KSÜ Tarım ve Doğa Derg 27 (4), 892-900, 2024
KSU J. Agric Nat 27 (4), 892-900, 2043
https://doi.org/10.18016/ksutarimdoga.vi.1329294

The Effects of Priming With NaCl Solutions on Salt Stress During Germination and Seedling Stages in Maize

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ABSTRACT

In this study, germination and seedling growth under salt stress (175 mM) of maize pretreated (priming) with different salt (NaCl) solutions (0, 150, 175, and 200 mM) were investigated. Unprimed seeds were used as control. The study was carried out with two maize cultivars (ADA-9510 and Simpatico) in a petri dish and pot media. The effects of cultivar and priming treatments on germination and seedling characteristics of maize under salt stress were significant ($P<0.01$) in both environments. In the ADA-9510 variety, the average values of the examined traits were found to be higher. The germination rate of the Simpatico variety was very low in salt stress, but after priming, it showed an increase of up to 224% in Petri dishes and up to 44% in pots. In pot conditions, priming improved crude protein content, root dry matter ratio, and emergence speed in ADA-9510, while root dry matter ratio, emergence rate, and speed of the Simpatico variety improved when compared to control. Accordingly, as a result of the study, it was determined that the application of priming with 150 and 175 mM NaCl solutions, even with normal water, reduced the negative effects of salt stress on germination and seedling growth in maize.

Field Crops

Research Article

Article History
Received : 18.07.2023
Accepted : 18.01.2024

Keywords
Priming
Salt stress
Maize
Germination
Seedling growth

Tohumlara NaCl Çözeltileri ile Priming Uygulanmasının Mısırda Çimlenme ve Fide Aşamalarında Tuz Stresine Etkileri

ABSTRACT

Bu çalışmada farklı tuz (NaCl) çözeltileriyle (0, 150, 175 ve 200 mM) ön işlem uygulanan (priming) mısırın tuz stresi (175 mM) altında çimlenme ve fide gelişimi incelenmiştir. Kontrol olarak priming uygulanmamış tohumlar kullanılmıştır. Çalışma iki adet mısır çeşidi (ADA-9510 ve Simpatico) ile petri ve saksı koşullarında yürütülmüştür. Mısırın tuz stresi altında çimlenme ve fide özellikleri üzerinde çeşit ve priming uygulamalarının etkisi hem petri hem de saksı ortamında önemli ($P<0.01$) olmuştur. ADA-9510 çeşidinde, incelen özelliklere ait ortama değerler daha yüksek bulunmuştur. Simpatico çeşidinin çimlenme oranı tuz stresinde çok düşük olmuş, ancak priming sonrası petri kaplarında %224'e, saksılarda %44'e varan bir artış göstermiştir. Saksı koşullarında, kontrolle kıyaslandığında priming uygulamaları ADA-9510 çeşidinde ham protein içeriğini, kök kuru madde oranı ve sürme hızını, Simpatico çeşidinde ise kök kuru madde oranı, sürme oranı ve hızını geliştirmiştir. Buna göre çalışma sonucunda 150 ve 175 mM NaCl çözeltileri ile hatta su ile yapılan priming uygulamasının da mısırda tuz stresinin çimlenme ve fide gelişimi üzerindeki olumsuz etkilerini azalttığı belirlenmiştir.

Tarla Bitkileri

Araştırma Makalesi

Makale Tarihçesi
Geliş Tarihi : 18.07.2023
Kabul Tarihi : 18.01.2024

Anahtar Kelimeler
Priming
Tuz stresi
Mısır
Çimlenme
Fide gelişimi

To Cite : Nazlı, S., & Başaran, U., (2024). Priming The Seeds With NaCl Solutions Alleviates Salt Stress During Germination And Seedling Stages İn Maize. *KSU J. Agric Nat* 27 (4), 892-900. https://doi.org/10.18016/ksutarimdoga.vi.1329294

Atıf Şekli: Nazlı, S., & Başaran, U., (2024). Tohumlara NaCl Çözeltileri İle Priming Uygulanmasının Mısırda Çimlenme ve Fide Aşamalarında Tuz Stresine Etkileri. *KSÜ Tarım ve Doğa Derg 27* (4), 892-900. https://doi.org/10.18016/ksutarimdoga.vi.1329294

