Akademik Ziraat Dergisi 13(1): 169-174 (2024)
ISSN: 2147-6403 e-ISSN: 2618-5881 DOI: http://dx.doi.org/10.29278/azd.1452660

Araştırma
(Research)

Effect of Na_2SO_4 Application on the Growth, Yield and Cd uptake of Wheat

Faruk ÖZKUTLU[1*], Özlem ETE AYDEMİR[1]

[1]Department of Soil Science and Plant Nutrition, Faculty of Agriculture, Ordu University, Ordu/TÜRKİYE

Alınış tarihi: 14 Mart 2024, Kabul tarihi: 30 Nisan 2024
Sorumlu yazar: Faruk ÖZKUTLU, e-posta: farukozkutlu@hotmail.com

Abstract

Objective: Durum wheat accumulates more cadmium (Cd) in the grain than bread wheat. The aim of this study was to determine the effect of Na_2SO_4 salt on Cd uptake in wheat grain.

Material and Method: The experiment was conducted by using durum wheat cultivar (*Triticum durum*, cvs. Balcalı-2000) under greenhouse condition. After 43 day of growth in the greenhouse, the shoots were harvested and dried at 70 ºC for determination of shoot dry matter production. It was also analyzed Cd concentration in shoot. The concentration of shoot Cd was measured by (ICP-OES, Varian, Australia).

Results: Our results conclude that soil salinity increases Cd accumulation in the shoot even when soil Cd rates are very low. Furthermore, salinity in Cd-contaminated soils may accelerate cadmium transport to the shoot.

Conclusions: The findings of this study revealed that shoot Cd concentration increased with increasing applied Cd and Na_2SO_4 rates.

Key Words: Salt, Durum Wheat, Cadmium, Yield

Na_2SO_4 Uygulamasının Buğdayın Büyümesi, Verimi ve Cd Alımı Üzerine Etkisi

Öz

Amaç: Makarnalık buğday ekmeklik buğdaya göre daha fazla Cd biriktirmektedir. Bu çalışmanın amacı, Na_2SO_4 tuzunun makarnalık buğday tanesinde Cd alımına etkisini belirlemektir.

Materyal ve Yöntem: Deneme, sera koşullarında makarnalık buğday çeşidi (*Triticum duru*m, cvs. Balcalı-2000) kullanılarak yürütülmüştür. Serada 43 günlük büyümenin ardından yeşil aksam olarak hasat edilmiştir. Yeşil aksamda kuru madde üretiminin belirlenmesi amacıyla bitki örnekleri 70 ºC'de kurutulmuştur. Ayrıca, yeşil aksam Cd konsantrasyonu (ICP-OES, Varian, Avustralya) cihazi ile ölçülmüştür.

Araştırma Bulguları: Araştırma sonuçlarına göre topraktaki Cd miktarı çok düşük olsa bile toprak tuzluluğunun sürgünlerdeki Cd birikimini arttırdığı saptanmıştır. Ayrıca Cd ile kirlenmiş topraklardaki tuzluluğun kadmiyumun yeşil aksama taşınmasını hızlandırabileceği tespit edilmiştir.

Sonuç: Bu çalışmanın bulguları, uygulanan Cd ve Na_2SO_4 dozlarının artmasıyla yeşil aksam Cd konsantrasyonunun arttığını ortaya koymuştur.

Anahtar kelimeler: Tuz, Makarnalık Buğday, Kadmiyum, Verim

Introduction

Investigating the effect of salinity on Cd accumulation in wheat is one of the current topics. When the salinity of NaCl is high in agricultural soils, the salinity, especially Cl^- and SO_4 salts, causes more Cd uptake by plants. The application of sodium sulphate (Na_2SO_4) in agricultural applications has been a subject of considerable interest due to its potential effect on plant growth and nutrient uptake. In particular, the interaction between Na_2SO_4 application and the uptake of heavy metals such as Cd in plants, especially in crops such as wheat, has received attention in recent research (Özkutlu, 2020). Understanding the effects of Na_2SO_4 application on Cd uptake is crucial for sustainable agriculture and food security, as Cd contamination in crops can pose serious health risks to humans when consumed. Cadmium is a toxic heavy metal and can be easily transported and accumulated in plants through soil contamination that causes potential health hazards when crops grown on

