afr J Biotech. 7:2156–2162.

Yazdani R, Rezvani Moghaddam P, Koocheki A, Amiri MB, Fallahi J, Dayhimfar R. 2010. Effects of seed nourished by different levels of nitrogen, different biofertilizers and drought stress on germination indices and seedling growth of wheat (*Tritium aestivum*) cv. Sayonz. J Agroecol. 2:266–276.

Zheng C, Jiang D, Liu F, Dai T, Liu W, Jing Q, Cao W. 2009. Exogenous nitric oxide improves seed germination in wheat against mitochondrial oxidative damage induced by high salinity. Environ Exp Bot. 67:222–227.

Zhu JK. 2001. Plant salt tolerance. Trends Plant Sci. 6:66–71.