Kırşehir Ahi Evran Üniversitesi Ziraat Fakültesi Dergisi
(Journal of Kırşehir Ahi Evran University Faculty of Agriculture)

Ahi Ziraat Der – J Ahi Agri
e-ISSN: 2791-9161
https://dergipark.org.tr/tr/pub/kuzfad

KUZ FAD

Research article

Damage Mitigating Effects Of Salicylic Acid On Some Growth Parameters Of Maize Cultivars (*Zea Mays* L.) Exposed To Salinity Conditions[a]

Tuğba Hasibe GÖKKAYA[1], Mehmet ARSLAN[2*]

[1] Batı Akdeniz Agricultural Research Institute, Antalya, Türkiye

[2] Akdeniz University, Faculty of Agriculture, Department of Field Crops, Antalya, Türkiye

* Sorumlu yazar (Corresponding author): mehmetarslan@akdeniz.edu.tr

Makale alınış (Received): 01.06.2023 / Kabul (Accepted): 12.09.2023 /Yayınlanma (Published): 31.12.2023

ABSTRACT

The aim was to evaluate the salicylic acid (SA) effects on the germination and growth of maize cultivars exposed to salinity stress levels. The investigation was set according to the factorial experimental design in completely random blocks with four replications. The maize (*Zea mays* L.) cultivars (Side, Pehlivan and Burak) was chosen as plant material. NaCl compound was used for solutions prepared at concentrations of 0-75-150 mM and and salicylic acid in doses of 0-0.1-0.2 mM. The growth parameters in Side cultivar was naturally higher than the other cultivars. The minimum means prominently were indicated in Pehlivan cultivar. As anticipated, the maximum means were realised in control, as the minors were reported in 150 mM NaCl application. Due to the unfavorable influence of salinity, only the germination time gave the highest average at 150 mM. The most affected feature was determined root length, 150 mM NaCl was three times lower than control. The fact that the best germination time was obtained at 0.2 mM SA, as the worst was recorded at 0.1 mM SA, that explained the complex effect of SA. Germination index impressed substantially and regularly with enhancing SA applications. Augmenting SA dose caused a well elongation in shoot length, moreover by contrast lead to shortening in root length, but these were not numerically markedly different. Albeit, the root length of the control application was well, the best value in fresh weight was recorded at 0.2 mM SA. In this experiment,

[a] **Atıf bilgisi / Citation info:** Gökkaya TH, Arslan M (2023). Damage mitigating effects of salicylic acid on some growth parameters of maize cultivars (*Zea mays* L.) exposed to salinity conditions**.** Ahi Ziraat Der/J Ahi Agri 3(2): 255-269

realised that salicylic acid applications diminished and ameliorate this effect under salinity stress conditions that maize seeds may encounter during the germination period.

Keywords: Salicylic acid, Maize Cultivars, Salinity, Growth, Germination

Araştırma makalesi

Tuzluluk koşullarına maruz kalan mısır çeşitlerinin (*Zea mays* L.) bazı büyüme parametreleri üzerinde salisilik asidin iyileştirici etkileri

ÖZ

Bu çalışmada amaç, salisilik asidin (SA) tuzluluk stresi seviyelerine maruz kalan mısır çeşitlerinin çimlenmesi ve büyümesi üzerindeki etkilerini değerlendirmektir. Deneme, tesadüf blokları faktöriyel deneme deseni kullanılarak dört tekerrürlü olarak düzenlenmiştir. Bitki materyali olarak mısır (*Zea mays* L.) çeşitleri (Side, Pehlivan ve Burak) kullanılmıştır. Tuz stresi 0-75-150 mM konsantrasyonlarda NaCl bileşiği ile ve 0-0.1-0.2 mM dozlarda salisilik asit ile hazırlanmıştır. Genel olarak Side çeşidinde elde edilen gelişme parametreleri en yüksek ortalamalar olarak bulunmuştur. Pehlivan çeşidinde minimum ortalamalar belirgin olarak belirtilmiştir. Çimlenme ve gelişim parametreleri, 150 mM NaCl uygulamasında minimum ortalamalar ve tahmin edildiği gibi de kontrolde maksimum ortalamalar ile rapor edilmiştir. Tuzluluğun olumsuz etkisinden dolayı sadece çimlenme süresi 150 mM ile en yüksek ortalamayı vermiştir. En çok etkilenen özelliğin kök uzunluğu olduğu belirlenmiş, 150 mM NaCl kontrole göre üç kat daha düşük elde edilmiştir. SA'nın karmaşık etkisi, en iyi çimlenme süresinin 0,2 mM SA'da elde edilmesi ve en kötü çimlenme süresinin ise 0,1 mM SA'da kaydedilmesi ile açıklanmaktadır. Çimlenme indeksi, artan SA uygulamalarıyla önemli ölçüde ve düzenli olarak etkilenmiştir. Arttırılan SA dozu, sürgün uzunluğunda iyi bir uzamaya neden olmuş, aksine kök uzunluğunda kısalmaya yol açmıştır, ancak bunlar sayısal olarak belirgin bir şekilde farklı olmamıştır. Kontrol uygulamasında kök uzunluğu en iyi olarak sonuçlanmış, ayrıca taze ağırlıkta ise en iyi değer 0,2 mM SA'da kaydedilmiştir. Bu denemede, mısır tohumlarının çimlenme döneminde karşılaşabilecekleri tuzluluk stresi koşullarında salisilik asit uygulamalarının bu etkiyi azalttığı ve poztif etki ettiği belirlenmiştir.