INTRODUCTION

Salt stress is one of the most important and common abiotic stress factors that negatively affect agricultural production (Vinocur & Altman, 2005). Salinity makes water uptake difficult due to osmotic degradation and causes disruption of physiological processes in plants by ion stress. In addition, it limits photosynthesis by reducing the amount of green tissue in plants and reduces the nutrient content by limiting the activity of various enzymes (Munns et al., 2006). Soil salinity can be caused by many compounds such as chlorides ($NaCl$, $CaCl_2$, $MgCl_2$), Sulfates (Na_2SO_4, $MgSO_4$), nitrates (Na_2NO_3, KNO_3), Carbonates, bicarbonates ($CaCO_3$, Na2CO3, $NaHCO_3$) and borates (Yetissin & Karakaya, 2022). The most important and most common of these compounds is sodium chloride (NaCl) and, high NaCl content in the environment leads to ion competition and reduces Ca^{+2}, $K^{+1,}$ and Mg^{+2} uptake (Parida & Das, 2005).

Although there is a general perception that salinization occurs only in arid and semi-arid regions, no climatic region is exempt from this problem (Rengasamy, 2006). Current information from 118 countries covering 85% of global land area, express that more than 424 million hectares of topsoil (0-30 cm) and 833 million hectares of subsoil (30-100 cm) are salt-affected (FAO, 2023). Salinity is encountered in an area of approximately 1.5 million hectares in Turkey, which constitutes 5.48% of the country's total arable land (Sönmez, 2003). The salinity seen in agricultural areas may be due to soil, as well as incorrect agricultural practices, excessive or insufficient irrigation, irrigation water, and temperature increase may be effective in the formation of salinity or its reaching further dimensions. The continuation of wrong agricultural practices and especially the changes in the climate in recent years may cause an increase in the salinity problem. It is predicted that global climate change will cause an increase in temperatures in large areas, including Turkey, and a decrease in precipitation and water resources. The expansion of salt-affected areas poses a major threat to food supply security around the world. It is predicted that 10% of agricultural lands will become salinized every year due to irrigation with salt water, low precipitation, and high evapotranspiration, and salinity problems may occur in more than 50% of arable land rapidly by 2050 (Jamil et al., 2011). Therefore, cultural, physiological, and genetic studies that increase salt tolerance of basic crops are of great importance for sustainable agricultural production.

Maize (*Zea mays* L.) is grown in many countries and is one of the most basic products for human and animal nutrition worldwide (Agami, 2013). Maize is the third cereal after wheat and barley in terms of production amount in Turkey and it is of great importance, especially for animal nutrition. It is a highly crucial crop for both plant and animal production in the Turkish agricultural system. Moreover, its importance is gradually increasing due to the increase in demand, especially in the livestock sector. Maize is a moderately sensitive plant to salt (Carpıcı et al., 2009) and soil salinity is a serious limiting factor for maize production all over the world (Farooq et al., 2015). Pitann et al. (2009) reported differential responses of maize cultivars to salt stress based on biochemical data at the cellular level. Salinity causes stress for plants at all stages of development. However, it poses a greater risk, especially during the germination and seedling stages (Goldsworthy, 1994). Like all plants, Mize is much more sensitive to salinity during germination and seedling periods. Therefore, improving the salinity tolerance of maize during the germination and early development period is critical for the yield and quality of maize and, of course, its sustainable production. The susceptibility of maize to high salt stress was revealed by the decrease in growth and development of underground and aboveground parts (Neubert et al., 2005; Sazalai & Janda, 2009). Therefore, intensive efforts are made to increase the resistance of maize to salt stress, including seed priming (Bakht et al., 2011; Gebreegziabher & Qufa, 2017).

