# Corn Germination and Seedling Characteristics as Influenced by Seed-Priming with Potassium Nano Chelate and Potassium Sulfate Fertilizers under Salinity Stress Conditions

**M. Zahedifar**

*Department of Rangeland and Watershed Management, College of Agriculture and Natural Resources, Fasa University, Fasa, IR of Iran*

*Corresponding author, Email: maryamzahedifar2000@yahoo.com*

**Abstract**

Seed germination is the most important stage of plant life that is influenced by various environmental factors e.g., salinity-stress. Seed priming can increase plant tolerance against salinity. A laboratory experiment of completely randomized design with three replicates was carried out to investigate the effect of seed priming with different sources of potassium ( K) on germination and seedling-characteristics of corn under salinity stress conditions. Treatments consisted of three levels of K nano chelate (0, 1.5 and 3%), three levels of K sulfate (0, 1.5 and 3%) and five levels of salinity (0, 0.5, 1, 1.5 and 2% prepared from equal equivalents of NaCl and $CaCl_2$). Seed priming increased germination-percentage (GP) and rate (GR), plumule-fresh-weight (PFW), radicle-fresh-weight (RFW) and plumule-dry-weight (PDW), significantly. The highest GR and GP were observed in seeds primed with 1.5% K-nano-chelate without any salinity-stress. Whereas, the lowest-value of the aforementioned traits were obtained in non-primed-seeds subjected to the highest-level of applied-salinity, i.e., 2%. By increasing salinity-levels, mean-germination-time (MGT) of primed and non-primed seeds increased. However, the effect of salinity on primed-seeds was less than that of non-primed-seeds. The highest PFW was obtained with priming of seeds with 1.5% K-nano-chelate at salinity-level of 0.5%. Whereas, its lowest-value was obtained in seeds primed with 3% K-nano-chelate at salinity-level of 2%. The effect of salinity on PDW of primed-seed with K-nano-chelate or K-sulfate was less than that of non-primed-seeds. Seed-priming with low level (1.5%) of applied K-nano-chelate or K-sulfate increased radicle-length (RL); whereas, high-level (3%) of applied K-nano-chelate or K-sulfate was not effective, significantly. Our findings emphasis seed-priming is a useful way to increase seedling-tolerance under salinity stress conditions.

***Keywords:*** germination rate, germination percentage, mean germination time, plumule fresh and dry weight, radicle length

## Introduction

Soil salinization is a problem in many parts of the world. FAO (2007) reported that about 20 % of the total agricultural lands are affected by salt, accounting for more than 6% of the world's total land area. Saline soils often occur in irrigated land in semi-arid or arid zones of the world. About 50% of irrigated areas of the world are either salinized or have the potential to be so in future. Generally, salinity affects crop yield and beneficial soil biota, leading to economic losses. It affects the growth and survival of microorganisms, plants and soil animals (Yuan et al., 2007; Kadukova and Kalogerakis, 2007). Seed germination is one of the most important stages of plant life cycles. Meanwhile it is an important process in seedling growth (De Villiers et al., 1994). This stage of growth is strictly influenced by environmental factors, especially, temperature, humidity and salinity so that many researches believed that between plant growth stress, salinity may affect germination and seedling growth through reduced osmotic potential, increased availability of a toxic ion, and reduced absorption of nutrients because of ion imbalance (Hayward and Bernstein, 1958; Soltani et al., 2008). A high salt level interferes with the germination of seeds. Salinity acts like drought on plants, preventing roots from performing their osmotic activity where water and nutrients move from an area of high concentration. Therefore, because of the salt levels in the soil, water and nutrients cannot move into the plant root (Bliss et al., 1984). Germination is delayed and reduced when salt stress exceeds a critical level and it is varies with species, genotype, environmental conditions, osmotic potential and specific ions (Ungar, 1978). Rahman et al (2008) assumed increasing salt concentration not only prevents the germination of the seeds but also extends the germination time by delaying the starting of germination.

