

**EVALUATION OF BORON-REMOVED GEOTHERMAL
WATER FOR WHEAT IRRIGATION: EFFECTS
ON SEEDLING DEVELOPMENT IN DIFFERENT
WHEAT VARIETIES**

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Abstract

The need for water has been increasing day by day with the growing industry and increasing population. Since global climate change and environmental problems have caused the depletion of water resources, it is necessary to make all kinds of water resources usable. Geothermal water resources, which are considered an alternative water source for this study, cannot be used directly in agricultural irrigation because they contain high levels of boron and heavy metals that are toxic for plants. For this reason, the usability of boron-removed geothermal resources in wheat agriculture was investigated. The irrigation water required for growing wheat has been brought to the desired limit values. The emergence and seedling development characteristics of the grown wheat were examined by using seeds of bread wheat and durum wheat which are two different wheat varieties as plant materials. According to the results of the study, decreases in the emergence percentages and seedling growth were observed in the comparisons made between the experiment and the controls. According to the comparison between varieties, bread wheat variety (Pehlivan) was more affected than durum wheat variety (Mirzabey-2000).

Key words: geothermal resource, boron, chemical precipitation, wheat

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Introduction. Agriculture is directly affected by many factors, such as climate change and population growth. Cereals are at the forefront of agriculture as a staple food worldwide. The most consumed cereal in the world is wheat. People meet a large part of their daily energy needs with wheat. Due to the growing population, the need for wheat production is increasing. However, climate change and limited soil and water resources are the leading factors that affect production and hinder its sustainability [1].

Geothermal waters differ from other waters on earth due to their structural features. Due to the presence of high rates of boron and heavy metals, which contain various elements and can have a toxic effect for plants, the water to be used in the presence of these elements disrupts the balance of agricultural areas and hinders agricultural activities. In order for geothermal waters to be usable for irrigation purposes, the boron level, which causes toxic effects, must be brought to an appropriate value [2].

The high boron content of geothermal waters causes environmental problems when it is used for irrigation purposes and when these waters combine with groundwater, causing pollution in agricultural areas [3]. It is important to remove boron from water so that the continuous direct use of these waters does not cause harmful effects on the environment and living beings. Today, various methods are used to remove boron. However, a certain amount of boron is necessary, as boron contributes to the regulation of minerals needed by the body with vitamin D, provides support for bone structure, preventing the reduction of the amount of minerals calcium (Ca) and magnesium (Mg).

In general, with the germination of seeds with low water content and high nutrient content, the biological availability of protein, vitamins and other nutrients increases, the efficiency of toxin and enzyme inhibitors decreases and their digestibility increases.

Geothermal waters have been considered an alternative solution for agricultural irrigation. This research is aimed at finding an alternative solution to the reduction of water resources in the world in recent years. In this study, first of all, the boron concentration value of geothermal water was decreased. Then, the effects of the wheat plant grown with the obtained water on the emergence and seedling growth were investigated.

Regardless of their level of development, countries need to maintain the security of wheat supply and ensure self-sufficiency independently of external sources. However, national independence carries risks in case of foreign dependency. In this context, considering the past wars and times of famine, it is concluded that wheat is a strategic product for countries [4].

Material and methods. This study was carried out in the Laboratory of Chemical Engineering, Department of the Faculty of Engineering of Çanakkale Onsekiz Mart University in 2021. Geothermal water samples were obtained from Tuzla geothermal field containing Lithium (4–7 ppm), Barium (1–4 ppm), Man-

ganese (1–5 ppm), Boron (> 13 ppm) above the determined limit values with fluid NaCl type salinity ($EC > 91$ mS/cm) in Tuzla geothermal field and some heavy metals in high concentrations such as Strontium (> 14 ppm). It contains high amounts of Silicon ($> 23\,800$ mg/kg) and Aluminium (> 9000 mg/kg) in the soil [5].

Pure water was used as irrigation water in control applications. In the first stage of this study, which was carried out in two stages, the boron concentration value of geothermal water was reduced by using the precipitation method. Calcium carbonate was chosen as the chemical precipitator in the study. This chemical was weighed and used in powder form without any preliminary preparation. Calcium carbonate, colloquially known as limestone, is the most abundant chemical compound in nature.