Anahtar Kelimeler: Salisilik asit, *Zea mays* L., Tuzluluk, Büyüme, Çimlenme.

Introduction

The nutritional needs of the increasing world population are increasing day by day, and they need to be met and a balanced diet is required. This can only be achieved through balanced agricultural and animal production. Maize (*Zea mays* L.) is a traditional grain used in human nutrition in temperate regions today and is used as animal feed by silage in many parts of the world. Moreover, it is considered as one of the most important roughages in animal nutrition, both as green and silage. Thereon, after rice and wheat, maize is the third most prominent grain product (El-Katony et al. 2019). Also, maize, cultivated on approximately 8.5 tonnes in Türkiye (TÜİK, 2023), get the ability to be grown in very different soil types and climatic conditions based on its wide genotypic variability, and it is a C4 species that is moderately salt sensitive (Mansour et al. 2005).

Furthermore, the most used plant in silage production in the world and in our country is maize. It is the most noteworty forage crop for silage with its features such as producing the highest green parts per unit area, easy harvesting, delicious and loved by animals, being suitable and easy to make silage, and having the best nutritional value (Öten et al. 2016). In addition to its high nutritional values, maize is a potential welding of carotenoids, phenolics, phytosterols and bioactive phytochemicals (Rouf Shah et al. 2016).

In general, maize is markedly threatened by salinity and drought (Banziger and Araus 2007). In semi-arid regions, salinity is substantial agent reducing harvested crop productivity (Flowers 2004). Moreover, irregularities in precipitation regime (Abdelgawad et al. 2016), restricted irrigation, saline water and inefficient drainage (Jayakannan et al. 2015) lead to improved saline soils in preponderantly arid and semi-arid world regions (Mohamed and Gomaa 2012 Cassaniti et al. 2013) creating conflicting effects at physiological (Yamaguchi and Blumwald 2005), biochemical (Jaleel et al. 2008) and molecular alterations (Tester and Davenport 2003; Latif and Mohamed 2016). The reagent of plants to salinity stress might modify linking on the type, level, exposure time of salt and its genotype, nonetheless some common reactions emerge in approximately all genotypes (Azooz 2009). Salinity stress causes more changes in plants seed germination (Moghaddam et al. 2020; Ozkorkmaz and Oner 2022), growth (Ceritoglu and Erman 2020), photosynthesis (Sudhir and Murthy 2004; Khodary 2004), DNA (Banu et al. 2010), RNA, protein synthesis (Hussein et al. 2007), respiration (Tufail et al. 2013), lipid metabolism (Sultan et al. 2021), mitosis, and energy generation (Niu et al. 2013; Ghonaim et al. 2020). The detrimental effects of salinity stress on plants may be concluded from osmotic and ionic stresses (Munns and Tester 2008) resulting in metabolic disturbances in the generation of reactive oxygen species in cells (Halliwell 2006). Therefore, strategies with a high percentage of success are required to enhance salt tolerance in agriculturally major grains (Yıldız et al. 2014).

Under salinity stress conditions, various signaling molecules are produced that diminish the unfavorable impacts and boost plant resistance to stress (Sultan et al. 2021). One of the most substantial of these signaling molecules is salicylic acid (SA), and its role in augmentation plant adaptation to salt stress has been proven by studies (Semida et al. 2017; Dempsey and Klessig 2017; Kudla et al. 2018). Indeed, SA impacts a wide specify of plant procedures from seed germination to growth and evolves the salt tolerance by augmenting the endogenous SA level (El-Mergawi and El-Wahed 2020). SA is a phenolic compound known as phytohormone, contributes to the regulation of growth and development stages such as control the ion uptake by roots (Raskin 1992, Kaya et al. 2023), photosynthesis (Noreen and Ashraf 2008, Ren et al. 2023), inhibition of ethylene biosynthesis (Khan et al. 2012b), respiration, flowering and senescence, especially germination (Rivas-San Vicente and Plasencia 2011, Gökkaya and Arslan 2023).

In line with this sensitivity of maize, since the salinity effect gets complex structure that trigger some difficulties in breeding, thus it is indispensable to explore for disparate applications namely methods that will derive ameliorated effects. In this context, in this study, it was aimed to ameliorate the negative effects of salinity stress in the first growth period of various silage maize varieties with gradually enhancing salicylic acid, a hormone that has a restorative effect in appropriate doses, application.

Material and Methods

This investigation was perused at the Forage Crops Laboratory of Department of Field Crops, Akdeniz University, Türkiye during the autumn of 2022. The maize (*Zea mays* L.) seeds were supplied from Batı Akdeniz Agricultural Research Institute. Three selected cultivars were Side, Pehlivan and Burak that were ensured for genetic materials. Ten seeds from each cultivar were chosen and placed in 9 mm petri dishes, two Whatman filter papers were lined in. The petri dishes were settled in a growth chamber at 20ºC under photoperiodic condition 16 hours light 8 hours dark. The experiment was carried out in four replications with factorial arrangement according to the randomized blocks design. Observations were recorded daily. NaCl (Sigma®) compound, three different salinity stress levels, 0-75-150 mM, were used as the salt source. Salicylic acid was administered at doses of 0-0.1-0.2 mM due to its therapeutic effect. 10 ml of solution was used for moistening in each application. The study ended on the seventh day.

