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Research Article

Determination of The Effect of Salicylic Acid Application on Salinity Stress at Germination Stage of Bread Wheat

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Abstract: Under changing climate, abiotic stresses especially salinity have posed serious threats to modern crop production systems of staple crops and chemo-priming with salicylic acid offers a promising remedy. The present study aimed at ameliorating the adverse effects of salt stress through optimization of salicylic acid (SA) for two bread wheat genotypes (DZ17-1 and Empire Plus). The trial was comprised of chemo-priming with different SA levels including 0, 0.5, and 1 mM applied to the seeds of bread wheat genotypes exposed to different salinity levels (0, 50, 100, 150, 200 mM NaCl). The response variables included germination indices, roots length, and weight along with seedling traits. The results revealed that increasing the level of salinity had a negative effect on both genotypes of wheat and all traits studied. The DZ17-7 genotype was found to be more tolerant to salt stress. Among SA concentrations, 1 mM imparted a significant influence on germination, root traits, and seedling parameters. Although SA showed positive effects in salt stress conditions in the study, further studies are needed to clarify the role of SA in providing stress tolerance of plants.

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Ekmeklik Buğdaya Salisilik Asit Uygulamasının Çimlenme Döneminde Tuzluluk Stresine Etkisinin Belirlenmesi

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Öz: Değişen iklim koşulları altında, abiyotik stresler, özellikle tuzluluk, temel ürünlerin üretiminde ciddi tehditler oluşturmakta ve salisilik asit bu etkilerin azaltılmasında umut verici bir çözüm sunmaktadır. Bu çalışma, iki ekmeklik buğday genotipine (DZ17-1 ve Empire Plus) salisilik asit (SA) uygulamasının tuz

Anahtar Kelimeler

Abiyotik stres,
Çimlenme,
Kök Uzunluğu

stresinin olumsuz etkilerini iyileştirmesi amaçlamıştır. Araştırmada, farklı tuzluluk seviyelerine (0, 50, 100, 150, 200 mM NaCl) maruz bırakılan ekmeklik buğday genotiplerinin tohumlarına 0, 0.5 ve 1 mM salisilik asit uygulanmıştır. Çalışmada çimlenme indeksleri, kök ve fide özellikleri incelenmiştir. Araştırma sonuçlarına göre, artan tuzluluk seviyesinin hem buğday genotiplerini hem de incelenen tüm özellikleri olumsuz etkilediğini ortaya koymuştur. DZ17-7 genotipinin tuz stresine daha toleranslı olduğu bulunmuştur. SA konsantrasyonları arasında 1 mM, çimlenme, kök özellikleri ve fide parametreleri üzerinde önemli bir etki sağlamıştır. SA, çalışmada tuz stresi koşullarında olumlu etkiler gösterse de bitkilerin stres toleransını sağlamada SA'nın rolünü netleştirmek için daha fazla çalışmaya ihtiyaç duyulmaktadır.

Dipnot: Bu makale Melikşah YILMAZ'ın Yüksek Lisans tezinden üretilmiştir.

1. Introduction

Globally, changing climate and global warming have threatened the food production systems and rapidly increasing human population demands proportionate increase in staple crops production. However, abiotic stresses especially frequent spells of drought and salinity have emerged as daunting challenges posed to multiply crops yield on a per hectare basis (Alghawry et al., 2021; Chowdhury et al., 2021; Iqbal et al., 2021). Wheat (*Triticum aestivum* L.) has been regarded as the most significant cereal crop for ensuring the food security and poverty alleviation strategy of farmers worldwide. It ranks second most important crop after rice and is being cultivated in all continents (Giraldo et al., 2019). It is a staple food for around 36% of the world's population and provides over 20% of daily calories and 55% of total carbohydrates to humans (Siddiqui et al. 2019; Kizilgeci, 2021). Currently, the wheat yield remains low and stagnant, primarily owing to suboptimal growth conditions. (FAO, 2016). Recently, climate change is feared to impart further adverse effects on germination, growth, and yield of wheat crops (Asseng et al., 2015).

Among abiotic stresses, salinity causes numerous biochemical and physiological damages in crop plants and ultimately deteriorates the grain yield and quality (Can et al., 2021). Salinity stress causes osmotic stress and ion toxicity by increasing the assimilation of Na^+ ions and decreasing the Na^+/K^+ ratio due to low osmotic potential in plant roots. Furthermore, this ionic imbalance affects the uptake and transport of other essential ions in target cells and inhibits important plant processes and functions (Arif et al., 2020). In general, among field crops, wheat is more sensitive to salinity, which inhibits plant growth and development. Salinity is the most adverse factor affecting the quality and productivity of wheat by changing its physiological activities as well as its biochemical activities. Soil salinity adversely affects various morphological structures of wheat including seedling growth, plant height, shoot and root length, root, leaf, fresh and dry weight, root/shoot ratio, and chlorophyll content (Iyem et al., 2020). Salinity stress accelerates all phenological stages of wheat (Grieve et al., 1994), reduces the number of tillering (Abbas et al., 2013), the number of spikelets per spike (Frank et al., 1987), grain weight (Abbas et al., 2013), and negatively affect grain yield (Sorour et al., 2019). Ali et al. (2009) reported that wheat exposed to salt stress caused a decrease of up to 45% in yield.

