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Original article

Evaluation of the Effectiveness of Silicon Dioxide on Some Germination and Vegetative Growth Parameters of Radish Cultivars in Saline Conditions

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Abstract

The salt tolerance level of the radish (*Raphanus sativus* L.), which has a rich nutritional content, varies depending on the cultivar (cv). In this study, which was carried out using two radish cv. (big red, little red), it was aimed to determine the effect of exogenous silicon dioxide (0.5, 1, 1.5, 2 mM SiO_2) applications on germination and vegetative growth parameters under salt stress conditions (150 mM NaCl). After determining the germination percentage (GP), germination index (GI), germination rate coefficient (CVG), mean germination time (MGT) and germination rate index (GRI) for germinating seeds, shoot and root length (mm), leaf width and length (mm), root and shoot fresh weights (g) were measured and seedling vigour index (SVI) was calculated. SiO_2 applications had a positive effects on germination parameters in both cultivars under both non-stress and salt stress conditions. While 1.5 mM SiO_2 application caused an increase in germination rate in little red cultivar, it was determined that 1 mM application was more effective under salt stress conditions and increased the germination rate by 2 fold (from 24% to 48%). In the big red cv., 2 mM SiO_2 application had a positive effect on germination parameters both in salinty and unsalinity conditions. Exogenous SiO_2 pre-treatment had also the positive effects on vegetative growth in both cultivars under stressed and unstressed conditions. According to the results of variance analysis, interaction was determined (***p<0.001) between cultivars and applications and all other parameters except root fresh weight. 1.5 mM application dose significantly increased all vegetative growth parameters in little red cultivar under non-stress and salt stress conditions. In the big red cv., a similar effects were obtained as a result of 1 mM SiO_2 application.

Keywords: Germination, *Raphanus sativus*, Silicon dioxide, Priming, Vegetative.

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INTRODUCTION

Salinization, especially seen in arid and semi-arid areas of the world, is a problem that limits agricultural production. Soil salinity prevents water uptake by the roots of the plant, as in drought stress. It is necessary to increase the salt tolerance level of crops in order to overcome this problem, which causes growth and yield losses via morphological, physiological and biochemical changes in plants (Kuşvuran & Ellialtıoglu, 2021; Baghaei et al., 2014; Noreen & Ashraf, 2008). Silicon is one of the beneficial elements that increase growth and yield in plants. Some plants take silicon from the soil and accumulate it inside and outside the cell. Silicon, which strengthens the cell walls of plants, also increases the yield by providing resistance to the plant. Although it is not critically important for all plants, it increases the plant's resistance to biotic and abiotic stresses when present at low levels (Baghaei et al., 2014; Kaur et al., 2016). Under salt stress conditions in tomato, silicate crystals accumulated in epidermal cells act as a barrier, reducing water loss from the cuticle and diluting excess salt (Romero-Arnada et al., 2006). Another mechanism of action of silicon is provided by increasing antioxidant enzyme activities. In this way, it has been shown to reduce the harmful effects of salt stress in barley (Liang et al., 2003) and cucumber (Zhu et al., 2004). On the other hand, in wheat, it alleviated the effects of salt stress by increasing the chlorophyll and photosynthetic activity as well as the relative water content (Bybordi, 2014).

Raphanus sativus is a plant belonging to the *Brassicaceae* family, which includes important crop species (Verkerk et al., 2008). Radish, which is a vegetable rich in Vitamin C, potassium, calcium and zinc, is an important vegetable for health due to its digestive system stimulating and expectorant propertie. In addition to being low in calories and fiber, its rich vitamin and antioxidant content is protective against many diseases. Radish, which is one of the oldest cultivated root vegetables, is advantageous for the producer as it can be harvested in a short time and easy cultivation. On the other hand, the fact that it is significantly affected by some abiotic stresses causes problems in the production of good quality radish root (Manzoor et al., 2021; Gamba et al., 2021; Olivera Viciedo et al., 2017; Beevi et al., 2012; Gutiérrez et al., 2004).

