Journal Homepage: http://dergipark.gov.tr/ethabd
DergiPark
AKADEMİK
ETHABD
Erciyes Tarım ve Hayvan Bilimleri Dergisi
ISSN:2651-5334

Role of Gibberellic Acid (GA3) in Improving Salt Stress Tolerance of Wheat (Triticum avestivum)

Araştırma Makalesi/Research Article

Atıf İçin: Doruk Kahraman, N., Okumuş, O. (2024). Gibberellik Asit (GA3)'in Buğdayın (Triticum aestivum) Tuz Stresi Toleransını Artırmadaki Rolü. Erciyes Tarım ve Hayvan Bilimleri Dergisi, 7(2): 86-93

To Cite: Doruk Kahraman, N., Okumuş, O. (2024). Role of Gibberellic Acid (GA3) in Improving Salt Stress Tolerance of Wheat (Triticum avestivum). Journal of Erciyes Agriculture and Animal Science, 7(2): 86-93

Neslihan DORUK KAHRAMAN[1*], Onur OKUMUŞ[2]
[1]*University of Selcuk, Faculty of Agriculture, Department of Field Crops, Konya, Türkiye*
[2]*University of Erciyes, Faculty of Agriculture, Department of Field Crops, Kayseri, Türkiye*
***sorumlu yazar**:* neslihan.doruk@selcuk.edu.tr
Neslihan DORUK KAHRAMAN, ORCID No: 0000-0002-3613-4399, Onur OKUMUŞ, ORCID No: 0000-0001-6957-3729

Yayın Bilgisi

Geliş Tarihi: 02.10.2024
Revizyon Tarihi: 18.10.2024
Kabul Tarihi: 20.10.2024
doi: 10.55257/ethabd.1560194

Role of Gibberellic Acid (GA3) in Improving Salt Stress Tolerance of Wheat (Triticum avestivum)

Abstract

Salinity is an abiotic stress factor that has negative effects on plant growth and development. The aim of this study was to determine the effects of gibberellic acid (GA3) treatments at different levels of salt stress (0, 5 and 10 dS/m NaCl) on germination, shoot length, root length and seedling wet and dry weight on two wheat cultivars (Demirhan and Fazılbey). GA3 was applied at concentrations of 0, 100 and 200 ppm to reduce the negative effects of salt stress. The results showed that GA3 significantly increased germination percentage, shoot length and root length in both cultivars. Demirhan cultivar showed more pronounced responses at higher salt stress. Biplot analysis revealed the interaction between GA3 application, salinity levels and variety performance and the positive effect of GA3 in reducing the effects of salinity stress. These findings suggest that GA3 may be an effective strategy to enhance wheat growth in saline soils. Further studies are recommended to optimize GA3 concentrations and evaluate its long-term effects under field conditions.

Buğdayda (Triticum avestivum) Tuz Stresine Toleransını Geliştirmede Gibberellik Asitin (GA3) Etkisi

Özet

Tuzluluk, bitki büyüme ve gelişmesi üzerinde olumsuz etkiler yaratan abiotik stres faktörüdür. Bu çalışmanın amacı, iki buğday çeşidi (Demirhan ve Fazılbey) üzerinde farklı tuz stresi seviyelerinde (0, 5 ve 10 dS/m NaCl) gibberellic asit (GA3) uygulamalarının çimlenme, sürgün uzunluğu, kök uzunluğu ve fide yaş ve kuru ağırlık üzerindeki etkilerini belirlemektir. Tuz stresinin olumsuz etkilerini azaltmak için 0, 100 ve 200 ppm konsantrasyonlarında GA3 uygulanmıştır. Sonuçlar, GA3'ün her iki çeşitte de çimlenme yüzdesini, sürgün uzunluğunu ve kök uzunluğunu önemli ölçüde artırdığını göstermiştir. Demirhan çeşidinin, daha yüksek tuz stresinde daha belirgin tepkiler gösterdiği saptanmıştır. Yapılan biplot analizi ile GA3 uygulaması, tuzluluk seviyeleri ve çeşit performansı arasındaki etkileşimi ve GA3'ün tuzluluk stresinin etkilerini azaltmadaki olumlu etkisi belirlenmiştir. Bu bulgular, GA3'ün tuzlu topraklarda buğday büyümesini artırmada etkili bir strateji olabileceğini göstermektedir. GA3 konsantrasyonlarının optimize edilmesi ve arazi koşullarındaki uzun vadeli etkilerinin değerlendirilmesi için konuyla ilgili farklı çalışmaların yapılması önerilmektedir.

