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Effect of *Bacillus* sp. application on the germination of coriander (*Coriandrum sativum* L.) under salt stress

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A B S T R A C T

Coriander (*Coriandrum sativum* L.), one of the annual herbaceous plants widely used as a medicinal and aromatic herb, is used as flavor and aroma, to treat digestive system diseases, as antipyretic, etc. Salinity, which is one of the soil quality index parameters, is one of the most important abiotic stress factors limiting the production of agricultural products. This study examined the effect of *Bacillus* sp. application on germination rate (%), germination speed (days), average daily germination (days), peak and germination values of coriander at different salt (NaCl) concentrations (0, 50, 100, 150, 200 mM). It was determined that the *Bacillus* sp. and salt application were significant at the level of 1% in the investigated parameters and that the bacterial application minimized the negative effects of increasing salt concentrations on the germination biology. The germination rate (67%), germination speed (8.4 days), average daily germination (4.5 days), peak (2.33%), and germination values (10.5%) were obtained. It was determined that no *Bacillus* sp. + 50 mM salt application provided the best germination values in coriander seeds.

1. INTRODUCTION

Plants that have been used frequently in folk medicine for centuries have been beneficial in the treatment of many diseases. Coriander, which is one of these plants, is widely used among the public as flavor and aroma, pain reliever, sedative, antipyretic, appetizer, digestive system regulator, diuretic and antimicrobial (Kadioglu et al., 2021a, 2021b, 2021c). The green sections and seeds of coriander (*Coriandrum sativum* L.) are used for medicinal and aromatic purposes. Coriander, produced from seed, grows in lime-rich, sandy-loam, lightly textured, neutral and slightly alkaline soils. Plants grow best in the conditions that are optimal for them. Soil salinity constitutes most of the mineral stress, one of the abiotic stresses. Soil quality encompasses the physical, chemical and biological properties of the soil. Soil salinity, one of the soil quality parameters, is formed as a result of the capillary rise of salts dissolved in the under groundwaters to the soil surface with high ground water, where the water is separated from the soil by evaporation. Salt stress directly affects plant diversity. Plants have different tolerances to salt stress (Parida & Das, 2005) and are affected by salt stress in their environment during growth and development. The period when plants are most sensitive to salt stress is the germination period (Shrivastava et al., 2015; Forni et al., 2017). Germination begins with the absorption of water by the seed, and the humidity of the environment increases the germination power and speed. Salinity, which is one of the soil quality parameters, negatively affects the fertility of the soils and causes large agricultural dead zones. Since the reclamation of saline soils is not economical and practical, the cultivation of salt-resistant plant species and genotypes has been considered the most rational way to make use of these areas in recent years.

As a result of excessive use of chemical fertilizers used to increase yield, problems such as salinization, nutrient deficiency, deterioration of microorganism activity occur in the soil, and bacteria that encourage plant growth are used to prevent such problems. Bacterial strains such as *Bacillus, Lactobacillus, Paenibacillus, Arthobacter, Pseudomonas* are included in the bacteria class that promotes plant growth (Çakmakçı et al., 2001), PGPRs are soil and environmentally friendly fertilizers that increase productivity. The present study examined the effect of PGPR bacteria application at different salt concentrations on the germination biology of coriander seed, which is a medicinal and aromatic plant.

2. MATERIAL AND METHOD

This study, which was carried out under controlled conditions (25±1°C) in 2023, aimed to determine the effect of plant growth-promoting rhizobacteria (PGPR) application at different salt concentrations during the germination period of coriander (*C. sativum* L.) seeds. The study was carried out with 10 replications following the factorial design of random plots. Five different doses of NaCl and *Bacillus* sp. bacteria (control (salt + no bacteria), 50 mM NaCl, 100 mM NaCl, 150 mM NaCl, 200 mM NaCl, control (salt + bacteria), 50 mM NaCl + *Bacillus* sp. 10^8 CFU, 100 mM NaCl +*Bacillus* sp. 10^8 CFU, 150 mM NaCl +*Bacillus* sp. 10^8 CFU, 200 mM NaCl +*Bacillus* sp. 10^8 CFU) were applied to the seeds. To ensure surface sterilization of the seeds, the seeds were sterilized in 5% sodium hypochlorite solution for 10 minutes. Sterilized seeds were planted in petri dishes with a diameter of 9 cm and a height of 1.5 cm, with 50 seeds in each petri dish, on 2 layers of filter paper (Whatman No: 2) placed at the bottom of the dishes. 10 ml of laboratory-prepared saline and saline + bacteria solutions were added to each petri dish (Prodo et al., 2000). Filter papers were changed at every 2 days to prevent salt accumulation in Petri dishes (Kiremit et al., 2017). In the experiment, coriander seeds were considered germinated when they had a root length of 2 mm (ISTA, 2003). The germination rate (%), germination speed (days), daily germination average (%), peak value (%) and germination value (%) were determined (Czabator, 1962; Ellis & Roberts, 1981; Matthews & Khajeh-Hosseini, 2007; Gairola et al., 2011).