As in many other plants, salt stress significantly affects seed germination and seedling emergence in radish. Salinity, which inhibits germination completely at high levels, causes dormancy at low levels. It causes a decrease in germination rate and seedling emergence in radish, as well as a decrease in the strength of seedlings (Yildirim et al., 2008; Jamil et al., 2007). Priming has positive effects on both germination and seed formation and development under stressed and normal conditions (Rhaman et al., 2020). Silicon priming in corn (Parveen et al., 2019), and wheat (Hameed et al., 2013; Ahmed et al., 2016) increased the stress tolerance of plants under drought stress conditions. Silicon also increased the yield by providing stress tolerance in the radish plant under drought stress, especially by improving the roots (Acevedo et al., 2022). There are very limited studies investigating the effects of silicon in radish in salty conditions. Therefore, in this study, the effects of silicone priming, which is an easy and effective method, on the germination and vegetative growth parameters of radish plants in saline conditions were investigated and the possibilities of using this environmentally friendly preparation as an alternative material for sustainable agriculture in the future were investigated.

MATERIALS and METHODS

Plant material

In the study, big red and little red radish cultivars purchased from a commercial company were used.

Germination ve vegetative growth experiments of radish seeds

The study was carried out in the Laboratory of the Department of Plant and Animal Production, Vocational School of Technical Sciences at Akdeniz University.

Before germination studies, radish seeds were washed with detergent and then surface sterilized by keeping them in 10% sodium hypochlorite solution for 10 minutes and in 70% alcohol for 2 minutes. Silicon priming was applied to the seeds by keeping them in 4 different SiO_2 concentrations (0.5, 1, 1.5, 2 mM) at room temperature for 24 hours. Control seeds were kept in distilled water under the same conditions. After the silicon priming, the seeds were taken into petri plates (90 x 15 mm) with double-layer blotting paper, and the control seeds were irrigated with distilled water and the others with a solution containing 150 mM NaCl, by checking every day until the end of the experiment. The cultures were kept in a climate room with a photoperiod of 16/8 hours at 24±1ºC.

At the end of the 14th day, the germination trials were completed, after the germination parameters were calculated, the shoot length (SL, mm), root length (RL, mm), leaf width (LW, mm) and length (LL, mm), shoot and root fresh weight (SFW, RFW, gr) were measured and SVI value determined. Germination parameters were calculated using the following formulas.

GP (%) = Number of germinated seeds / Total number of seeds X 100 (Gosh et al., 2014**)**

MGT: Σ Dn / Σn D = days counted from the beginning of the test, n = number of seeds germinated on day D (Ellis & Roberts, 1981; Sivritepe, 2012).

CVG: N1+N2+….+Nx/100xN1T1+……+NxTx (Kotowski, 1926) T: number of days corresponding to N, N: number of seed germinated each day

GRI (%/day): G1/1+G2/2+……+Gx/x (Esechie, 1994)

G1: Germination percentage x100 at the first day after sowing, G2: Germination percentage x100 at the second day after sowing, GI: (14xn1) + (13xn2) +…..+ (1xn14) n1, n2,…, n14: number of germinated seeds on the first, second and subsequent days until the 14th; 14, 13…., and 1 are weights given to the number of germinted seeds on the first, second and subsequent days respectively (modified from Benech et al. 1991).

SVI = [Seedling length (cm) x GP (%)] (Baki & Anderson 1973)

Statistical Analysis

Trials were repeated in 3 replicates and 20 seeds were used per trial. The evaluation of germination and vegetative growth parameters data were made with the analysis of variance in the MINITAB 17 package program and the differences were determined by the Tukey test.

RESULTS and DISCUSSION

The effects of silicon applications on germination parameters of two radish cultivars