Germination tests were carried out according to ISTA rules (2017). The seed of germination (MGT) was calculated using formulas described by Majda et al. (2019). Germination rate (GR) was calculated according to Xia et al. (2019). Germination index (GI) and seedling vigor index (SVI) were counted by the method of Xia et al. (2019). The root/shoot ratio (R/S ratio) was calculated as the following equation (Shtaya et al. 2021). The calculation of stress tolerance indices formulas as described by Nawaz et al. (2014).

$$\text{MGT (day)}=\sum \frac{number\ of\ seeds\ germinated\ on\ the\ i^{th}\ day}{number\ of\ days\ to\ count\ the\ n^{th} day} \quad (1)$$

$$\text{GR(\%)}=\frac{\text{number of germinated seed/}}{\text{total number of seed tested}}*100 \quad (2)$$

$$\text{GI}=\sum \frac{\text{the number of germinated seeds in day}}{\text{day of counting seed germination}} \quad (3)$$

$$\text{SVI}=\frac{\text{germination percentage}*\text{average seedling lenght}}{100} \quad (4)$$

$$\text{R/S ratio}=\frac{\text{roots lenght}}{\text{shoot lenght}} \quad (5)$$

$$\text{SLSI (\%)}=\frac{\text{Shoot lenght of stressed plant}}{\text{shoot lenght of control}}*100 \quad (6)$$

$$\text{RLSI (\%)} = \frac{\text{Root lenght of stressed plant}}{\text{root lenght of control}} * 100 \quad (7)$$

$$\text{SFSI (\%)} = \frac{\text{Shoot fresh weight of stressed plant}}{\text{Shoot fresh weight of control}} * 100 \quad (8)$$

$$\text{RFSI (\%)} = \frac{\text{Root fresh weight stress of stressed plant}}{\text{Root fresh weight of control}} * 100 \quad (9)$$

Datas determined all the study subjected to analysis variance using R (ANOVA) and compared with Duncan's multiple range, which differed significantly at 0.05 levels. (4.3.19).

Results and Discussion

Based on the variance analysis of the effects of salicylic acid doses on germination, growth and stress tolerance of maize cultivars under salinity condition was given in Table 1 and 2.

According to analysis of variance, maize cultivars had a statistically significant 1% effect on experimental parameters except GI and SFSI, only RLSI was affected at $p<0.05$. The parameters examined in the experiment were substantial ($P<0.01$) influenced by the boosting salinity stress level. Salicylic acid applications at different doses caused a statistically noteworthy change ($P<0.01$) in germination, growth and stress tolerance parameters of mazie varieties under salinity stress condition. C*SL and SL*SA interaction conditions showed a meanful effect on approximately whole parameters examined in the study. Closely, mean germination time, germination index, seedling vigor index, SLSI and RFSI were markedly affected by enhancing cultivar and salicylic acid doses interaction by 1%. That applications did not cause a statistically significant change in the GR, SL, RL R/L rate, RLSI and SFSI. SFW, RFW and TB were only affected by C*SA interactions ($P<0.05$). Albeit, determined that C*Sl*SA interactions predominantly did not cause a major change in mazie varieties, this triple interaction was observed to be significant only at the level of 1% in MGT and stress tolerance parameters (Table 1 and 2).

The averages of different salicylic acid doses on germination and growth of maize cultivar under saline condition were given in Table 3. In this study conducted on silage maize cultivars, a difference was obtained as expected, but this difference was not found to be excessively divergent numerically. The growth parameters in Side cultivar was naturally higher than the other cultivars. The minimum means prominently were indicated in Pehlivan cultivar. Germination time was long in Burak cultivar, nevertheless the maximum germination was recorded in this cultivar. Furthermore, Pehlivan cultivar had worst root growth parameters, the root lengths of other cultivars have been noted to be approximately twice as long as the shoots. Contrary to all these, yet the germination rate was low, growth parameters were observed at a high level in Side variety (Table 3).

The germination and growth parameters of maize cultivars exposed to salt stress were shown in Table 4. As anticipated, the maximum means were realised in control, as the minors were reported in 150 mM NaCl application. Due to the unfavorable influence of salinity, only the germination time gave the highest average at 150 mM. The most affected feature was determined root length, 150 mM NaCl was three times lower than control. Moreover, similar results were also observed for the total weight. On the other hand, shoot length, shoot and root fresh weight were more twice. On the other hand, shoot length, shoot and root fresh weight were approximately twice as higher with boosting salinity stress. Additionally, enhancing salinity level showed negative effect for growth, this might be due to the inhibitory effect of salinity (Table 4). It is known that salinity could get a negative influence on cells (Wang et al. 2019), tissues (Roy et al. 2017) and organs.

Salt stress caused oxidative damage in plants (Nazar et al. 2011: Khan et al. 2012a), producing reactive oxygen species, can damage and reduce photosynthesis (Lin et al. 2017) by disrupting stomatal behavior, inhibition of photochemical processes (Steduto et al. 2000) and homeostasis of ions and essential mineral nutrients (Munns 2008). Decreased photosynthesis led to diminished growth and yield (Khan et al. 2010). Salinity caused to fall mean of germination percentage (Ibrahim et al. 2016), germination index, shoot length (Mittal et al. 2018), root length (Xie et al. 2019), seedling vigor index, shoot fresh weight (Mohammed Ibrahim Elsiddig et al. 2022; Guo et al. 2022) and root fresh weight (Tenikecier and Ates 2022) but enhanced mean germination time (Rajabi Dehnavi et al. 2020).

In plants, salinity affected the germination process by changing the water absorption of seeds due to the low osmotic potential of the germination moderate, retarded water absorption and therefore inhibited germination, causing adverse effects (Jamil et al. 2006; Khan and Weber 2008). Under saline conditions the diminution of shoot and root lengths was a common occurrence in numerous plants, because roots were the first organs subjugated to salinity and were in straight contact with the soil, absorbing water from the soil and supplying it to the shoot (Asasi 2009).