Seed priming is beneficial technique to improve seed germination and growth in stress conditions in many crops (Halmer, 2003). The theory of seed priming was proposed by Heydecker (1973). Seed priming is a controlled hydration treatment in which seeds are allowed to imbibe before radical protrusion (Bradford, 1986) and improves the germination rate, uniformity of germination, and sometimes greater total germination percentage (Basra et al., 2006; Farooq et al., 2006). This hydration is sufficient to permit pre-germinative metabolic events but insufficient to allow radicle protrusion through the seed coat (Heydecker et al., 1977). Priming allows some of the metabolic processes necessary for germination to occur without germination take place. In priming, seeds are soaked in different solutions with high osmotic potential (Ghobadi et al., 2012). After treatment with initiators, plant seeds exhibit not only enhanced emergence rate and even emerge of seedlings (Bradford, 1986) but also improved resistance or tolerance to cold (Yuan-Yuan et al., 2010 after Lu and Fu, 1990), drought (Yuan-Yuan et al., 2010 after Lia and Zhu, 1997 and Wang et al., 2004) and salt (Sivritepe et al., 1999; Yuan-Yuan et al., 2010 after Ruan et al., 2003). This technique has become a common seed treatment that can improve rate, percentage and uniformity of germination or seedling emergence, mostly under unfavorable environmental circumstances. Harris et al. (1999) showed that seed priming led to better establishment and growth, earlier flowering and greater yield. Nowadays hydro priming, osmopriming and solid-matrix priming are three technologies used for to seed priming (Halmer, 2003; Ashraf and Foolad, 2005). Osmotic priming is widely used to improve seed quality. This priming is the improvement of physiological and biochemical events in seeds during suspension of germination by low osmotic potential and decreases solute leakage during seed imbibition. Fazliani (2011) reported that primed pea seeds with PEG (8000) significantly affect germination when compared with control. So that DNA replication, RNA and protein synthesis will be increased which result in more level of ATP synthesis, cell division, embryo growth and cell membrane repairing and lower level of leaching of cytoplasm solutes. The composition and quantity of membrane phospholipids may also change during priming. However, it is uncertain whether the reduction in electrolyte leakage is caused by changes in membrane structure or simply by washing electrolytes from seeds during priming (Moeinzadeh et al., 2010). Many researchers have reported the improved effects of priming on seed germination and early seedling growth in crops. For instance Arif et al. (2007) reported that seed hydro priming has been successfully demonstrated to improve germination and emergence in seeds of many crops, particularly seeds of vegetables and small seeded grasses. Aminifar et al. (2013) showed that seed priming with 20 g K $L^{-1}$ treatments increased plumule length, plumule/radicle ratio and germination rate, significantly. Sanchez et al. (2001) reported seedling root length of cucumbers and peppers increased, significantly by hydro priming. Ahmadvand et al. (2012) illustrated that at the highest level of salinity stress, soybean radicle length of non-primed seeds was reduced by 65 %, whereas, the decline was 26 % in primed seeds with potassium nitrate. They reported that at the salinity levels of 0 and 8 dS $m^{-1}$, plumule length of primed seeds was more than that of non-primed seeds by

6.9 and 44.1 %, respectively. Use of nano fertilizers increases agricultural production and their quality. Moreover, they protect environment from pollution. Plants can absorb nano-composites completely and resolve needs and shortages. For this reason nano-composites can be a good alternative to chemical fertilizers. Peyvandi et al. (2011) indicated that Ocimum basilicum growth parameters increased in plants treated with 7.5 Kg Fe fertilizer $ha^{-1}$ and with less than 5 Kg nano-Fe-fertilizer $ha^{-1}$. They reported that the highest shoot, root and leaf fresh weight, shoot, root and leaf dry weight and root length were observed with application of 1 Kg $ha^{-1}$ of nano-Fe-fertilizer. The effect of some chemical fertilizers on seed germination and growth of plants have been studied in many researches, however not much researches has been conducted about the effect of seed priming with nano-fertilizers on seed germination. On the other hand, salinity is one of the major limiting factors in seed germination of plants. Therefore, the objective of this study was to evaluate the effect of seed priming with two sources of potassium consisted of its nano chelate and sulfate on seed germination characteristics of corn under salinity conditions.

## Materials and Methods

### Experimental Design

To determine the effect of seed priming with potassium nano-chelate and sulfate on germination and emergence traits of corn under salinity stress, a factorial laboratory experiment of completely randomized design with 3 replicates was carried out. Treatments consisted of three levels of priming with $K_2SO_4$ (0, 1.5 and 3%) and three levels of priming with K-nano-chelate including 27% K (0, 1.5 and 3%) and 5 salinity levels of 0, 0.5, 1, 1.5 and 2% prepared from the equal equivalents of NaCl and $CaCl_2$.