Salt stress, which causes germination inhibition by causing the seeds to go into dormancy or deteriorate the hormonal and enzymatic activities, also reduces the germination rate in radish and decreases the durability of germinated seedlings, causing yield loss (Yildirim et al., 2008; Jamil et al., 2007). The germination percentage, seedling growth, fresh and dry weight of radish seeds decreased significantly under increasing salt conditions. In a study conducted with 6 different radish cultivars, intraspesific variation was observed in terms of salt tolerance of the cultivars (Noreen & Ashraf, 2008). In the other study investigating the effects of salicylic acid on the germination and vegetative growth properties of radish under salinity stress, the threshold value for salinity stress was determined as 150 mM NaCl (Ulukapı et al., 2020). In the current research, the effects of salinity were determined with the same salt concentration, and similarly, the effect of salt stress on germination differed according to the cultivar. Although 150 mM salt application did not decrease the germination rate in big red cultivar, it had a rather inhibitory effect on the germination of the little red cultivar. The germination rate, which was 73% in control seeds, decreased to 24% in saline conditions and decreased approximately three fold (Figure 1). Priming with silicon is an effective and simple method that enables plants to develop tolerance against abiotic stress (Parveen et al., 2019). Silicon priming in this cultivar stimulated germination parameters in both normal and saline conditions in this study. 1.5 mM pre-treatment under unstressed conditions had a positive effect on all germination parameters. In particular, the highest germination rate (%99) and germination index (70 %) were obtained as a result of this application. The highest SVI value, which is an indicator of the strength of the seedlings developing from germinating seeds, was obtained by pre-application of 2 mM SiO_2 priming under stress free condition. This value, which was 54.57 for control seeds, increased to 126.852 in 2 mM SiO_2 applied seeds. In salt stress conditions, 1 mM SiO_2 application doubled the germination rate and increased it from 24% to 48%. As a result of the same application, the GI value increased from 0.17 to 0.34. However, the highest SVI value was obtained with 1.5 mM silicon application (Figure 1). Similarly, silicon pretreatment of the carrot seeds increased the germination parameters in saline conditions and promoted germination even at high salt concentrations (Nasircilar et al., 2021).