Anahtar Kelimeler
Gibberellik asit, buğday, tuzluluk, çimlenme, biplot analizi

Keywords
Gibberellic acid, wheat, salinity, germination, biplot analysis

1. INTRODUCTION

Abiotic stress is an important problem that significantly limits agricultural production worldwide (Yilmaz and Yaman 2015; Yaman and Yilmaz 2022;Kopecká et al., 2023). Salinity, among the abiotic stress factors, negatively affects plant growth and development (Prasad et al., 2008). Plants are sensitive to salinity in the early developmental stages, especially during germination and seedling development (Okumus et al., 2024). Wheat is a cereal used in the nutrition, trade and crop rotation systems of Türkiye and many world countries (Bilgiçli and Soylu, 2016). The wheat cultivation area in the world in 2022 is 219 million ha and production is 808 million tons (FAO, 2022). Wheat, which has been the most critical food source in Anatolia for thousands of years, has a cultivation area of 6.8 million ha and a production of 22 million tons according to 2023 data, and the share of bread wheat in total wheat cultivation areas is around 82% (TUIK, 2023). Among the main reasons why wheat production is so widespread worldwide, the adaptability of widespread cultivation worldwide, the ease of processing and storage stages, low cost and providing an economical content in terms of nutrition come to the fore (Zeybek et al., 2021).

In successful wheat cultivation, seed germination and seedling development is the most critical period for healthy plant growth (Almansouri et al., 2001). Healthy plant development depends on the outcome of the interaction between the environment in the seedbed and seed quality (Khajeh-Hosseini et al., 2003). Drought and salinity are the most critical environmental stress factors that negatively affect seed germination and seedling development (Sadeghian and Yavari, 2004; Bahrami and Razmjoo, 2012). Salinity, another environmental stress, is one of the most important factors limiting wheat yield. In Türkiye, approximately 1.500.000 hectares of agricultural soils have salinity problem (Serin, 2024).

Salt stress is an abiotic stress that affects the quality and marketability of cereals worldwide (Patwa and Penning, 2020). There is a need for appropriate varieties and practices to minimize yield losses due to salinity problem that limits productivity in crop production (Oral et al., 2019). Various types of research are carried out to accelerate germination in seeds sown in crop production and to ensure homogenous emergence (Duman and Esiyok, 1998; Col and Akinerdem 2017). Promising applications (folding, soaking in water, acid etching, treatment with growth regulators and hormones, etc.) are performed for this purpose (Yildiz et al., 2017). Among these, hormones, especially GA3 (Gibberellic acid), are used intensively (Oral et al., 2019).

Global climate change, excessive irrigation and fertilization and unconscious agricultural practices increase the amount of salt in the soil. For this reason, it is important to identify varieties adapted to saline soils and to determine sustainable activities to minimize salt damage. This study aimed to investigate the response of wheat plant, which is of strategic importance for the world and Türkiye agriculture, to salt stress at different GA3 doses.

2. MATERIALS AND METHODS

Demirhan, and Fazılbey wheat cultivars (Ankara Field Crops Central Research Institute) were used as plant material in the study. NaCl (Merck, Germany) was used for salt stress in the study. Salt levels were adjusted as control, 5 EC and 10 EC. The study was carried out under controlled conditions at 25oC temperature. The study was carried out in the laboratory of Erciyes University, Faculty of Agriculture under controlled conditions.

The seeds to be used in the study were sterilized with 1% sodium hypochlorite for 5 minutes and then rinsed 3 times with pure water. The seeds were sown in 25 replicates between 3 filter papers and sealed with a ziplock bag to prevent moisture loss. For each filter paper, 7 mL of solution was added. Seeds were considered germinated when the root (≥2 mm) emerged and germinated seeds were counted for 14 days. At the end of the 14th day, germination percentage (number of germinated seeds/25 x 100, %) was calculated, and shoot and root length (cm), wet weight (mg/plant), and dry weight (mg/plant) data were analyzed in 10 randomly selected seedlings.