$$Germination\ rate = \frac{n}{\sum n} \times 100 \qquad (1)$$

n: Number of germinated seeds

$\sum n$: Total number of seeds

Germination speed: $n_1/t_1 + n_2/t_2 + \ldots\ldots$

n_1, n_2, … number of germinated seeds t_1, t_2, …days

$$Mean\ daily\ germination = \frac{Total\ number\ of\ germinated\ seeds}{Total\ number\ of\ days} \qquad (2)$$

$$Peak\ value = \frac{Highest\ seed\ count}{Highest\ seeding\ day} \qquad (3)$$

$$Germination\ value = Mean\ daily\ germination \times Peak\ value \qquad (4)$$

Differences between analysis of variance and means were analyzed in the LSD multiple comparison test program JMP 5.0.1.

3. RESULTS AND DISCUSSION

3.1. Germination Rate (GP%)

The germination rate showed that bacteria and salt application were significant at 1%, while the bacteria × salt interaction was insignificant. The *Bacillus* sp. strain was effective, and its germination rate decreased as the salt concentration increased. The best results were obtained with 50 mM salt application (67.25%). As the salt concentration in the bacteria × salt interaction increased, the germination rate decreased, and the highest rate was obtained from 50 mM salt × *Bacillus* sp. application with 81% (Figure 1).

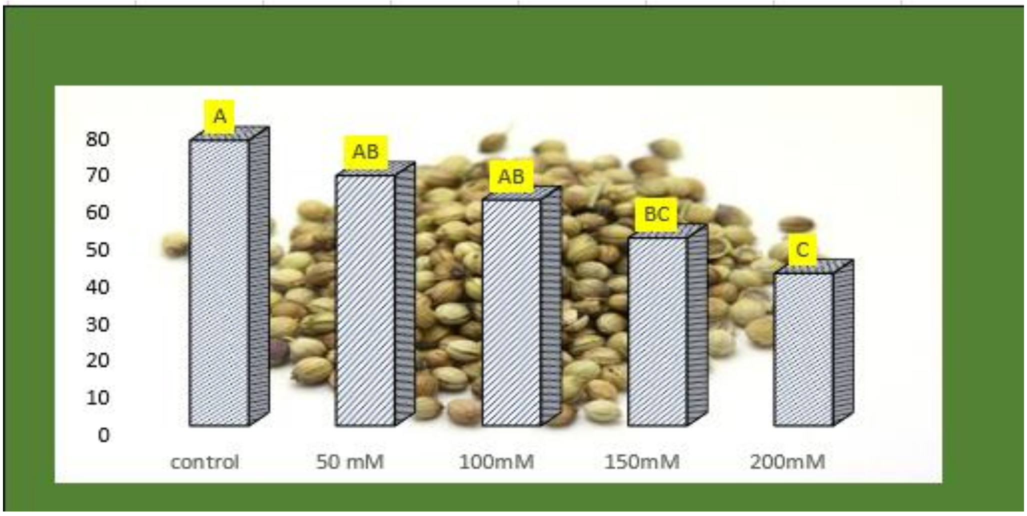

Figure 1. Germination rate of *Coriandrum sativum* L. in salt application (%)