The curative effect of low and different salicylic acid doses on maize cultivars germination and growth under salinity stress conditions was seen in Table 5. The fact that the best germination time was obtained at 0.2 mM SA, as the worst was recorded at 0.1 mM SA, that explained the complex effect of SA. The fact that the best germination time was obtained at 0.2 mM SA, as the worst was recorded at 0.1 mM SA, that explained the complex effect of SA. Germination index impressed substantially and regularly with anhancing SA application. Augmenting SA dose caused a well elongation in shoot length, moreover by contrast lead to shortening in root length, but these were not numerically markedly different. Albeit, the root length of the control application was well, the best value in fresh weight was recorded at 0.2 mM SA. Albeit, the root length of the control application was well, the best value in fresh weight was recorded at 0.2 mM SA. Thereby, said that alleviating SA application on salinity stress prominently worked and occasionally it did not (Table 5). In similar subject, the salicylic acid healing effects on the damage occurring under stress conditions were followed (Khodary 2004; Gunes et al. 2007). In full agreement with those published by Farahbakhsh and Saiid (2011) and Singh et al (2015a), SA stimulated growth and biomass weight in salt-stressed maize plants (Moghaddam et al. 2020).

SA applications impress growth and photosynthetic capacity of plant in salinity stress (Khan et al. 2012; Arfan 2009). The applications of SA markedly boosted shoot (Purcarea and Cachita-Cosma 2010) and root length (Tufail et al. 2013; El-Tayed 2005; Vazirimehr et al. 2014; Tuna et al. 2007), shoot and root weight (El-Katony et al. 2019) under stress conditions (Jini and Joseph 2017) and had possitive influence on MGT (Afzal et al. 2006). Anaya et al. (2015) reported that the fresh weight decreased with salt applications, and in cases where SA was applied, lower values were obtained than the control, although it prevented the decrease.

With a few exceptions, sturdy relationships were observed in these traits. As in these conditions, the main correlations were with SL*TB, GI*SVI, SLSI*SFSI and SLSI*RFSI, with correlations greater than 96% being strong and recorded as positive. There was a weak negative correlation between the R/L ratio and GR, GI, and a moderately negative correlation between the MGT and the R/L ratio. In addition, a negative and marked association of MGT with GI, SVI, SL, RL, SFW, RFW and TB was determined (Table 6). Gulser et al. (2019), it was observed that the formed salinity was negatively related to the germination time and also the plant length was also significantly related.

It has been demonstrated by studies over time that salinity has a negative correlation with GP, GI, and SVI (Rehman et al. 2000). However, the level or importance of this negative correlation varies be linked on the salt concentration, low NaCl concentrations allow the seeds to rest, and high NaCl concentrations prevent the germination of seeds (Khan and Weber 2008). Ibrahim et al. (2020) recorded that a negative correlation between salinity and shoot length, root length might be due to the deleterious salinity stress effect that consists when causing physical dehydration by the osmotic effect that inhibits water movement in plants.

Table 1. Results of variance analysis on germination and growth parameters of salicylic acid doses and salinity stress levels in maize cultivars

Source of Variance	df	MGT	GR	GI	SVI	SL	RL	R/L rate
C	2	224.89**	269.39**	0.03	55.59**	208.14**	431.42**	138.30**
SL	2	109.25**	485.52**	506.77**	506.65**	615.22**	433.27**	35.15**
SA	2	8.90**	26.39**	96.15**	94.79**	108.25**	75.45**	225.97**
C*SL	4	197.44**	8.65**	21.12**	20.49**	34.03**	32.15**	7.11**
C*S	4	7.14**	2.07	4.40**	4.33**	2.30	2.08	1.46
SL*SA	4	8.51**	41.91**	8.39**	8.32**	6.13**	7.11**	5.47**
C*SL*SA	8	19.56**	2.03	1.30	1.45	0.64	0.79	1.90

*Significant at the 0.05 probability level.**Significant at the 0.01 probability level. (Cultivar: C, Salinity level: SL, Saliyclic acid: SA, Mean germination time: MGT, Germination Rate: GR, Germination index: GI, Seedling Vigor index: SVI, Shoot length: SL, Root length: RL, Root/shoot rate:R/S)

Table 2. Results of variance analysis on growth parameters and stress tolerances of salicylic acid doses and salinty stress levels in maize cultivars.

Source of variance	df	SFW	RFW	TB	SLSI	RLSI	SFSI	RFSI
C	2	43.27**	534.86**	264.56**	23.98**	3.45*	2.32	14.13**
SL	2	474.31**	607.12**	644.90**	76.44**	13.35**	104.85**	77.76**
SA	2	84.25**	121.83**	122.42**	4464.94**	1669.43**	3330.44**	20006.88**
C*SL	4	8.99**	18.25**	12.41**	20.27**	7.47**	3.44*	19.36**
C*SA	4	3.26*	2.84*	3.16*	6.25**	1.84	2.23	7.33**
SL*SA	4	5.44**	10.50**	9.15**	20.58**	8.53**	28.67**	22.32**
C*SL*SA	8	1.98	1.99	0.35	5.34**	2.11*	3.31**	6.10**

*Significant at the 0.05 probability level.**Significant at the 0.01 probability level. (Cultivar: C, Salinity level: SL, Saliyclic acid: SA, SFW: Shoot fresh weight, RFW: Root fresh weight, Shoot lenght stress tolerance index: SLSI, Root lenght stress tolerance index: RLSI, Shoot fresh weight stress tolerance index: SFSI, Root fresh weight stress tolerance index: RFSI)

Table 3. The effects of salicylic acid doses on growth parameters of maize cultivars exposed to salinty stress levels.