Seed pretreatment procedures:

The study used 100, 200 ppm GA solutions for seed pretreatment.

Preparation of GA (100 ppm): To prepare 100 ppm GA3, 1g GA tablet was dissolved in 1 lt water and 100 ml of this solution was taken with a measuring cylinder and added to 1 lt water.

Preparation of GA (200 ppm): To prepare 200 ppm GA3, 1g GA tablet was dissolved in 1 lt water and 200 ml of this solution was taken with a measuring cylinder and added to 1 lt water.

In the experiment, pretreated seeds were treated with different doses of GA (100, 200 ppm) (Vahit et al., 2008), for 4 hours and untreated seeds were used as control.

Statistical Analysis:

The research was established as a factorial trial design in random plots with 3 replications. The data obtained as a result of the research were analyzed on the computer with the 'JMP 13.2.0' programme according to the factorial trial design in random plots. Treatment means were compared using the Tukey Multiple Comparison Test (Snedecor and Cochran, 1967).

3. RESULTS AND DISCUSSION

As a result of the study, the results of variance analysis of different GA3 and NaCl doses in barley varieties are given in Table 1.

This study evaluated the effects of gibberellic acid (GA3) on the germination, shoot length, root length, and biomass of two wheat cultivars (Demirhan and Fazılbey) under saline conditions. The results indicate that GA3 positively impacted these parameters, particularly under higher salt stress conditions.

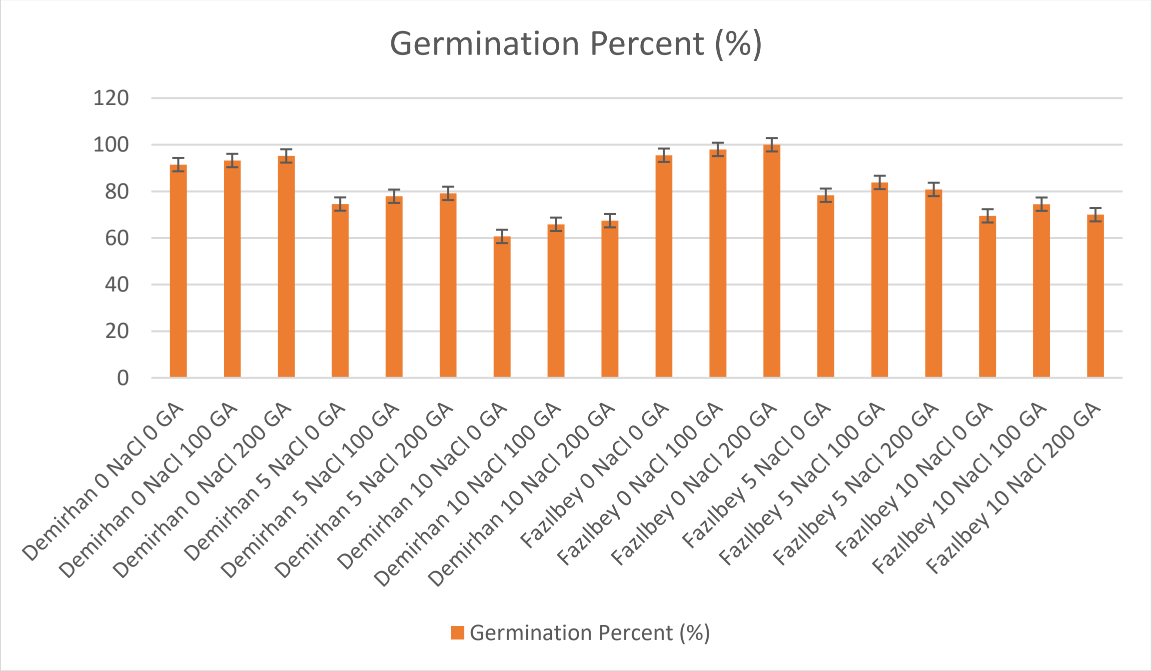
Table 1. Analysis of variance and tukey grouping