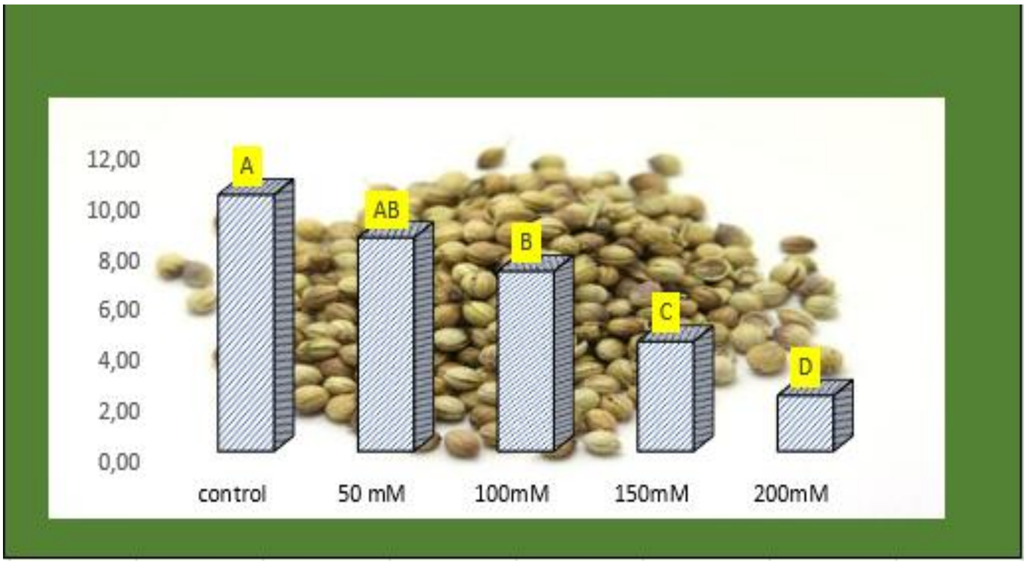

Figure 2. Germination time of *Coriandrum sativum* L. in salt application (days)

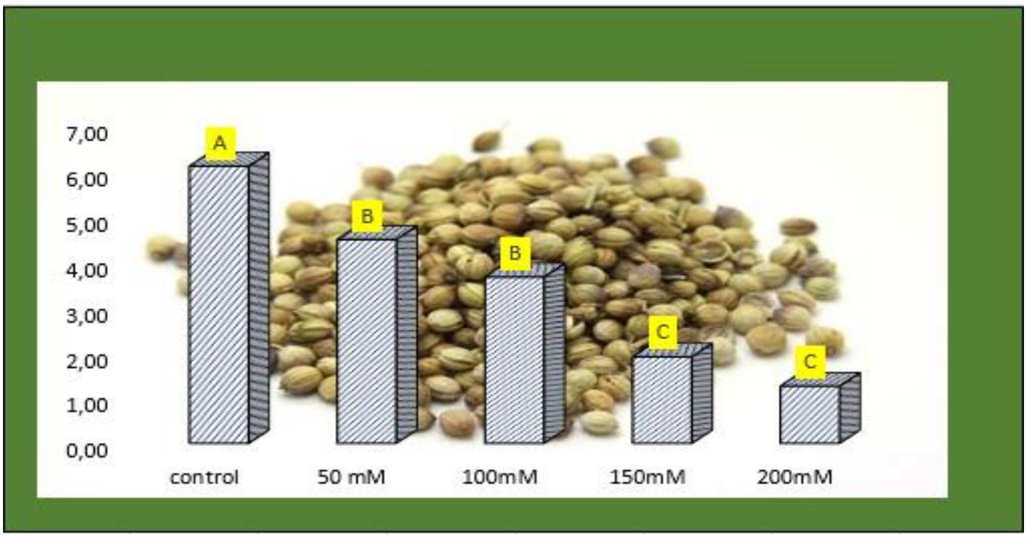

Figure 3. Average daily germination time of *Coriandrum sativum* L. in salt application (days)

