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Investigating the toxic effects of boron on root and shoot growth and leaves of *Triticum aestivum* and *Triticum durum* genotypes

Extended Essay (Biology)

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ABSTRACT

Recently boron is a hot topic for it is an energy source and it is widely used in industry. It is said to be the "energy of the future". Turkey is an important boron deposit in the world besides being an agriculture country where boron deposits are mainly located in agriculture regions. In this respect, to determine the tolerant species for toxic levels of boron is quite important. In this study, toxic effects of boron were investigated on two species of wheat, *Triticum aestivum* and *Triticum durum* by using three genotypes from each.

My research question was "What are the toxic effects of boron on the growth of roots, shoots, leaves of *Triticum aestivum* and *Triticum durum* genotypes?"

It was hypothesized that as *T. aestivum* and *T.durum* are grown in soil containing toxic dosage of boron, they will show the signs of toxication.

In order to test the hypothesis and to answer the research question three replications were performed from both test groups (to which boron was applied at toxic level-20 ppm) and control groups (boron negative) of each genotype and the results were evaluated by using two parameters: 1) Root and shoot growth inhibition 2) 1-5 scale for evaluation of the color changes on the leaves.

At the end of the experiment, it is seen that the toxic effect of boron on both species of wheat is significant whereas durum wheat is much more sensible. Also genetic variation exists in response to boron toxicity in different genotypes of the same species. Statistical analysis also proved significant difference between the species and genotypes of the same species. It is concluded that tolerant and sensible genotypes can be determined and tolerant species can be used in agriculture.

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INTRODUCTION

This topic draw my attention in a report which said that the 63% of the boron deposits of the world are found in Turkey.[1,2] It is also mentioned that boron is the "energy of the future" and it is used in industries of glass, porcelain and wood, in electronics and space technologies, in many fields including, energy, metallurgy, isolation, health and agriculture. It is an important value regarding economics. But after some investigation, I found out that on the other hand, boron toxicity is an important abiotic stress factor on plants depressing the yield. It affects the root and shoot growth and the leaves of the plants. It is especially true in middle Anatolia which is an arid and semi-arid region and where drought is an increasing problem. I learned that Eskişehir-Kırka is the biggest boron deposit known in the world.[1] So, although it is an exceptional situation for our country to have such boron deposits, it is a necessity to be aware of the fact that boron can be a problem regarding agricultural production since Turkey is a country of agriculture at the same time.

Boron (B), the only non-metal among the elements of Group III in the periodic table is an essential element required for growth and development of plants (Loomis and Durst, 1992)[3]. Considerable research activities have been directed toward characterizing the physiological and biochemical roles of B in growth and development of plants. However, the exact role of B in growth is still a matter of discussion.

High concentrations of B may occur naturally in the soil or in groundwater, or be added to the soil from mining, fertilizers, or irrigation water. In Turkey, severe toxic levels of boron are found in Konya-Çomaklı and in Eskişehir-Hamidiye which are important production areas of durum wheat in Turkey[1]. Soil in Konya-Çomaklı location contains, on average, 9 and 12 ppm B in the 0-30 cm and 30-60 cm depths, respectively. In Eskişehir-Hamidiye location soil contains 6 and 18 ppm B in the corresponding depths (Kalaycı *et al.,* 1998)[4] which are toxic levels because boron must not exceed 2 ppm.

Of all the potential sources, irrigation water is the most important contributor to high levels of soil B (Chauhan and Powar, 1978)[5]. Surface mining, fly ash are other sources of B. The main application of B is, however, the use of sodium perborate as an oxidation bleaching

agent in domestic and industrial cleaning products. The discharge of sodium perborate into the environment during production and end use of detergents has resulted in the accumulation of B in nature (Vengosh *et al.,* 1994)[6].

There is genetic variation in response to high concentrations of B. This means that some genotypes are more tolerant to boron toxicity and they show toxicity signs over a longer period of time or at higher concentrations. Recent advances in genetic engineering are increasing the potential for breeding B tolerant plant species. Until more information is available, however, selection of B tolerant species will be dominated by trial and error experimentation. Amongst a wide variety of plant species, the typical visible symptom of B toxicity is leaf burn- chlorotic and/or necrotic patches, often at the margins and tips of older leaves (Bennett, 1993; Bergmann, 1992; Eaton, 1944)[7,8,9].