Salicylic acid (SA) or ortho hydroxybenzoic acid [C_6H_4 (OH)CO_2H] is a phenolic type endogenous growth regulator having the potential to ameliorate adverse effects of salt stress under varying pedo-climatic conditions (Javid et al., 2011; Moghaddam et al., 2020). The SA application holds the potential to increase the rate of photosynthesis, stomatal conductivity, and transpiration rate that assist plants to cope with the saline environment (Khan et al., 2003; Arfan et al., 2007). In addition, SA activates antioxidant protection (Xu et al., 2008) along with inhibiting the accumulation of Na^+ and Cl^- in plant cells (Gunes et al., 2007). Furthermore, Abhinandan et al. (2018) reported that SA application remained effective in triggering the vegetative growth of crop plants which reduced the deleterious effects of salinity by virtue of robust growth. In addition, Ma et al. (2017) inferred that SA exogenous application remained effective in improving germination, seedling growth, photosynthesis rate, antioxidant biosynthesis, numerous enzymes activation, stomata opening regulation, and chloroplast development. Moreover, SA was reported to have a critical role in triggering the carotenoids bio-synthesis along with enhancing the rate of de-epoxidation in wheat under saline environment (Moharekar et al., 2003). Previously, it has also been exhibited that SA imparted robustness to the antioxidant system in Brassica species (Yusuf et al., 2008). The SA application as chemo-priming (pre-sowing seed soaking for 6-72 hrs) might offer one of the biologically viable and promising approaches to cope with adverse effects of salinity on germination and early seedling growth through activation of numerous enzymes and biosynthesis of antioxidants (Choudhary et al. 2021; Zahoor et al., 2021). However, most of the studies have addressed the salinity stress at terminal stages of crop plants while research gaps exist regarding SA application as a seed priming agent in triggering the seed germination and seedling growth traits under saline environments of varying extent.

Thus, it was hypothesized that SA dose optimization for chemo-priming may assist in improving germination rate and seedling growth traits of wheat under varying levels of salinity. To this end, the prime aim of this trial was to assess the impact of different doses of SA on wheat genotypes germination and seedling growth parameters under saline conditions.

2. Material and Methods

The present study was executed in the laboratory of the Field Crops Department of the Faculty of Agriculture, Şırnak University, Turkey in 2020. In the research, material was advanced bread wheat line DZ17-1 (developed by Dicle University, Turkey) and Empire Plus bread wheat genotype. The trial was comprised of different levels of SA (0, 0.5, and 1 mM) applied as a seed priming agent to wheat under varying levels of imposed salinity (0, 50, 100, 150, and 200 mM). The trial was executed as a factorial experiment under a completely randomized design having three replications. The genotypes were subjected to a seed priming process with 10% Sodium Hypochlorite (NaClO) to prevent contamination. The disinfected seeds were then rinsed 3 times with distilled water. The seed priming duration was 12 hours and then dried with drying towels at room temperature. 15 seeds from each genotype were placed on the filter paper in 9 cm plastic petri dishes, which is the germination medium. The trial was carried out in a germination chamber at a constant temperature of 24±1 °C for 8 days, with a day and night length of 18/6 hours. To create salt stress, NaCl solutions were prepared at doses of for each application, and 10 ml were applied to the seeds placed in petri dishes and allowed to germinate. Characteristics examined in the study we are determined according to Yildirim et al. (2015) (coleoptile length, seedling length (mm), root length (cm), shoot dry weight (mg), germination rate (%), germination vigour (%)).

2.1 Statistical analysis

The analysis of variance (ANOVA) of the data obtained from the study was performed using the JMP 10 package program according to the factorial experiment under a completely randomized design. Differences between means were interpreted according to the 5% LSD test.

3. Results and Discussions

3. 1. Coleoptile length

The coleoptile length and multiple comparisons of bread wheat genotypes subjected to salicylic acid and salt stress are given in Table 1.

The highest coleoptile length value was recorded for the DZ17-1 genotype using 1 mM SA + 50 mM NaCl, while the lowest (5.47 mm) was obtained in the DZ17-1 genotype from the application of 0.5 mM SA + 200 mM NaCl. The increase in salt stress caused significant reductions in the coleoptile length of both genotypes. DZ17-1 genotype was found to be more resistant to salt stress conditions than Empire Plus variety. It was determined that salicylic acid application to salt doses had no effect on coleoptile length (Figure 1).

