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Tomato Halopriming for Improving Germination and Seedling Growth under Normal and Saline Conditions

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Abstract

This study was carried out to investigate the effects of halopriming on germination and seedling growth of tomato cv. Ace 55VF seeds under normal and saline conditions. Halopriming was done by exposing seeds to aerated solutions of NaCl (0.05 M and 6M) and KNO_3 (25mM and 2%). There was no significant effect of halopriming treatments on germination percentage, however, halopriming had a significant effect on germination rate and mean germination time. Halopriming with 2% KNO_3 increased germination rate and decreased mean germination time. Also, the 2% KNO_3 halopriming treatment had the highest significant values for No of leaves, stem length and diameter, fresh and dry weights of shoot and root, and leaf chlorophyll content. In general, KNO_3 halopriming treatments had a positive effect on germination and seedling growth as compared to NaCl halopriming. Under saline conditions, halopriming increased final germination percentage and improved seedling growth compared to unprimed treatment. NaCl halopriming treatment increased adaptation of seedlings to salt tolerance compared to control treatment (unpriming) followed by KNO_3 halopriming treatment. However, final germination percentage was highest significantly with KNO_3 halopriming. Therefore, it can be said that the germination and seedling growth of tomato are improved by halopriming treatments, especially with KNO_3, under normal and saline conditions.

Keyword: Tomato, halopriming, germination, seedling growth, salinity**.**

Introduction

Salinity is a major challenging environmental constraint to crop productivity world-wide, with adverse effects on germination, plant vigor and crop yield (**Munns and Tester, 2008**). The high salinity of the used groundwater in irrigation is considered one of the major limitations on agricultural development in many countries (**Ghassemi *et al*., 1995**). Due to increased salinity problems, the need to develop crops with higher salt tolerance has increased strongly.

The cultivated tomato, *Solanum lycopersicum* L., is moderately sensitive to salinity at all stages of development, including seed germination and early seedling growth stage, which is generally the most sensitive stage to salt stress and is a critical stage for the establishment of plants growing in saline soil. Salinity is responsible for both inhibition or delayed seed germination and seedling establishment (**Foolad, 2004**). Salinity may affect the germination of seeds either by creating a lower osmotic potential external to the seed preventing water uptake, or through the toxic effects of Na^+ and Cl^- ions on the germinating seed (**Khajeh-Hosseini *et al*., 2003**).

Rapid and uniform seed germination and early-seedling growth are of vital importance for crop production in saline soils. Various pre-sowing seed priming treatments have been used to improve seed establishment by reducing the germination time, increasing the rate and uniformity of germination and, in some cases, to enhance crop yield. These priming treatments include hydropriming, halopriming, thermopriming, solid matrix priming, and biopriming (**Ashraf and Foolad, 2005**). In halopriming, the seeds are soaked in salt solutions such as NaCl and KNO_3, which help to invigorate the seed and facilitate the process of seed germination and seedling emergence evenly under adverse environmental conditions. Many studies have shown that salt tolerance of plants can be improved by treating seed with solutions of inorganic or organic salts before sowing. Therefore, the seed priming strategy has been developed as an indispensable, economical and simple method for elevating the tolerance capacity of plants against various biotic and abiotic stresses (**Jisha *et al*., 2013**).

Tomato is among the crops which are responsive to priming. Plant salt tolerance could be increased by seed pre-sowing treatment with NaCl solution, where primed seeds were adapted more easily and quickly to saline conditions **(B.P. Strogonov, 1964 c.a. Cayuela *et al*., 1996)**. **İşeri *et al.* (2014)** reported that tomato seed priming with 0.05M NaCl solution reduced mean germination time and increased final germination percentage together with energy of germination. Also, tomato seedlings from primed seeds have been tolerated to different NaCl levels than seedlings from non-primed seeds **(Cayuela *et al*., 1996; El-Saifi *et al*., 2010; İşeri *et al.*, 2014** and **Ebrahimi *et al.*, 2014)**. Effect of NaCl seed priming was extended to the later growth stages, where, plants from primed seeds in 1 M NaCl for 36 h were more adapted to salinity and produced a greater fruit yield at low (35 mM NaCl) and moderate (70 mM NaCl) salt levels in the irrigation water than non-primed seed **(Cano *et al.*, 1991)**.