I chose wheat as a testing plant because it is the predominating agriculture plant in boron rich regions of Turkey. I wanted to test the toxic effects of boron on this plant and also to find out if there is a difference in response to boron toxicity between two species of wheat (*Triticum aestivum* and *Triticum durum*) and their three genotypes. Utilization of the varieties tolerant to boron toxicity seems to be the most practical solution of boron toxicity problem. For this purpose, in the present study, durum wheat and bread wheat were characterized in terms of their tolerance to boron toxicity by using root and shoot growth inhibition, 1-5 scale approaches which will be explained in detail in method section[10].

So, the research question of this study is **"What are the toxic effects of boron on the growth of roots, shoots, leaves of *Triticum aestivum* and *Triticum durum* genotypes?"**

HYPOTHESIS

It is known that boron is an important element for various fields in industry and agriculture. It is the energy of the future. It is also essential for plant growth process. Its exact role on plant physiology and biochemistry is still discussed but there are a lot of researches still going on in order to answer these questions. Boron seems to be of crucial importance for the maintenance of structural integrity of plasma membranes. Possibly, B may protect plasma membranes against peroxidative damage by toxic O_2 species (Çakmak and Römheld, 1997)[11]. But B is harmful for plants at toxic dosages. Toxic concentrations change according to sensitive and tolerant species. Referring to Keren and Bingham (1985)[12], safe concentrations of B differ for sensitive plants (*i.e.* avacado, apple and bean), for semi tolerant plants (*i.e*. oat, maize, potato), and for tolerant plants (*i.e.* carrot, alfalfa and sugar beeet). Concentrations exceeding these levels cause decrease in the yield.

It can be hypothesized that as *T. aestivum* and *T.durum* are grown in soil containing toxic dosage of boron, they will show the signs of toxication. This phenomenon will be observed by comparing the root and shoot growths, leaves of the plants. It can be predicted that the resistant plants which will be grown in boron rich soil will show less deterioration while sensitive ones will have more apparent signs on their roots, shoots and leaves (as the color changes) in a shorter time.

METHOD DEVELOPMENT AND PLANNING

In order to test whether different species as well as different genotypes of the same species of plants response differently to the same toxic level of boron, I decided to use two species of wheat, *Triticum aestivum* (bread wheat) and *Triticum durum* (durum wheat), and three genotypes for each of these species. I selected wheat to use in this study, because it is the dominating plant in boron rich regions in our country. Also, I thought that I can easily perform the designed experiment at home conditions.

The soil used to grow wheat is very important. Because the contents of soil ($CaCO_3$, organic materials, P, N, K, Fe, Zn etc) affect plant's growth, it is important to know them. Soil samples from research field of Central Research Institute for Field Crops (CRIFC) in Yenimahalle were analysed in the Department of Soil Science of Faculty of Agriculture in Ankara University (See Appendix I). According to the literature the minimum toxic dosage of boron is generally accepted to be 2-3 ppm. Because the boron content of the soil (0.6 ppm) is less than 2 ppm and its other characteristics are optimum, this soil was considered to be acceptable to use for this experiment. Also the soil must contain some other elements like N, K, P and Fe for the plant growth. The 36 pots all containing 1650 g soil will be given 200 ppm N in the form of $Ca(NO_3)_2$. $4H_2O$, 100 ppm K and P in the form of KH_2PO_4 and 2.5 ppm Fe as Ethylene diamine tetraacetic acid Iron (III)-sodium salt for both + (18 pots) and – dosages (18 pots). Only + dosage pots will be given 20 ppm B (toxic dosage) in the form of H_3BO_3.

Wheat samples were also obtained from Central Research Institute for Field Crops (CRIFC) in Yenimahalle. 3 varieties of bread wheat (Bayraktar, Demir, Tosunbey) and 3 varieties of durum wheat (Ç-1252, Kızıltan, Mirzabey) were supplied. Each of the varieties was approximately 50 grams.

In deciding the water to be used I preferred distilled water because mineral content of the tap water may change and it may contain some harmful substances that can affect the plant growth. During the experiment plastic containers and plastic graduated cylinders will be used, because there is a risk of boron penetration to the water if glass containers are used. Since the

experiment is done at ppm levels, this can be important. Watering frequency depends on the environment the experiment is carried out. The amount of water used in this experiment is 100 ml. for every two weeks for each of the 36 pots. Since the experiment will take 8 weeks; 36 pots x 100 ml x 4 weeks = 14.4 lt distilled water will be used for watering the pots.