cadmium contamination are consumed by humans or animals (Korkmaz et al., 2010; Korkmaz et al., 2017; Korkmaz et al., 2018; Aydemir et al., 2022). Wheat, a staple food crop for a large proportion of the world's population, is susceptible to Cd contamination, with durum wheat varieties being particularly Cd-intolerant. Therefore, strategies to reduce Cd uptake in wheat grains are essential to ensure food security and environmental sustainability (Özkutlu and Kara, 2018; Akgül et al., 2022; Ece et al., 2022; Aydemir et al., 2023). Sodium sulfate, a common salt compound, is known for its role in improving soil structure, enhancing nutrient availability, and influencing plant growth. However, the specific effects of Na_2SO_4 application on Cd uptake in plants, particularly in wheat, are still not fully understood. Research has shown conflicting results regarding the impact of Na_2SO_4 on Cd accumulation in plant tissues, with some studies suggesting an increase in Cd uptake while others report no significant effect. Soil salinity is one of the most important problems affecting wheat yield. Salinity is widespread in arid and semi-arid regions of the world (Atlassi et al, 2009; Korkmaz et al., 2020; Dinler et al., 2021). Soils are influenced by various salts, primarily chlorides and sulphates of sodium, calcium, and magnesium. (Akram et al., 2002; Uyanık et al., 2014; Ekbic et al., 2020,). Soils containing inorganic salts can provide the necessary nutrients to the plant, but when the concentration of these salts is high, they can be harmful for plant growth (Jouyban, 2012). The interaction between Na_2SO_4 and Cd uptake in plants is complex and can be influenced by various factors such as soil properties, plant species, growth stage, environmental conditions and Cd-contaminated soil (Shi et al., 2020). Understanding these interactions is crucial for developing effective strategies to reduce Cd accumulation in crops and minimize health risks associated with heavy metal contamination. The aim of this research was to determined the mechanisms underlying the interaction between Na_2SO_4 and Cd uptake and the potential implications for food safety. Investigating the effect of Na_2SO_4 application on Cd uptake in wheat plants is essential for the development of sustainable agricultural practices that promote food safety and environmental health. Determining these interactions is extremely important for researchers and practitioners to minimize heavy metal contamination in various crops of durum wheat and contribute to safe food production.

Material and Method

The experiment was carried out in greenhouse conditions according to the random plots experimental design. Durum wheat seeds (*T. turgidum* L. durum) Balcalı-2000 cultivar was planted in each plastic pots 1.65 kg of dry soil containing and wheat crops grown under greenhouse conditions. Çukurova University Agriculture Faculty Adana/Turkey. The soil used contained 0.10 mg Zn Soil extractable with DTPA Fe, Mn, and Cu concentrations of 3.51, 5.81, and 0.87, and total Zn and Cd concentrations of 55 mg Zn kg^{-1} and 0.24 mg Cd kg^{-1}, respectively. In experiment, soil used had a clay loam texture and organic matter content was 1.04%. The chemical and physical properties of soils were analyzed using standard methods given by Jackson (1959).

Before sowing wheat seeds in pots, the following basic fertilizers were added to all pots. Applied as basic fertilization and mixed into the soil 200 mg kg^{-1} N {$Ca(NO_3)_2.4H_2O$}, 100 mg kg^{-1} P {KH_2PO_4}, 2.5 mg kg^{-1} Fe (Fe-EDTA) ve 1.0 mg kg^{-1} Zn ($ZnSO_4$. $7H_2O$). The experiment was conducted with 3 different doses of Cd (0, 0.2 and 1.0 mg Cd $(CdS0_4)_3.8H_2O$ kg^{-1}- soil) and 4 different doses of Na_2SO_4 salt (0, 0.125, 0.5 and 2.0 g Na_2SO_4 kg^{-1}) in a randomized design with 4 replications. The plant of shoot were harvested on the 43rd day of growth, taking into account Cd and salt toxicity symptoms. Shoot samples were dried in an oven at 70 ºC for 48 hours and dry weights were taken. After this process, the plants were ground. In order to measure Cd in shoot samples, 0.25 g of the samples were taken and burned in a mixture of 2 ml of distilled water, 2 ml of H_2O_2 (30%) and 4 ml of HNO_3 (65%) in the microwave (Milestone, Italy). Cd in the samples was measured by ICP-AES (Inductively Coupled Plasma-Atomic Emission Spectrometer; JY 138 Ultrace).