Flasks with volume of 250 mL were used for precipitation experiments. In order to pre-adjust the amounts of the precipitating substances to be used in the study, the desired weighings with 0.01 precision were made with the Weightlab WL-2002L Digital Precision Balance. In order to keep the temperature constant at 25 °C, MIPRO MCS series brand agitated water bath was used. Ohaus, ST2100-F desktop pH meter was used to adjust the solutions to the desired pH values. HACH DR/1900 brand spectrophotometer was used to measure boron concentration values in the samples taken from the experiment.

For the boron removal process, 2.5 g of limestone was weighed into 50 mL of filtered geothermal water and placed in a flask. The samples prepared by adding 0.5 mL phosphoric acid (H_3PO_4) to the solution were shaken in a shaking water bath at 25 °C and 140 rpm for 24 h, and the water samples were filtered with the help of filter paper.

In the second stage, the effects of the wheat plant grown with the boron-depleted geothermal water on the emergence and seedling growth were investigated. Wheat seeds (Pehlivan and Mirzabey-2000) were used as plant material in the study. Pot experiments were established according to random plots and divided plots trial design with 3 replications. Immediately after planting, each pot was given 100 mL of distilled water to start germination. After planting the wheat seeds, 50 mL of boron-depleted geothermal water was applied to experimental pots. Fifty mL of distilled water was applied to the control pots. This process was applied regularly until the cotyledon leaf appears.

Harvesting, observation and measurement of the plants took place 16 days of development after sowing the seeds. For each experimental and control group, five plant samples were randomly selected and the necessary measurements and their properties were examined.

Shoot length (cm): At the end of the 16-day trial, five randomly selected plants were selected from each pot and the average was found by measuring the distance from the root tip to the seedling tip.

Root Length (cm): Five randomly selected plants were selected from each pot, and the average was found by measuring the distance between the root collar and root tip.

Shoot wet weight (g): Fresh weights of 5 randomly selected plants from each pot were weighed one by one with the help of precision scales and the average was found.

Root wet weight (g): After five randomly selected plants from each pot were cut from the root collar one by one, the remaining root part was weighed on a precision scale and the average was found.

Shoot dry weight (g/plant): The shoot parts of the plants were dried in an oven at 70 °C (for 24 h) until a constant weight was reached; the dry shoot weight was determined for each plant using precision scales and dividing it into five.

Root dry weight (g/plant): The root parts of the plants were dried in an oven at 70 °C (for 24 h) until a constant weight was reached; then the dry root weight was determined for each plant using precision scales and dividing it into five.

The data were subjected to analysis of variance (ANOVA) with the Agricola and R package program and the LSD test was performed [6].

Results and discussion. Some analysis results of the boron-removed geothermal irrigation water obtained as a result of the precipitation processes and used for irrigation purposes throughout the experiment to grow wheat are shown in Table 1.

T a b l e 1
Irrigation water analysis results

Electrical conductivity (mS/cm)	88.4
Salinity (%)	63.1
pH	11.01
Temperature (°C)	23.1
Boron (mg/L)	0.4
Fe (µg/L)	2.704
Mg (mg/L)	0.004
Mn (µg/L)	2.985
Ni (µg/L)	5.603
P (mg/L)	0.002
Zn (µg/L)	6.860
K (mg/L)	261.4
N (mg/L)	11.98

In our study, the effects of irrigation with boron-removed geothermal water on emergence and seedling development of two different wheat varieties were investigated. In the first trial, there was no emergence in wheat varieties irrigated with



Fig. 1. Wheat genotypes at the end of the 12th day

T a b l e 2

Some shoot characteristics of wheat sprouts after irrigation treatment

Genotypes	Shoot length (cm)	Shoot wet weight (g)	Shoot dry weight (g)
Boron depleted geothermal resource			
Pehlivan	29.87 D	0.132 C	0.0753 AB
Mirzabey	37.53 C	0.168 B	0.0767 A
F values			
F irrigation:	720.11 ^{***}	10.34 [*]	5.938 ns
F genotype:	6.573 [*]	83.54 ^{***}	1.422
F irrigation × genotype:	52.769 ^{***}	5.44	0.970
Distilled water			
Pehlivan	56.47 A	0.136 C	0.053 B
Mirzabey	52.80 B	0.197 A	0.067 AB

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$, ns: not significant

boron-removed geothermal water. In the new system established for the second time, after giving pure water as life water, irrigation with boron-removed geothermal water was continued every other day and then plants were harvested. During the study, the characteristics were examined according to irrigation application. The mean values and variance analysis results for shoot characteristics are given in Table 2.