Table 1. Average values of coleoptiles length (mm) and multiple comparisons of bread wheat genotypes subjected to salicylic acid and salt stress

Genotypes	Salicylic acid (mM)	Salt stress (mM)				
		0	50	100	150	200
	0	25.42a-d	24.39abc	22.85c-f	19.33ghi	8.18op
DZ17-1	0.5	24.16a-d	23.32b-e	24.39a-d	13.90lm	5.47p
	1	26.70ab	27.19a	25.83abc	18.42g-j	5.64p
	0	21.60d-g	24.54a-d	20.52e-h	14.75klm	7.13op
Empire Plus	0.5	20.75e-h	18.12h-k	15.50j-m	12.83mn	9.35o
	1	19.65f-i	18.47g-j	16.38i-l	10.04no	7.25op
DZ17-1 mean		25.43A	24.97A	24.35A	17.22C	6.43E
Empire Plus mean		20.67B	20.38B	17.46C	12.54D	7.91E

Differences between means with the same lowercase and uppercase letter are not statistically significant.

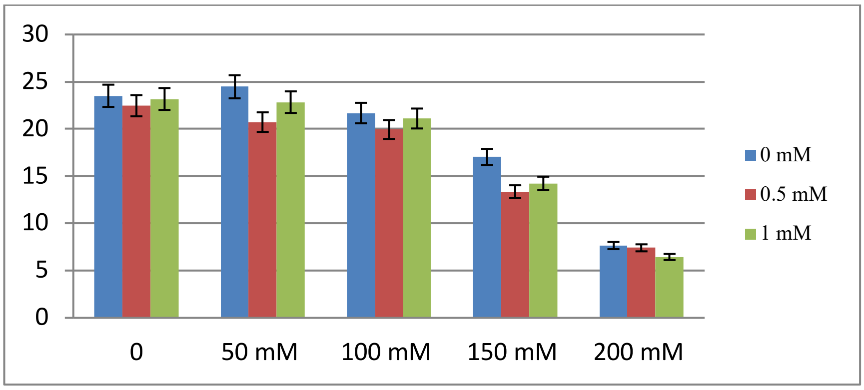

Figure 1. The effects of salicylic acid and NaCl application on the coleoptile length of bread wheat.

Kizilgeci (2021) reported that increasing salt concentrations and decreasing enzyme activities caused a decrease in the coleoptile length of the seeds. Many other researchers have also reported a significant decrease in coleoptile length due to the increase in salt stress (Yildirim et al., 2015; Iyem et al., 2020; Kizilgeci et al., 2020). Responses of genotypes to salicylic acid application under 200 mM salt stress conditions were similar. In our study, it was observed that salicylic acid application was ineffective in reducing the negative effects of salt stress on coleoptile length. Additionally, it was also observed that SA imparted an inhibitory effect in the Empire plus genotype. These findings are in contradiction with those of Canakci and Munzuroğlu (2007) who reported that SA exogenous application in low concentrations increased the coleoptile length under normal conditions, while its high concentrations caused an inhibitory effect on seedling growth and development.

3.2. Root length

The root length values and multiple comparisons of bread wheat genotypes subjected to salicylic acid seed priming under salt stress are given in Table 2.

It was observed that the highest root length (72.28 mm) was obtained in the DZ17-1 genotype by 1 mM SA under non-saline conditions, while the lowest value (6.21 mm) was obtained for Empire Plus genotype by 0.5 mM SA under 200 mM NaCl salt stress. The effects of salicylic acid application on root length properties differed under salt stress conditions (Figure 2). The increase in salt stress resulted in significant reductions in the root length of both genotypes. In accordance with our findings, many researchers have stated that increasing levels of salinity stress resulted in a higher degree of adverse effects on the root length of many field crops (Yildirim et al., 2015; Iyem et al., 2020; Kizilgeci et al., 2020). Additionally, it was also inferred that SA applications up to 100 mM salinity level imparted a positive effect on the root length of the DZ17-1 genotype. Moreover, Empire plus genotype was adversely affected by all doses of SA under varying salinity levels. These findings corroborate with those of Dolatabadian et al. (2009) who opined that SA enhanced the root length of wheat under severe saline conditions, while Zahra et al. (2011) reported that root elongation was inhibited in parallel with the increase in salicylic acid concentration under salt stress conditions.

Table 2. Average values of root length (mm) and multiple comparisons of bread wheat genotypes subjected to salicylic acid and salt stress

Genotypes	Salicylic acid (mM)	Salt stress (mM) 0	50	100	150	200
DZ17-1	0	44.80	37.02	22.74	18.93	9.46
	0.5	49.12	35.72	25.85	13.56	9.81
	1	72.28	41.27	31.72	14.79	9.43
Empire Plus	0	37.42	25.40	19.13	11.34	9.59
	0.5	21.97	21.99	12.60	10.10	6.21
	1	35.50	20.86	15.14	10.99	7.12
DZ17-1 mean		55.40A	38.00B	26.77CD	15.76E	9.57F
Empire Plus mean		31.63C	22.75D	15.62E	10.81EF	7.64F

Differences between means with the same lowercase and uppercase letter are not statistically significant.