Statistical Analysis

All plant data were analysed using Excel package programme. Results are shown as mean±standard deviation of 4 replicates.

Result and Discussion

Shoot Dry Matter Yield

In this study, as expected, it was found that there were differences in shoot dry matter yield of durum wheat Balcalı-2000 cultivar grown under greenhouse conditions for 43 days under different Cd doses (0, 0.2 and 1.0 mg kg^{-1}) and different Na_2SO_4 (0, 0.125, 0.5 and 2.0 g kg^{-1} soil) doses shown in Table 1.

Table 1. Shoot dry matter yield of durum wheat grown under different Cd doses and increasing Na_2SO_4 treatments

Soil treatments, mg kg^{-1}	Cd 0			Cd 0.2			Cd 1		
	Shoot Dry Matter (mg $plant^{-1}$)								
Control	656	±	7	711	±	58	649	±	80
125 Na_2SO_4	606	±	6	854	±	143	731	±	59
500 Na_2SO_4	637	±	25	692	±	95	688	±	41
2000 Na_2SO_4	637	±	51	721	±	44	616	±	51

mean ± standard deviation of 4 replications

Shoot dry matter yield was 656 mg $plant^{-1}$ in no cadmium and non-saline conditions. In non-cadmium (control) and 2.0 g Na_2SO_4 kg^{-1} treatment, shoot dry matter yield decreased by 2.9% to 637 mg $plant^{-1}$. In cadmium 1.0 mg Cd kg^{-1} soil and 2.0 g Na_2SO_4 kg^{-1}treatments, shoot dry matter yield decreased by 5% as 616 mg $plant^{-1}$ compared to the control.

Shoot Cd Concentration

Cd concentration in shoot of plants grown under different Cd doses and increasing Na_2SO_4 doses are given in Figure 1.