According to the comparison between the varieties, emergence percentages of Mirzabey-2000 variety were negatively affected compared to Pehlivan variety. Sprouts root length of Pehlivan variety showed lower performance compared to Mirzabey-2000 in Table 2. As seen in Table 2, the differences between irrigation

waters in terms of seedling fresh weight in wheat were found to be statistically significant at the 0.05 level, and the differences between varieties were found to be statistically significant at the 0.01 level. Irrigation $\times$ genotype interaction was found to be statistically insignificant. The letters A, B, C, and D indicate the significance of the differences between the means of the groups tested. In this context A indicates the highest performance group, B indicates the moderate group and C indicates the lowest performance group. According to that, under boron depleted geothermal conditions, Mirzabey outperformed Pehlivan in shoot length, wet weight, and dry weight, as indicated by the letter. This analysis suggests that the performance of the genotypes varies significantly depending on the environmental conditions, as indicated by the statistical significance values (F values) provided.

In Table 3, it was observed that the seedling fresh weight bread (Pehlivan) and durum (Mirzabey-2000) wheat varieties were lower than the control. For bread type (Pehlivan) fresh seedling weight was 0.132 g on average, and in the control treatment it was 0.137 g on average. In Mirzabey-2000 variety, the fresh seedling weight was 0.168 g on average, and in the control treatment it was 0.197 g on average. Durum wheat variety was more affected than bread wheat variety. While the boron-depleted geothermal water application of Pehlivan variety and the control application were in the same statistical group, the boron-removed geothermal water application of Mirzabey-2000 variety and the control application were in different statistical groups. According to ABACI and KAYA, the bread wheat va-

T a b l e 3
Some root characteristics of wheat sprouts after irrigation treatment

Genotypes	Root length (cm)	Root wet weight (g)	Root dry weight (g)
Boron depleted geothermal resource			
Pehlivan	11.86 C	0.072 A	0.0606 A
Mirzabey	14.06 C	0.073 A	0.0486 AB
LSD values			
Irrigation:	1.467	0.0071	0.0139
Irrigation $\times$ genotype	2.075	0.0100	0.0197
F values			
F irrigation:	261.630***	34.074**	7.189*
F genotype:	5.133	19.926**	0.122
F irrigation $\times$ genotype:	1.634	16.048**	5.993*
Distilled water			
Pehlivan	22.33 A	0.043 B	0.0313 B
Mirzabey	23.00 A	0.068 A	0.0473 AB

* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$, ns: not significant

riety (Pehlivan) has performed lower in all evaluated germination characteristics compared to the durum wheat variety (Mirzabey-2000) [5]. The study emphasized that durum wheat varieties are more sensitive than bread varieties [5,8]. Previous results are consistent with our study [2,5,8].

It was observed that shoot dry weight of bread (Pehlivan) and durum (Mirzabey-2000) wheat varieties was higher compared to the control. Bread wheat variety was affected more than durum wheat variety. While boron removed geothermal water application of Pehlivan wheat variety and control application of Mirzabey-2000 wheat variety were in the same statistical group, boron removed geothermal water application of Mirzabey-2000 wheat variety and control application of Pehlivan wheat variety were in different statistical groups.

According to the comparison made between the varieties, the bread wheat variety (Pehlivan) showed lower performance than the durum wheat variety (Mirzabey-2000) in all the traits considered. As seen in Table 2, the differences between irrigation applications and irrigation $\times$ genotype interaction in terms of shoot lengths in wheat sprouts were found to be statistically significant at the 0.01 level, while the differences between genotypes were found to be significant at the 0.05 level.

The shoots length averages and significant groups of the boron-removed geothermal water application are shown in Table 2. According to Table 2 the shoot lengths of bread (Pehlivan) and durum (Mirzabey-2000) wheat varieties were shorter than the control. The average shoot length was measured as 29.87 cm in Pehlivan variety and 56.47 cm in control treatment. The average seedling length was measured as 37.53 cm in Mirzabey-2000 variety and 52.80 cm in control treatment. The bread wheat variety was affected more than the durum wheat variety (Fig. 1).