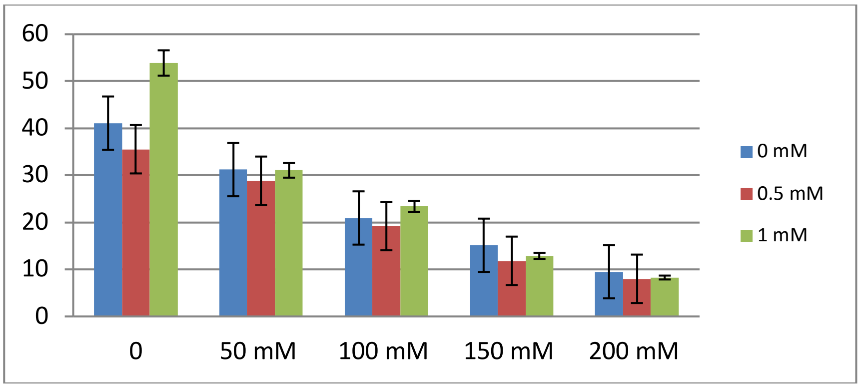

Figure 2. The effects of salicylic acid and NaCl application on the root length of bread wheat.

3.3. Seedling length

The impact of different doses of SA on seedling length of wheat genotypes under varying levels of salinity has been illustrated in Table 3.

Table 3. Average values of seedling length (mm) and multiple comparisons of bread wheat genotypes subjected to salicylic acid and salt stress

Genotypes	Salicylic acid (mM)	Salt stress (mM) 0	50	100	150	200
DZ17-1	0	89.92	74.97	52.95	24.54	8.18
	0.5	108.91	88.48	65.28	21.68	5.47
	1	91.86	79.81	60.44	25.68	5.64
Empire Plus	0	74.44	86.33	43.96	18.62	7.13
	0.5	74.87	52.30	40.33	20.63	12.72
	1	78.04	60.41	37.74	13.59	7.25
DZ17-1 mean		96.89A	81.09B	59.56D	23.97F	6.43H
Empire Plus mean		75.78BC	66.35CD	40.68E	17.61FG	9.03GH

Differences between means with the same lowercase and uppercase letter are not statistically significant.

The tallest seedling length (108.91 mm) was obtained for DZ17-1 genotype in 0.5 mM SA + 0 mM NaCl application, while the lowest (5.47 mm) was obtained for DZ17-1 genotype from 0.5 mM SA + 200 mM NaCl application.

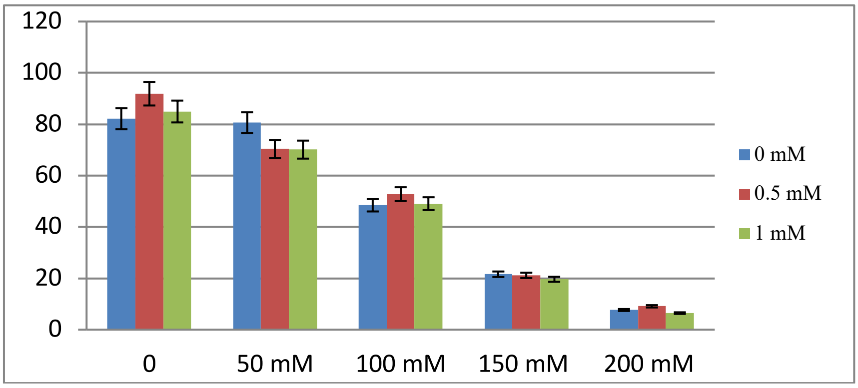

Figure 3. Seedling length in response to different doses of SA under varying levels of salinity.

The increase in salt stress caused significant reductions in the seedling length of both genotypes. However, it was observed that the DZ17-1 genotype was more affected at the highest salt stress compared to the control. It was observed that SA application did not have an effect on increasing seedling length. Likewise, Werner and Finkelstein (1995) reported that high salinity slowed down the plant's water uptake, thus inhibiting root and shoot elongation. Moreover, Shakirova et al. (2003) reported that SA increased the resistance of wheat seedlings to salinity, and 0.05 mM SA application improved plant growth and caused ABA and proline accumulation in wheat.

3.4. Root fresh weight

Table 4 illustrates the root fresh weight of wheat genotypes subjected to chemo-priming with different concentrations of SA under varying levels of induced salinity.