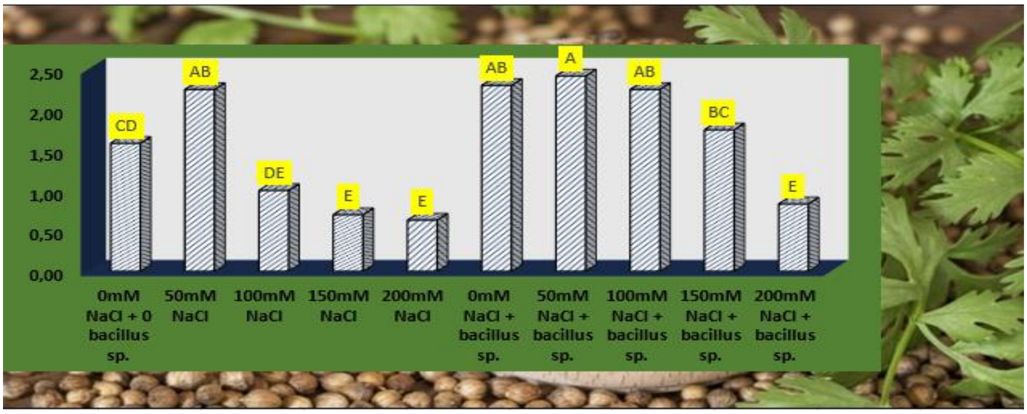

Figure 4. Peak (%) value of *Coriandrum sativum* L. in salt x bacteria interaction

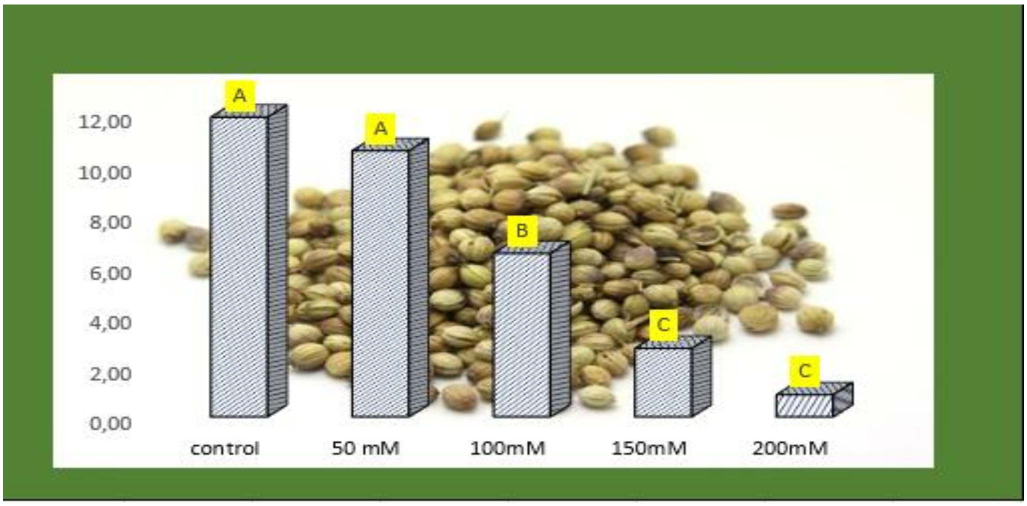

Figure 5. Germination value of *Coriandrum sativum* L. in salt application (%)

3.2. Germination Speed (GS days)

It was determined that bacteria and salt applications were significant at 1% during germination, whereas the bacteria × salt interaction was insignificant. It was determined that as the salt concentration increased, the germination speed was prolonged and the application of *Bacillus* sp. (7.19 day) minimized the negative effects of salt stress. In salt application, the highest value was obtained from 50 mM salt application with 8.4, while the lowest value was 2.20 day in 200 mM salt application. During germination, the lowest value of bacteria × salt interaction was 1.99 day under 200 mM salt + no *Bacillus* sp. conditions (Figure 2).

3.3. Mean Daily Germination (MDG days)

The average daily germination parameter showed that the interaction of bacteria and bacteria × salt was insignificant, while salt application was significant at 1%. In this parameter, the highest value of 4.5 day was obtained with 50 mM salt application, and the lowest value of 1.25 day was obtained with 200 mM salt application. The study showed that the mean daily germination time increased as the salt concentration increased. Although bacteria application had an effect on average daily germination, it was not statistically significant (Figure 3).