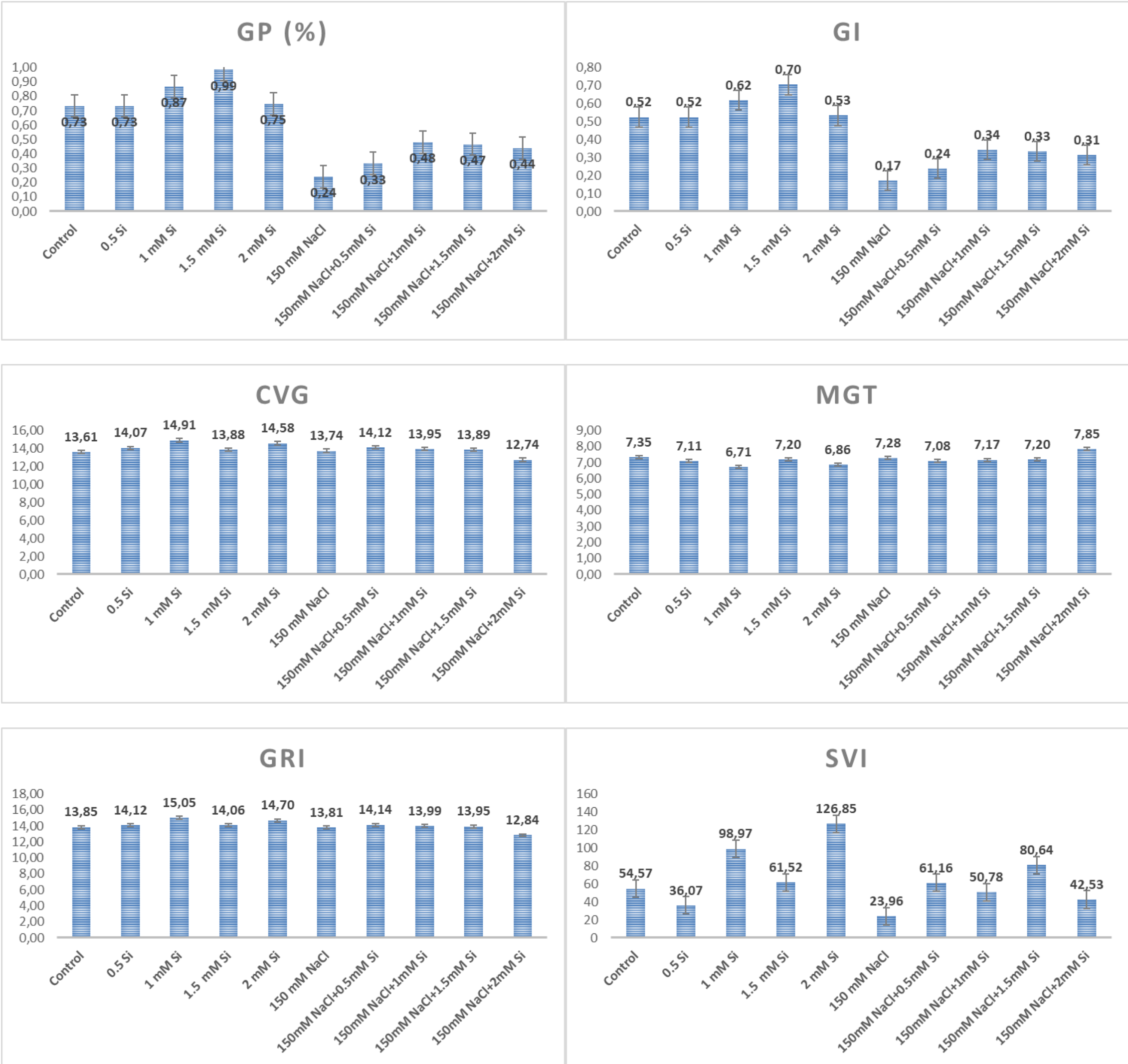

Figure 1. The effects of silicon on germination parameters of little red cultivar.

Germination parameters of big red cultivars were not affected by salt stress and approximately equal germination was obtained in both conditions. On the other hand, silicone applications had a positive effect on germination parameters in both non-stress and salt stress conditions. 1.5 and 2 mM applications under unstressed conditions increased the germination rate at almost the same rate (0.84, 0.85, respectively). Under salt stress, 2 mM pre-treatment was more effective and had an encouraging effect on germination rate and index. 1.5 mm application had a more positive effect on the SVI value, and this value, which was 65.11 in saline conditions, increased to 95.76 with 1.5 mm pre-application (Figure 2).