Cultivars	MGT (day)	GR (%)	GI (%)	SVI (%)	SL (cm)	RL (cm)	R/L	SFW (mg)	RFW (mg)	TB (mg)
Side	4.68b	60.88c	100.00	2.53a	4.15a	9.79a	2.37a	0.1349a	0.1788a	0.3137a
Pehlivan	5.96a	73.84b	99.99	2.25b	3.05b	4.29c	1.45c	0.1137b	0.0822c	0.1958c
Burak	6.03a	81.71a	99.73	2.54a	3.11b	5.55b	1.78b	0.1118b	0.1189b	0.2307b

*Different letters next to values indicate statistically different means at $P<0.05$ level, and $P<0.01$ levels.

Table 4. The growth parameters of maize cultivars exposed to salinity stress levels

SL (mM)	MGT (day)	GR (%)	GI (%)	SVI (%)	SL (cm)	RL (cm)	R/L	SFW (mg)	RFW (mg)	TB (mg)
0 mM	5.04c	86.11a	119.78a	2.93a	4.54a	9.57a	2.11a	0.1649a	0.1802a	0.3451a
75 mM	5.53b	72.45b	100.26b	2.45b	3.34b	6.26b	1.85b	0.1154b	0.1231b	0.2386b
150 mM	6.10a	57.87c	79.70a	1.94c	2.42c	3.81c	1.64c	0.0801c	0.0765c	0.1565c

*Different letters next to values indicate statistically different means at $P<0.05$ level, and $P<0.01$ levels.

Table 5. The effects of salicylic acid doses on growth parameters of maize cultivars.

SA (mM)	MGT (day)	GR (%)	GI (%)	SVI (%)	SL (cm)	RL (cm)	R/L	SFW (mg)	RFW (mg)	TB (mg)
0 mM	5.50b	69.91b	90.82c	2.22c	3.02c	7.80a	2.49a	0.1031c	0.1032c	0.2063c
0.1 mM	5.73a	70.60b	100.69b	2.45b	3.38b	6.45b	1.81b	0.1185b	0.1268b	0.2453b
0.2 mM	5.45b	75.93a	108.23a	2.65a	3.90a	5.39c	1.30c	0.1389a	0.1498a	0.2886a

*Different letters next to values indicate statistically different means at $P<0.05$ level, and $P<0.01$ levels

Table 6. Correlation of germination, growth and stress tolerance parameters in maize cultivars.

	MGT	GR	GI	SVI	SL	RL	R/L	SFW	RFW	TB	SLSI	RLSI	SFSI
GR	-0.14												
GI	-0.46**	0.75**											
SVI	-0.48**	0.71**	0.96**										
SL	-0.64**	0.42**	0.85**	0.88**									
RL	-0.60**	0.20*	0.50**	0.60**	0.74**								
R/L	-0.23*	-0.13	-0.06	0.06	0.17	0.76**							
SFW	-0.51**	0.54**	0.90**	0.90**	0.95**	0.62**	0.065						
RFW	-0.58**	0.29**	0.72**	0.83**	0.93**	0.77**	0.298**	0.85**					
TB	-0.57**	0.41**	0.82**	0.89**	0.97**	0.74**	0.214*	0.95**	0.98**				
SLSI	0.07	0.05	0.27**	0.24*	0.22*	-0.30*	-0.680**	0.24*	0.20*	0.22*			
RLSI	0.04	0.04	0.27**	0.26**	0.23*	-0.18	-0.507**	0.25**	0.23*	0.25*	0.91**		
SFSI	0.03	0.04	0.27**	0.26**	0.22*	-0.29**	-0.676**	0.26**	0.21*	0.24*	0.98**	0.89**	
RFSI	0.07	0.02	0.23*	0.20*	0.20*	-0.31**	-0.663**	0.23*	0.21*	0.22*	0.97**	0.86**	0.97**

*Significant at the 0.05 probability level.**Significant at the 0.01 probability level. (Mean germination time: MGT, Germination Rate: GR, Germination index: GI, Seedling Vigor index: SVI, Shoot length: SL, Root length: RL, Root/shoot rate:R/S, SFW: Shoot fresh weight, RFW: Root fresh weight, TB: Total biomass, Shoot lenght stress tolerance index: SLSI, Root lenght stress tolerance index: RLSI, Shoot fresh weight stress tolerance index: SFSI, Root fresh weight stress tolerance index: RFSI)

Conclusion

As a result of this study, it was determined that different salinity levels created with NaCl on germination and growth parameters were reduced the negative effects of salty environment. These different levels of salt were noted as different responses among the cultivars developed by the institute, salicylic treatments also had positive effects on germination at low salt levels. In addition, it was determined that salicylic acid applications at different doses applied to the seeds germinated in salty conditions reduced the negative effects of stress in the first growth. Therefore, it was thought that the effects of different salinity levels and salicylic applications detected in the experiment on germination and growth may be useful for further research.

Acknowledgements

This experiment was conducted Forage Crops Laboratory of the Department of Field Crops, Akdeniz University. The maize cultivars (*Zea mays* L.) obtained from the Batı Akdeniz Agricultural Research Institute.

Çıkar Çatışması

Author has declared no conflict of interest.