3.4. Peak Value (PV%)

The peak values showed that bacteria and salt applications were significant at 1%. Bacteria × salt interaction was found to be significant at 5%. It was determined that the *Bacillus* sp. strain was effective on the peak value and gave the highest value with 1.91%. In salt application, the highest value was 2.33% with 50 mM salt application, while the lowest value was 0.73% with 200 mM salt application. In the bacteria × salt interaction, the highest value of 2.4% was obtained in the 50 mM salt × *Bacillus* sp. interaction. It was determined that bacteria application was effective against salt stress and positively affected the investigated parameter (Figure 4).

3.5. Germination Value (GV%)

Germination value parameter analysis showed that it was significant in bacteria and salt applications at 1%. Bacteria × salt interaction was found to be insignificant. The *Bacillus* sp. strain was found to be effective against salt application, and 50 mM salt application gave the highest germination values with 10.5% (Figure 5).

This study determined that salt stress has a negative effect on the germination biology of coriander, and *Bacillus* sp. application reduces the effect of salt stress. Soil salinity is critical for seed germination. Salinity causes physiological and biochemical changes in seed germination and significantly affects seed germination and plant growth. The findings of the present study are in parallel with those reported by other studies. In a study in which different concentrations of salt were applied on three different sage cultivars to determine the effect of salt stress on seed germination in sage, it was determined that increasing salt concentrations in all three cultivars had a significant effect on seed germination biology, and germination parameters decreased in parallel with the increase in salt stress (Kadioglu, 2020). A study conducted on salt stress by Isİk (2022) indicated that as the salt concentration increased, the germination rate decreased. Çamlıca & Yaldiz (2017) determined that as salt concentrations increase, germination, shoot and root length decrease in basil. Another study reported that growth of sage was not affected much from different salt concentrations up to 100 mM salt level, but plant growth was adversely affected at levels above this salt level (Çamlıca et al., 2019). Since salinity damages plant metabolism, plant growth and germination are reduced. PGPR applications under optimal conditions minimize the negative effects of salt stress and increase plant growth, germination rate, root development and tolerance to extreme conditions such as drought/salinity by stimulating plant metabolism. A study in which PGPR was applied to linen under salt stress found that PGPR applications positively affected germination biology (Kadioglu, 2022). In a study examining the effects of the application of saline water during the germination period on the saline tolerance and morphological characteristics of linen, artichoke, safflower, and echinacea seeds, it was determined that linen and safflower seeds had more tolerance against salt stress when compared to echinacea and artichoke seeds and germination rate, offshoot and radicle lengths and plant dry weight characteristics of all plants decreased with the increasing salinity (Gholizadeh et al., 2016). Moreover, it was pointed out that increasing salinity levels caused decreases in germination parameters in sage, black cumin and linen (Yaldiz et al., 2016; Kiremit et al., 2017). Soil salinity, which is one of the soil quality index parameters, causes negative physiological and biochemical changes during the germination of seeds. The present study determined that the application of bacteria and salinity affected seed germination biology.

4. CONCLUSION

Soil salinity is a global problem due to its negative effects on agricultural productivity and sustainability. Salinity problems can occur in all climatic conditions due to both natural and human-induced actions. The relationship between salinity and humans has existed for centuries. The increase in salinity in agricultural areas is the biggest reason for the failure of agriculture. The best-known example of this is Mesopotamia. Soil salinity can occur due to natural causes or improper irrigation methods by reducing soil quality, compromising the integrity of the soil's buffering capacity. Soil salinity emerges as a dynamic problem in more than 100 countries and unfortunately spreads all over the world due to improper agricultural practices. Soil salinization affects plant growth and causes yield loss. Studies have been made and are being carried out to minimize yield loss, to improve salt-tolerant plant varieties and soil salinity. In our study, effects of *Bacillus* sp. application on the germination parameters of coriander in salty environment were investigated.

The results of the research showed that plant growth-promoting rhizobacteria (PGPR) used for germination biology in salty conditions was effective on germination rate, germination speed, average daily germination, peak value and germination value, and it was determined that the use of *Bacillus* sp. strain minimized the negative effect of salt stress on coriander seeds.

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The coriander seeds used in the research were collected from nature. The bacterial material used in the experiment was commercially available.

COMPLIANCE WITH ETHICAL STANDARDS

Conflict of Interest

The author declares that there is no conflict of interest.

Ethical Approval

For this type of study, formal consent is not required.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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