To test the effect of boron on wheat growth, it is planned to make two groups; one experimental and one controlled group. The dependent variable is plant growth. Independent variable will be the addition of boron at toxic dosage to the soil of the experimental group in each of the species. The controlled group will be grown in soil which contains necessary amount of boron which is 0.6 ppm for this experiment. This group will be accepted as literature value for the experiment which will help to compare and see the effect on the experimental group. Evaluation of the responses of durum and bread wheat varieties to toxic levels of B will be performed by using two qualitative parameters: (1) Root and shoot growth inhibition and (2) 1-5 scale. All tests were carried out as three replications.

Root and shoot growth inhibition test is the reduction of root and shoot lengths in percentage in the presence of toxic level of B. Symptoms of both 0 ppm B applied control group (which includes 0.6 ppm optimum amount of B, Appendix I) and 20 ppm B applied test group will also be evaluated qualitatively according to 1-5 scale (see Appendix II;1 = The most tolerant to boron = very similar to 0 ppm B applied control; 5 = The most sensitive to boron). Data obtained at the 8^{th} week is used in the analysis.

The other variables like humidity, temperature, light intensity etc. will be kept constant by keeping the two groups at the same place. The mean temperature of the room is 22°C, it takes daylight and the humidity is 36-41%.

I also need some petri dishes to test the root and shoot growth inhibition and pots to test the 1-5 scale while growing wheat. This test is planned to be carried out as 3 replications. So I need a total of 36 plastic petri dishes and 36 pots (No=6 type, Akyüz Ltd.) (3 replications x 6 genotypes =18 pots for test group (+ dosage) and 3 replications x 6 genotypes = 18 pots for control group (- dosage)). They must be the same size and contain same amount of soil (1650g).

Boron will be obtained from H_3BO_3 which is a chemical found in laboratories dealing with any kind of chemical experiments. I obtained H_3BO_3 from Ankara University Medical Genetics Department. It was a product of Merck© with a code number of 1.00165. In this

study 20 ppm B will be used which is the toxic dosage for plants. So to find the amount of H_3BO_3 for obtaining pure 20 ppm B I can do the following calculation:

H_3BO_3 MW(molecular weight) = 61.83

B= 10.81

If 61.83 mg H_3BO_3 contains 10.81 mg B

x 20.00 mg B

x=114.39 mg = 0.114 g H_3BO_3/ 1 lt dH2O = 20 ppm B

Twelve seeds are planned to be sown to each pot. After emergence, each pot will be arranged to be 10 plants/pot. The duration of the experiment will be 8 weeks which is supposed to be enough for evaluation.

METHOD

Materials and Apparatus Used in This Experiment

- 36 plastic petri dishes
- Filter paper
- 36 flower pots each containing 1650 gr. of soil
- Durum wheat seeds (3 genotypes- Ç-1252, Kızıltan, Mirzabey-50 g each)
- Bread wheat seeds (3 genotypes- Bayraktar, Demir, Tosunbey-50 g each)
- 5 plastic containers (1 for $Ca(NO_3)_2.2H_2O$ solution, 1 for KH_2PO_4 solution, 1 for Fe solution, 1 for B solution, 1 for distilled water)
- Plastic graduated cylinders (2x1000 ml**,** 2x100 ml; to be used for the solution preparations of the control and test groups and for the measurement of the water)
- Distilled water (14.4 l for watering the pots + 4 l for the solutions + 3.6 l to prepare the soil while giving the solutions + 1.5 l for the petri dishes = 23.5 l for the whole experiment)
- H_3BO_3 (0.114 g for the pots + 0.057 g to prepare 500 ml solution for the petri dishes = 0.171 g totally for the experiment)

Root and shoot growth inhibition test

It is the reduction of root and shoot lengths in percentage in the presence of toxic level of B. Following steps were done for this test:

1. 100 ppm B solution was prepared from H_3BO_3. It is the suitable test concentration to detect the performances of the seeds to B.
2. Double layer of filter papers were cut and placed into plastic petri dishes. (6 varieties x 3 replications) x 2 dosage (control and test) = 36 petri dishes were used.
3. 10 seeds were placed into each petri dishes.
4. 20 ml H_2O was given to the control group petri dishes and the same amount of 100 ppm B solution was given to the test group petri dishes.
5. They were left at room temperature for one week till the seeds germinate.