Cultivar	NaCl	GA3	Germination Percent	Shoot Lenght	Root Lenght	Fresh Weight	Dry Weight
Demirhan	Control	Control	91.46 c	10.80 cd	9.60 de	4.03 d	0.72 de
		100 ppm	93.23 c	12.60 b	11.27 bc	4.99 bc	0.88 b
		200 ppm	95.20 bc	14.13 a	10.83 cd	4.83 c	0.86 b
	5 EC	Control	74.57 fg	7.23 g	6.53 g	3.42 e	0.64 g
		100 ppm	77.90 ef	8.06 fg	7.40 fg	3.59 e	0.66 fg
		200 ppm	79.13 ef	8.50 f	7.10 fg	3.35 e	0.62 g
	10 EC	Control	60.67 i	3.87 j	2.50 h	1.81 i	0.39 i
		100 ppm	65.87 h	4.70 ij	3.10 h	2.20 fg	0.46 h
		200 ppm	67.43 h	4.76 hij	2.23 h	1.90 hi	0.37 i
Fazılbey	Control	Control	95.50 abc	12.33 b	12.33 ab	5.22 ab	0.90 ab
		100 ppm	98.00 ab	13.07 ab	13.17 a	5.40 a	0.93 a
		200 ppm	100.00 a	13.27 ab	11.77 bc	5.10 b	0.88 b
	5 EC	Control	78.33 ef	9.03 ef	8.13 f	4.03 d	0.70 ef
		100 ppm	83.83 d	9.73 de	8.33 ef	4.14 d	0.79 c
		200 ppm	80.83 de	10.93 c	7.57 fg	4.02 d	0.77 dc
	10 EC	Control	69.50 h	5.17 hi	3.47 h	2.14 fgh	0.46 h
		100 ppm	74.50 fg	5.80 h	2.77 h	2.34 f	0.49 h
		200 ppm	70.00 gh	5.40 hi	2.53 h	2.09 gh	0.40 i
		Cultivar	**	**	**	**	**
		NaCl	**	**	**	**	**
		GA3	**	**	**	**	**
		Cultivar x NaCl	*	*	**	**	**
		Cultivar x GA3	*	*	**	**	**
		NaCl x GA3	*nsg*	nsg	**	**	**
		Cultivar x NaCl x GA3	*	*	**	**	**

*p<0.5, **p<0.01

Germination Percentage

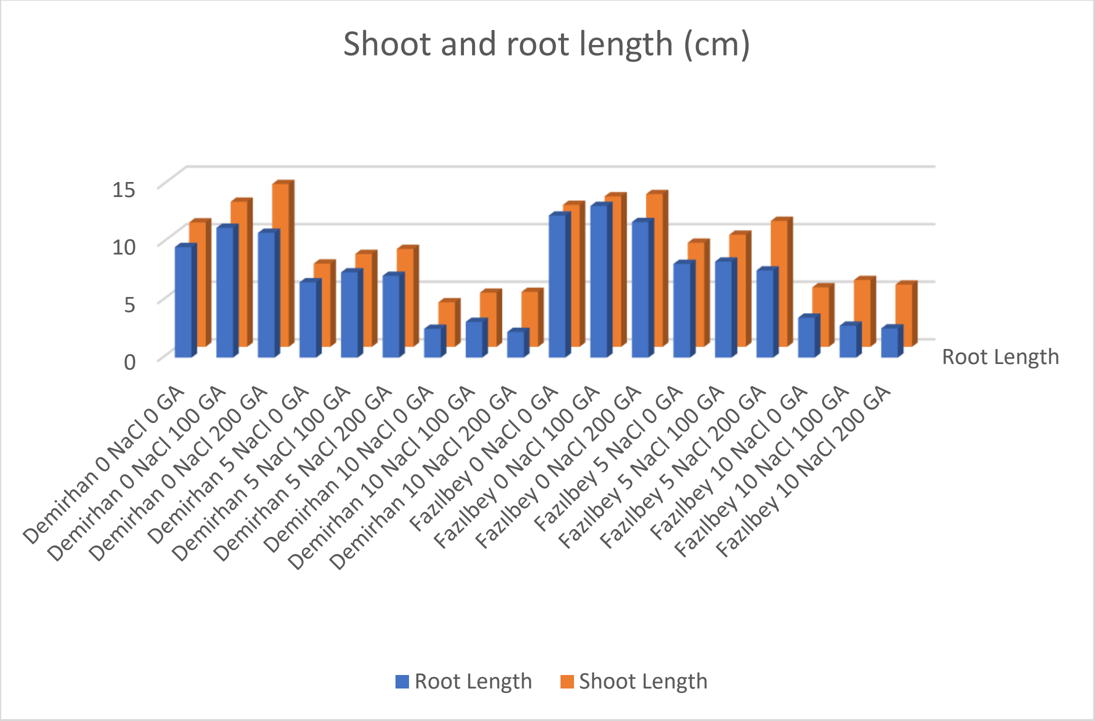
Salinity significantly reduced germination rates in both cultivars (Table 1). As previously reported in studies on various crop species, including barley and wheatder the highest salt dose (10 dS/m), the germination rate in Demirhan was 60.67% in the control group but increased to 67.43% with 200 ppm GA3 (Graph 1). Similarly, in Fazılbey, the germination rate rose from 69.50% to 70.00% with the same GA3 treatment. These findings align with previous research by Afzal et al. (2006), where GA3 was shown to mitigate the negative effects of salt stress on seed germination by enhancing water uptake and enzymatic activity. The positive effects on germination is likely due to its role in breaking seed dormancy and promoting the synthesis of hydrolytic enzymes, which mobilize stored nutrients in seeds.