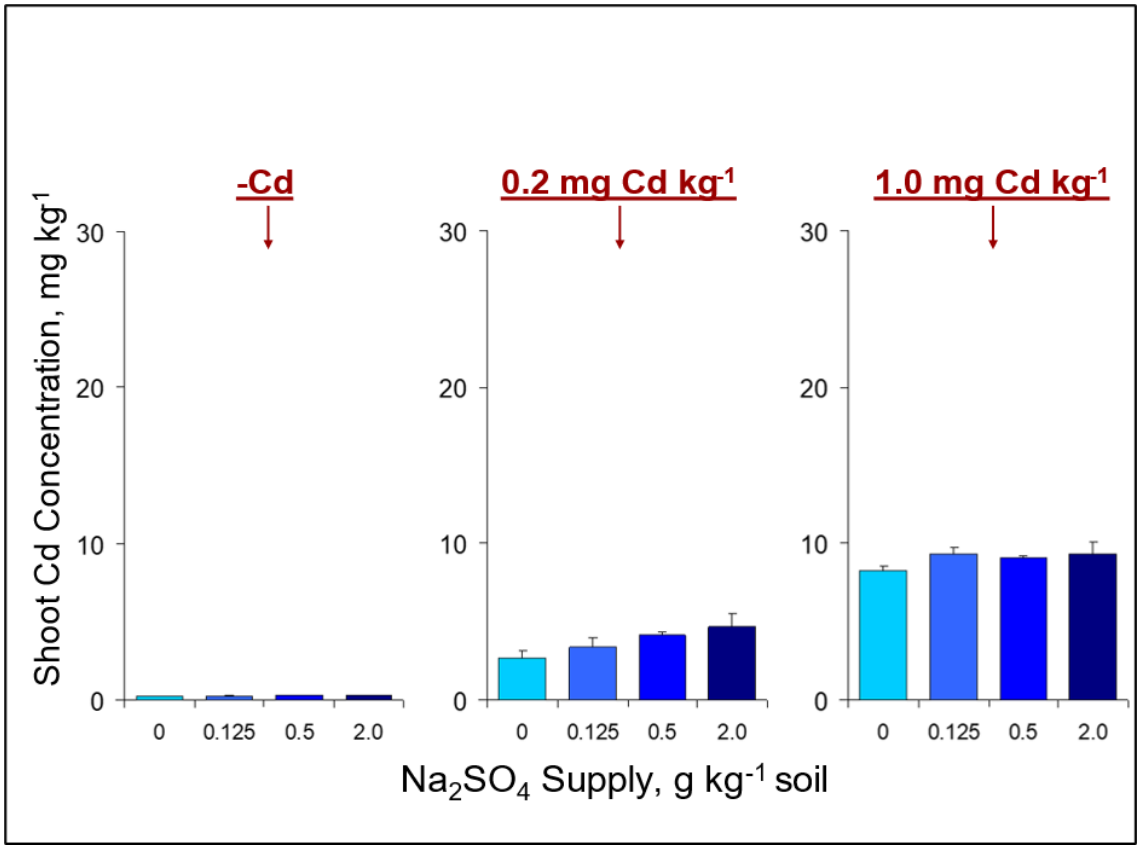

Figure 1. Concentration of Cd in shoot of durum wheat Balcalı-2000 cultivar

As seen in Figure 1, Cd concentration in shoot increased with increasing doses of (0, 125, 500 and 2000 mg Na_2SO_4 kg^{-1}) application to 0.2 mg Cd kg^{-1} contaminated soil compared to the control. The Cd content of shoot showed a similar trend to the concentration and increased with increasing doses of Na_2SO_4 application to untreated Cd (control) and low Cd contaminated 0.2 mg Cd kg^{-1} soil. However, when Na_2SO_4 was applied at increasing doses to 1.00 mg Cd kg^{-1} contaminated soil, the Cd content of shoot was 6.75, 6.36 and 5.72 µg $plant^{-1}$, respectively, compared to 5.36 µg $plant^{-1}$ in the control. 1.0 mg Cd kg^{-1} contaminated soil compared to the control (without salt application), the Cd content in shoot increased by 26% with low salt 125 mg Na_2SO_4 kg^{-1} application, while it increased by 6% with high salt 2000 mg Na_2SO_4 kg^{-1} soil application (Table 2).

Table 2. Cd content in shoot of durum wheat Balcalı-2000 cultivar grown under greenhouse conditions

Soil treatments, mg kg^{-1}	Cd 0	Cd 0.2	Cd 1
	Shoot Cd Content (µg $plant^{-1}$)		
Control	0.15 ± 0.01	1.92 ± 0.41	5.39 ± 0.69
125 Na_2SO_4	0.16 ± 0.03	2.89 ± 0.50	6.75 ± 0.41
500 Na_2SO_4	0.19 ± 0.02	2.83 ± 0.54	6.36 ± 0.53
2000 Na_2SO_4	0.19 ± 0.02	3.33 ± 0.34	5.72 ± 0.20

mean ± standard deviation of 4 replications

Discusion

The study explores the relationship between sodium sulfate application and cadmium uptake in wheat plants, highlighting its implications for agricultural practices, environmental health, and food safety. In the effect of Na_2SO_4 application on Cd uptake in wheat plants, some studies reported an increase in Cd concentrations in plant tissues following Na_2SO_4 application (Ashrafi et al., 2014; Xu et al., 2017; Wang et al., 2023), while others found no significant effect or even a decrease in Cd uptake (Zhou et al., 2018; Wu et al., 2018). Soil physicochemical properties are altered by sodium salts, with Na^+ application increasing pH, EC, SAR, and ESP values, while CEC and SOC values decrease slightly due to Na^+ occupying ion exchange sites (Ramakrishna and Viraraghavan, 2005) and stimulating organic matter mineralization (Mavi and Marschner, 2017). The growth and development of wheat plants are affected by salt stress, Cd pollution and the combination of these two stresses. Wang et al. (2023) showed that salt stress significantly reduced root, stem and grain biomass in wheat.