The mean values and the variance analysis results for root characteristics are given in Table 3. According to Table 3 the root lengths of bread (Pehlivan) and durum (Mirzabey-2000) wheat varieties were shorter compared to the control. The root length of Pehlivan variety was measured as 11.87 cm on average and 22.33 cm in the control treatment. In Mirzabey variety, the root length was measured as 14.07 cm on average and 23 cm in the control treatment. Bread wheat variety was affected more than durum wheat variety. While the boron-removed geothermal water applications of Pehlivan and Mirzabey-2000 varieties were in different statistical groups, the control applications of the two varieties were in the same group. Similarly, some researchers observed analogous outcomes in their investigation [2,7]. They noted that plants irrigated with a dilution of thermal water, equivalent to one-quarter strength, exhibited results close to the control plants in both canola and maize cultivation.

According to Table 3, the root fresh weight of bread (Pehlivan) and durum (Mirzabey-2000) wheat varieties was higher than the control. As seen in Table 3, according to LSD test there were three significance groups – A, B, C. The letters

A, B, C, and D indicate the significance of the differences between the means of the groups tested. In this context A indicates the highest performance group, B indicates the moderate group, and C indicates the lowest performance group. Overall, the data suggests that the genotype Mirzabey performs better in terms of root length under boron-depleted conditions, while Mirzabey shows superior performance in distilled water conditions for both root wet and dry weights. DEMIR-CIVI [3] also examined the responses of bean plants to geothermal water obtained from hot springs in different locations on germination and seedling development. The results were consistent with our study. They also stated that the responses to bean plants differed and that the highest averages were in the control plots [3, 5]. For bread variety (Pehlivan), the fresh root weight was 0.072 g on average, and in the control application it was 0.043 g on average. For durum variety (Mirzabey), the root fresh weight was 0.073 g on average, and in the control application it was 0.068 g on average. Bread wheat variety was affected more than durum wheat variety.

The control application of Pehlivan variety was in different statistical groups. In terms of root dry weight in wheat, the differences between irrigation waters and irrigation $\times$ variety interaction were found to be statistically significant at the 0.05 level, while the differences between varieties were found to be statistically insignificant. It was observed that the root dry weight of bread (Pehlivan) and durum (Mirzabey-2000) wheat varieties was higher than the control. The root dry weight Pehlivan variety was 0.060 g on average, while it was 0.031 g in the control application. The root dry weight in Mirzabey-2000 variety was 0.048 g on average, while it was 0.047 g in the control application. KUSCU et al. [9] also investigated the effects of different boron dosages (0, 0.5, 1, 2, 4 and 8 ppm) on germination of three different bread wheat varieties. They observed positive results on germination rate under boron dosage of 1 ppm, and a decrease in germination rate was observed as dosages above 1 ppm were increased [7, 9, 10]. According to the LSD test, germination rate values were observed as two different significant groups under boron depleted conditions and control. For Pehlivan variety under the boron depleted conditions the value was 84.444 A while for Mirzabey it was 75.556 B. For the control groups these values were Mirzabey: 100.00 A, Pehlivan: 97.77 B.

Regarding the germination rate for wheat sprouts, both genotypes exhibited a decrease in performance when subjected to boron-depleted geothermal resources compared to control conditions. Under boron depleted geothermal water conditions, the results regarding the germination rate are promising.

Conclusion. According to the comparison between the experiments and controls, emergence and some seedling development characteristics of wheat were negatively affected. While the highest emergence percentage according to the averages of the varieties was seen in the control application of Pehlivan and Mirzabey-2000 varieties, the boron-removed geothermal water application of Pehlivan and Mirzabey-2000 varieties was lower compared to the controls.

According to the comparison between the varieties, emergence percentages and shoots fresh weight of Mirzabey-2000 variety were negatively affected compared to Pehlivan variety. Sprouts root length of Pehlivan variety showed lower performance compared to Mirzabey-2000 variety.

Studies of geothermal water resources, which are considered an important alternative water source for agriculture, should be continued. In addition, it is recommended that yield trials be conducted by using different plant materials and taking into account the crop pattern suitable for the vegetation in the regions where geothermal water resources are located, and that long-term studies be conducted on the subject to reveal its possible effects. As mentioned, boron has a narrow range of deficiency and toxicity limits for plants. It is a trace element essential for plant growth, therefore it has an important place in agricultural production [10, 11].

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