Grapg 1. Germination percentage (%)

Shoot and Root Length

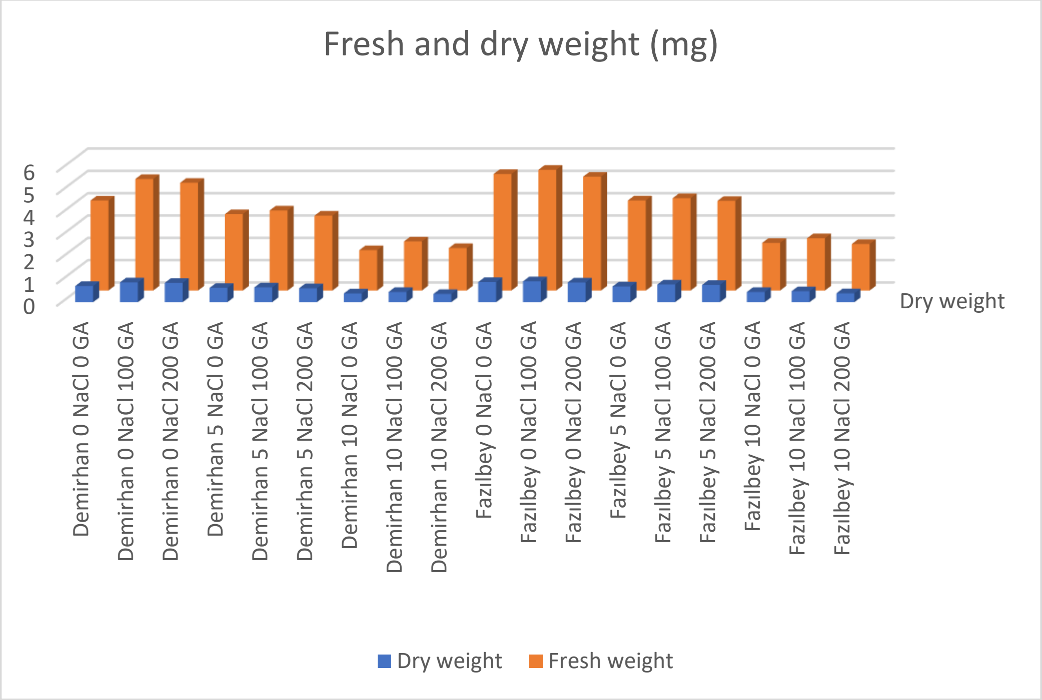
Salt stress also had a notable negative impact on shoot length, as observed in both cultivars. Under 10 dS/m salt stress, the shoot length of Demirhan was 3.87 cm in the control group but increased to 4.76 cm with 200 ppm GA3 (Table 1). In Fazılbey, shoot length increased from 5.17 cm to 5.40 cm with the same treatment. This suggests that GA3 effectively promotes shoot elongation, even under saline conditions, by stimulating cell division and elongation, as reported in previous studies (Benlioglu and Ozkan 2015; Benlioglu and Ozkan 2021) barley cultivars treated with GA3 under salt stress exhibited increased shoot length, further supporting the role of GA3 in counteracting the osmotic and ionic stresses induced by salinity. Root length was also affected by salinity. In Demirhan, root length in the control group under 10 dS/m was 2.50 cm, which increased to 2.23 cm with 200 ppm GA3. Fazılbey showed a similar trend, with root length increasing from 3.47 cm to 2.53 cm. These results align with the work of Zhu (2001), who emphasized that salinity interferes with water uptake and nutrient acquisition in roots, ultimately leading to stunted root growth. However, the application of GA3 appears to partially these effects by promoting the synthesis of enzymes involved in cell wall loosening, allowing for better root elongation.