6. Each day all petri dishes were controlled and if the filter papers of them dried, they were given only H_2O.
7. At the end of one week, the shortest and the longest roots of each individual seed were measured and the mean value of root length of an individual seed was recorded. The same procedure was repeated for all the seeds in a petri dish and the mean of each replication was calculated. Finally, the replication means were calculated for each variety. These values were given in Table 1 and Table 2 for durum wheat and bread wheat varieties, respectively.
8. In the same way, the shoot lengths of each plant in a petri dish were measured and mean of them was calculated. Finally, the replication means were calculated for each variety. These values were given in Table 1 and Table 2 for durum wheat and bread wheat varieties, respectively.
9. From these values growth inhibitions of roots and shoots in percentage for each variety were calculated as follows:

Growth Inhibition % = [(Length of control value – Length of test value) x 100] / Control value

Such as for the root growth inhibition of Ç-1252:[(4.53 -1.78) x100] 4.53 = 60.71 %

1-5 scale

These tests were carried out in an empty room of home. A total of 36 flower pots (No=6 type, Akyüz Ltd.) were used in the test (3 replications x 6 varieties = 18 pots for 20 ppm B applied test group (+ dosage) and 3 replications x 6 varieties = 18 pots for 0 ppm B applied control group (- dosage)).

The pots containing 1650 g soil were given 200 ppm N in the form of $Ca(NO_3)_2$. $4H_2O$, 100 ppm K and P in the form of KH_2PO_4 and 2.5 ppm Fe as Ethylene diamine tetraacetic acid Iron (III)-sodium salt (Assay 12-14 % Fe) for both + and – dosages. Only + dosage pots were given 20 ppm B (toxic dosage) in the form of H_3BO_3.

Twelve seeds were sown to each pot. After emergence, each pot was arranged as 10 plants / pot. Symptoms of both 0 ppm B applied control group (which includes 0.6 ppm optimum amount of B present in Yenimahalle soil (Appendix I)) and 20 ppm B applied test group were evaluated qualitatively according to 1-5 scale at the 8^{th} weeks of sowing.

RESULTS

Results Related to Root and Shoot Growth Inhibitions

Table 1. Evaluation of the durum wheat varieties by root and shoot growth inhibition parameters.

	Ç-1252			**Mirzabey**			**Kızıltan**			
	Control	**Test**	**Growth Inhibition (%)**	**Control**	**Test**	**Growth Inhibition (%)**	**Control**	**Test**	**Growth Inhibition (%)**	**Mean Inhibition of Varieties**
Mean Root Growth/ Plant (cm)	4.53	1.78	60.71	3.84	1.90	50.52	4.05	2.48	38.77	50.00
Mean Shoot Growth / Plant (cm)	3.91	1.08	72.38	2.76	1.33	51.81	2.48	1.31	47.18	57.12

*All the values in the table are the means of the three replications.

Table 2. Evaluation of the bread wheat varieties by root and shoot growth inhibition parameters.*

	Bayraktar			**Demir**			**Tosunbey**			
	Control	**Test**	**Growth Inhibition (%)**	**Control**	**Test**	**Growth Inhibition (%)**	**Control**	**Test**	**Growth Inhibition (%)**	**Mean Inhibition of Varieties**
Mean Root Growth /Plant (cm)	3.93	3.44	12.47	5.67	4.28	24.52	4.71	3.32	29.51	22.17
Mean Shoot Growth /Plant (cm)	3.08	2.58	16.23	5.23	3.74	28.49	3.19	1.98	37.93	27.55

*All the values in the table are the means of the three replications.

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Results Related To 1-5 Scale

Table 3. Evaluation of the durum wheat varieties by 1-5 scale which indicates the color changes of the leaves

Varieties	**Replication I**	**Replication II**	**Replication III**	**Mean of Replications**
Ç-1252	5	5	5	5.00
Mirzabey	4	5	4	4.33
Kızıltan	3	3	4	3.33
Mean of Varieties				4.22

Table 4. Evaluation of the bread wheat varieties by 1-5 scale.

Varieties	**Replication I**	**Replication II**	**Replication III**	**Mean of Replications**
Bayraktar	1	1	2	1.33
Demir	2	2	2	2.00
Tosunbey	3	2	3	2.67
Mean of Varieties				2.00

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DATA ANALYSIS

The study was carried out on two species of wheat including *T.aestivum* (bread wheat) and *T.durum* (durum wheat). Each group included three different subgroups including Bayraktar, Demir and Tosunbey for bread wheat and Ç-1252, Mirzabey and Kızıltan for durum wheat. All these six subgroups also had their control groups. Each subgroup and its control consisted of three pots (a total of 6 pots for each subgroup), including 10 seeds in each pot. Table 5 shows the group details.