Also, seed priming with KNO_3 increased germination percentage, germination index, root length, shoot length and seedling fresh weight **(Ells, 1963 and Nawaz *et al*., 2011)**. Osmopriming with KNO_3 improved the rate and generally improved the uniformity of seedling emergence in tomato **(Heydecker *et al*. 1973; Ozbingol *et al*. 1998 and Farooq *et al*., 2005)**. Tomato seeds primed in solutions that contained KNO_3 had much shorter time spread of germination than those primed in solutions other than KNO_3 (**Haigh and Barlow, 1987**). **Jumsoon *et al.* (1996)** found that primed seeds in 150 mM KNO_3 had higher percentage germination than unprimed seeds at 15 or 20°C under both water and saline stress.

Therefore, the aim of this study was to evaluate the effects of priming by both of sodium chloride (NaCl) and potassium nitrate (KNO_3) on the germination and growth of tomato seedlings under normal and saline conditions.

Materials and Methods

The experiment was conducted under net greenhouse conditions at the Agricultural Experiment Station (AES) of the Faculty of Agriculture, Cairo University, Giza, Egypt, during the 2012 and 2013 spring plantings. Tomato cv. Ace 55 VF (salt sensitive) was used in this study. Seeds were produced and harvested at fruit mature stage during the winter season 2012 in greenhouses of AES. Seeds were extracted and stored in Kraft paper bags under refrigerator conditions.

The effect of seed halopriming with NaCl and KNO_3 solutions on germination and seedlings growth of tomato was examined as compared to unprimed treatment (control). According to results of some previous studies, the priming conditions were chosen as shown in Table 1. Tomato seeds were put in jars filled to half with inorganic salt solutions and incubated on a shaker under the priming conditions. After priming, the seeds were washed 3-4 times with distilled water and allowed to dry at room temperature.

Table 1. The priming conditions of tomato seeds**.**

Inorganic salt	Solution	Priming period	Reference
NaCl	0.05 M	1 day	**Nawaz *et al*. (2011)**
	6 M	3 days	**Cayuela *et al*. (1996)**
KNO_3	25 mM	1 day	**Nawaz *et al*. (2011)**
	2% (w:v) (10 ml soluation / 1 g seeds)	1day	**Arin and Kiyak (2003)**

Effect of seed priming on germination

To investigate the effect of halopriming on germination, an experiment carried out as a completely randomized design (CRD) with 4 replications. Twenty five seeds with each replicate per treatment were germinated in incubator at 25 °C in dark in 9 cm Petri dishes on two layers of Whatman No 1 filter paper and moistened with 5 ml distilled water for fifteen days. Seeds were considered germinated when at least 2 mm long radicle protruded through the seed coat. The number of germinated seeds was counted daily for 15 days after which no further seed germination was occurred (**ISTA, 1985**). Parameters measured in this experiment were as follows:

- **Germination percentage (GP)** measured in the fifteenth day using the formula GP (%) = (total No of germinated seeds/ total No of seeds) × 100.
- **Mean germination time (MGT)** was calculated according to the equation **MGT = ΣDn/Σn (Ellis and Roberts, 1981),** where n is the number of germinated seeds on day D, and D is the number of days counted from the beginning of germination.
- **Germination rate (GR)** provides a measure of the time course of seed germination. Germination rate is calculated by the formula GR $=\sum \frac{N_i}{T_i}$. Where N is the number of germinated seeds and T is time (day).

Effect of seed halopriming on tomato seedling growth under normal and salinity conditions

To investigate effect of NaCl and KNO_3 halopriming on seedling growth under normal and saline conditions, an experiment was carried out as a randomized complete block design (RCBD) with 4 replications. Each replicate was half Styrofoam tray having 209 conical cells (tray dimensions: 65 cm × 38 cm × 8.3 cm). Dried seeds were sown in trays filled with a mixture of peat-moss and vermiculate (volume 1:1) enriched with macro and micro elements on the first half of March of 2012 and 2013 seasons. The trays were divided into two groups, the first group was irrigated with fresh water and the second group was irrigated with saline water, which is originated from a groundwater well in AES, Wadi El-Natrun, Beheira, and presented its analysis in Table 2. For irrigation the seedling trays by saline water without damaging the vegetative growth, the trays were put in plastic basins filled with saline water for 30 min/day, until growing media and roots absorbed water from drainage holes in the tray base.