Grapg 2. Shoot and root length

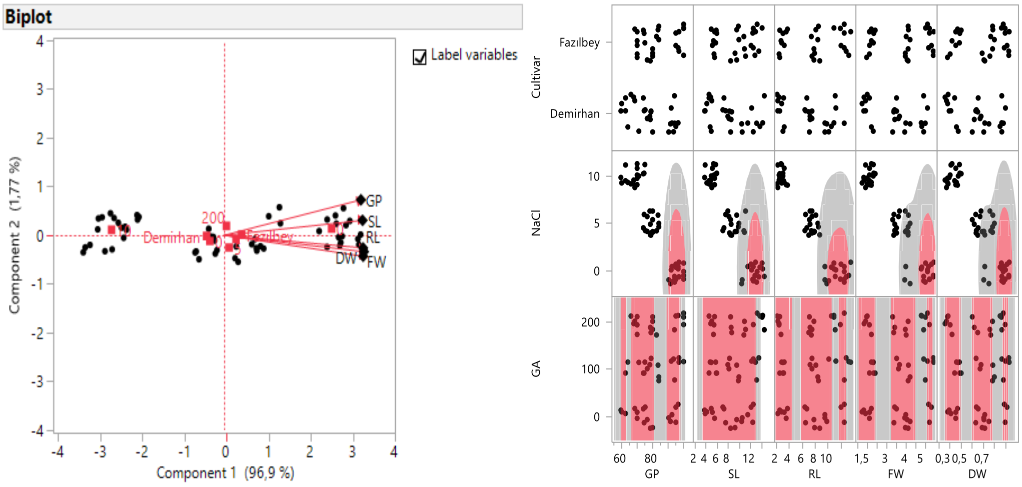
Fresh and Dry Weight

The adverse effects of salinity were evident in seedlings' fresh and dry weights. In Demirhan, fresh weight decreased to 1.81 mg/plant under 10 dS/m salt stress; however, GA3 treatment improved it to 1.90 mg/plant (Table 1). Similarly, in Fazılbey, fresh weight slightly decreased from 2.14 mg/plant to 2.09 mg/plant under the same conditions. Dry weight followed a similar trend, with 200 ppm GA3 slightly decreasing dry weight from 0.39 mg to 0.37 mg in Demirhan (Graph 3). These findings are consistent with those of Okumuş et al. (2023), who reported that magnetic field treatment combined with GA3 improved salt tolerance and biomass accumulation in barley seedlings. Wahid et al. (2008) also highlighted that priming with GA3 enhances metabolic processes that improve seedling vigor and growth under stress conditions (Doruk Kahraman and Topal 2024). The results of this study demonstrate that deviate some of the adverse effects of salinity on wheat germination and early growth. The efficacy of GA3 varied between the two cultivars, with Demirhan showing a more pronounced response in shoot length and germination percentage. These findings are consistent with previous research on the role of GA3 in promoting plant growth under stress by improving enzyme activity and nutrient mobilization . Further research is needed to optimize GA3 application rates and explore its lonp performance under saline conditions, as suggested by studies such as those by Munns and Tester (2008).



Grapg 3. Fresh and dry weight

The biplot clearly visualized the interaction effects of GA3, salt stress, and cultivar on the studied parameters (Graph 4). Both Demirhan and Fazılbey showed distinct patterns in response to GA3 treatment under different salt stress levels. This underscores the importance of selecting the appropriate GA3 concentration and cultivar when managing salt stress in wheat. The PCA graph also supported these findings by showing that germination, shoot length, and biomass were positively influenced by higher GA3 doses, even under increasing salt stress.