Explained that, soil salinisation (increased soluble salt concentration) affects not only wheat growth and productivity but also wheat quality (Cd contamination). Shafi et al. (2011) revealed that 2 µM, 4 µM Cd and 75 mM, 150 mM NaCl treatments decreased shoot and root dry weight (DW) of wheat. Increasing Cd and NaCl concentrations negatively affected root morphology of wheat. The combined effect of Cd and NaCl on these parameters was higher than Cd and NaCl alone. Due to the interaction between salinity and cadmium (Cd) stress, Cd uptake in cereals is higher in durum wheat than in bread wheat, especially under saline conditions. Studies have shown that soil salinity can increase Cd accumulation in durum wheat grain even at low soil Cd levels (Özkutlu and Kara, 2019). In durum wheat, a grain sensitive to Cd toxicity, it has been explained that The application of NaCl and Cd stress significantly increased shoot Cd concentration compared to Cd stress alone (Özkutlu, 2023). When plants are exposed to salt stress, due to increased ion toxicity and altered osmotic pressure, nutrient deficiencies and increased oxidative stress, which retard plant growth, result in impaired plant growth (Zhu, 2003). Our results are consistent with those reported in studies that salinity increases Cd uptake.

In our results, Na_2SO_4 applications at increasing doses caused decreases in dry matter yield of wheat, while low Cd contamination caused increases in shoot Cd content. Chloride (Cl^-) and sulphate (SO_4) salts have different effects on cadmium (Cd) uptake in plants (Özkutlu, 2020). It is hypothesized that Na_2SO_4 may influence Cd availability in the soil by altering soil pH or competing with Cd ions for uptake by plant roots. Studies have shown that soil sulphate salinity can have a significant effect on Cd uptake by plants and that there is a complex relationship between SO_4 salinity and Cd uptake (McLaughli et al., 1998). On the other hand, chloride application was found to increase Cd uptake in several plant species (Lopez-Chuken et al., 2012). This suggests that Cl^- ions play a role in promoting Cd uptake in plants (Özkutlu et al., 2007). Result have shown that sulfate salinity in soil can have a significant impact on Cd uptake by plants, indicating a complex relationship between SO_4 salinity and Cd uptake. Cd uptake was slightly reduced in the application of 2000 mg Na_2SO_4 kg^{-1} compared to the application of low and medium (125 and 500 mg Na_2SO_4 kg^{-1}) doses to soil with high Cd contamination. These findings suggest that Na_2SO_4 can have beneficial effects on plant growth under certain conditions and that these effects can be utilized to improve crop productivity and sustainability. Future research in this field may focus on understanding the molecular mechanisms

underlying the interaction between Na_2SO_4 application and Cd uptake in wheat plants.

Conclusion

Na_2SO_4 application affects plant Cd uptake differently in soils with low and high Cd contamination. Na_2SO_4 application will have effects on soil health, microbial communities and crop quality and it may be useful to focus research in this area. In conclusion, Na_2SO_4 application affects Cd uptake in wheat plants and its far-reaching implications for food safety is a complex scientific issue that needs to be explored. By continuing to investigate this topic through interdisciplinary research approaches and collaborative efforts, scientists can improve our understanding of how soil amendments such as Na_2SO_4 interact with heavy metals such as Cd in plant systems. This results can guide the development of evidence-based strategies to minimize heavy metal contamination in crops and ensure safe food production for current and future generations.

Conflicts of Interest

There is no conflict of interest between the authors.

Authors statement of contribution

FÖ: Contributing to the establishment and execution of trials, laboratory analysis, statistics of data and writing of the article.

ÖEA: The evaluation of the data and the writing of the article.

References

Akgül, S., Aydemir, Ö. E., & Özkutlu, F. (2022). Gidya uygulamalarının ekmeklik ve makarnalık buğdayların kadmiyum ve besin elementi alımı üzerine etkisi. *Akademik Ziraat Dergisi*, 11(2), 353-362.