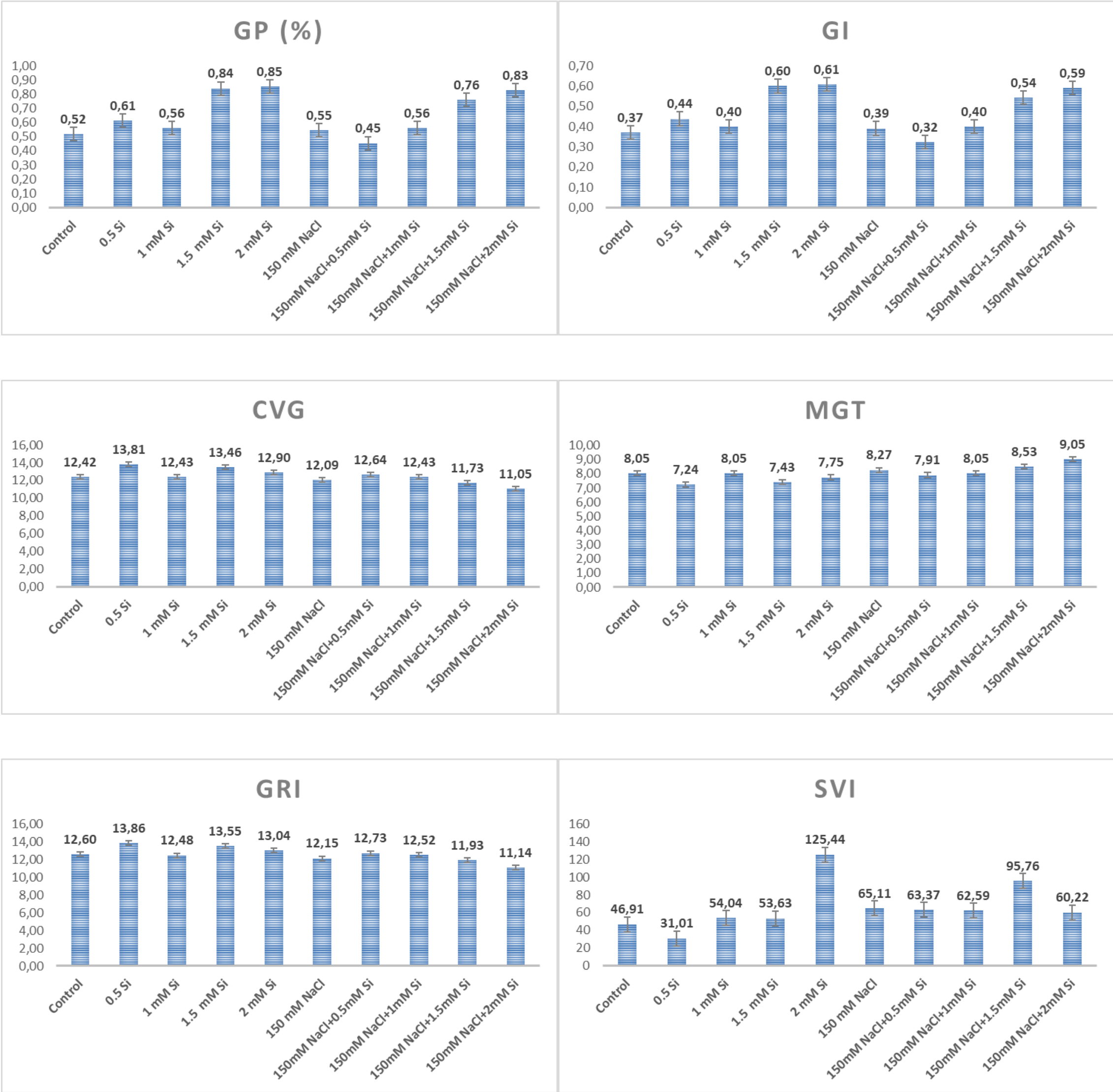

Figure 2. The effects of silicon on germination parameters of big red cultivar.

The effects of silicon priming on vegetative growth parameters in radish

The results of the variance analysis results of silicon pre-application, the cultivars and the combination of them on the vegetative growth of cultivars in saline conditions are given in Table 1. All of them had a statistically significant effect on all parameters except root fresh weight. According to the results of the variance analysis, a significant relationship at the $p<0.001$ level was determined between all the parameters examined, except for those between cultivar and SVI. There is a statistically significant relationship at $p<0.01$ level between cultivar and SVI.

Table 1. Descriptives and variance analysis result with respect to the vegetative growth of radish cultivars.

Variation source	df	SL (mm)	RL (mm)	LW (mm)	LL (mm)	SFW (g)	RFW (g)	SVI
C	1	***	***	***	***	***	ns	**
A	9	***	***	***	***	***	ns	***
C*A	9	***	***	***	***	***	ns	***
Mean		42.3	65.0	7.26	8.25	0.133	0.055	64.8
Minimum		13.4	18.6	3.47	3.26	0.059	0.005	23.0
Maximum		66.4	133.0	20.1	14.0	0.292	0.989	128.0
Standart deviation		14.6	29.0	3.28	2.56	0.056	0.126	27.7

***p<0.001, **p<0.01 SL: Shoot length, RL: Root length, LW: Leaf width, LL: Leaf length, SFW: Shoot Fresh Weight, RFW: Root Fresh Weight, SVI: Seedling Vigour Index.

According to the correlation table between the parameters, it was seen that there was statistically significant ($p<0.001$) positive correlation some vegetative growth parameters (Table 2). There was a strong positive correlation determined between RL and SL (r= 0.615), LW and RL (r= 0.885), SFW and SL (r= 0.846), SFW and RL (r= 0.618).

Table 2. Correlation of vegetative growth parameters of the radish cultivars.

	SL	RL	LL	LW	SFW	RFW	SVI
SL	—						
	—						
RL	0.615	—					
	< .001	—					
LL	0.070	0.183	—				
	0.598	0.161	—				
LW	0.583	0.885	0.093	—			
	< .001	< .001	0.482	—			
SFW	0.846	0.618	0.159	0.659	—		
	< .001	< .001	0.225	< .001	—		
RFW	0.281	0.438	0.030	0.386	0.232	—	
	0.030	< .001	0.818	0.002	0.075	—	
SVI	0.559	0.580	0.140	0.463	0.574	0.203	—
	< .001	< .001	0.287	< .001	< .001	0.119	—