Graph 4. Principal component analysis (PCA) and scatterplot matrix

4. CONCLUSION

These findings align with previous research, suggesting that GA3 enhances stress tolerance by promoting enzyme activity and nutrient mobilization. However, the degree of improvement varies between cultivars, indicating that genetic differences affect salt stress tolerance mechanisms. In conclusion, the GA3 application presents a promising strategy for enhancing crop performance in saline soils. Future research should focus on optimizing GA3 concentrations and exploring its long-term effects on wheat and other crops under various environmental stress conditions.

REFERENCES

Afzal, I., Basra, S.M.A., Shahid, M., and Farooq, M., 2006. Gibberellic acid mediated seed priming enhances germination and seedling vigor of wheat under saline conditions. Journal of Agronomy and Crop Science, 192(1), 38-44.

Almansouri, M., Kinet, J.M. and Lutts, S., 2001. Effect of salt and osmotic stress on germination in durum wheat (Triticum durum Desf.). Plant Soil, 231, 245-256. and tolerance to subsequent exposure to cold and salt stress in capsicum.

Bahrami, H., and Razmjoo, J., 2012. Effect of salinity stress (NaCl) on germination and early seedling growth of ten sesame cultivars (Sesamum indicum L.).

Benlioglu, B., and Ozkan, U., 2015. Bazı arpa çeşitlerinin (Hordeum vulgare L.) çimlenme dönemlerinde farklı dozlardaki tuz stresine tepkilerinin belirlenmesi. Tarla Bitkileri Merkez Araştırma Enstitüsü Dergisi, 24(2), 109-114. (In Turkish).

Benlioglu, B., and Ozkan, U., 2021. The influence of salinity and drought stress on some oat cultivars (Avena sativa L.) by determining some stress indexes and growth performances at the germination stage. Fresen Environ. Bull, 30, 771-778.

Bilgiçli, N., and Soylu, S., 2016. Buğday ve un kalitesinin sektörel açıdan değerlendirilmesi. Bahri Dağdaş Bitkisel Araştırma Dergisi; 5 (2): 58-67. (In Turkish).

Çöl, N., Akınerdem, F. 2017. Patates Bitkisinde (Solanum tuberosum L.) Farklı Miktarlardaki Hümik Asit Uygulamalarının Verim ve Verim Unsurlarına Etkisi. Selcuk Journal of Agriculture & Food Sciences, 31(3). (In Turkish).

Doruk Kahraman, N., and Topal, A., 2024. Tuz stresine maruz kalan makarnalık buğday çeşitlerinde tohum çimlenmesinin fizyolojik göstergelerindeki farklılıklar. Mustafa Kemal Üniversitesi Tarım Bilimleri Dergisi, 29(1), 148-157. (In Turkish).

Duman, İ., and Eşiyok, D., 1998. Ekim öncesi PEG ve KH2PO4 uygulamalarının havuç tohumlarının çimlenme ve çıkış oranı ile verim üzerine etkileri. Tr. J. of Agriculture and Forestry, 22: 445–449. (In Turkish).

FAO, 2022. Food and Agriculture Organization of the United Nations. http://www.fao.org/faostat/en/ [Erişim tarihi: 24.04.2023].

Hussain, M., Malik, M.A., Farooq, M., Khan, M.B., Akram, M., and Saleem, M.F., 2009. Exogenous glycine betaine and salicylic acid application improves water relations, all ometry and quality of hybrid sunflowe runder water deficit conditions. J Agron Crop Sci, 195:98–109

Khajeh-Hosseini, M., Powell, A.A., and Bingham, I.J., 2003. The interaction between salinity stress and seed vigour during germination of soybean seeds. Seed Science & Technology, 31: 715-725.

Kopecká, R., Kameniarová, M., Cerny, M., Brzobohatý, B., and Novák, J., 2023. Abiotic stress in crop production. Int. J. Mol. Sci. 24, 6603.

Mano, Y., and Takeda, K., 1997. Mapping quantitative trait loci for salt tolerance at germination and the seedling stage in barley (Hordeum vulgare). Euphytica, 94(3), 263-272.