Table 4. Average values of root fresh weight (mg) and multiple comparisons of bread wheat genotypes subjected to salicylic acid and salt stress

Genotypes	Salicylic acid (mM)	Salt stress (mM)				
		0	50	100	150	200
DZ17-1	0	36.7e-k	29.9e-m	37.4e-k	50.5cde	19.7g-m
	0.5	40.3e-i	45.5def	38.8e-j	37.3e-k	35.6e-l
	1	170.8a	73.6bc	84.9b	66.1bcd	42.2e-h
Empire Plus	0	28.9e-m	23.2f-m	23.1f-m	26.4f-m	15.3j-m
	0.5	22.2f-m	12.4lm	24.6f-m	13.8klm	7.2m
	1	43.3d-g	51.4cde	27.7e-m	17.4i-m	19.3h-m
DZ17-1 mean		82.6A	49.7B	53.7B	51.3B	32.5C
Empire Plus mean		31.5C	29.0C	25.1CD	19.2CD	13.9D

Differences between means with the same lowercase and uppercase letter are not statistically significant.

The results revealed that the maximum root fresh weight (170.8 mg) was obtained in the DZ17-1 genotype that was chemo-primed with 1 mM SA and was grown under non-saline conditions, while the lowest value (7.2 mg) was determined in the Empire Plus genotype from the application of 0.5 mM SA + 200 mM NaCl.

The effects of salicylic acid application on root fresh weight properties differed under salt stress conditions (Figure 4). The highest root fresh weight was determined in the combination of 0 mM NaCl +1 mM SA, while the lowest value was determined at 200 mM NaCl + 0 mM SA and 0.5 mM SA.

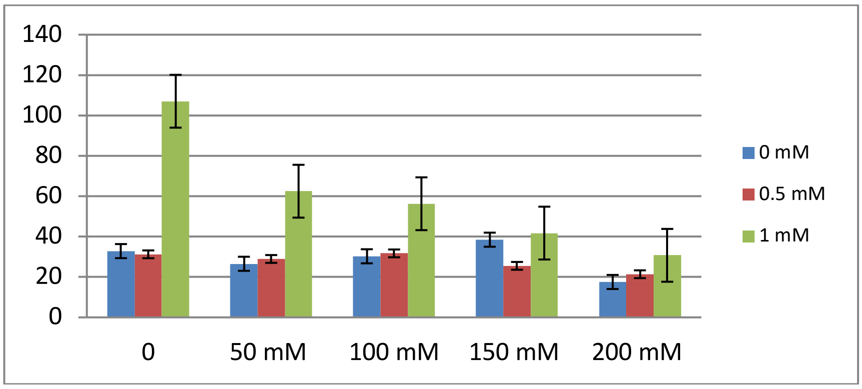

Figure 4. The effects of salicylic acid and NaCl application on the root fresh weight of bread wheat.

The increase in salt stress resulted in significant decreases in root fresh weight of both genotypes. It was observed that the 1 mM SA dose applied in the study had a positive effect on this feature under all stress conditions.

3.5. Seedling fresh weight

Average values of seedling fresh weight and multiple comparisons of bread wheat genotypes subjected to salicylic acid and salt stress are given in Table 5.

Table 5. Average values of seedling fresh weight (mg) and multiple comparisons of bread wheat genotypes subjected to salicylic acid and salt stress

Genotypes	Salicylic acid (mM)	Salt stress (mM)				
		0	50	100	150	200
DZ17-1	0	249.8cd	2404cde	174.9d-j	167.3d-k	30.9no
	0.5	364.7b	294.8bc	196.6c-h	86.3i-o	112.4g-o
	1	505.6a	373.4b	354.6b	153.6d-l	66.5k-o
Empire Plus	0	218.4c-f	213.5c-g	128.1f-n	76.8j-o	26.3no
	0.5	94.3h-o	47.4mno	55.6l-o	50.6l-o	21.6o
	1	145.8e-m	183.5d-i	72.1j-o	33.6no	23.0o
DZ17-1 mean		373.4A	302.8B	242.1C	135.7DE	69.9FG
Empire Plus mean		152.9D	148.1D	85.3EF	53.7FG	23.6G

Differences between means with the same lowercase and uppercase letter are not statistically significant.

As per recorded data, the highest seedling fresh weight (505.6 mg) was obtained in the DZ17-1 genotype that was subjected to chemo-priming with 1 mM SA and grown under optimum growth conditions, while the lowest (21.6 mg) was recorded for Empire Plus genotype having chemo-priming with 0.5 mM SA and was grown under maximum salinity level of 200 mM NaCl.

The increase in salt stress resulted in significant decreases in the seedling fresh weight of both genotypes. Kizilgeci et al. (2020) reported that as the severity of salt stress increased, the seedling's fresh weight decreased. In the present study, it was observed that SA application had an improving effect on seedling fresh weight under stress conditions. Similar to our study, Tepe (2011) reported that SA application has an increasing effect on seedling fresh weight compared to control. Bahrani and Pourreza (2012), in their study investigating the effect of the different salicylic acid applications on seedling fresh weight under salinity stress, obtained the highest seedling fresh weight value in 1.5 mg L^{-1} SA application.