One of the most common priming is halo-priming in which water uptake is ensured in 50 - 200 mM salty (KCl and NaCl) solutions (Kumar et al., 2016). Priming is based on the principle of stimulating seed germination by controlling moisture, ensuring certain metabolic processes, and stopping the process before root emergence occurs (Singh & Kumar, 2021). With priming, homogeneous and strong seedling development is aimed at increasing the germination and seedling emergence rate. In addition to germination performance, protection systems, and stress tolerance increase in seeds stimulated by priming (Khan et al., 2022). In many studies, it has been revealed that priming positively affects the germination and development of salt-stressed plants and has an effect on tolerance to different stress factors (Agami, 2013; Munns & Gilliham, 2015; Baghel et al., 2019; Farooq et al., 2019; Yetissin & Karakaya, 2022). Ashraf & Rauf (2001) reported that priming with chlorinated salts can reduce the negative effect of salt stress on germination (Mahara et al., 2022), seedling development (Kaya & Gözübenli 2020), and growth (Bakht et al., 2011) in maize.

As it is known, the pretreatment of seeds with biological, chemical, or physical agents has changed germination characteristics and seedling growth in many plants. These findings inspired new studies by raising the question of whether the plant's response to stress conditions can be ameliorated by priming

(Faroq et al., 2015). Priming is not simply a process of biochemical changes associated with early germination in seeds. In the priming stage, metabolic activities occur in RNA and protein production, structural and genetic repair, and antioxidant mechanisms, which are decisive for good germination and seedling development (Akshay et al., 2022; Li et al., 2022). At this stage, by applying sufficient stress to the seeds, the systems that respond to stress are activated, and thanks to this information, the seeds are better prepared for the stress they will encounter (Bhanuprakash & Yogeesha, 2016). Therefore, the present study was planned to determine the response of maize seeds primed with solutions with different salt concentrations to salt stress during germination and seedling stages.

MATERIAL and METOD

This study was carried out as a petri dish and pot experiment in the laboratory of the Department of Field Crops, Faculty of Agriculture, Yozgat Bozok University. Plant material Simpatico (FAO 300) and Ada-9510 (FAO 650) maize varieties were used in the study. Maize seeds were primed with different salt solutions and then germination and seedling growth under salt stress were investigated. Unprimed seeds were used as a control

Priming

For priming, maize seeds were kept in solutions containing 0, 150, 175, and 200 mM salt (NaCl) for 18 hours at 24 °C. Then they were washed thoroughly with distilled water and dried in an oven at 40 °C for 5 hours. Finally, the seeds were packaged and made ready for use in the experiment.

Salt Stress

Primed and Control seeds were tested in petri dishes and pots. To create salt stress, saline solution (175 mM, NaCl) was used in the initial irrigation in both media, and subsequent irrigations (for the pot media) were made with distilled water.

Petri Trial

The effect of treatments on the germination rate and speed of maize in the Petri dish was investigated. 10 seeds of all treatments were placed in petri dishes with a layer of filter paper in triplicate and then saline solution (175 mM) was added to the petri dishes. The prepared petri dishes were wrapped with parafilm and left to germinate. They were kept in dark conditions for the first two days, then in 16 hours light-8 hours dark conditions at a constant temperature of 24 °C. Germination results were started on the second day after planting and were completed at the end of the 7th day. In the experiment, the seeds whose root length reached 0.5 cm were accepted as germinated and the following characteristics were examined.

Germination rate: GR (%) = (Number of germinated seeds/total number of seeds) ×100 (Kayaçetin et al., 2018).

Germination speed: GS= $\sum[(G_1/D_1) + (G_2/D_2) +\ldots.. + (Gn/Dn)]$. G: number of germinated seeds, D: number of days (Czabator, 1962).

Pot Trial

Primed and control seeds were tested in 0.5 L pots to determine emergence and early seedling growth characteristics. 300 grams of peat was placed in each pot and 10 seeds were planted at a depth of 3 cm. After planting, the pots were irrigated with salt solution (175 mM) to field capacity and placed in conditions with 16 hours of light - 8 hours of darkness, and a constant temperature of 24 °C. This process was repeated 3 times for each application. Follow-up irrigations were made with pure water at 100% when each pot reached half of the field capacity. The pot experiment was continued for 21 days. Emerging speed and rate were determined in the first 10 days, and seedling characteristics were determined at the end of the 21st day.

Emergence traits

Emergence rate*: ER (%) = (Number of seeds to emergence/total number of seeds)×100

Emergence speed*: ES (day^{-1}) = $\sum[(E_1/D_1) + (E_2/D_2) +\ldots+ (En/Dn)]$

E: number of emergence in the counting day, D: days.
* those with a coleoptile length of 1 cm were counted for emergence.