Table 2. Saline water analysis**.**

Anions (meq/l)				Cations (meq/l)							
CO_3^{--}	**HCO_3^-**	**CL^-**	**SO_4^{--}**	**Ca^{++}**	**Mg^{++}**	**Na^+**	**K^+**	**pH**	**SAR[z]**	**ESP[y]**	**Ec (dSm^{-1})**
0	11.4	22	1.54	5.32	3.2	26	0.23	7.9	7.25	8.62	5.5

[z]SAR: sodium adsorption ratio.
[y]ESP: exchangeable sodium percentage.

At the end of 5 weeks, seedlings were harvested and evaluated for the final germination percentage (FGP) of tomato seeds by counting the number of germinated seeds after 5 weeks from sowing. Ten transplants were randomly chosen from the center of replicate per treatment and harvested 5 weeks after sowing. Measurements of stem length (taken from soil surface to top of transplant canopy), stem diameter (at the soil surface), number of leaves, leaf SPAD chlorophyll value, and fresh and dry weights of transplants (after drying for 72 h at 70°C in a forced-air oven) were recorded.
At the end of 5 weeks, seedlings (shoot + root) were harvested and evaluated for their responses to salinity by determining content of proline and Na^+ in shoots and roots. Proline content in fresh plant materials was determined according to **Bates *et al*. (1973)**. Na^+ seedling content was determined in the dried samples according to **Imamul Huq and Alam (2005)** by using of a flame-photometer.

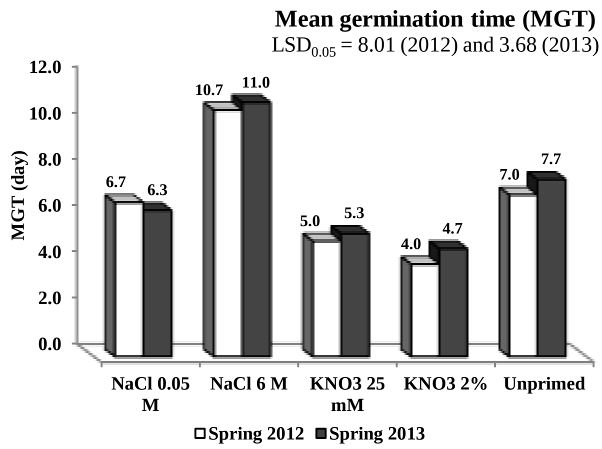
Statistical Analysis

Data were statistically analyzed using MSTAT-C v. 2.1 (Michigan State University, Michigan, USA) and mean comparisons were based on the least significant difference (LSD) test **(Maxwell and Delaney, 1989)**.

Results and Discussion

Effect of seed priming on seed germination parameters under normal conditions

Germination is an important index affecting the stand establishment, survival and population dynamics of a crop. Analysis of variance showed a significant difference between seed halopriming treatments and the control treatment (unpriming) (Fig. 1). The 2% KNO_3 halopriming treatment gave the lowest significant value of MGT across the two seasons, followed by 25 mM KNO_3 halopriming treatment without significant differences. The control treatment was not significantly different from 25 mM KNO_3 halopriming treatment in the first season and also for 0.05 M NaCl halopriming treatment in the two seasons for MGT. The 6M NaCl halopriming treatment increased MGT for tomato seeds as compared to other halopriming and control treatments; it gave the highest MGT. In terms of GR, also the 2% KNO_3 halopriming gave the highest significant value followed by the 25mM KNO_3 halopriming without significant differences among them. The 6M NaCl halopriming treatment decreased GR as compared to other halopriming and control treatments; it gave the lowest GR. Halopriming treatments did not affect FGP (Table 3); there were no significant differences between the control treatment and most of halopriming treatments. The 6M NaCl halopriming treatment recorded the lowest significant FGP across the two seasons.