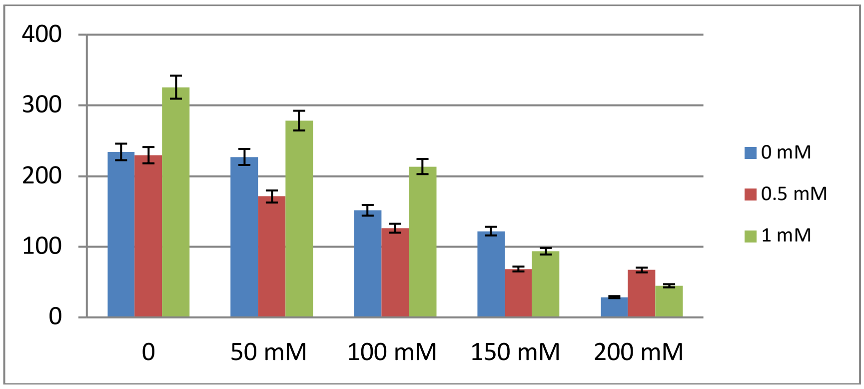

Figure 5. The effects of salicylic acid and NaCl application on the seedling fresh weight of bread wheat.

3.6. Root dry weight

Average values of root dry weight and multiple comparisons of bread wheat genotypes subjected to salicylic acid and salt stress are given in Table 6.

Table 6. Average values of root dry weight (mg) and multiple comparisons of bread wheat genotypes subjected to salicylic acid and salt stress

		Salt stress (mM)				
Genotypes	**Salicylic acid (mM)**	**0**	**50**	**100**	**150**	**200**
DZ17-1	0	23.0	17.2	42.8	31.3	11.6
	0.5	27.5	31.8	25.9	30.5	12.8
	1	40.5	33.1	44.6	41.2	20.1
Empire Plus	0	23.1	15.0	13.2	14.5	8.1
	0.5	11.9	10.5	9.1	12.3	7.2
	1	14.4	28.0	11.8	7.3	6.9
DZ17-1 mean		30.3AB	27.4B	37.8A	34.3AB	14.8CD
Empire Plus mean		16.5C	17.8C	11.4CD	11.3CD	7.4D

Differences between means with the same lowercase and uppercase letter are not statistically significant.

The highest root dry weight value (44.6 mg) was obtained for the DZ17-1 genotype that was chemo-primed with 1 mM SA under 100 mM salinity level, while the lowest value (6.9 mg) was obtained in the Empire Plus genotype chemo-primed with 1 mM SA and exposed to 200 mM salinity level.

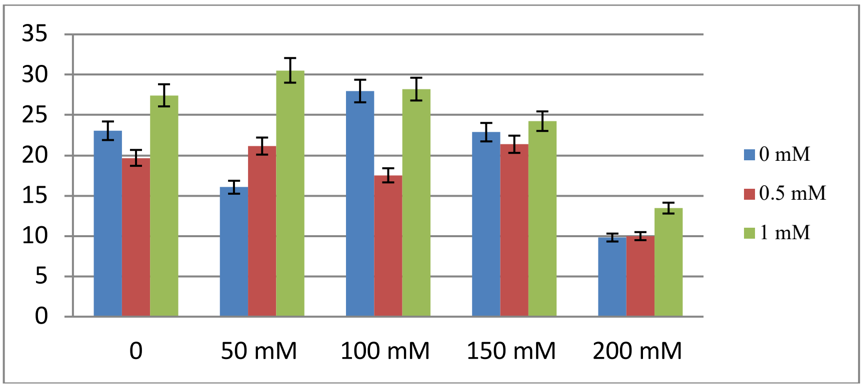

Figure 6. The effects of salicylic acid and NaCl application on the root dry weight of bread wheat.

Salt stress caused a decrease in root dry weight and these results corroborate with those of Yildirim et al. (2015) who also observed a significant decrease in root growth parameters (fresh and dry weight) in wheat. In addition, Sourour et al. (2014) stated that the toxic effects of a saline environment may be due to the accumulation of salts in cells which disrupted numerous physiological and chemical process, and ultimately root growth was negatively affected, and ultimately significantly lowered root dry weight was recorded. In our study, it was observed that salicylic acid application had an increasing effect on root dry weight. Similarly, Karlidag et al. (2009) obtained the highest root dry weight value of 1 mM SA application in their study.

3.7. Seedling dry weight

The seedling dry weight of bread wheat genotypes as affected by seed priming of salicylic acid under varying levels of salt stress are given in Table 7.