Seedling characteristics

At the end of the 21st day, shoot and root lengths were determined by measuring the actual lengths of the above-ground and underground parts of 5 seedlings in each pot. For the shoot and root dry matter ratio, the roots and shoots of all seedlings in each pot were weighed freshly and then dried in an oven at 65°C until constant weight. Finally, dry matter ratios were determined by the formula (Dry weight/fresh weight x 100).

Dried samples were ground in a mill to pass through a sieve with a diameter of 1 mm. Then crude protein, ADF (Fiber insoluble in acid detergent), NDF (Fiber Insoluble in Neutral Detergent), Potassium (K), Phosphorus (P), Calcium (Ca), and Magnesium (Mg) (%) contents were determined using Near Infrared Reflectance Spectroscopy (NIRS) (Foss 6500 and IC-0904-FE package program).

Statistic Analysis

The experiment was arranged in a split-plot design with three replications. Varieties were analyzed separately for a priming effect. The analysis of the data was made using the MSTAT_C statistical package program and differences between treatments were compared with Duncan's multiple range test (Bricker, 1991).

RESULTS and DISCUSSION

The effect of variety and priming on the germination rate and speed of maize in Petri media is given in Table 1. The difference between varieties was found to be significant ($P<0.01$) and, ADA-9510 had higher values in terms of both germination rate (75.33%) and germination speed (3.79 day^{-1}).

The effect of priming treatments on germination rate and speed was significant ($P<0.01$) in both cultivars. The highest germination rate of ADA-9510 was determined in control (93.33%), P0 (86.67%), and P3 (76.67%) applications, and the lowest in P2 (56.67%) and P1 (56.67%) applications. Accordingly, a positive effect of priming processes on the germination rate of the ADA-9510 variety was not observed in the petri dish. The germination rate of the Simpatico cultivar was significantly higher than the control (26.67%) in all priming treatments and was the highest in P0 (86.67%), P2 (76.67%) and P3 (63.33%) treatments (Table 1). These results show that Simpatico has a germination problem in saline conditions (175 mM), and this problem can be largely overcome by priming.

Table 1. Effect of priming on germination characteristics of maize varieties under saline (175 mM) conditions (Petri media)

Çizelge 1. Priming işleminin mısır çeşitlerinin tuzlu koşullarda (175 mM) çimlenme özelliklerine etkisi (petri ortamı)

Variety**	Priming **	Characteristic			
		GR (%)	±*Se*	GS (day^{-1})	±*Se*
ADA-9510	Control	93.33 a	*2.72*	3.73 ab	*0.12*
	P0 (0 mM)	86.67 a	*3.45*	4.53 a	*0.32*
	P1 (150 mM)	63.33 b	*4.21*	3.57 ab	*0.31*
	P2 (175 mM	56.67 b	*3.45*	2.63 b	*0.31*
	P3 (200 mM)	76.67 ab	*2.72*	4.50 a	*0.43*
	Mean	*75.33 A*		*3.79 A*	
Simpatico	Control	26.67 c	*3.82*	0.97 c	*0.27*
	P0 (0 mM)	86.67 a	*2.72*	5.30 a	*0.37*
	P1 (150 mM)	46.67 bc	*3.45*	1.53 c	*0.15*
	P2 (175 mM	76.67 ab	*3.90*	2.53 bc	*0.14*
	P3 (200 mM)	63.33 ab	*3.82*	3.43 b	*0.39*
	Mean	*60.00 B*		*2.75 B*	

**:$P<0.01$. *Se*: Standard error. There is no difference between the averages in the same column and with the same letter for each variety. GR: germination rate, GS: germination speed.

Similarly, germination speed was affected by priming in both cultivars and showed a parallel change with germination rate. The lowest germination speed in ADA-9510 was determined in the P2 (2.63 day^{-1}) treatment while the other treatments were in the highest group with values ranging from 3.73 to 4.53 days^{-1}. The germination rate of the Simpatico cultivar was highest in the P0 (5.30 day^{-1}) treatment while it was lowest in control (0.97 day^{-1}) and P1 (1.53 day^{-1}) treatments (Table 1). Accordingly, in terms of germination properties, priming application did not show any relieving effect on salt stress in ADA-9510 in petri conditions. On the other hand, priming affected the germination rate and speed positively in the Simpatico variety, but this effect was higher in water priming than in salty priming and decreased in salty priming depending on salt concentration.