Table 5: Group details

I.	**Group Bread wheat**		
	1a. Breadwheat-Bayraktar	3 pots (x10 seeds)	= 30 seeds
	Control-Bayraktar	3 pots (x10 seeds)	= 30 seeds
	1b.Breadwheat-Demir	3 pots (x10 seeds)	= 30 seeds
	Control-Demir	3 pots (x10 seeds)	= 30 seeds
	1c.Breadwheat-Tosunbey	3 pots(x10 seeds)	= 30 seeds
	Control-Tosunbey	3 pots (x10 seeds)	= 30 seeds
II.	**Group Durum wheat**		
	2a.Durum-ç-1252	3 pots (x10 seeds)	= 30 seeds
	Control-ç-1252	3 pots (x10 seeds)	= 30 seeds
	2b.Durum-Mirzabey	3 pots (x10 seeds)	= 30 seeds
	Control-Mirzabey	3 pots (x10 seeds)	= 30 seeds
	2c.Durum-Kızıltan	3 pots (x10 seeds)	= 30 seeds
	Control-Kızıltan	3 pots (x10 seeds)	= 30 seeds

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In this study toxic effects of boron was investigated on plants and the (a) root and (b) shoot growth inhibition, and (c) the color change in leaves were the main study outcomes.
SPSS 15.0 was used for the statistical analysis and student's t- test was used where appropriate.

Root Growth Inhibition

Table 6. Results related to Root Growth Inhibition in the group of bread wheat

group = Bread wheat,		n	Mean± Std. Deviation	P value
subgroup = bayraktar	control	30	3,93±0,38	0,178>0,05
	boron	30	3,44±0,36	
subgroup = demir	control	30	5,67±0,7	0,000<0,001*
	boron	30	4,28±0,19	
subgroup = tosunbey	control	30	4,71±0,43	0,005<0,01*
	boron	30	3,32±0,098	