It has been determined that silicon nonoparticles prevent the toxic effects of salt stress in radish in salty conditions, cause physiological improvement in plants and activate the antioxidant defense mechanism of the plant (Taqdees et al. 2022). SiO_2 priming had an encouraging effect in both normal and salt stress conditions in terms of vegetative growth parameters as well as germination parameters in this research. 1.5 mM application provided the best results in terms of promoting vegetative parameters under stress-free conditions in the little red cultivar. In saline conditions, different silicon concentrations had an encouraging effect on different parameters. Although most of the applications were statistically in the same group, the longest shoot and root length was obtained with 1.5mM and 1 mM silicon priming respectiveley (Table 3). Exposure to salt stress causes excessive ion accumulation in plants, which leads to water starvation. It not only inhibits plant growth, but also causes defoliation and chlorosis (Tavallali et al., 2008). Silicon provides an increase in the amount of nutrients taken from the soil in radish plants (Baghaei et al., 2014). It has been suggested that silicon also eliminates the harmful effects of heavy metal stress by precipitating heavy metals that accumulate in the soil. In this way, it provided tolerance to the harmful effects of heavy metal stress in radish (Ashraf et al., 2020). Considering that salinity affects germination by facilitating the uptake of toxic ions from the soil by germinating seeds (Yildirim et al., 2008), the curative effect of silicon in salty conditions may also be through this mechanism. Under salt stress conditions, shoot and root fresh weight and leaf area (Jamil et al., 2007) and shoot and root dry weight and leaf number (Yildirim et al., 2008) were significantly reduced in radish. Similarly, in this study, salt stress inhibited all vegetative growth parameters in both cultivars.

Table 3. Vegetative growth parameters of the little red cultivar.

Application	SL (mm)	RL (mm)	LL (mm)	LW (mm)	SFW (g)	RFW (g)
Control	29.33 e	45.40 d	3.84 c	6.32 d	0.0664 c	0.0233
0.5 mM SiO_2	34.94 cde	78.79 b	4.11 c	10.09 b	0.0936 b	0.0390
1 mM SiO_2	49.01 b	120.13 a	7.49 b	13.20 a	0.1870 a	0.1055
1.5 mM SiO_2	59.59 a	125.73 a	7.42 b	12.76 a	0.1882 a	0.1011
2 mM SiO_2	57.07 a	114.52 a	7.62 b	12.23 a	0.1843 a	0.3977
150 mM NaCl	13.94 f	35.47 d	3.60 c	5.25 d	0.0606 c	0.0058
150 mM NaCl+0.5 mM SiO_2	18.33 f	43.79 d	18.49 a	5.64 d	0.0662 c	0.0088
150 mM NaCl+1 mM SiO_2	30.40 de	69.49 bc	9.78 b	8.68 c	0.0993 b	0.0404
150 mM NaCl+1.5 mM SiO_2	38.28 c	67.47 bc	7.31 b	8.53 c	0.0970 b	0.0429
150 mM NaCl+2 mM SiO_2	37.48 cd	59.17 c	7.52 b	8.91 bc	0.0973 b	0.0464

Although the inhibition effect of salt stress on the germination parameters of the big red cultivar was not significant, it decreased the vegetative growth parameters. On the other hand, silicon dioxide applications encouraged all vegetative growth parameters, both under stress and normal conditions. In both conditions, 1 mM silicon priming was determined the best application in terms of all germination parameters (Table 4).

Table 4. Vegetative growth parameters of the big red cultivar.

Application	SL (mm)	RL (mm)	LL (mm)	LW (mm)	SFW (g)	RFW (g)
Control	35.91 de	55.55 cd	5.60 de	7.18 c	0.1277 de	0.0240 c
0.5 mM SiO_2	42.63 c	53.85 d	6.39 cd	7.56 c	0.1484 cd	0.0294 b
1 mM SiO_2	63.79 a	83.81 a	10.04 a	9.84 a	0.2742 a	0.0511 a
1.5 mM SiO_2	62.76 a	78.05 a	9.94 a	9.64 a	0.1962 b	0.0477 a
2 mM SiO_2	60.43 a	65.59 b	7.89 b	5.75 e	0.1125 e	0.0294 b
150 mM NaCl	31.07 e	19.76 f	4.51 f	6.27 de	0.1017 ef	0.0142 d
150 mM NaCl+0.5 mM SiO_2	39.72 cd	24.10 f	4.53 f	6.43 d	0.1100 ef	0.0145 d
150 mM NaCl+1 mM SiO_2	54.49 b	63.90 bc	7.08 c	8.84 b	0.1894 b	0.0296 b
150 mM NaCl+1.5 mM SiO_2	53.92 b	57.86 cd	6.91 c	8.45 b	0.1689 bc	0.0267 bc
150 mM NaCl+2 mM SiO_2	33.01 e	39.54 e	5.27 ef	3.45 f	0.0838 f	0.0149 d

Conclusion

Silicon priming in two different radish cultivars used in this study was found to have a stimulating effect on germination and vegetative growth parameters in both saline and normal conditions. 2 mM SiO_2 application in big red radish and 1 mM SiO_2 in little red radish increased germination rate two fold under salt stress conditions. Especially the increase of SVI by SiO_2 is very important for the seedling period, which is the first stage of cultivation. Therefore it can be recommended as an alternative preparation for sustainable agriculture in order to avoid the bottleneck created by increased abiotic stress conditions in crop production.