Table 7. Average values of seedling dry weight (mg) and multiple comparisons of bread wheat genotypes subjected to salicylic acid and salt stress

Genotypes	Salicylic acid (mM)	Salt stress (mM)				
		0	50	100	150	200
DZ17-1	0	43.2	38.3	75.7	32.5	9.7
	0.5	55.4	47.7	37.4	21.5	7.7
	1	62.4	50.2	60.3	31.8	36.1
Empire Plus	0	41.8	35.8	22.8	15.3	7.2
	0.5	16.8	17.4	9.9	12.2	7.4
	1	23.1	35.5	13.3	6.1	5.7
DZ17-1 mean		53.6	45.4	57.8	28.6	17.8
Empire Plus mean		27.2	29.5	15.4	11.2	6.7

Differences between means with the same lowercase and uppercase letter are not statistically significant.

The maximum seedling dry weight (62.4 mg) was obtained in the DZ17-1 genotype in the application of 1 mM SA + 0 mM NaCl, according to the general averages of the genotypes, while the lowest seedling dry weight (5.7 mg) was obtained in the Empire Plus genotype by1 mM SA application under salinity level of 200 mM NaCl.

The increasing level of salinity caused a proportionate decrease in the dry weight of the seedlings. These results are in complete agreement with those of Iyem et al. (2020) who reported that salinity significantly enhanced the dry weight of wheat owing to increased biosynthesis of antioxidants and various enzymes which ameliorated the adverse effects of salinity and ultimately seedling growth was promoted which resulted in the maximized seedling weight of wheat. The effects of SA acid application on seedling dry weight under salt stress conditions were similar. El-Tayeb (2005) reported that SA pre-treatment increased the dry weight of barley seedlings under stress conditions and Khodary (2004) reported that SA increased the fresh and dry weight of shoots of maize plants under salt stress.

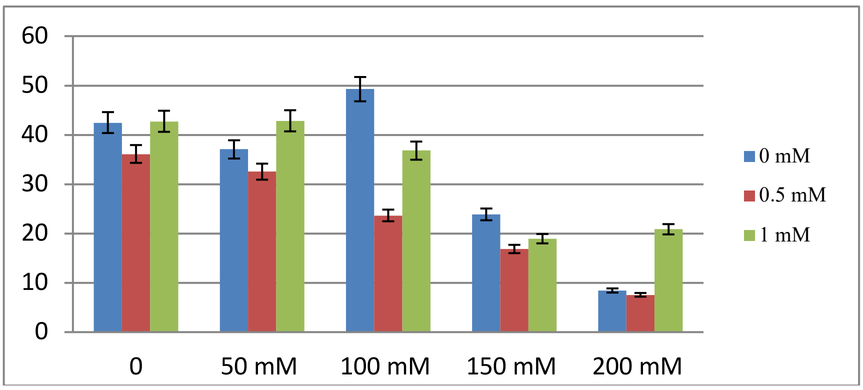

Figure 7. The effects of salicylic acid and NaCl application on the seedling dry weight of bread wheat.

3.8. Germination rate

The impact of chemo-priming with different concentrations of SA on wheat genotypes exposed to different levels salinity have been presented in Table 8.

Table 8. Average values of germination rate (%) and multiple comparisons of bread wheat genotypes subjected to salicylic acid and salt stress

Genotypes	Salicylic acid (mM)	Salt stress (mM) 0	50	100	150	200
DZ17-1	0	76.92a	59.62b-e	65.38abc	65.38abc	69.23ab
	0.5	53.85b-f	48.08d-h	55.77b-f	51.92c-g	36.54ghi
	1	59.62b-e	51.92c-g	69.23ab	67.31abc	53.85b-f
Empire Plus	0	57.69b-f	63.46a-d	57.69b-f	57.69b-f	55.77b-f
	0.5	57.69b-f	42.31fgh	46.15e-h	53.85b-f	25.00ij
	1	61.54a-e	65.38abc	42.31fh	32.69hij	19.23j
DZ17-1 mean		63.46A	53.21BC	63.46A	61.54AB	53.21BC
Empire Plus mean		58.97AB	57.05ABC	48.72C	48.08C	33.33D

Differences between means with the same lowercase and uppercase letter are not statistically significant.

The maximum germination rate (76.92%) was obtained in the DZ17-1 genotype in the application of 0 mM SA + 0 mM NaCl, according to the general averages of the genotypes, while the lowest (19.23%) was obtained in the Empire plus genotype from the application of 1 mM SA + 200 mM NaCl.