*Student's –t test

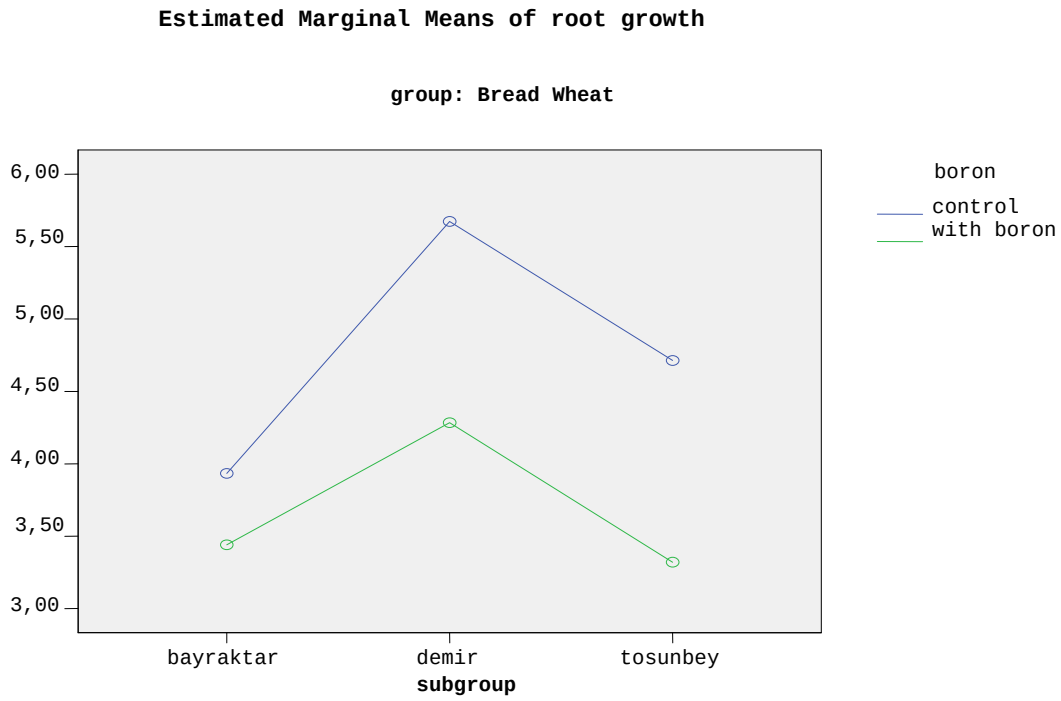

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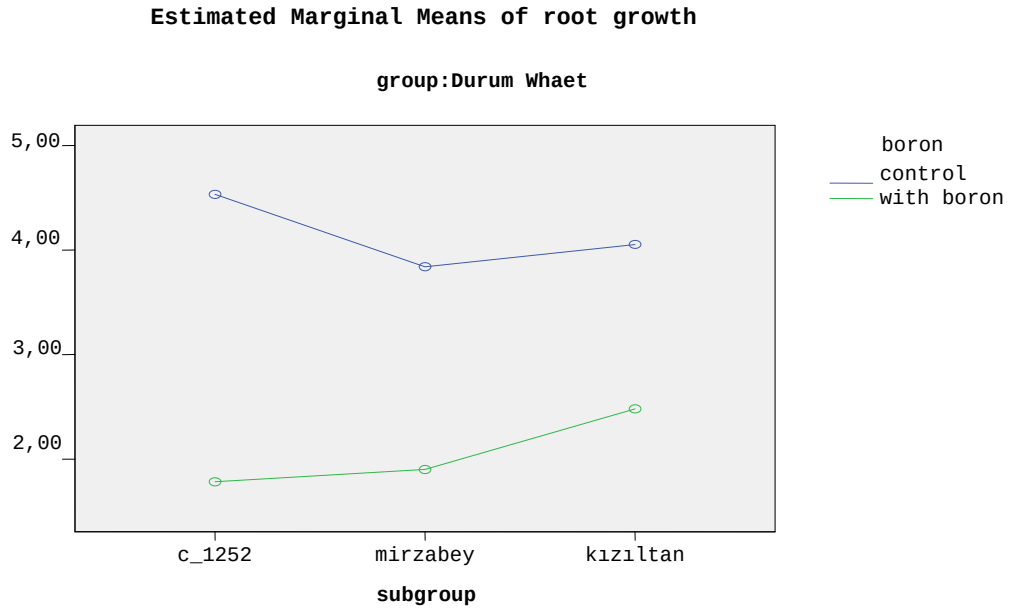
Table 7. Results related to root growth inhibition in the group of durum wheat

group= Durum wheat		n	Mean± Std. Deviation	P value
subgroup = ç-1252	control	30	4,53±0,23	0,001<0,01*
	boron	30	1,78±0,51	
subgroup = mirzabey	control	30	3,84±0,84	0,033<0,05*
	boron	30	1,90±0,64	
subgroup = kızıltan	control	30	4,05±0,26	0,001<0,01*
	boron	30	2,48±0,12	

Student's –t test



Explanation: Boron caused a statistically significant decrease in the root growth of durum wheat and this effect was observed in all subgroups of durum wheat. On the other hand, although boron caused a significant deleterious effect in the root growth in bread wheat, this effect was seen two subgroups including demir and tosunbey but not in bayraktar subgroup.

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Shoot growth inhibition

Table 8. Results related to shoot growth inhibition in the group of bread wheat

group = bread wheat		n	Mean± Std. Deviation (cm)	P value
subgroup = bayraktar	control	30	3,08±0,46	0,146>0,05
	boron	30	2,58±0,14	
subgroup = demir	control	30	5,23±0,34	0,003<0,01*
	boron	30	3,74±0,18	
subgroup = tosunbey	control	30	3,19±0,11	0,001<0,01*
	boron	30	1,98±0,19	