References

AbdElgawad H, Zinta G, Hegab M M, Pandey R, Asard H and Abuelsoud W (2016). High salinity induces different oxidative stress and antioxidant responses in maize seedlings organs. Frontiers in Plant Science 7(3): 276.

Afzal I, Basra S M, Farooq M and Nawaz A (2006). Alleviation of salinity stress in spring wheat by hormonal priming with ABA, salicylic acid and ascorbic acid. Int. J. Agric. Biol. 8(1): 23-28.

Anaya F, Fghire R, Wahbi S and Loutfi K (2017). Antioxidant enzymes and physiological traits of *Vicia faba* L. as affected by salicylic acid under salt stress. J. Mater Environ Sci. 8(7): 2549-2563.

Arfan M (2009). Exogenous application of Salicylic acid through rooting medium modulates ion accumulation and antioxidant activity in spring wheat under salt stress. Int. J. Agri. Biol. 11: 437-442.

Asaadi A M (2009). Investigation of salinity stress on seed germination of *Trigonella foenum-graecum*. Res. J. Biol. Sci. 4: 1152–1155

Azooz M M (2009). Salt stress mitigation by seed priming with salicylic acid in two faba bean genotypes differing in salt tolerance. Int J Agric Biol. 11(4): 343-350.

Banu N A, Hoque A, Watanabe-Sugimoto M, Islam,M M, Uraji M, Matsuoka K, Nakamura Y and Murata Y (2010). Proline and glycinebetaine ameliorated NaCl stress via scavenging of hydrogen peroxide and methylglyoxal but not superoxide or nitric oxide in tobacco cultured cells. Biosci. Biotech. Bioch. 74(10): 2043e2049.

Banziger M and Araus J (2007). Recent advances in breeding maize for drought and salinity stress tolerance. Advances in Molecular Breeding Towards Drought and Salt Tolerant Crops. SpringerLink, Berlin, 587-601.

Cassaniti C, Romano D, Ho M C and Flowers T J (2013). Growing floricultural crops with brackish water. Environ. Exper. Bot. 92: 165-75.

Ceritoglu M. and Erman M (2020). Mitigation of salinity stress on chickpea germination by salicylic acid priming. Uluslar. Tar. ve Yaban Hayatı Bil. Der. 6(3): 582-591.

Dempsey D M A and Klessig D F (2017). How does the multifaceted plant hormone salicylic acid combat disease in plants and are similar mechanisms utilized in humans? B.M.C. Biol. 15: 1-11.

El-Katony T M, El-Bastawisy Z M and El-Ghareeb S S (2019). Timing of salicylic acid application affects the response of maize (*Zea mays* L.) hybrids to salinity stress. Heliyon 5(4): e01547.

El-Mergawi R A and El-Wahed M S (2020). Effect of exogenous salicylic acid or indole acetic acid on their endogenous levels, germination, and growth in maize. Bull. Nat. Res. Centre 44: 1-8.

Farahbakhsh H and Saiid M S (2011). Effects of foliar application of salicylic acid on vegetative growth of maize under saline conditions. Afr. J. Plant Sci. 5: 575-578.

Flowers T J (2004). Improving crop salt tolerance. J. Exp. Bot. 55: 307-319.

Ghonaim M M, Mohamed H I and Omran A A (2020). Evaluation of wheat salt stress tolerance using physiological parameters and retrotransposon-based markers. Genet. Resour. Crop Evol. 68: 227-242.

Gökkaya T H, Arslan M. (2023). Exogenous salicylic acid application during germination of silage maize (*Zea mays* L.) exposed to PEG-induced drought condition. Turkish Journal of Range and Forage Science 4(1): 43-52.

Gunes A, Inal A, Alpaslan M, Eraslan F, Bagci E G and Cicek N (2007). Salicylic acid induced changes on some physiological parameters symptomatic for oxidative stress and mineral nutrition in maize (*Zea mays* L.) grown under salinity. J. Plant Physiol 164: 728-36.

Guo X, Zhi W, Feng Y, Zhou G and Zhu G (2022). Seed priming improved salt-stressed sorghum growth by enhancing antioxidative defense. Plos one 17(2): e0263036.

Gülser F, Gülser C and Gökkaya T H (2019).The effects of selenium application on germination parameters of pumpkin (*Cucurbita pepo* L.) and osmotic potential of growth media under drought conditions. 10th International Soil Science Congress on "Environment and Soil Resources Conservation". p. 249-255.

Halliwell B (2006). Reactive species and antioxidants. Redox biology is a fundamental them of aerobic life. Plant Physiolog 141: 312–322.

Hussein M M, Balbaa L K and Gaballah M S (2007). Salicylic acid and salinity effects on growth of maize plants. Research J. of Agri. and Biol. Sci. 3(4): 321-328.

Ibrahim M E H, Zhu X, Zhou G and Nimir N E A (2016). Comparison of germination and seedling characteristics of wheat varieties from China and Sudan under salt stress. Agronomy Journal 108: 85-92.

ISTA 2017. International for Seed Testing Rules. International Seed Testing Association, Zurich, Switzerland.

Jaleel C A, Kishorekumar A, Manivannan P, Saankar B, Gomathinayagam M and Panneerselvam R (2008). Salt stress mitigation by calcium chloride in *Phyllanthus amarus*. Acta Bot. Croat. 67: 53–62.

Jamil M, Lee D B, Jung K Y, Ashraf M, Lee S C and Rha E S (2006). Effect of salt (NaCl) stress on germination and early seedling growth of four Vegetable species. J. Cent. Eur. Agric. 7: 273-282.