Munns, R., and Tester, M., 2008. Mechanisms of salinity tolerance. Annual Review of Plant Biology, 59, 651-681.

Okumus, O., Say, A., Eren, B., Demirel, F., Uzun, S., Yaman, M., and Aydın, A., 2024. Using Machine Learning Algorithms to Investigate the Impact of Temperature Treatment and Salt Stress on Four Forage Peas (Pisum sativum var. arvense L.). Horticulturae, 10, 656. https://doi.org/10.3390/ horticulturae10060656

Okumuş, O., Kahraman, N. D., Oğuz, M. Ç., and Yıldız, M., 2023. Magnetic field treatment in barley: improved salt tolerance in early stages of development. Selcuk Journal of Agriculture and Food Sciences, 37(3), 556-569.

Oral. E., Altuner, F., Tunçtürk, R., and Baran, İ., 2019. Gibberellik asit ön uygulamasına tabi tutulmuş Triticale (x Triticosecale Wittmack)'de tuz (NaCl) stresinin çimlenme üzerine etkisi. Kahramanmaraş Sütçü İmam Üniversitesi Tarım ve Doğa Dergisi, 22, 235-242. (In Turkish).

Patwa, N., and Penning, B. W., 2020. Environmental impact on cereal crop grain damage from preharvest sprouting and late maturity alpha-amylase, in Sustainable agriculture in the era of climate change. Eds. Roychowdhury, R., Choudhury, S., Hasanuzzaman, M. and Srivastava, S. (Cham: Springer), 23-41.

Prasad, P. V. V., Staggenborg, S. A., & Ristic, Z. (2008). Impacts of drought and/or heat stress on physiological, developmental, growth, and yield processes of crop plants. Response of crops to limited water: Understanding and modeling water stress effects on plant growth processes, 1, 301-355.

Serin Ü., 2024. Bazı ekmeklik buğday (Triticum aestivum) çeşitlerinde tuz stresinin çimlenme ve fide gelişimine etkisi. Çukurova Üniversitesi Fen Bilimleri Enstitüsü 98ss. (In Turkish).

Snedecor, GW, and Cochran, W.G.,1967. Statistical methods. Iowa State College Press, Iowa, USA. 6th ed., pp: 96. [Erişim tarihi: 24.01.2024].

TUİK, 2023. Türkiye İstatistik Kurumu. http://www.tuik.gov.tr

Sadeghian, S.Y., and Yavari, N., 2004. Effect Of Water-Deficit Stress On Germination And Early Seedling Growth İn Sugar Beet. Journal of Agronomy & Crop 71 Science, 190(2): 138-144.

Wahid, A., Noreen, A., Basra, S. M., Gelani, S., and Farooq, M. 2008. Priming-induced metabolic changes in sunflower (Helianthus annuus) achenes improve germination and seedling growth. Botanical Studies, 49(2), 343-350.

Yamaguchi, S., 2008. Gibberellin metabolism and its regulation. Annual Review of Plant Biology, 59, 225-251.

Yaman, M., Yilmaz, K.U., 2022. The effects of different chemicals on runner yield and quality of 'Kabarla'strawberry young plants grown in Cappadocia region. Erwerbs-Obstbau, 64(1), 85-90.

Yıldız, S., Karagöz, F.P., and Dursun, A., 2017. Giberellik asit ön uygulamasına tabi tutulmuş hüsnüyusuf (Dianthus barbatus L.) tohumlarının tuz stresinde çimlenmesi. Atatürk Üniv. Ziraat Fak. Derg. 48 (1): 1-7. (In Turkish).

Yilmaz, K.U., Yaman, M. 2015. The effects of different chemicals on yield and quality of'Sweet Ann'strawberry nursery plants grown in

Cappadocia Region–preliminary results. In III Balkan Symposium on Fruit Growing 1139 (pp. 559-564).

Zeybek, Ş., Ardıç, M., Sezer, O., and Olgun, M., 2021. 6 farklı buğday çeşidinin bazı ekofizyolojik ve 6 farklı buğday çeşidinin bazı ekofizyolojik ve morfolojik parametrelerin incelenmesi. Research Journal Of Biologysciences, 14(2): 222-226 (In Turkish).

Zhu, J. K., 2001. Plant salt tolerance. Trends in Plant Science, 6(2), 66-71.