### Germination Test

Seeds of corn (*Zea mays* L. Var SC 704)) sterilized with 3% sodium hypochlorite for three minutes then washed with distilled water. Then seeds were placed in pots saturated with solutions of aforementioned K-nano-chelate and K-sulfate for four hours. Ten seeds were placed on filter paper in a glass petri dish of 9 cm diameter and added 16 ml salinity solution of desired treatment was added. Seed germination was recorded daily at a certain time (A seed was considered as germinated when its radicle emerged by about 2 mm in length). After the $12^{th}$ day, radicle and plumule lengths and fresh weights were measured. Then seedling radicles and plumules were dried in oven for 48 hours at 72°C and their dry weights were measured.

In this study germination percentage (GP) and germination rate (GR) were calculated according to the International Seed Testing Association (ISTA, 1996) method as shown in equations below

$$GP = \left(\frac{\text{Number of normally germinated seeds}}{\text{Total number of seed}}\right)\times 100$$

$$GR = \sum_{i-1}^{j} \frac{n_i}{D_j}$$

Where $n_i$ is the number of seeds emerged on $i^{th}$ day and $D_i$ is the number of days counted from the beginning of the experiment. J is set to 12 days in this experiment.

Also, mean germination time (MGT) was calculated using the following equation (Ellis and Roberts, 1981):

$$MGT = \frac{\sum n.d}{\sum n}$$

Where n is the number of seeds germinated on day and d is the number of days from the start of experiment.

Data were analyzed statistically using MSTATC (Michigan State University, East Lansing, MI, USA) and Excel (Microsoft, Redmond, WA, USA) software packages and the mean values of seed traits were compared statistically using Duncan's Multiple Range Test at probability level of 0.05.

## Results and Discussion

### Germination Rate (GR)

Effect of salinity stress and seed priming with potassium nano-chelate and sulfate on germination rate of corn has been showed in Figure 1. Comparison of mean germination rates in different salinity levels showed that the mean germination

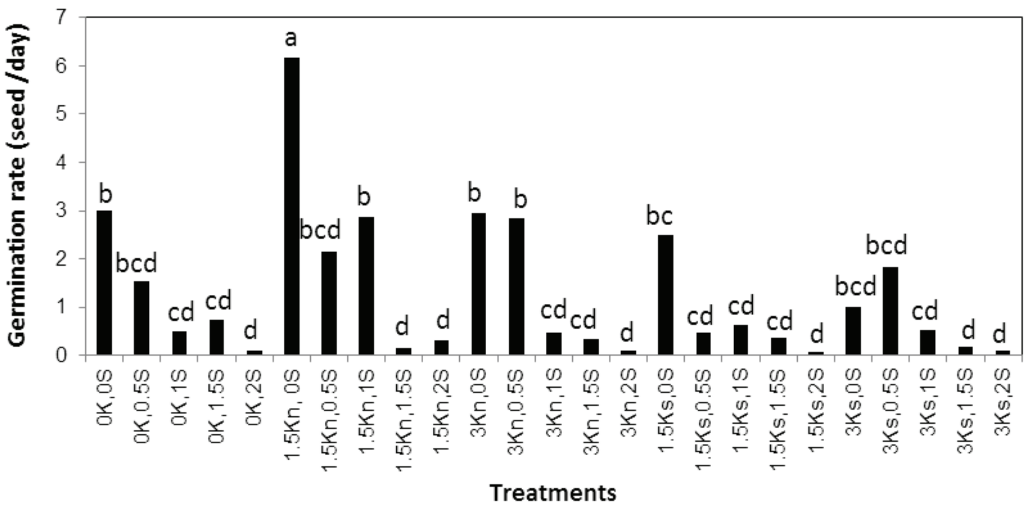


**Figure 1** Effect of salinity stress and K priming on germination rate of corn seeds as compared to that of control, 0K, 0S. Treatments consisted of salinity (0S, 0.5S, 1S, 1.5S and 2S, shows salinity stress of 0, 0.5, 1, 1.5, and 2 %, respectively), potassium nano-chelate (0K, 1.5Kn and 3Kn shows seed priming with 0, 1.5 and 3% of K nano chelate) and potassium sulfate (0K, 1.5Ks, and 3Ks shows seed priming with 0, 1.5 and 3 % of K sulfate, respectively). Columns by the same lower letters are not statistically different at the probability level of 0.05 by Duncan's Multiple Range Test.