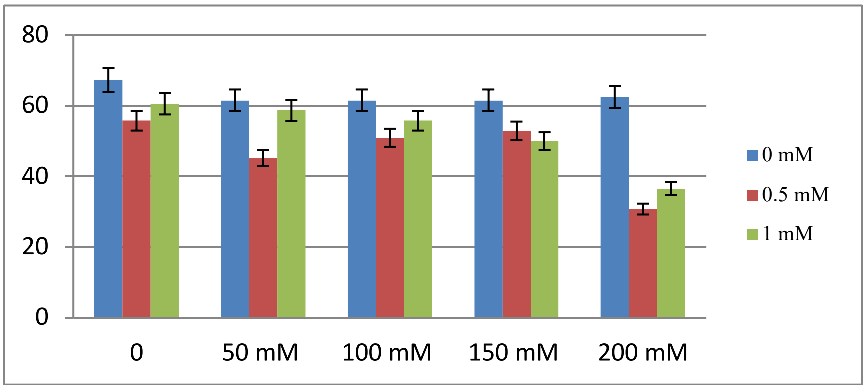

Figure 8. The effects of salicylic acid and NaCl application on the germination rate of bread wheat.

3.9. Germination vigour

Average values of germination vigour and multiple comparisons of bread wheat genotypes subjected to salicylic acid and salt stress are given in Table 9.

The highest germination vigour (92.31%) was obtained in DZ17-1 and Empire Plus genotypes in 0 mM SA + 0 mM NaCl application, while the lowest (36.54%) was obtained in DZ17-1 genotype from 0.5 mM SA + 200 mM NaCl application.

Variety characteristic is an important factor affecting the germination performance of the seed. In previous studies, it was reported that different wheat varieties have different germination rates (Rahman et al., 2008; Moud and Maghsoudi, 2008; Kochak-zadeh et al., 2013). Salt stress had adverse effects on the germination rate of both genotypes. It was observed that the increase in salt stress caused a decrease in the germination rate. Iyem et al. (2020) reported that the increase in salt stress negatively affects germination vigour. Furthermore, El Sabagh (2019) reported that salinity stress delays or reduces germination of wheat probably owing to delayed seed imbibition as saline environment hindered the moisture absorption by wheat seeds.

Table 9. Average values of germination vigour (%) and multiple comparisons of bread wheat genotypes subjected to salicylic acid and salt stress

Genotypes	Salicylic acid (mM)	Salt stress (mM)				
		0	50	100	150	200
DZ17-1	0	92.31	63.46	75.00	67.31	71.15
	0.5	90.38	63.46	57.69	55.77	36.54
	1	88.46	71.15	73.08	65.38	53.85
Empire Plus	0	92.31	71.15	63.46	61.54	55.77
	0.5	84.62	55.77	50.00	53.85	38.46
	1	90.38	73.08	40.38	32.69	36.55
DZ17-1 mean		90.38A	66.03B	68.59B	62.82BC	53.85CD
Empire Plus mean		89.10A	66.67B	51.28DE	49.36DE	43.59E

Differences between means with the same lowercase and uppercase letter are not statistically significant.

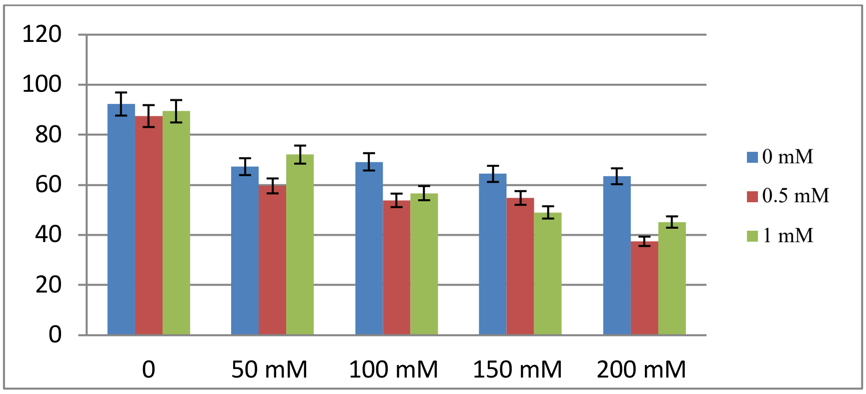

Figure 9. The effects of salicylic acid and NaCl application on germination vigour of bread wheat.

Conclusion

The research findings remained as per postulated hypothesis as varying levels of salinity had adverse effects on seed germination and seedling growth traits, while SA seed priming in varying concentrations remained effective in ameliorating the deleterious effects of saline environment. All levels of salinity had adverse effects on germination and seedling growth of wheat genotypes. It may also be inferred from results that wheat genotype DZ17-1 was salt tolerant compared to Empire Plus genotype, while lower concentration of salicylic acid (1 mM) remained effective in mitigating the adverse effects of salinity as indicated by higher germination, root growth and seedling traits. Although, results of this trial are encouraging in the sense that salt tolerant genotype and most promising SA priming concentration have been determined, but further in-depth trials entailing more genotypes and SA concentrations need field evaluation in order to formulate strategy for general adoption in Turkey and regions having similar climatic conditions.

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