In the pot conditions, slightly different results were found, which indicates that the growing conditions are also determinant in the response of plants to salt stress. The effect of variety and priming treatments on the emergence and seedling growth characteristics of maize was also significant ($P<0.01$) in the pot conditions (Table 2). On average, the highest emergence rate (66.31%), emergence speed (3.23 day^{-1}), root length (17.3 cm), and shoot length (31.63 cm) were determined in ADA-9510, and root dry weight (13.09 g) in Simpatico variety (Table 2). The effect of priming on emergence rate and speed was significant ($P<0.01$) in both cultivars. In terms of emergence rate, control (84.33%) and P0 (80.55%) treatments were in the highest group together in the ADA-9510 variety, while all other treatments formed the lowest group. In the Simpatico, the priming, except for P3, was found to be above the control. Priming treatments had a positive effect on the emergence speed in both varieties. P0 and P1 in the ADA-9510 variety and all priming treatments in Simpatico were above the control regarding emergence speed. In this context, apart from the emergence rate of ADA-9510, priming with saline agents significantly improved the germination properties at low concentrations (150 and 175 mM). When seeds were primed with 200 mM solution, the positive effect was reduced and germination values were similar to the control. This indicates that the high salt content in the priming agent may have a toxic effect on maize. Many previous studies seem to be in great agreement with these results. Kaya & Gözübenli (2020) investigated the effect of priming with NaCl solutions on seedling development in two maize varieties (Pasha and P-31A34) in saline soils and reported that priming seeds with 5 g L^{-1} NaCl positively affects seedling growth. They also emphasized the importance of variety selection in saline soils. Similarly, Mahara et al. (2022) reported that seed priming with 5 g L^{-1} NaCl solution alleviated the inhibitory effect of salt stress on germination and seedling growth of maize.

Table 2. The effect of priming on emergence and seedling characteristics of maize cultivars under saline (175 mM) conditions (Pot media)

Çizelge 2. Priming işleminin mısır çeşitlerinin tuzlu koşullarda (175 mM) çıkış ve fide özelliklerine etkisi (saksı ortamı)

		Characteristic											
Variety**	Priming **	ER (%)	±*Se*	ES (gün^{-1})	±*Se*	RL (cm)	±*Se*	SL (cm)	±*Se*	RDMR (%)	±*Se*	SDMR (%)	±*Se*
ADA-9510	Control	84.33a	2.84	3.44 b	0.35	17.8	1.61	33.27 a	2.61	9.37 bc	1.13	9.52	1.71
	P0 (0 mM)	80.55 a	3.06	4.89 a	0.26	15.1	2.21	34.13 a	1.04	6.92 c	1.28	8.84	0.53
	P1 (150 mM)	61.11 b	3.84	3.31 ab	0.43	18.0	1.53	31.60 ab	1.89	15.44 a	3.92	9.00	0.25
	P2 (175 mM	55.56 b	3.54	2.36 b	0.13	17.7	0.52	32.20 ab	0.57	11.42 abc	1.07	10.28	0.94
	P3 (200 mM)	50.00 b	4.87	2.17 b	0.22	17.9	0.88	26.95 b	2.32	11.92 ab	3.21	9.80	0.73
	Mean	*66.31 A*		*3.23 A*		*17.3 A*		*31.63 A*		*11.02 B*		*9.49*	
Simpatico	Control	55.56 b	3.35	2.30 b	0.23	12.3	1.10	30.67 a	2.79	10.34 b	0.92	8.75	*0.42*
	P0 (0 mM)	80.56 a	1.36	3.81 a	0.38	12.5	1.00	24.47 b	1.91	11.99 b	0.37	9.15	0.60
	P1 (150 mM)	63.89 ab	5.90	3.33 a	0.30	13.1	0.48	24.20 b	1.23	17.15 a	1.71	9.20	0.28
	P2 (175 mM	75.00 a	5.19	3.64 a	0.28	13.2	1.37	27.88 ab	2.27	12.47 b	1.16	7.83	1.09
	P3 (200 mM)	55.56 b	3.01	2.53 ab	0.36	12.9	1.46	27.13 ab	1.98	13.52 b	1.44	8.06	0.58
	Mean	*66.11 B*		*3.12 B*		*12.8 B*		*26.87 B*		*13.09 A*		*8.60*	

**: $P<0.01$. *Se*: Standard error. There is no difference between the averages in the same column and with the same letter for each variety. ER: Emergence rate, ES: Emergence speed, RL: Root length, SL: Shoot length, RDMR: Root dry matter ratio, SDMR: Shoot dry matter ratio.