rate of seeds decreased significantly as salinity increased. So that application of 2% salinity decreased GR of corn by about of 95% as compared to that of control. Our results were in close agreement with the findings of Ramezani and Fatemi-Nik (2013) who reported that increasing concentrations of poly ethylene glycol (PEG), potassium nitrate and sodium chloride resulted in reduced germination rate, suggesting that increased salinity increases osmotic pressure and reduces water uptake by corn seeds. Results show that the highest mean values of GR of seeds was obtained in seeds soaked in 1.5% potassium nano-chelate. In general the mean value of GR in K-primed seeds was significantly higher than that of non-primed seeds. Positive effect of seed priming was only observed at low applied level of potassium nano-chelate i. e. 1.5%. In other words the high level of applied K-nano-chelate did not affect it positively. This would be probably due to the presence of anion and cation amounts more than usual that having toxic effects on growth and decrease the water potential. As a consequence plant cannot absorb water. Our results were in close agreement with the findings of some investigators such as Aminifar et al. (2013) who reported that corn seed priming especially at the level of 2 g $L^{-1}$ K as solupotasse had the positive effects on GR and increased it, significantly. Nascimento (2003) also revealed that priming in salt solutions of potassium nitrate or phosphate led to faster germination than priming in mannitol or poly ethylene glycol. Whereas, the result was not in accordance to the findings of Ramezani and Rezaei Sokht-Abandani (2013) who stated that the maximum and minimum GR of corn seeds were obtained at control and pretreatment of seeds with 2% KCl.

Results showed that the GR of K primed seeds decreased, significantly as salinity increased. Baninasab and Baghbanha (2013) showed that seed priming of cucumber seeds with 1 mM salicylic acid under salt stress led to salt tolerance especially at higher concentrations of NaCl. Shannon and Grieve (1999) illustrated that low salt concentration decreases the germination rate. Turhan et al. (2011) showed that germination rate of some spinach cultivars were not considerably decreased between non salty and low NaCl concentrations, while increased NaCl concentrations after 50 mM caused significant losses in germination rate. Our results revealed that at the highest level of salinity, the reduction of GR decreased as seed primed with 1.5% K-nano-chelate.

## Germination Percentage (GP)

The effects of corn seed priming with K-nano chelate and sulfate under salt stress on GP were summarized in Figure 2. Results showed that the mean value of GP decreased significantly by about of 83% as compared to that of control when salinity increased up to 2%. Turhan et al. (2011) showed that increasing NaCl concentration at levels of higher than 100 mM decreased GP of spinach, significantly. Khan et al. (2000) illustrated that in many plant types, GP occurs in non-salty conditions and its reduction depends on the increasing salt concentrations. Seed germination begins with water intake but with increasing salt, it is decreased (Othman, 2005). The decrease in seed water intake in saline conditions, osmotically and by the ion toxicity with accumulation of Na and Cl ions highly around the seed, prevents the seed germination (Murillo-Amodor et al., 2002).

The mean value of GP in seeds subjected to priming with K-nano chelate was significantly more than that of potassium sulfate; meanwhile, lower level of applied K was more effective than the higher levels. Soltani et al. (2008) showed that hydro priming of cotton seeds increased GP as compared to that of control. The same results were also reported by Kaya et al. (2006) for sunflower plants.

The highest GP (about 44%) was observed in seeds primed with 1.5% K-nano chelate without any salinity stress; whereas, the lowest GP was observed with application of 2% salinity (Figure 2). At the highest level of applied salinity (2%), reduction of GP in seeds primed with 1.5% K-nano chelate was lower than that of seeds without any priming treatment (6.67 vs. 3.33%).

Ghodrat and Rousta (2012) showed that salinity decreased GR and GP of corn seeds and priming with gibberellic acid ($GA_3$) had no significant effect on seed germination under saline conditions.

## Mean Germination Time (MGT)

Results showed that MGT of primed and non-primed seeds increased under salinity conditions, but the effect of salinity on MGT of primed seeds was less than that of non-primed seeds (Figure 3). In other words, application of 2% salinity resulted in a 3.9 and 3 fold increases in MGT of non-primed and 1.5% K-nano chelate primed seeds in comparison to that of control, respectively. In addition, results showed that the mean value of MGT in seeds subjected to priming with 1.5% K-nano chelate was the lowest in comparison to that of the other levels of potassium nanochelate or sulfate. Bocian and Holubowicz (2008) also showed that seed priming with $KNO_3$ for 6 and 12 hours, improved seed germination of tomato and reduced the MGT. Ramezani and Rezaei Sokht-Abandani (2013) revealed that the highest and