Jayakannan M, Bose J, Babourina O, Rengel Z and Shabala S (2015). Salicylic acid in plant salinity stress signalling and tolerance. Plant Growth Regulation 76: 25-40.

Jini D and Joseph B (2017). Physiological mechanism of salicylic acid for alleviation of salt stress in rice. Rice Sci. 24 (2): 97e108.

Kaya C, Ugurlar F, Ashraf M and Ahmad P. (2023). Salicylic acid interacts with other plant growth regulators and signal molecules in response to stressful environments in plants. Plant Physiol. Biochem. 196: 431–443.

Khan M A and Weber D J (2008). Ecophysiology of High Salinity Tolerant Plants (Tasks for Vegetation Science), 1st ed.; Springer Science and Business Media: Amsterdam, The Netherland.

Khan M I R, Iqbal N, Masood A and Khan N A (2012a). Variation in salt tolerance of wheat cultivars: Role of glycinebetaine and ethylene. Pedosphere 22: 746-754.

Khan N A, Syeed S, Masood A, Nazar R and Iqbal N (2010). Application of salicylic acid increases contents of nutrients and antioxidative metabolism in mungbean and alleviates adverse effects of salinity stress. Int. J. of Plant Bio. 1(1): e1.1-8.

Khan S U, Asghari B and Gurmani A R (2012b). Abscisic acid and salicylic acid seed treatment as potent inducer of drought tolerance in wheat (*Triticum aestivum* L.). Pak. J. Bot. 44(1): 43-49.

Khodary S E A (2004). Effect of salicylic acid on the growth, photosynthesis and carbohydrate metabolism in salt stressed maize plants. Int. J. Agric. Biol. 6(1): 5-8.

Kudla J, Becker D, Grill E, Hedrich R, Hippler M, Kummer U, Parniske M, Romeis T and Schumacher K (2018). Advances and current challenges in calcium signaling. New Phytol. 218: 414-31.

Latif H H and Mohamed H (2016). Exogenous applications of moringa leaf extract effect on retrotransposon, ultrastructural and biochemical contents of common bean plants under environmental stresses. South Afr. J. Bot. 106: 221-231.

Lin J, Wang Y, Sun S, Mu C and Ya X (2017). Effects of arbuscular mycorrhizal fungi on the growth, photosynthesis and photosynthetic pigments of *Leymus chinensis* seedlings under salt-alkali stress and nitrogen deposition. Sci. Total Environ. 576: 234-241.

Majda C, Khalid D, Aziz A, Rachid B, Badr A S, Lotfi A and Mohamed B (2019). Nutri-priming as an efficient means to improve the agronomic performance of molybdenum in common bean (*Phaseolus vulgaris* L.). Science of the Total Environment 661: 654-663.

Mansour M M F, Salama K H A, Ali F Z M and Abou Hadid A F (2005). Cell and plant responses to NaCl in *Zea mays* L. cultivars differing in salt tolerance. Gen. Appl. Plant Physiol. 31(1-2): 29e41.

Mittal N, Thakur S, Verma H and Kaur A (2018). Interactive effect of salinity and ascorbic acid on *Brassica rapa* L. plants. Gl. J. of Bio-Sci. and Biotech. 7: 27-29.

Moghaddam S S, Rahimi A, Pourakbar L and Jangjoo F (2020). Seed Priming with salicylic acid improves germination and growth of *Lathyrus sativus* L. under salinity stress. Yuzuncu Yil Uni. Journal of Agricultural Sciences 30(1): 68-79.

Mohamed H I and Gomaa E Z (2012). Effect of plant growth promoting *Bacillus subtilis* and *Pseudomonas fluorescens* on growth and pigment composition of radish plants (*Raphanus sativus*) under NaCl stress. Photosynt 50(2): 263–272. https://doi.org/10.1007/s11099- 012-0032-8.

Mohammed Ibrahim Elsiddig A, Zhou G, Nimir N E A and Yousif Adam Ali A (2022). Effect of exogenous ascorbic acid on two sorghum varieties under different types of salt stress. Chilean journal of agricultural research 82(1): 10-20.

Munns R and Tester M (2008). Mechanisms of salinity tolerance. Annual Reviews of Plant Biology 59: 651-681.

Nawaz F, Ashraf M Y, Ahmad R, Waraich E A and Shabbir R N (2014). Selenium (Se) regulates seedling growth in wheat under drought stress. Hindawi Publishing Corporation. Advances in Chemistry, Article ID 143567, 7p.

Nazar R, Iqbal N, Syeed S and Khan N A (2011). Salicylic acid alleviates decreases in photosynthesis under salt stress by enhancing nitrogen and sulfur assimilation and antioxidant metabolism differentially in two mungbean cultivars. Journal of plant physiology 168(8): 807-815.

Niu G, Rodriguez , Dever J and Zhang J (2013). Growth and physiological responses of five cotton genotypes to sodium chloride and sodium sulfate saline water irrigation. J. Cotton Sci. 17(2): 233–244.

Noreen S and Ashraf M (2008). Alleviation of adverse effects of sunflower (*Helianthus annus* L.) by exogenous application of salicylic acid growth and photosynthesis. Pak. J. Bot. 40(4): 1657-1663

Öten M, Kiremitçi S and Çınar O (2016). Bazı yem bitkileri ve karışımlarıyla hazırlanan silajların silaj kalitelerinin farklı yöntemlerle belirlenmesi. And. Ege Tar. Araş. Ens. Der. 26(2): 33-43.