While shoot length and root dry matter ratio were significantly ($P<0.01$) different, root length and shoot dry matter ratio were found to be similar among the priming treatments in maize varieties (Table 2). The shoot length of ADA-9510 showed a significant decrease in P3 (26.95 g) but was similar in other treatments. In Simpatico, P2, P3, and control were in the highest group in terms of shoot length, but a significant decrease was recorded in P0 and P1 treatments. Interestingly, although the roots of the plants are first exposed to salt stress, the shoots may be more affected (Muns & Sharp, 1993). In both cultivars, an increase was recorded in the root dry matter ratio when priming with saline solution. The root dry matter ratio of the ADA-9510 variety was determined to be significantly higher, especially in saline priming (P1, P2, and P3). The highest root dry matter ratio of Simpatico was determined in P1 (17.15 g), and all other treatments were in the lowest group together (Table 2). These results show that priming in saline solutions has a positive effect on root dry matter ratio in maize, but this effect may vary depending on the variety and salt dose in the priming solution.

The effect of variety and priming on crude protein and mineral content of maize is given in Table 3. Crude protein content was affected by cultivars and was found to be higher in Simpatico (25.86%) on average. The effect of priming treatments on crude protein content was significant only in the ADA-9510 variety. The crude protein content of the ADA-9510 variety was above the control (23.04%) in priming, and the highest was detected in P1 (25.20%) and P2 (25.44%) treatments. The crude protein content of Simpatico was similar in all treatments and was between 25.18% (P3) and 26.86% (control). Growth and development in plants is a process dependent on physiological and biochemical mechanisms. In this respect, salt stress affects the chemical content of plants as well as their morphological features, and this effect is due to the combination of dry matter accumulation, ion uptake and relationships, water status, biochemical reactions, and/or many physiological reactions (Sohan et al., 1999). Therefore, the response of plants against salt stress depends on the effectiveness of these mechanisms. The protein mechanism and accumulation of mazie undergo significant changes under salt stress, and the level of salt stress is also important in this change. Indeed, the change in protein regulation of protein roots and shoots in maize under 25 mM NaCl stress was 45% and 31%, respectively, while this level was 80% for total separated proteins under 100 mM NaCl salt stress (Zörb et al., 2004). Arora et al. (2008) found that the pre-sowing treatment of maize seeds with 28-homobrassinolide promoted antioxidative enzyme activity, resulting in a decrease in lipid peroxidation and an increase in protein content.

Table 3. Effect of priming on crude protein and mineral matter (P-K-Ca-Mg) content of maize seedlings grown in salty conditions (175 mM) (Pot media)

Çizelge 3. Priming işleminin tuzlu koşullarda (175 mM) yetişen mısır fidelerinin ham protein ve mineral madde (P-K-Ca-Mg) içeriğine etkisi (saksı ortamı)

Variety**	Priming **	Characteristic					
		Crude protein (%)	±*Se*	P (%)†	K (%)†	Ca (%)†	Mg (%)†
ADA-9510	Control	23.04 c	*0.08*	0.57 bc	4.40 d	0.40 a	0.17 b
	P0 (0 mM)	24.76 b	*0.05*	0.58 b	4.65 b	0.41 a	0.18 b
	P1 (150 mM)	25.20 a	*0.10*	0.59 a	4.62 bc	0.41 a	0.19 a
	P2 (175 mM	25.44 a	*0.08*	0.59 ab	4.71 a	0.41 a	0.17 b
	P3 (200 mM)	21.77 d	*0.08*	0.56 c	4.59 c	0.34 b	0.17 b
	Mean	*24.04 B*		*0.58 B*	*4.59 A*	*0.39*	*0.18 A*
Simpatico	Control	26.86	*0.33*	0.62	4.76	0.32	0.14 b
	P0 (0 mM)	25.31	*0.68*	0.62	4.32	0.42	0.21 a
	P1 (150 mM)	26.39	*0.65*	0.58	3.79	0.37	0.22 a
	P2 (175 mM	25.58	*0.27*	0.60	4.28	0.43	0.18 ab
	P3 (200 mM)	25.18	*0.19*	0.60	4.15	0.35	0.19 ab
	Mean	*25.86 A*		*0.60 A*	*4.26 B*	*0.38*	*0.19 B*