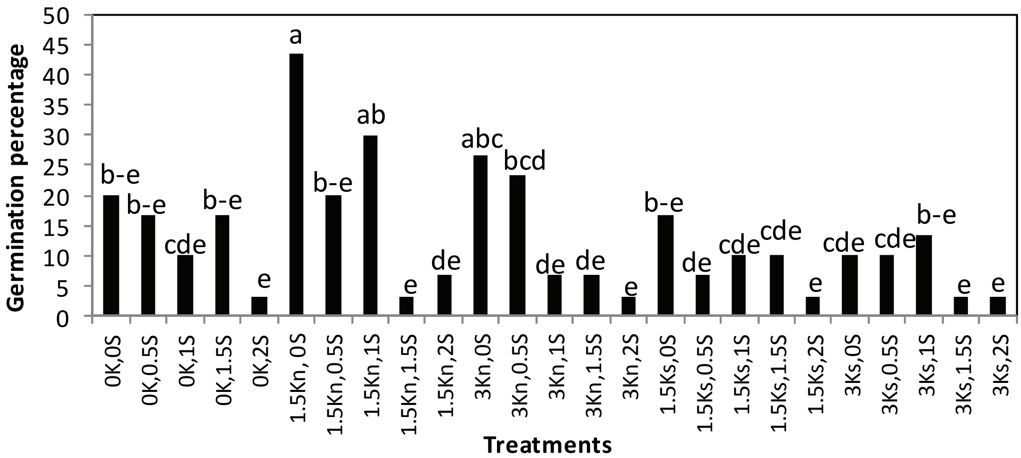


**Figure 2** Effect of salinity stress and K priming on germination percentage of corn seeds as compared to that of control, 0K, 0S. Treatments consisted of salinity (0S, 0.5S, 1S, 1.5S and 2S, shows salinity stress of 0, 0.5, 1, 1.5, and 2 %, respectively), potassium nano-chelate (0K, 1.5Kn and 3Kn shows seed priming with 0, 1.5 and 3% of K nano chelate) and potassium sulfate (0K, 1.5Ks, and 3Ks shows seed priming with 0, 1.5 and 3 % of K sulfate, respectively). Columns by the same lower letters are not statistically different at the probability level of 0.05 by Duncan's Multiple Range Test.

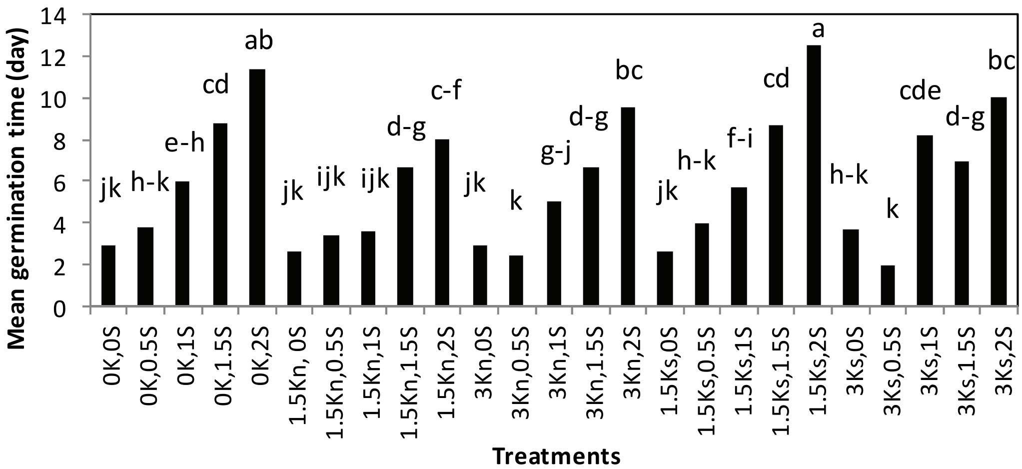


**Figure 3** Effect of salinity stress and K priming on mean germination time of corn seeds as compared to that of control, 0K, 0S. Treatments consisted of salinity (0S, 0.5S, 1S, 1.5S and 2S, shows salinity stress of 0, 0.5, 1, 1.5, and 2 %, respectively), potassium nano-chelate (0K, 1.5Kn and 3Kn shows seed priming with 0, 1.5 and 3% of K nano chelate) and potassium sulfate (0K, 1.5Ks, and 3Ks shows seed priming with 0, 1.5 and 3 % of K sulfate, respectively). Columns by the same lower letters are not statistically different at the probability level of 0.05 by Duncan's Multiple Range Test.

lowest MGT of corn seeds were obtained for pretreatment with 2% potassium chloride and water by about of 4.20 and 2.23 days, respectively. Arif (2005) reported that MGT was accelerated by hydro priming without changing amount of water uptake in watermelon seeds. Turhan et al. (2011) reported that MGT of spinach increased with increasing salinity levels after 50 mM.