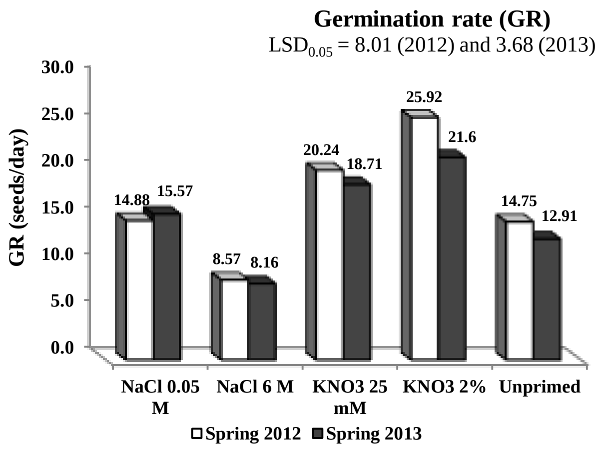


Fig. 1. Effect of NaCl and KNO_3 halopriming on mean germination time and germination rate of tomato cv. Ace 55VF seeds under normal conditions.

Table 3. Effect of NaCl and KNO_3 halopriming on germination and seedling growth of tomato cv. Ace 55VF.

Halopriming Treatment	FGP [z] (%)	No of leaves	Stem length (cm)	Stem diameter (mm)	Fresh weight (g)		Dry weight (g)		Chlorophyll content (SPAD value)
					Shoot	Root	Shoot	Root	
					2012				
0.05 M NaCl	98.67 a	6.67 bc	12.57 bc	2.47 c	4.22 b	1.59 b	0.64 b	0.34 bc	48.26 ab
6 M NaCl	90.67 b	5.33 d	11.46 d	2.53 c	3.98 b	1.31 c	0.57 c	0.32 c	47.35 b
25 mM KNO_3	98.33 a	7.72 ab	13.33 ab	3.36 ab	4.60 b	1.60 b	0.64 b	0.39 b	50.93 ab
2% KNO_3	99.33 a	7.78 a	13.77 a	3.41 a	5.50 a	1.92 a	0.70 a	0.44 a	52.83 a
Unprimed	98.00 a	6.55 c	12.05 cd	3.02 b	4.42 b	1.57 b	0.63 b	0.36 bc	48.18 b
$LSD_{0.05}$	**3.14**	**1.07**	**0.92**	**0.38**	**0.69**	**0.24**	**0.03**	**0.06**	**4.62**
					2013				
0.05 M NaCl	98.00 a	6.67 c	12.25 b	2.50 c	4.04 c	1.42 bc	0.61 b	0.35	47.4
6 M NaCl	89.33 b	5.67 d	11.17 c	2.57 c	3.50 d	1.29 c	0.58 b	0.33	44.4
25 mM KNO_3	99.00 a	7.72 ab	13.44 a	3.48 a	4.06 bc	1.58 a-c	0.61 b	0.38	46.3
2% KNO_3	99.67 a	8.00 a	13.67 a	3.31 ab	4.26 a	1.84 a	0.68 a	0.41	48.2
Unprimed	98.67 a	6.89 bc	11.94 b	2.97 bc	4.21 ab	1.67 ab	0.61 b	0.34	46.6
$LSD_{0.05}$	**3.28**	**0.92**	**0.62**	**0.47**	**0.17**	**0.37**	**0.06**	**NS**	**NS**

[z]FGP: final germination percentage.

The 2% KNO_3 halopriming treatment had the highest significant values of GR and FGP and the lowest significant value of MGT across two seasons followed by the 25 mM KNO_3 treatment without significant differences. There was no significant difference between 25mM KNO_3 halopriming treatment and unpriming treatment in MGT (the first season only), GR, and FGP. KNO_3 treatment did not improve GP; there were no significant differences between it and unprimed seeds. These results agreed with those reported by **Agerich and Bradford (1989) and Mavi *et al*. (2006),** who concluded that KNO_3 priming did not affect tomato GP.