Akram, M., Hussain, M., Akhtar, S., & Rasule, E. (2002). Impact of NaCl salinity on yield components of some wheat accessions/varieties. *International Journal of Agriculture & Biology,* 156-158.

Ashrafi, A., Zahedi, M., Fahmi, K., & Nadi, R. (2014). Neighbour effects of purslane (*Portulaca oleracea* L.) on Cd bioaccumulation by soybean in saline soil. *Plant Soil*, 60, 439–445.

Atlassi, P. V., Nabipour, M., & Meskarbashee, M. (2009). Effect of salt stress on chlorophyll content, fluorescence, Na^+ and K^+ ions content in rape plants (*Brassica napus* L.). *Asian Journal of Agriculture*, 3, 28-37. http://dx.doi.org/10.3923/ajar.2009.28.37.

Aydemir, Ö. E., Korkmaz, K., & Özkutlu, F. (2022). The effect of foliar application of different amino acids (L-histidine, methionine) on cadmium and zinc uptake of wheat. *Turkish Journal of Agriculture-Food Science and Technology*, 10(8), 1482-1485.

Aydemir, Ö. E., Akgün, M., Erdem, H., Korkmaz, K., & Özkutlu, F. (2023). The effect of different lime forms on cadmium uptake of durum wheat varieties. *Turkish Journal of Agriculture-Food Science and Technology*, *11*(8), 1365-1371.

Dinler, B. S., Cetinkaya, H., Akgun, M., & Korkmaz, K. (2021). Simultaneous treatment of different gibberellic acid doses induces ion accumulation and response mechanisms to salt damage in maize roots. *Journal of Plant Biochemistry and Physiology*, 9(3), 258.

Ece, D., Aydemir, Ö. E., & Özkutlu, F. (2022). The effect of ca-bentonite aplication on cadmium uptake and shoot dry matter of bread wheat. *Türk Doğa ve Fen Dergisi*, 11(4), 50-54.

Ekbic, E., Cagıran, C., Korkmaz, K., Kose, M. A., & Aras, V. (2017). Assessment of watermelon accessions for salt tolerance using stress tolerance indices. *Ciência e Agrotecnologia*, 41, 616-625.

Jackson, M. L. (1959). Soil chemical analysis. Englewood Cliffs, New Jersey.

Jouyban, Z. (2012). The effects of salt stress on plant growth. *Technical Journal of Engineering and Applied Sciences*, 2(1), 7-10.

Korkmaz, K., Kara, S. M., Ozkutlu, F., & Gul, V. (2010). Monitoring of heavy metals and selected micronutrients in hempseeds from North-western Turkey. *African Journal of Agricultural Research*, 5(6), 463-467.

Korkmaz, K., Kara, S. M., Özkutlu, F., Akgün, M., & Cenkal, B. C. (2017). Profile of heavy metal and nutrient elements in some sideritis species. *Indian Journal of Pharmaceutical Education and Research*, 51(3), 209-212.

Korkmaz, K., Ertürk, Ö., Ayvaz, M. Ç., Özcan, M. M., Akgün, M., Kirli, A., & Alver, D. O. (2018). Effect of cadmium application on antimicrobial, antioxidant and total phenolic content of basil genotypes. *Indian Journal of Pharmaceutical Education and Research*, 52(4), S108-S114.

Korkmaz, K., Akgün, M., Kırlı, A., Özcan, M. M., Dede, Ö., & Kara, Ş. M. (2020). Effects of gibberellic acid and salicylic acid applications on some physical and chemical properties of rapeseed (Brassica napus L.)

grown under salt stress. *Turkish Journal of Agriculture-Food Science and Technology*, 8(4), 873-881.

Lopez-Chuken, U. J., López-Domínguez, U., Parra-Saldivar, R., Moreno-Jiménez, E., Hinojosa-Reyes, L., Guzmán-Mar, J. L., & Olivares-Sáenz, E. (2012). Implications of chloride-enhanced cadmium uptake in saline agriculture: modeling cadmium uptake by maize and tobacco. *International Journal of Environmental Science and Technology*, 9, 69-77.