Student's –t test

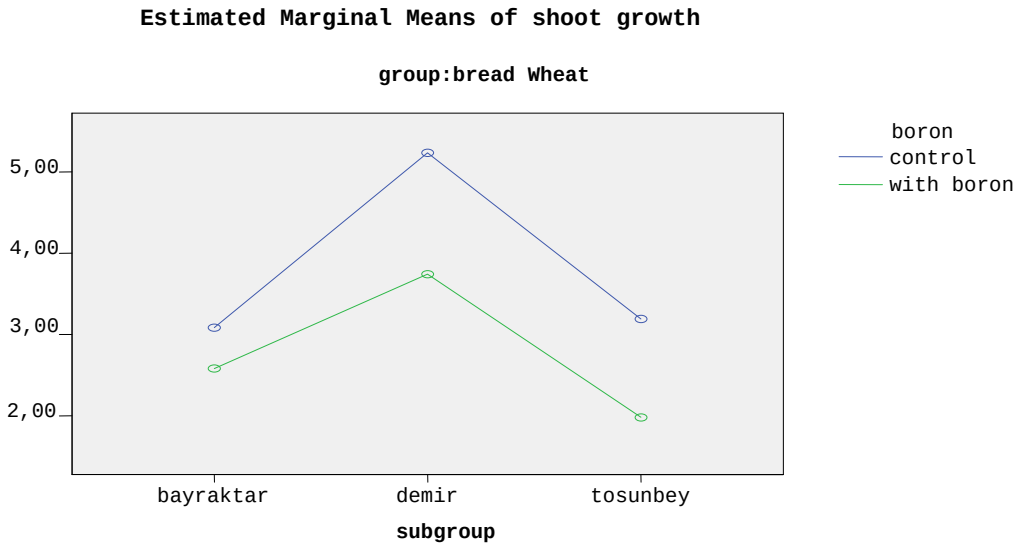

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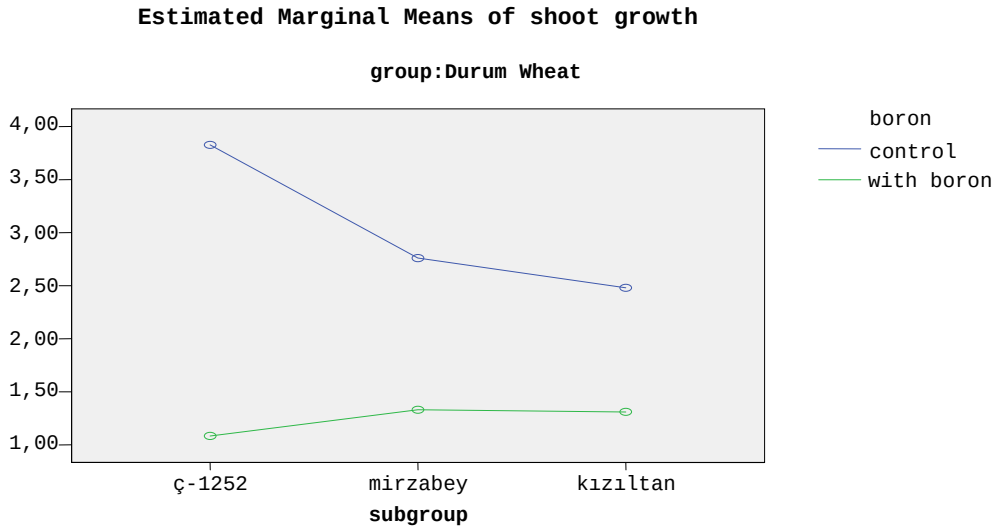
Table 9. Results related to shoot growth inhibition in the group of durum wheat

group= Durum wheat		n	Mean± Std. Deviation	P value
subgroup = ç-1252	control	30	3,84±0,84	0,000<0,001**
	boron	30	1,90±0,64	
subgroup = mirzabey	control	30	2,76±0,22	0,001<0,01*
	boron	30	1,33±0,12	
subgroup = kızıltan	control	30	2,48±0,29	0,003<0,01*
	boron	30	1,31±0,11	

Student's –t test



Explanation: Boron caused a statistically significant decrease in the shoot growth in durum wheat and this effect was observed in all subgroups of durum wheat. On the other hand, although boron caused a significant deleterious effect regarding the shoot growth in bread wheat, this effect was seen two subgroups including demir and tosunbey but not in bayraktar group.

Table 10. Color Change of the Leaves

Group		N	Median(Minimum-Maximum)
durum varieties	Ç-1252	30	5(5-5)
	mirzabey	30	4(4-5)
	kızıltan	30	3(3-4)
bread varieties	bayraktar	30	1(1-2)
	demir	30	2(2-2)
	tosunbey	30	3(2-3)

In this table the effect of boron on the color of the leaves is shown according to 1-5 scale, 1 indicated no change whereas 5 indicated the most deleterious effect. Median values of the color changes in the leaves were used to compare. Color change was most evident in ç-1252 subgroup. On the other hand color change was less evident in bread wheat group and was least in bayraktar group.

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EVALUATION

The results of the experiment support the hypothesis and the research question is answered by comparing the root and shoot lengths and color changes of the leaves of two species of wheat and three genotypes of each. Two qualitative parameters are used to determine the differences in response to the toxic levels of boron: 1) Root and shoot growth inhibition test, 2) 1-5 scale. Three replications were done for each of 6 varieties.