In general, results indicate that KNO_3 halopriming treatments improved germination potential of tomato seeds and it proved better option than NaCl halopriming. **Haigh and Barlow (1987)** found that KNO_3 was beneficial in decreasing the emergence spread of tomato, carrot, onion and sorghum seeds. **Mavi *et al*. (2006)** found that KNO_3 priming caused the earliest germination as compared to NaCl treatment. **Tzortzakis (2009)** expressed that KNO_3 priming improved GR and stated that priming is a practical method with economic benefit for producers. Besides, some studies reported that KNO_3 primed seeds excelled over all other priming agents including NaCl (**Alvarado *et* al., 1987; Liu *et al*., 1996; Mavi *et al*., 2006; Nawaz *et al*., 2011 and Ebrahimi *et al.,* 2014**). Additional data about the different effects of mineral salts come from **Haigh *et al*. (1986)** who found the advantageous effects of K salts in comparison to other minerals, and that PO_4 ion gives an additional extra benefit to these K salts because it is imbibed by seed itself. **Mauromicale and Cavallaro (1997)** also pointed out that the embryo and endosperm K^+ content of tomato seeds primed in KNO_3 + KH_2PO_4 was increased by 65 and 33% of the control value, respectively, and by this reason, higher water absorption in seed primed with potassium salt was observed during osmopriming. **Nawaz *et al*. (2011)** found that the better performance of haloprimed seeds may be due to lower electrical conductivity (EC) of seed leachates, higher total and reducing sugars along with increased α-amylase activity.

The 6M NaCl halopriming had a negative impact on germination parameters, where it reduced GP and GR and increased MGT as compared to unprimed treatment (Fig. 1). These effects might be attributed to that NaCl treated seeds had taken up more Na^+ and/or Cl^- from the high concentration salt solution, hence leading to the toxic effect as suggested by **Bradford (1995)**. However, 0.05M NaCl halopriming was not significantly different from the control treatment in GP, MGT, and GR and these results were in partial agreement with the findings of **İşeri *et al*. (2014)**, who pointed out that 0.05M NaCl priming reduced MGT and increased GP of tomato seeds.

During some earlier studies, it was evident that primed seeds of different crops cause improvement in germination. Seed priming may help in dormancy breakdown that may be due to embryo development or leaching of emergence inhibitors (**Farooq *et al*., 2005**), which increased GP. Early germination, as indicated by MGT and GR, in primed seeds may be due to earlier and faster synthesis and repair of DNA, RNA, and proteins, and germination metabolites (**Farooq *et al*., 2007**). Increase in various free radical scavenging enzymes, such as superoxide dismutase, catalase and peroxidase have also been demonstrated to influence the germination (**Nawaz *et al*., 2011**).

Effects of seed priming on tomato seedlings properties under normal conditions

Halopriming treatments have significant effects on tomato seedlings growth (Table 3). The 2% KNO_3 halopriming treatment have the highest significant values for No. of leaves, stem length and diameter, fresh weight of shoot and root, and dry weight of shoot across the two seasons. Also, this treatment gave the highest significant value for dry weight of root and chlorophyll leaf content (SPAD value) in the first season only, where there was no significant differences between the treatments in the second season for these traits. The 25 mM KNO_3 halopriming ranked second after 2% KNO_3 halopriming for all studied traits without significant differences among them for most of the studied traits followed by unpriming treatment (control) and 0.05M NaCl halopriming treatment. The 6M NaCl halopriming treatment failed to improve seedling vigour, where it gave the lowest significant values of the studied traits.

According to these results, seed halopriming not only enhances germination capacity, but also improves seedling growth. The KNO_3 halopriming improved rate and uniformity of seedling emergence in tomato (Fig. 1), where KNO_3 primed seeds had much shorter time spread of germination than those NaCl and unprimed seeds **(Farooq *et al*., 2005 and Nawaz *et al*., 2011)**. Also, tomato seedlings from the KNO_3 haloprimed seeds, especially 2%, evolved earlier and were more uniformly than seedlings from the NaCl haloprimed and unprimed seeds and therefore, were better and more vigorous. Tomato seedling vigour appeared clearly through estimates of No. of leaves, stem length and diameter, and fresh and dry weight of shoot and root. Higher stem length and diameter of seedlings raised from treated seeds might be the result of earlier germination and emergence **(Nawaz *et al*., 2011)** or might be the result of higher embryo cell wall extensibility (**Afzal *et al*., 2011**). The results regarding shoot and root fresh and dry weights are in agreement with those of **Mavi *et al*. (2006) and Nawaz *et al*. (2011)** who reported that fresh and dry weights of tomato seedlings from KNO_3 haloprimed seeds were significantly higher than NaCl primed and unprimed seeds.