Additional Statement

This study was presented to the AGRİBALKAN 2022 congress as an oral presentation.

REFERENCES

Acevedo, A. F. G., da Silva Marques, I. C., Dellabiglia, W. J., Ferraz, A. K. L., Basílio, L. S. P., & Broetto, F. (2022). Silicon as a mitigator of water deficit stress in radish crop. *Scientia Horticulturae,* 291: 110600**.**

Ahmed, M., Qadeer, U., Ahmed, Z.I., & Hassan, F.U. (2016). Improvement of wheat (*Triticum aestivum* L.) drought tolerance by seed priming with silicon. *Archives of Agronomi and Soil Scence, 62:* 299–315.

Ashraf, M., Atta, A., Almas, M.H., Shahzad, S.M. & Imtiaz, M. (2020). Silicon nutrition effects on growth, yield and metal accumulation in radish (*Raphanus sativus* L.) grown with municipal wastewater. *Journal of Soil and Plant Biology, 1*: 129-137.

Baghaei, M., Ashraf, S., & Alipour, Z. T. (2014). Effects of salicylic acid and silica on the nutrients absorption in the plant radishes under salinity stress. *International Journal of Farming and Allied Sciences, 3*(10): 1075-1079.

Baki, A.A. & Anderson, J. D. (1973). Vigour determination in soybean by multiple criteria. *Crop Science*, 13: 630-633

Beevi, S. S., Mangamoori, L. N., & Gowda, B. B. (2012). Polyphenolics profile and antioxidant properties of *Raphanus sativus* L. *Natural Product Research*, *26*(6): 557-563.

Benech, A, R. L., Fenner, M. & Edwards, P. J. (1991). Changes in germinability, ABA content and ABA embryonic sensitivity in developing seeds of *Sorghum bicolor* (L.) Moench. induced by water stress during grain filling. *New Phytologist*, 118(2): 339-347

Bybordi A. (2014). Interactive effects of silicon and potassium nitrate in improving salt tolerance of wheat. *Journal of Integrative Agriculture, 13*(9): 1889-1899.

Ellis, R. H. & Roberts, E. H. (1981). The Quantification of Ageing and Survival in Orthodox Seeds. *Seed Science and Technology*, 9: 373-409.

Esechie, H. A. (1994). Interaction of salinity and temperature on the germination of sorghum. *Journal of Agronomy and Crop Science*, 172(3): 194-199.

Gamba, M., Asllanaj, E., Raguindin, P. F., Glisic, M., Franco, O. H., Minder, B., ... & Muka, T. (2021). Nutritional and phytochemical characterization of radish (Raphanus sativus): A systematic review. *Trends in Food Science & Technology*, *113*: 205-218.

Gutiérrez, R. M. P., & Perez, R. L. (2004). Raphanus sativus (Radish): their chemistry and biology. *The Scientific World Journal*, *4*: 811.

Hameed, A., Sheikh, M.A., Jamil, A., & Basra, S.M.A. (2013). Seed priming with sodium silicate enhances seed germination and seedling growth in wheat (Triticum aestivum L.) under water deficit stress induced by polyethylene glycol. *Pakistan Journal of Life and Social Sciences, 11*(1): 19-24.

Jamil, M., Lee, K. J., Kim, J. M., Kim, H. S., & Rha, E. S. (2007). Salinity reduced growth PS2 photochemistry and chlorophyll content in radish. *Scientia Agricola*, *64*, 111-118.

Kaur, S., Kaur, N., Siddique, K. H., & Nayyar, H. (2016). Beneficial elements for agricultural crops and their functional relevance in defence against stresses. *Archives of Agronomy and Soil Science*, *62*(7): 905-920.

Kotowski, F. (1926). Temperature relations to germination of vegetable seed. *Proceedings of the American Society for Horticultural Science*, 23: 176-184.