Purcarea C and Cachita-Cosm D (2010). Studies regarding the effects of salicylic acid on maize (*Zea mays* L.) seedling under salt stress. Studia Universitat, Seria Tiintele Vietii *1*: 63-68.

Rajabi Dehnavi A, Zahedi M, Ludwiczak A, Cardenas Perez S and Piernik A (2020). Effect of salinity on seed germination and seedling development of sorghum (*Sorghum bicolor* (L.) Moench) genotypes. Agronomy 10(6): 859.

Raskin I (1992). Role of salicylic acid in plants. Ann. Rev. of Plant Physiol. Mol. Boil. 43: 439-463.

Rehman S, Harris P J C, Bourne W F and Wilkin J (2000). The relationship between ions; vigour and salinity tolerance of Acacia seeds. Plant Soil 220: 229-233.

Ren H, Wang X, Zhang F, Zhao K, Liu X, Yuan R, ... and Wang J. (2023). Salicylic acid and pyraclostrobin can mitigate salinity stress and improve anti-oxidative enzyme activities, photosynthesis, and soybean production under saline–alkali regions. Land 12(7): 1319.

Rivas-San Vicente M and Plasencia J (2011). Salicylic acid beyond defence: its role in plant growth and development. J. of Experimental Botany 62(10): 3321-3338.

Rouf Shah T, Prasad K and Kumar P (2016). Maize-A potential source of human nutrition and health: a review. Cogent Food and Agriculture 2 (1): 1166995.

Roy J, Galano J M, Durand T, Le Guennec J Y nad Chung-Yung Lee J (2017). Physiological role of reactive oxygen species as promoters of natural defenses. The FASEB Journal 31(9): 3729-3745.

Semida W M, Abd El-Mageed T A, Mohamed S E and El-Sawah N A (2017). Combined effect of deficit irrigation and foliar applied salicylic acid on physiological responses, yield, and water-use efficiency of onion plants in saline calcareous soil. Archives of Agronomy and Soil Science 63(9): 1227-1239.

Shtaya M J, Al-Fares H, Qubbaj T, Abu-Qaoud H and Shraim F (2021). Influence of salt stress on seed germination and agromorphological traits in chickpea (*Cicer arietinum* L.). Legume Research-An International Journal 44(12): 1455-1459.

Singh P K, Shahi S K and Singh A P (2015). Effects of salt stress on physico-chemical changes in maize (*Zea mays* L.) plants in response to salicylic acid. Indian J. Plant Sci. 4: 2319-3824.

Steduto P, Albrizio R, Giorio P and Sorrentino G (2000). Gas-exchange response and stomatal and non-stomatal limitations to carbon assimilation of sunflower under salinity. Env. and experimental botany 44(3): 243-255.

Sudhir P and Murthy S D S (2004). Effects of salt stress on basic processes of photosynthesis. Photosyn. 42: 481-6.

Sultan I, Khan I, Chattha M U, Hassan M U, Barbanti L, Calone R, .. and Usman S (2021). Improved salinity tolerance in early growth stage of maize through salicylic acid foliar application. Italian Journal of Agronomy *16*(3): 1-11.

Tenikecier H S and Ateş E (2022). Impact of salinity on germination and seedling growth of four cool-season turfgrass species and cultivars. Polish Journal of Environmental Studies. 31(2): 1813-1821.

Tester M and Davenpor R (2003). Na^+ tolerance and Na^+ transport in higher plants. Ann. Biol. 91: 503-7.

Tufail A, Arfan M, Gurmani A R, Khan A and Bano A (2013). Salicylic acid induced salinity tolerance in maize (*Zea mays*). Pak. J. Bot. 45(S1), 75-82.

TUIK 2023. https://data.tuik.gov.tr/Bulten/Index?p=Bitkisel-Uretim-Istatistikleri-2022-45504#:~:text=Bir%20%C3%B6nceki%20y%C4%B1la%20g%C3%B6re%2C%20bu%C4%9Fday,artarak%20365%20bin%20ton%20oldu.

Tuna A L, Kaya C, Dikilitaş M, Yokaş İ, Burun B and Altunl H (2007). Comparative effects of various salicylic acid derivatives on key growth parameters and some enzyme activities in salinity stressed maize (*Zea mays* L.) plants. Pak. J. Bot. 39(3):787-798.

Vazirimehr M, Rigi K and Branch Z (2014). Effect of salicylic acid in agriculture. International Journal of Plant, Animal and Environmental Sciences 4: 291e296

Wang Y H, Zhang G, Chen Y, Gao J, Sun Y R, Sun M F, et al. (2019). Exogenous application of gibberellic acid and ascorbic acid improved tolerance of okra seedlings to NaCl stress. Acta Physiologiae Plantarum 41:93.

Xia F S, Wang Y C, Zhu H S, Ma J Y, Yang Y Y, Tian R and Dong K H (2019). Influence of priming with exogenous boron on the seed vigour of alfalfa (*Medicago sativa* L.). Legume Research-an International Journal *42*(6): 795-799.

Xie X, He Z, Chen N, Tang Z, Wang Q and Cai Y (2019). The roles of environmental factors in regulation of oxidative stress in plant. BioMed Research International 9732325.

Yamaguchi T and Blumwald E (2005). Developing salt-tolerant crop plants: Challenges and opportunities. Trends Plant Sci. 12: 615–620.

Yıldız M, Terzi H and Akçalı N (2014). Bitki Tuz Stresi Toleransında Salisilik Asit ve Poliaminler. Afyon Kocatepe Uni. J. of Science and Engineering 14(2): 7-22.