Halopriming with NaCl could have stimulative effect related to salt acclimation and a toxic effect due to salt stress. At the high NaCl pretreatment level (6 M), the toxic effect would be increased and the stimulative effect would be nullified. This finding is further supported by the data of germination and seedling growth in Fig. 1 and Table 3. Several studies on halopriming in germinating seeds depicted that during this stage the seeds were in particular sensitive to the NaCl concentration (**Bewely and Black, 1982**). The NaCl halopriming might show toxicity problems as ions accumulate in tissues as reported in various vegetable species including tomato (**Nawaz *et al*., 2011**) that is why reduction occurs in emergence percentage of seeds.

Effects of halopriming on germination and seedlings growth under saline conditions

Soil salinity affects the seed germination either by creating osmotic potential external to the seeds preventing water uptake or through the toxic effects of Na^+ and Cl^- ions on germinating seed. The objective of present study was to determine the effects of seed halopriming with NaCl and KNO_3 solutions on germination and seedling growth of tomato cv. Ace 55VF which irrigated with saline water (5.5 dSm^{-1} or 3520 ppm). Halopriming treatments of tomato seeds with KNO_3 and NaCl significantly increased FGP as compared to unprimed seeds (Table 4). The KNO_3 halopriming treatments gave the highest significant value of FGP followed by 0.05M NaCl halopriming without significant differences between them. There were no significant differences among halopriming treatments in the second season.

There were significant differences of halopriming treatments on tomato seedling traits of tomato cv. Ace 55VF (Table 4). Overall, halopriming in KNO_3 was better than NaCl. KNO_3 halopriming treatments gave the highest significant values of No. of leaves, stem length and diameter, and fresh and dry weight of shoot and root without significant differences among them as compared to NaCl halopriming or unprimed treatments. NaCl halopriming treatments improves seedlings growth as compared to unprimed treatment. The 6M NaCl halopriming was better than 0.05M NaCl haopriming treatment for most of tomato seedling growth traits. Accordingly, halopriming improved salt tolerance of tomato seedlings by increasing fresh and dry weight of shoot and root of seedlings, in addition to increasing in No. of leaves and stem length and diameter. Similar findings were noticed by **El-Saifi *et al*. (2010)**, **Ebrahimi *et al.* (2014)** and **İşeri *et al.* (2014)**.

Table 4. Effect of NaCl and KNO_3 halopriming on germination and seedling growth of tomato cv. Ace 55VF under saline conditions.

Halopriming treatment	FGP[z] (%)	No of leaves	Stem length (cm)	Stem diameter (mm)	Fresh weight (g)		Dry weight (g)	
					Shoot	Root	Shoot	Root
				2012				
NaCl 0.05 M	87.00 ab	5.94 ab	8.89 ab	3.14 b	3.51 a	0.85 b	0.43 b	0.176 b
NaCl 6 M	81.67 b	6.17 ab	8.61 b	3.15 b	3.75 a	0.96 a	0.47 a	0.196 ab
KNO3 25 mM	92.00 a	6.72 a	9.67 a	3.53 a	3.76 a	0.97 a	0.47 a	0.197 ab
KNO3 2%	92.00 a	6.77 a	9.22 ab	3.25 ab	3.74 a	0.98 a	0.46 a	0.203 a
Unprimed	58.00 c	5.67 b	5.81 c	2.25 c	2.79 b	0.78 b	0.39 c	0.153 c
LSD0.05	**7.22**	**0.88**	**0.93**	**0.36**	**0.48**	**0.08**	**0.02**	**0.02**
				2013				
NaCl 0.05 M	86.00 a	5.61 ab	8.83 ab	3.15 a	3.25 ab	0.92 a	0.47 ab	0.16 b
NaCl 6 M	79.67 a	5.33 b	8.39 b	3.09 a	3.38 a	1.01 a	0.53 a	0.21 a
KNO3 25 mM	85.67 a	6.55 a	9.39 a	3.15 a	3.62 a	0.98 a	0.49 ab	0.19 a
KNO3 2%	84.33 a	6.55 a	9.08 ab	3.16 a	3.47 a	0.93 a	0.49 ab	0.20 a
Unprimed	60.67 b	4.67 b	6.22 c	2.07 b	2.66 b	0.68 b	0.35 b	0.15 b
LSD0.05	**10.88**	**1.00**	**0.93**	**0.32**	**0.63**	**0.15**	**0.15**	**0.02**