**Plumule Fresh Weight (PFW)**

Table 1 shows the effect of salinity stress and seed priming with K treatments on plumule fresh weight (PFW) of corn. Results indicated that increasing of salinity led to significant decrease of PFW in primed and non-primed seeds. Our findings showed that the mean value of RFW decreased significantly by about of 8, 28, 45 and 56% compared to that of control at salinity levels of 0.5, 1, 1.5 and 2 %. Bijeh Keshavarzi et al. (2011) showed that increasing the level of salinity from 0 to 150 mM, decreased the fresh weight of spinach seedling, significantly. It has been reported that salinity resulted in closing stomata, reduction of water entrance into plant and plant photosynthesis, as a consequence the weight of plant decreased (Massai et al., 2004). Priming of seeds with 1.5% K-nano chelate or sulfate increased the mean value of RFW significantly by about of 25 and 12% compared to that of control, respectively. Whereas, seed priming with 3% of K-nano chelate or sulfate did not affect RFW, significantly. The highest PFW (420 mg) was obtained in seeds subjected to priming with 1.5% K-nano chelate at 0.5% salinity level; whereas, the lowest PFW (113 mg) was observed in primed seeds with 3% K-nano chelate at salinity level of 2%. Ghodrat and Rusta (2012) reported that seed socking of corn with 1.5 mg $L^{-1}$ GA3 increased the total fresh weight of seeds subjected to salinity conditions of 10, 12 and 15 dS m-1 by about of 20, 28 and 40%, respectively. Ramezani and Rezaei Sokht-Abandani (2013) determined the effects of various different priming techniques on germination traits and seedling weight of corn. They showed that the highest record of seedling fresh weight (1.27 g) was observed in control; whereas, the lowest seedling fresh weights (0.92 and 0.87 g) were obtained in seeds primed with 10% polyethylene glycol and 2% KCl, respectively.

**Radicle Fresh Weight (RFW)**

Effects of salinity stress and seed priming with potassium-nano chelate and sulfate on radicle fresh weight were summarized in Table 2. Results showed that RFW decreased significantly by about of 47, 57, 69 and 78% compared to that of control when seeds subjected to salinity levels of 0.5, 1, 1.5 and 2 %, respectively. Seed priming led to more positive effects on seedling RFW so that the PFW of primed seeds were significantly more than that

**Table 1** Effect of salinity stress and K priming on plumule fresh weight, PFW, (mg) of corn.

| Salinity (%) | Priming treatment | | | | | Mean |
|---|---|---|---|---|---|---|
| | K-nano chelate (%) | | | K-sulfate (%) | | |
| | 0 | 1.5 | 3.0 | 1.5 | 3.0 | |
| 0 | 257 cde | 340 b | 320 bc | 357 ab | 190 d-i | 293 A |
| 0.5 | 213 d-g | 420 a | 210 d-g | 267 cd | 237 def | 269 A |
| 1.0 | 250 c-f | 233 def | 150 ghi | 240 def | 177 e-i | 210 B |
| 1.5 | 200 d-h | 170 f-i | 117 i | 177 e-i | 147 ghi | 162 C |
| 2.0 | 127 hi | 140 ghi | 113 i | 123 hi | 140 ghi | 129 D |
| Mean | 209 BC | 261 A | 182 C | 233 AB | 178 C | |

Mean in each row or column followed by the same lowercase or capital letters are not significantly different ($P < 0.05$) by Duncan's Multiple Range Test.

