Assessment of Resistance of Wheat Genotypes *(T. Aestivum and T. Durum)* To Boron Toxicity

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Abstract**—**Research on the boron (B) toxicity problems had recently considerable relation, especially in the dry regions of the world. Development of resistant varieties to B toxicity is a high priority on these regions, where the soils have high levels of B. Thus, this study aimed to assessment the resistance of wheat genotypes to B toxicity using the agronomic and physiologic parameters. For this aim, a pot experiment, based on a completely randomized design with three replications, was conducted using the soil of calcareous usthochrepts. In the study, twenty different wheat genotypes of *T. aestivum* and *T. Durum* were used. Boron fertilizer at the levels of 0 (-B), 30 mg B kg^{-1} (+B) as H_3BO_3 was applied to the pots. After harvest, plant dry matter yield was recorded, and total B concentrations in tops of wheat plants were determined. The results have revealed the existence of a large genotypic variation among wheat genotypes to their physiologic and agronomic susceptibility to B toxicity.

Keywords**—**Boron, B toxicity, B uptake, wheat genotypes.

I. Introduction

RECENTLY, considerable relation has been given to solve the boron (B) toxicity problems, especially in the dry regions of the world. Boron toxicity occurs mainly in dry areas, especially in alkaline soils. It has been demonstrated that B toxicity tolerance as well as drought tolerance are needed in dry areas having high levels of subsoil B [1]. On these conditions, B toxicity symptoms in wheat could be confounded with symptoms caused by other abiotic stresses like drought or salinity. On the other hand, B availability to plants also depends on a large number of factors and their interactive relationships [2]. For example, soil pH and lime content are the most important soil factors that affect B use eficiency. Many studies revealed that there was a significant interaction between soil pH and B availability to plants especially above pH 6.5 [3]. Additionally, over-fertilization and irrigation with water containing high levels of B could lead to B toxicity.

However, crop sensitivity to B deficiency or toxicity vary widely depending on plant species and some agro-physiological mechanisms together with soil and other environmental interactions affecting B availability and optimal plant growth [4-7]. For example, it has been revealed that wheat cultivars responded to the application of B in a different manner, and *Triticum durum* cultivars were affected to a much greater extent than *Triticum aestivum* cultivars [8]. Many other studies carried out with other cereals also indicated different responses of varied cultivars to B toxicity and B fertilization [9-12]. While many researches on the problems of excessive soil B in recently, physiologic and agronomic susceptibility of new cultivars to B toxicity was not adequately recognized. Thus, development of new resistant varieties to B toxicity is a high priority on these regions, where the soils have high levels of B. Hence, higher tolerance to B toxicity could be used in breeding programs in order to develop more B-tolerant cultivars under the B-toxic soils.

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II. Materials and Method

In this study, a pot experiment, based on a completely randomized design with three replications, was conducted using the soil of calcareous usthochrepts. Twenty different wheat genotypes of Ankara-98 (*T. durum*), BDME-98/3K (*T. aestivum),* BDME-98/4S (*T. aestivum),* BDME-98/5S (*T. aestivum),* BDMM-98/11S (*T. durum),* BDME-98/33S-CIT (*T. aestivum),* BDME-00/1K (*T. aestivum),* BDME-00/2S (*T. aestivum),* BDME-00/3S (*T. aestivum),* BDME-00/4S (*T. aestivum),* Bezostaya-1 (*T. aestivum),* Dağdaş-94 (*T. aestivum),* Gerek-79 (*T. aestivum),* Gün-91 (*T. aestivum),* Kınacı-97 (*T. aestivum),* Kızıltan-91 (*T. durum),* Kunduru-1149 (*T. durum),* Selçuklu-97 (*T. durum),* Sultan-95 (*T. aestivum),* Yılmaz-98 (*T. durum)* were used for this study. Boron fertilizer at the levels of 0 (-B), 30 mg B kg^{-1} (+B) as H_3BO_3 was applied to the pots. Phosphorus fertilizer as ortho-phosphoric (H_3PO_3) at the levels of 80 mg P kg^{-1} was applied to the pots. In addition, a basal dressing of some macro and micro nutrients were applied to all pots for normal plant growth. The plants were harvested after 54 days, and dry weights in top of wheats were recorded. Plants were then washed thoroughly in distilled water and dried in the oven set at 65°C., and than dry matter yield was recorded. Boron concentrations in the tops of tomato plants (shoots + leaves) were determined by the method of Azometin-H [13]. The composite soil samples used for the experiment were air-dried and ground to pass through a 2 mm sieve for further analysis. The extractable soil B contents were determined by ICP [14]. Determinations were also made for available soil phosphorus [15], soil organic matter [16], saturation percent and electrical conductivity (E.C.) [17], $CaCO_3$ [18] and pH [19].