[z]FGP: final germination percentage.

To infer the effect of halopriming on some chemical characteristics related to salt tolerance in seedlings grown under saline conditions, leaf chlorophyll content and proline and sodium contents in shoot and root were estimated and the results are presented in Fig. 2. Salinity may affect leaf chlorophyll content by inhibition of synthesis of chlorophyll or an acceleration of its degradation with a significant decrease of photosynthetic quantum and net CO_2 uptake yield as demonstrated in two sorghum varieties at high salinity (**Netondo *et al*., 2004**). Seedlings of haloprimed seeds have highest significant SPAD values of leaf chlorophyll (Fig. 2) as compared to seedlings of unprimed seeds. There were no significant differences among NaCl and KNO_3 halopriming treatments. Overall, halopriming in NaCl was better than KNO_3, where it gave highest significant SPAD values of leaf chlorophyll. Accordingly, halopriming treatments contributed to reduce the harmful effect of salinity on chlorophyll leaf content, where it increases in haloprimed seed seedlings compared to unprimed seed seedlings and those results were consistent with those reported by **Mavi *et al*. (2006)** and **İşeri *et al*. (2014)**.

Cytosolic proline helps to maintain osmotic adjustment as well as its contribution to membrane stability and reducing the disruptive effect of NaCl on cell membrane as a free radical scavenger **(Mansour, 1998)**. According to Fig. 2, shoot and root proline contents of tomato seedlings increased with halopriming treatments compared to unpriming treatment. Proline content in root seedlings was higher than shoot seedlings. The NaCl halopriming treatments gave the highest values of shoot proline contents without significant differences among them across two seasons followed by KNO_3 halopriming treatments. While, unpriming treatment gave the lowest shoot proline value. Concerning root proline content, the 6M NaCl halopriming gave the highest value followed by 0.05M NaCl halopriming treatment with significant differences among them. These results are supported by **Cayuela *et al*. (1996)** and **İşeri *et al*. (2014)** who found that NaCl priming of tomato enhanced proline accumulation in seedlings. Therefore, the higher adaptation capacity of tomato haloprimed seedlings to salinity could be due to osmoregulation induced by proline.

The results in Fig. 2 show an increase Na^+ content in root compared to shoot of tomato seedlings. There were significant differences between halopriming treatments and unpriming treatment for shoot and root Na^+ content. Overall, halopriming treatments led to increase of shoot and root Na^+ contents compared to unpriming treatment. The 6M NaCl halopriming treatment gave the highest significant value for Na^+ content of shoot and root followed by 0.05 M NaCl treatment with a significant difference among them. The KNO_3 halopriming treatments led to increased shoot and root Na^+ content of tomato seedlings compared to unpriming treatment. Results demonstrate the ability of the haloprimed seedlings to use salty water for growth. **Parida and Das (2005)** reported that plants under high salinity conditions stored excessive Na^+ in their vacuoles to maintain metabolic functions.

Overall, the increase of proline content especially in the shoot and root provides osmoprotection against water stress under salinity conditions. A low rate of Na^+ transport to leaves which is dependent on the ability of the root to exclude Na^+ from the xylem sap (**Kaya *et al*., 2007**) and/or the ability to compartmentalize these ions in vaculoes to prevent their build up in cytoplasm or cell walls are among the mechanisms of salt tolerance (**Munns, 2002**). However, if the ions are transported to leaves, effects of salt become apparent in leaves as well.