**Table 2** Effect of salinity stress and K priming on radicle fresh weight, RFW, (mg) of corn.

| Salinity (%) | Priming treatment | | | | | Mean |
|---|---|---|---|---|---|---|
| | K-nano chelate (%) | | | K-sulfate (%) | | |
| | 0 | 1.5 | 3.0 | 1.5 | 3.0 | |
| 0 | 150 ab | 163 ab | 60 de | 190 a | 80 cd | 129 A |
| 0.5 | 50 de | 60 de | 40 de | 63 de | 130 bc | 69 B |
| 1.0 | 50 de | 50 de | 43 de | 53 de | 80 cd | 55 BC |
| 1.5 | 40 de | 13 e | 23 de | 80 cd | 43 de | 40 CD |
| 2.0 | 23 de | 13 e | 23 de | 40 de | 40 de | 28 D |
| Mean | 63 B | 60 B | 38 C | 85 A | 75 A | |

Mean in each row or column followed by the same lowercase or capital letters are not significantly different ($P<0.05$) by Duncan's Multiple Range Test.

of non-primed seeds (except at high level of salinity for seeds primed with 1.5% K-nano chelate. Results showed that the maximum RFW of 190 mg was obtained for seeds primed with 1.5% K-sulfate without any salinity stress.

**Plumule Dry Weight (PDW)**

Results indicated that high level of salinity stress i.e., 1.5 and 2 % decreased PDW of corn, significantly. Redmann and Belyk (1994) showed that the reduction in plumule and radicle dry weight of canola which is results of enhancing the salinity concentration is a normal phenomenon and probably it is the result of low water absorbance by germinating seeds. Anbumalarmathi and Mehta (2013) demonstrated that plumule dry weight of rice had inverse relationship with salt concentration. Bijeh Keshavarzi et al. (2011) illustrated that with increasing salinity up to 150 mM, seedling dry weight of spinach decreased. Finding revealed that the adverse effect of salinity on PDW of primed seed (with K-nano chelate and sulfate) was less than that of non-primed seeds, so that at 2% salinity level, PDW of non-primed seeds decreased by about of 4.16 folds, but in primed seeds it decreased by about of 1.33, 1.29, 3.63 and 1.63 folds in seeds primed with 1.5 and 3% K-nano chelate and 1.5 and 3% K-sulfate, respectively. The highest PDW was observed in seed primed with 3% K-nano chelate at salinity level of 1% (Table 3). Ahmadvand et al. (2012) showed that seedling dry weight of soybean seeds subjected to priming with potassium nitrate was more than that of non-primed seeds. Afkari (2010) found that seedlings dry weight of NaCl primed seeds of sunflower were more than non-primed seeds at all of their studied

**Table 3** Effect of salinity stress and K priming on plumule dry weight, PDW, (mg) of corn.

| Salinity (%) | Priming treatment | | | | | Mean |
|---|---|---|---|---|---|---|
| | K-nano chelate (%) | | | K-sulfate (%) | | |
| | 0 | 1.5 | 3.0 | 1.5 | 3.0 | |
| 0 | 25.0 b | 14.7 b | 14.7 b | 40.0 b | 18.0 b | 22.5 AB |
| 0.5 | 12.3 b | 25. 7 b | 12.2 b | 19.0 b | 23.3 b | 18.5 AB |
| 1.0 | 8.67 b | 16. 7 b | 70.0 ab | 17.7 b | 14.0 b | 25.4 AB |
| 1.5 | 7.23 b | 11.0 b | 11.3 b | 13.3 b | 12.5 b | 11.1B |
| 2.0 | 6.00 b | 11.0 b | 11.3 b | 11.0 b | 11.0 b | 10.1 B |
| Mean | 11.8 B | 15.8 A | 23.9 A | 20.2 A | 15.8 A | |

Mean in each row or column followed by the same lowercase or capital letters are not significantly different ($P < 0.05$) by Duncan's Multiple Range Test.

**Table 4** Effect of salinity stress and K priming on plumule length, PL, (mm) of corn.

| Salinity (%) | Priming treatment | | | | | Mean |
|---|---|---|---|---|---|---|
| | K-nano chelate (%) | | | K-sulfate (%) | | |
| | 0 | 1.5 | 3.0 | 1.5 | 3.0 | |
| 0 | 75.0 a | 75.0 a | 1.67 d | 63.7 ab | 2.00 d | 43.5A |
| 0.5 | 50.0 b | 6.33 d | 32.7 c | 58.7 ab | 53.3 b | 40.2 A |
| 1.0 | 5.00 d | 7.00 d | 4.00 d | 2.00 d | 2.00 d | 4.00 B |
| 1.5 | 8.33 d | 4.00 d | 4.00 d | 3.00 d | 3.67 d | 4.60 B |
| 2.0 | 3.00 d | 2.00 d | 3.00 d | 1.00 d | 3.00 d | 2.40 B |
| Mean | 28.3 A | 18.9 BC | 9.07 D | 25.7 AB | 12.8CD | |

Mean in each row or column followed by the same lowercase or capital letters are not significantly different ($P<0.05$) by Duncan's Multiple Range Test.

salinity levels. Mohammadi (2009) revealed that seed priming of soybean with $KNO_3$ increased seedling dry weight significantly than control. Ghodrat and Rousta (2012) determined the effect of priming with GA3 on germination and growth of corn under saline conditions. Their results showed that seed priming with GA3 increased dry weight of seedling.