Kusvuran, S. & Ellialtioglu, S. S. (2021). Assessment of different organic matters on antioxidative enzyme activities and nutritional components under salt stress in salad rocket (*Eruca sativa*). *Japs: Journal of Animal & Plant Sciences*, *31*(5): 1319-1328

Liang, Y.C., Chen, Q., Zhang, W.H., & Ding, R.X. (2003). Exogenous silicon (Si) increase antioxidant Enzyme activity and reduces lipid peroxidation in roots of salt-stressed barley (*Hordeum vulgare* L.). *Journal of Plant Physiology, 160,* 1157-1164.

Manzoor, A., Bashir, M. A., Naveed, M. S., Cheema, K. L., & Cardarelli, M. (2021). Role of Different Abiotic Factors in Inducing Pre-Harvest Physiological Disorders in Radish (*Raphanus sativus*). *Plants*, *10*(10): 2003.

Nasırcılar, A. G., Ulukapı, K., & Üstüner, H (2021). Exogenous Silicon Dioxide Treatment in Carrot (*Daucus carota* L.) Under Salt Stress Conditions. *Türk Tarım ve Doğa Bilimleri Dergisi*, *8*(4), 1094-1102.

Noreen, Z., & Ashraf, M. (2008). Inter and intra specific variation for salt tolerance in turnip (Brassica rapa L.) and radish (*Raphanus sativus* L.) at the initial growth stages. *Pakistan Journal of Botany*, *40*(1):229-236.

Olivera Viciedo, D., de Mello Prado, R., Lizcano Toledo, R., Nascimento dos Santos, L. C., & Peña Calzada, K. (2017). Response of radish seedlings (*Raphanus sativus* L.) to different concentrations of ammoniacal nitrogen in absence and presence of silicon. *Agronomía Colombiana*, *35*(2): 198-204.

Parveen, A., Liu, W., Hussain, S., Asghar, J., Perveen, S., & Xiong, Y. (2019). Silicon priming regulates morpho-physiological growth and oxidative metabolism in Maize under drought stress. *Plants*, *8*(10): 431.

Rhaman, M. S., Rauf, F., Tania, S. S., & Khatun, M. (2020). Seed priming methods: Application in field crops and future perspectives. *Asian Journal of Research in Crop Science, 5*(2): 8-19.

Romero-Arnada, M.R., Jourado, O., & Cuartero, J. (2006). Silicon alleviates the deleterious salt effects on tomato plant growth by improving plant water status. *Journal of Plant Physiology, 163:* 847-855.

Sivritepe, H.Ö. (2012). Tohum Gücünün Değerlendirilmesi. *Alatarım Dergisi*, 11(2): 33-44

Taqdees, Z., Khan, J., Kausar, S., Afzaal, M., & Akhtar, I. (2022). Silicon and zinc nanoparticles-enriched miscanthus biochar enhanced seed germination, antioxidant defense system, and nutrient status of radish under NaCl stress. *Crop and Pasture Science*, *73*(5): 556-572.

Tavallali, V., Rahemi, M., & Panahi, B. (2008). Calcium induces salinity tolerance in pistachio rootstocks. *Fruits*, *63*(5): 285-296.

Ulukapı, K., Nasırcılar, A. G., & Kurt, Z. (2020). Determination of Salt Tolerance Levels of Some Radish Cultivars and Evaluation of the Effectiveness of Salicylic Acid on Germination in Saline Conditions. *Turkish Journal of Agriculture-Food Science and Technology*, *8*(3): 632-637.

Verkerk, R., Schreiner, M., Krumbein, A., Ciska, E., Holst, B., Rowland, I., De Schrijver, R., et al., (2008). Glucosinolates in Brassica vegetables: the influence of the food supply chain on intake, bioavailability and human health. *Molecular Nutrution and Food Research.*, *Suppl 2(S2):S219*, 53. https://doi.org/10.1002/mnfr.200800065. S219–S219.

Yildirim, E., Turan, M., & Donmez, M. F. (2008). Mitigation of salt stress in radish (*Raphanus sativus* L.) by plant growth promoting rhizobacteria. *Romanian Biotechnology Letters, 13*: 3933-3943.

Zhu, Z. G., Wei, G.Q., Li, J., Qian, Q.Q., & Yu J Q. (2004). Silicon alleviates salt stress and increases antioxidant enzymes activity in leaves of salt-stressed cucumber (*Cucumis sativus* L.). *Plant Science,* 167: 527-533.