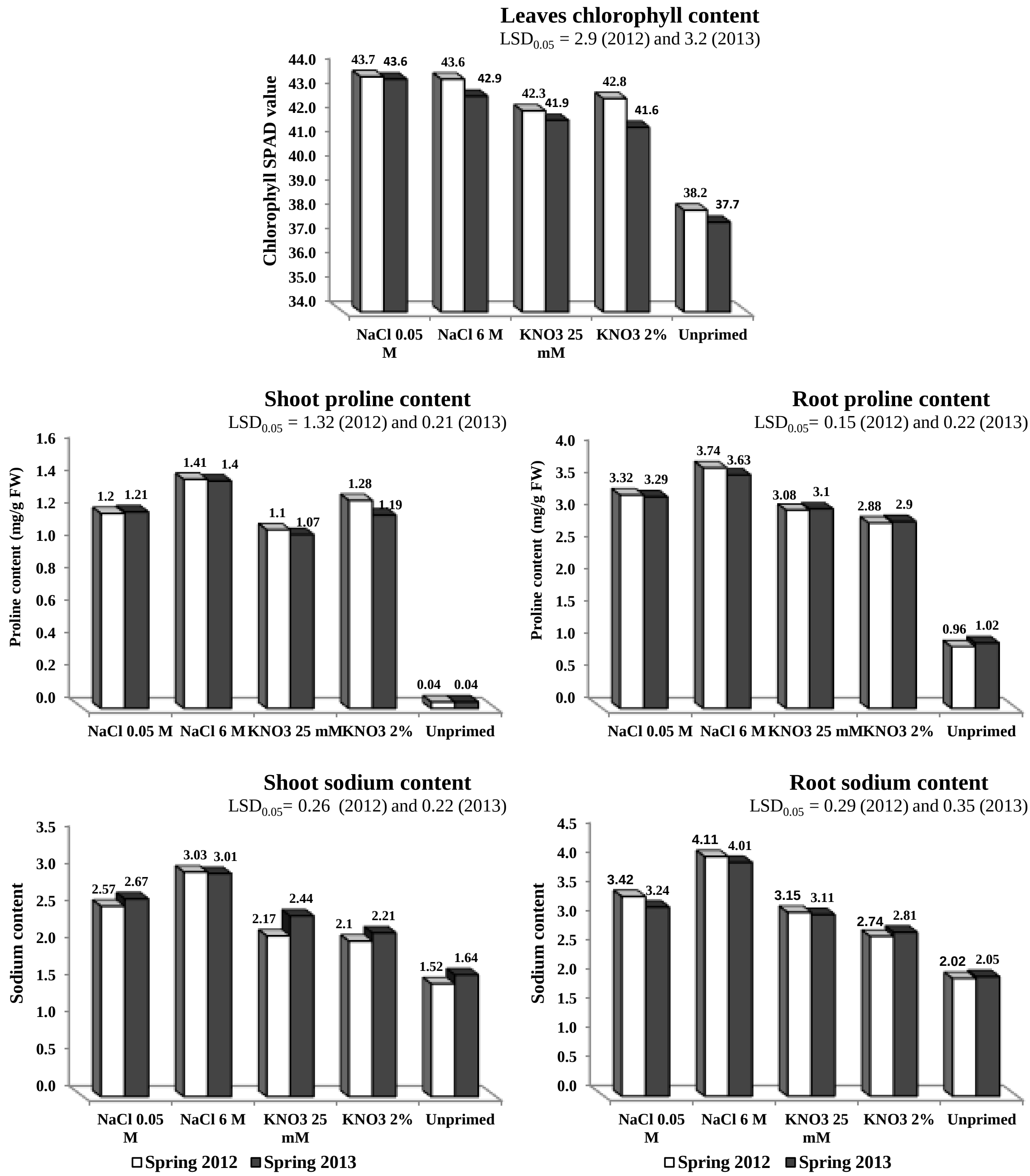


Fig. 2. Effect of halopriming with NaCl and KNO_3 on proline and sodium content of shoot and root tomato seedlings after 5 weeks from sowing under saline conditions.

Therefore, it can be said that germination and seedling growth of tomato are improved by halopriming treatments, especially with KNO_3 under normal and saline conditions.

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