**Plumule Length (PL)**

Results indicated that salinity levels of 1, 1.5 and 2% decreased PL, significantly by about of 91, 89 and 94% as compared to that of control (Table 4). In another word only salinity level of 0.5% did not affect PL, significantly. The effect of seed priming with 1.5% K-nano chelate and K-sulfate on PL was the same at non-stressed salinity conditions (Table 4). Similar results were reported by Ahmadvand et al., (2012). The maximum value of PL was observed in seeds primed with 1.5% K-nano chelate without any salinity stress, however, it was not statistically different from that of control.

**Radicle Length (RL)**

The effect of salinity stress and seed priming with K-nano chelate and sulfate on RL of corn were summarized in Table 5. Results showed that RL of seedling decreased significantly by 67, 91 and 94% in response to application of the salinity levels of 1, 1.5 and 2%. Bijeh Keshavarzi et al. (2011) also reported that with increasing salinity up to 150 mM, seedling radicle and plumule length of spinach decreased. Idikut (2013) showed that increasing salt concentration decreased radicle length, coleoptile length and plumula length of maize. Khan and Ungar (1998) stated that salinity results in osmotic pressure that leads to reduction in water absorbance, as a consequence cell division and

**Table 5** Effect of salinity stress and K priming on radicle length, RL, (mm) of corn.

| Salinity (%) | Priming treatment | | | | | Mean |
|---|---|---|---|---|---|---|
| | K-nano chelate (%) | | | K-sulfate (%) | | |
| | 0 | 1.5 | 3.0 | 1.5 | 3.0 | |
| 0 | 37.3 c | 81.0 a | 2.67 d | 70.0 a | 2.00 d | 38.6 A |
| 0.5 | 51.7 b | 3.00 d | 57.3 b | 57.7 b | 28.4 c | 39.6 A |
| 1.0 | 2.33 d | 55.3 b | 2.00 d | 2.00 d | 2.00 d | 12.7 B |
| 1.5 | 2.00 d | 4.33 d | 3.33 d | 2.00 d | 6.33 d | 3.60 C |
| 2.0 | 2.00 d | 2.00 d | 2.00 d | 2.00 d | 3.00 d | 2.20 C |
| Mean | 19.1 B | 29.1 A | 13.5 C | 26.7 A | 8.33 C | |

Mean in each row or column followed by the same lowercase or capital letters are not significantly different ($P < 0.05$) by Duncan's Multiple Range Test.

differentiation reduce and reduction of plumule and radicle length will be reasonable. They also concluded that NaCl concentration had more limiting effect on embryo tissues appearance than the other salinity factors. Seed priming with K-nano chelate and sulfate, increased RL in comparison to that of non-primed seeds; whereas, high level (3%) applied of K-nano chelate and sulfate was not effective. Ahmadvand et al. (2012) showed that with increasing of salinity stress, radicle and plumule length of soybean cultivars reduced, significantly. Furthermore, they indicated that at the conditions of non-salinity stress, radicle length of both primed and non-primed seeds were the same, statistically, and increasing the level of salinity from 4 to 8 dS $m^{-1}$, did not adversely affect the radicle length of primed seeds, significantly. Hopper et al. (1979) indicated that in primed seeds because of more water uptake efficiency and faster metabolic activity in terms of germination, radicle and plumule appeared faster. Salehi and Tamaskani (2008) reported that nano silver seed priming increased germination percentage, plumule and radicle length of wheat.

## Conclusions

Results indicated that seed priming with potassium nano chelate or sulfate improved seedling traits of corn under salinity stress conditions. However, the effectiveness of K-nano chelate was significantly more than that of K-sulfate. Among applied treatments, application of 1.5% K-nano chelate was the most effective. Our findings emphasis seed priming is a useful way to increase seedling tolerance under salinity conditions.

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