Evaluation of the bread and durum wheat varieties and their controls by root and shoot growth inhibition parameters is done in Table 1 and 2. It can be seen that durum wheat is much more sensible to toxic amounts of boron, regarding root and shoot growth. Also there is difference between the genotypes of the same species. For example ç-1252 and Tosunbey are the most sensible genotypes within the *T. durum* and *T. aestivum* groups respectively.

Results related to 1-5 scale are given in Table 3 and 4 for two species and their varieties. It can be concluded that bread wheat is more tolerant to boron which is now evaluated by changes in the leaves. Again Tosunbey and Ç-1252 are the most sensitive ones. Responses of two wheat species to B toxicity are significantly different from each other and *T. durum* is more susceptible than *T. aestivum.*

To justify the results, student's t-test was done. It showed the difference between the test and control groups. Also the results tested whether there was any difference between the subgroups regarding boron toxicity. In tables **6** and **8** root and shoot growth inhibition were evaluated as the mean of three replications in bread wheat subgroups. Demir and Tosunbey subgroups were significantly affected from excess boron compared with control groups whereas inhibition was not statistically significant in Bayraktar subgroup, because the P value was >0.05. Statistical evaluation of root and shoot growth inhibition as the mean of three replications in durum wheat subgroups are shown in tables **7** and **9**. Inhibitions are statistically significant in all subgroups of durum wheat with respect to their P values.

The effect of boron on the color of the leaves was also evaluated according to 1-5 scale; 1 indicated no change and 5 indicated the most deleterious effect (Table 10). Median values were used to compare. In the durum wheat group, color change was observed in all subgroups when compared to controls. It was most evident in ç-1252 subgroup. But I observed that color change was less evident in bread wheat group and it was least evident in bayraktar subgroup.

One possible source of error in this experiment may be the small sample size. In order to achieve more significant results larger samples sizes are needed. Another point is that 1-5 scale is a subjective method for the evaluation of toxicity, it does not provide objective measurements. Its evaluation depends on just observation so it is not a reliable scientific method. The methods used in this experiment are qualitative methods, so to obtain robust experiment results quantitative methods should be used.

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CONCLUSION

According to the results of the experiments, it can be seen clearly that the effect of boron on plant growth (wheat here), is extremely high. Boron is an essential element on plant growth at optimum levels but on the other hand its toxic levels inhibit root and shoot growth and affect the leaves in a negative manner. As in many different arid and semi arid regions of the world, boron toxicity is an important abiotic stress factor depressing the yield in some area of West Asia and North Africa (WANA) which is the major durum wheat production area of the world. For example, as part of this region, in Turkey, severe toxic levels of boron are found especially in middle Anatolia where also wheat yield is abundant.

In this respect, utilization of the varieties tolerant to boron toxicity seems to be the most practical solution of boron toxicity problem. Development of a good germplasm and identification of new sources of genes tolerant to boron toxicity in wheat are very important for breeding programs carried out in this region. For this purpose, in the present study specially developed, durum wheat and bread wheat genotypes were characterised in terms of their tolerance to boron toxicity by using qualitative- root and shoot growth inhibition and 1-5 scale approaches, comparatively.

According to the results obtained **it can be concluded that, there is genetic variation in response to toxic concentrations of boron.** This means, some species and also some genotypes of the same species are more sensible and some are more tolerant to high concentrations. The tolerant genotypes can be used in boron rich regions in order to obtain better yield. In the future, by the advance of genetic engineering, more tolerant species can be obtained.

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APPENDIX

Appendix I. Analysis results of soil from CRIFC's research field in Ankara- Yenimahalle.

Characteristic Of The Soil	Analysis Result
pH	7.87
EC (mmhos / cm)	0.24
% $CaCO_3$	8.72
% Organic material	1.07
% Sand	47.61
% Clay	29.76
% Silt	22.63
P (ppm)	143
Zn (ppm)	1.20
B (ppm)	0.60

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Appendix II. Scale used in the evaluation of B toxicity.

Number in the Scale	% of individual leaf area showing B toxicity symptoms
1	< 5
2	5-25
3	25-45
4	45-70
5	70 <

ç-1252: One of the test group pot.

ç-1252: One of the control group pot.

Figure 1. Photographs illustrating the test and control group pots belong to the most susceptible variety Ç-1252.

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