The calcareous soil used in this study was clay-loam in texture with 30, 32 and 38% clay, silt and sand, respectively, and the calcium carbonate content was 169 g kg^{-1}. It had also the chemical properties of pH (soil:H_2O=1:2.5) = 7.9, available phosphorus= 3.0 mg P kg^{-1}, organic matter content= 1.2, cation exchange capacity = 36.9 me 100 g^{-1}, exchangable K = 1.1 me 100 g^{-1}, available B = 1.18 µg g^{-1}, DTPA extractable Fe = 2.1 µg g^{-1}, Zn = 0.11 µg g^{-1}, Cu = 1.0 µg g^{-1} and Mn = 3.6 µg g^{-1}.

III. Results And Discussion

A. Agronomic Efficiency of B in Wheat Genotypes

By increasing of B fertilizer level, dry weights were significantly decreased as an average of wheat genotypes (Table I). Average dry matter yield of 3.12 g pot^{-1} was found in control treatment, whereas an average yield of of 2.77 g pot^{-1} was found at the level of 30 mg B kg^{-1} treatment. Thus, soil extractable B levels above 1.5 mg B kg^{-1} have the potential to cause B toxicity in sensitive crops. It has been reported that symptoms of B excess in sandy, loamy sand, loamy, and clayey soils occur when B content extracted with boiling water exceeds 0.80 mg kg^{-1}, 1.00 mg kg^{-1}, 1.20 mg kg^{-1} and 2.00 mg kg^{-1}, respectively [20]. Thus, considering the narrow range between optimum and toxic B concentrations, it is necessary to be careful when applying B fertilizers to the soils [21].

TABLE I
Dry matter yield and agronomic B efficiency of bread and durum wheat genotypes

Genotypes	Dry matter yield, g pot^{-1}			Agronomic B Efficiency, % [a]
	-B	+B	Av.	B0/B30
Ankara-98	3.87	3.32	3.59	117
BDME-98/3K	2.84	2.73	2.78	104
BDME-98/4S	2.39	2.21	2.30	108
BDME-98/5S	2.42	2.16	2.29	112
BDMM-98/11S	5.92	4.58	5.25	129
BDME-98/33S-CIT	3.02	3.00	3.01	101
BDME-00/1K	2.79	2.53	2.66	110
BDME-00/2S	2.84	2.66	2.75	95
BDME-00/3S	1.98	2.01	1.99	99
BDME-00/4S	2.40	2.27	2.33	105
Bezostaya-1	2.82	2.66	2.74	106
Dağdaş-94	2.67	2.43	2.55	110
Gerek-79	3.51	3.32	3.41	106
Gün-91	3.01	2.94	2.97	102
Kınacı-97	3.02	2.78	2.90	109
Kızıltan-91	3.67	2.96	3.31	124
Kunduru-1149	2.74	2.23	2.48	123
Selçuklu-97	3.85	2.91	3.38	132
Sultan-95	2.61	2.50	2.55	104
Yılmaz-98	4.08	3.19	3.63	128
Average	3.12	2.77		

[a] Agronomic B Efficiency = Per cent value related to the response of a genotype to supplied B level. In B efficient genotype, per cent B efficiency value is higher, which means that the genotype has lower response or non-response to the supplied B levels.

Significant differences among wheat genotypes were also found for dry matter yield. The highest dry matter yield of 5.25 g pot^{-1} was obtained in BDME-98/11S (*T.aestivum*), whereas the lowest dry matter yield of 1.99 g pot^{-1} was obtained in BDME-00/3S (*T.aestivum*) as average of B treatments. On the other hand, the response of a specific wheat variety to B toxicity was not the similar under the high B levels. By increasing of B levels, BDME-98/3K, BDME-98/4S, BDME-98/33S-CIT, BDME-00/3S, Gün-91 and Sultan-95 slightly responded, whereas Ankara-98, BDME-98/5S, BDMM-98/11S, Dağdaş-94, Kınacı-97, Kızıltan-91, Kunduru-1149 and Selçuklu-97 highly responded to higher B level. In other genetic studies carried out with different crops, great variations among cultivars in response to B toxicity have also been found [22-25], meaning that the use of B tolerant varieties was an important strategy for solving the B toxicity problems in cultivated areas.

B. Physiological Efficiency of B in Wheat Genotypes

Significant differences were also found among wheat genotypes for P concentration depending on toxic level of B treatment (Table II).

TABLE II
B concentration of bread and durum wheat genotypes

Genotypes	B concentration, mg kg^{-1}			Difference, %
	-B	+B	Av.	
Ankara-98	17.35	43.19	30.27	149
BDME-98/3K	15.79	38.51	27.15	112
BDME-98/4S	14.42	30.55	22.48	112
BDME-98/5S	15.68	49.29	32.48	214
BDMM-98/11S	20.34	46.25	33.29	127
BDME-98/33S-CIT	16.61	45.73	31.17	175
BDME-00/1K	15.80	46.84	31.32	196
BDME-00/2S	17.62	39.18	28.40	122
BDME-00/3S	12.73	28.52	20.62	124
BDME-00/4S	18.55	43.61	31.08	135
Bezostaya-1	14.26	39.45	26.85	177
Dağdaş-94	15.72	51.50	33.61	228
Gerek-79	16.11	50.72	33.41	215
Gün-91	17.59	46.56	32.07	165
Kınacı-97	14.26	31.73	22.99	123
Kızıltan-91	20.02	44.41	32.21	122
Kunduru-1149	16.37	42.46	29.41	159
Selçuklu-97	19.74	47.63	33.68	141
Sultan-95	13.12	30.17	21.64	130
Yılmaz-98	18.43	43.74	31.08	137
Average	16.52	37.81		