Mavi, M. S., & Marschner, P. (2017). Impact of salinity on respiration and organic matter dynamics in soils is more closely related to osmotic potential than to electrical conductivity. *Pedosphere*, 27, 949–956.

McLaughlin, M. J., Andrew, S. J., Smart, M. K., & Smolders, E. (1998). Effects of sulfate on cadmium uptake by swiss chard: I. effects of complexation and calcium competition in nutrient solutions. *Plant Soil,* 202, 211-6.

Özkutlu, F. (2023). The effect of zinc application on growth and alleviating shoot concentration of cadmium in durum wheat plant growth under conditions of salt and cadmium stress. *International Journal of Agriculture Environment and Food Sciences*, *7*(4), 785-791.

Özkutlu, F., Öztürk, L., Erdem, H., McLaughlin, M., & Cakmak, I. (2007). Leaf-applied sodium chloride promotes cadmium accumulation in durum wheat grain. *Plant Soil*, 290, 323–331.

Özkutlu, F. (2020). Farklı tuz uygulamalarının makarnalık (*Triticum durum* L.) buğdayda kadmiyum ve çinko alımı üzerine etkisi. *Türk Tarım ve Doğa Bilimleri Dergisi*, *7*(4), 1010-1017.

Özkutlu, F., & Kara, Ş. M. (2019). Cd concentration of durum wheat grain as influenced by soil salinity. *Akademik Ziraat Dergisi*, 8 (1), 97-100.

Özkutlu, F., & Kara, Ş. M. (2018). The effect of zinc (Zn) fertilization on alleviating cd accumulation in durum wheat grain. *Journal of Agricultural Science and Technology B*, *8*, 203-208.

Ramakrishna, D.M., Viraraghavan, T. (2005). Environmental impact of chemical deicers-a review. *Water, Air, & Soil Pollution*, 166, 49–63.

Shafi, M., Bakht, J., Raziuddin, Hayat, Y., &., Zhang, G. P. (2011). Genotypic differences in the inhibition of photosynthesis and chlorophyll fluorescence by salinity and cadmium stresses on stresses in wheat. *Journal of Plant Nutrition*, 34, 315-23.

Shi, G., Lu, H., Liu, H., Lou, L., Zhang, P., Song, G., Zhou, H., & Ma, H. (2020). Sulfate application decreases translocation of arsenic and cadmium within wheat (*Triticum aestivum* L.) plant. *Science of the Total Environment*, 713, 136665.

Uyanık, M., Kara, Ş. M., & Korkmaz, K. (2014). Determination of responses of some winter canola *(Brassica napus* L.) cultivars to salt stress at germination period. *Tarım Bilimleri Dergisi*, 20(4), 368-375.

Wang, L., Qin, L., Sun, X., Zhao, S., Yu, L., Chen, S., & Wang, M. (2023). Salt stress-induced changes in soil metabolites promote cadmium transport into wheat tissues. *Journal of Environmental Sciences*, 127, 577-588.

Wu, J., Mock, H. P., & Mühling, K. H. (2018). Sulfate supply enhances cadmium tolerance in Vicia faba L. plants. *Environmental Science and Pollution Research*, 25(33), 33794-33805.

Xu, Z. M., Li, Q. S., Yang, P., Ye, H. J., Chen, Z. S &., Guo, S. H., (2017). Impact of osmoregulation on the differences in Cd accumulation between two contrasting edible amaranth cultivars grown on Cd-polluted saline soils. *Environmental Pollution*, 224, 89–97.

Zhu, J.K., (2003). Regulation of ion homeostasis under salt stress. *Current Opinion in Plant Biology*, 6, 441–445.

Zhou, J., Hao, M., Liu, Y., Huang, G., Fu, Q., Zhu, J., & Hu, H. (2018). Effects of exogenous sulfur on growth and Cd uptake in Chinese cabbage (*Brassica campestris* spp. pekinensis) in Cd-contaminated soil. *Environmental Science and Pollution Research*, 25, 15823-15829.