*:P<0.05, **: P<0.01. *Se*: Standard error. †: *Se*<0.01. There is no difference between the averages in the same column and with the same letter for each variety.

The effect of variety on the P, K, and Mg content of maize was significant (P<0.01). The average P content was found to be higher in Simpatico (0.60%) and, the K and Mg content was higher in ADA-9510 (4.59% and 0.18%) (Table 3).

Priming treatments affected the mineral content significantly (P<0.01), especially in ADA-9510. In general, the mineral content of ADA-9510 was positively affected by priming except Ca. The highest P, K, and Mg contents in ADA-9510 were detected in priming with saline solution. This positive effect is particularly evident in priming with low-salt solutions (P1 and P2). The Ca content of ADA-9510 was adversely affected by high-salt solution priming (P3) but was similar in other treatments. In Simpatico, treatments were only effective on Mg content and all priming treatments were in the same group and above control in terms of Mg. Under salt stress, the uptake of nitrogen, calcium, potassium, magnesium, and iron by plants decreases (Karimi et al., 2005; Kaya et al., 2010) and excess sodium and chlorine in salty soils limit the uptake of other elements, leading to imbalance in the chemical content of maize (Turan et al., 2010). Present results showed that priming affected the chemical response of maize to salt stress related to protein and mineral content. In previous studies, the stress-reducing effect of different priming agents has been reported. Seed priming with NaCl stimulates various metabolic and physiological processes in plants during germination and early growth stages (Abraha & Yohannes, 2013; Kaya & Gozubenli, 2020). It was reported that 60 and 120 mM NaCl significantly reduced growth, development, photosynthesis, and enzyme (catalase and peroxidase) activity and leaf anatomy in maize, but the toxic effect of salt stress was alleviated by presoaking the seed with salicylic acid and 24-epibrassinolide (Agami, 2013). Gunes et al. (2005) reported that exogenously applied salicylic acid significantly enhances plant growth in both saline and unsalted conditions by acting as an endogenous signaling molecule responsible for inducing abiotic stress tolerance. The authors also reported that salicylic acid strongly inhibited the accumulation of Na and Cl, but stimulated N, Mg, Fe, Mn, and Cu concentrations of salt-stressed maize plants, so it could be used as a potential growth regulator to improve salinity stress resistance of the plant. Similarly, the application of Brassinosteroids, a phytohormone group of steroids to rice seeds alleviated the adverse effects of salt stress by restoring the pigment level, increasing nitrate reductase, nucleic acid, and proteins (Anuradha & Rao 2001).

CONCLUSION

Seed priming with water and salty (NaCl) solutions improved germination characteristics, seedling growth, and the chemical content of maize under salinity stress. However, this effect was significantly dependent on the variety and the salt concentration of the priming agent. Priming with water was also effective in reducing the negative consequences of salt stress. However, it was observed that saline agents at certain concentrations could be more effective. In this study, 150 and 175 mM NaCl solutions were found to be effective for maize. On the other hand, the results showed that the cultivars differed very significantly in both salt resistance and priming response. The germination and emergence results in the control treatment showed that Simpatico variety is more sensitive to salinity (175 mM), but this can be alleviated highly by priming. According to general results, the ADA-9510 variety is more durable under salt stress and also responded positively to the applied priming treatments. This shows that priming with low-salty solutions and water may alleviate the negative effects of salt stress in both salt-tolerant and sensitive varieties.

ACKNOWLEDGEMENTS

Produced from Sema Nazlı's master's thesis

Statement of Conflict of Interest

The authors have declared no conflict of interest.

Author's Contributions

The contribution of the authors is equal.

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