The B concentration of wheat genotypes highly increased with increasing B levels from 0 to 30 mg B kg^{-1}. On the other hand, significant differences among wheat genotypes were also found for B concentration as average of B treatment. The highest average B concentration was detected in Selçuklu 97 (*T. durum),* whereas BDME-00/3S (*T. aestivum)* had the lowest B concentration. It has also been emphasized that B-tolerant varieties were characterized by a decreased B concentration in their leaf tissues in comparison to non-tolerant varieties [26], probably due to a reduced uptake of B into both roots and shoots. A suggestion that durum wheat could tolerate higher tissue B concentration than bread wheat was also put forwarded [27]. Thus, it has been reported that wheat cultivars responded to the application of B in a different manner, and *Triticum durum* cultivars were affected to a much greater extent than *Triticum aestivum* cultivars [8]. The B contents and physiological B efficiency index of wheat genotypes were significantly varied depending on wheat genotypes with increasing B level (Table III).

TABLE III
TOTAL B CONTENT AND PHYSIOLOGICAL B EFFICIENCY (EI) OF BREAD AND DURUM WHEAT GENOTYPES

Genotypes	Total B content µg pot^{-1}			Efficiency Index, EI[a]
	-B	+B	Av.	
Ankara-98	67.14	143.39	105.26	129
BDME-98/3K	44.84	105.13	74.98	144
BDME-98/4S	34.46	67.51	50.98	229
BDME-98/5S	37.94	106.46	72.20	174
BDMM-98/11S	120.41	211.82	166.11	100
BDME-98/33S-CIT	50.16	137.19	93.67	108
BDME-00/1K	44.08	118.50	81.29	149
BDME-00/2S	50.04	104.21	77.12	118
BDME-00/3S	25.20	57.32	41.26	235
BDME-00/4S	44.52	98.99	71.75	156
Bezostaya-1	40.21	104.93	72.57	155
Dağdaş-94	41.97	125.14	83.55	144
Gerek-79	56.54	168.39	112.46	99
Gün-91	52.94	136.88	94.91	110
Kınacı-97	43.06	88.20	65.63	180
Kızıltan-91	73.47	131.45	102.46	150
Kunduru-1149	44.85	94.68	69.76	216
Selçuklu-97	75.99	138.60	107.29	163
Sultan-95	34.24	75.42	54.83	199
Yılmaz-98	75.19	139.53	107.36	152
Average	52.86	117.68		

[a]Efficiency Index (EI) = dry matter $yield^2$ / total B content, and it provides to select wheat genotypes with improved B utilization characters

Total amounts of B taken up by plants fallowed a similar pattern to great increase in B concentrations of wheats with increasing B levels. Thus, total B content of wheat genotypes highly increased with increasing B levels. Significant differences among wheat genotypes were also found for B content as average of B treatment. The highest total B content was found in BDMM-98/11S (*T. durum)*, whereas the lowest total B content was found in bread variety of BDME-00/3S (*T. aestivum).* Efficiency index (physiologic B efficiency) also varied among the genotypes depending on their dry matter yield and total B content. The highest average efficiency index was obtained for BDME-00/3S (*T.aestivum*) and BDME-98/4S (*T. aestivum)*, whereas Gerek-79 (*T.aestivum*) and BDMM-98/11S (*T. durum)* had the lowest efficiency index, respectively.

IV. CONCLUSION

As a conclusion remark, while B is an essential plant nutrient for the growth and development of plants, relatively small amounts of B are required to support the process of plant growth. Crop sensitivity to B deficiency or toxicity vary widely depending on plant species together with soil and other environmental interactions affecting B availability and optimal plant growth. The results have revealed the existence of a large genotypic variation among wheat genotypes to their physiologic and agronomic susceptibility to B toxicity based on the severity of decreases in dry matter production caused by B toxicity. Thus, the performance of a specific wheat variety to tolerance B toxicity was not the similar under the high B levels. Agronomic B efficiency ratio of bread wheat were higher than that of drum wheat genotypes, which means that bread wheats seemed to be more B tolerance than that of drum bread wheats under B toxicity condition. But, it has been found that durum and wheat genotypes showed intra and interspesific differences in agronomic and physiologic B efficiency, and agronomic B efficiency of bread wheat were higher than that of durum wheat genotypes. Thus, development of new resistant varieties to B toxicity is a high priority on these regions, where the soils have high levels of B. The results clearly showed that wheat genotypes with higher tolerance to B toxicity could also be used in breeding programs in order to develop more B-tolerant cultivars under the B-toxic soils.

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