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EVALUATION OF BORON TOXICITY IN FIG (*Ficus carica* L.) CULTIVARS

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Abstract

This research was carried out to investigate the differential responses of nine different fig cultivars against the boron toxicity and the effects of boron toxicity on dry matter yield, morphological properties and plant boron concentrations. A pot experiment was designed (perlite+sand mixture, 1:1) with two levels of boron (normal 0.46; high 8 mg B l^{-1}) and nine different fig cultivars (Ficus carica L. Akçakum, Bardakçı, Göklop, Halebi, Koca ana, Mor incir, Morgöz, Sarılop and Siyahkuş) under the controlled conditions. All of the fig cultivars showed different response against boron toxicity. Boron concentrations in all of the leaf parts increased significantly by increasing the B supply. Leaf tips were the dominant sites of B accumulation compared to the other leaf parts. The toxic level of boron application leads to significant reduction on plant height, internodal length, leaf numbers, shoot diameter and total dry matter while it decreased root length. The highest reduction was obtained by the total dry matter and it was followed by internodal length, leaf numbers and shoot diameter respectively. In terms of dry matter yield and plant height, among the cultivars, Bardakçı cv. was affected the least from the boron toxicity.

Keywords: *boron toxicity, fig, cultivars.*

INTRODUCTION

Boron (B) is a requisite element required for normal growth of plants. B toxicity can easily occurs especially arid and semi-arid regions in worldwide owing to the fact that the range of B deficiency and B toxicity is narrow (Eaton, 1944; Gupta et al., 1985). B toxicity sources are listed as follows soil B content, unconscious industrial waste management, thermal waters which rich soluble B and discharge of this thermal water to river, lake, irrigation waters and soils (Cartwright et al., 1984; Nable et al., 1997). Recently study (Aydın and Seferoğlu, 2009; Aydın et al., 2010; Kaptan, 2013) has showed that boron toxicity being a major problem at Great Meandros valley because of activity of geothermal plant and discharge of geothermal waste water. Fluids emerging from some of these areas contain high boron concentrations and cause environmental problems for irrigation waters in agricultural areas where boron contaminates aquifers and soils (Gemici and Tarcan, 2002). Boron has been accumulated in the plant over the requirement in the area (Koç, 2007). Boron is normally accumulated in leaves at concentrations of 10-50 mg kg^{-1}. However, many species are quite sensitive to high levels of B in their tissues, showing severe toxicity symptoms at tissue levels of about 50 mg kg^{-1}. Generally, toxic levels of B leads to leaf injury, decreasing plant growth and yield potential. Usually the initial symptoms were lesions with chlorotic borders at finally necrotic areas in the oldest leaves. Among the orchards species fig is known as a very sensitive to B toxicity and shows significant decreases in yield when grown in B toxic soil (Maas, 1990). Dried fig (*Ficus carica* L.) production has limited small numbers country worldwide. Turkey is the world's largest fig producer. In 2010, its fresh and dried figs production 23.9% and 54.7% in the world respectively (Anonymous, 2013). Fig is one of the important species at Great Meandros valley also in the Aegean region of Turkey. Turkey's dried fig production is cultivated entirely Aegean region mostly Great

Meandros valley. There was limited research on the effects of B toxicity on fig cultivars. The B toxicity affected plant growth parameters and fruit quality was also known but clear data were not available. The objectives of the study were examine differential responses nine different fig cultivars against the boron toxicity and the effects of boron toxicity on its leaf boron concentrations, yield and some morphologic parameters.

MATERIALS AND METHODS

Nine fig cultivars (*Ficus carica* L. Akçakum, Bardakçı, Göklop, Halebi, Koca ana, Mor incir, Morgöz, Sarılop and Siyahkuş) were grown under the controlled conditions at Adnan Menderes University Agricultural Faculty, Soil Science and Plant Nutrition Department, in 2009.

The experimental scions were produced by hard-wood cuttings, rooted under a mist propagation system. Fig plants were transplanted in 5L plastic pots containing inert perlite:sand (1:1) media mixture. The plants were grown in a growth room with a min/max temperature of 18/32^{0}C and a optimum temperature of 26^{0}C. Plants were initially irrigated with tap water (0.06 mg B l^{-1}, 0.45 dS m^{-1}) every 2 days for one week. Moreover, they were irrigated with Hoagland nutrient solution (Hoagland and Arnon, 1950). The irrigation volume every two days was 500 ml pot^{-1} and this quantity was enough to allow some leaching from bottom and to avoid salt accumulation. An one-factor factorial design that consisted of two treatments of B concentrations as a normal and toxic level of B (0.46 and 8 mg B l^{-1}). The 0.46 mg B l^{-1} treatment was considered as normal level of B since previous experiment. This concentration was determined adequate B concentration for fig plants growth. Both treatments and cultivars consisted of four replications. All plants were harvested almost 100 days of growth.

At harvest, leaf boron concentrations, plant height, internodal length, leaf numbers and shoot diameters were measured. The leaves were seperated into tip, blade and petiole .All samples were washed twice with distilled water, dried at 70^{0}C for 48 h. Leaf B concentration determinations were made by dry ashing 0.5 g of dry tissue material, placed in porcelain crucibles and heated a muffle furnace at 500 ^{0}C for 6 h (Kacar and İnal, 2008). The ash was dissolved in 0.1 N H_2SO_4 and B was determined colorimetrically (430 nm) by the Azomethine-H method (Wolf, 1974).

Data was analyzed using analysis of variance (PASW Statistics, Ver: 18.0), with multiple comparisons (Duncan multiple range test) between means of and cultivars were carried out by the least significant differences (LSD) at P ≥0.05.

RESULTS AND DISCUSSIONS

The boron application caused boron toxicity symptoms were appeared on the older leaves of plant. The B toxicity symptoms started in 45th day and they appeared as a white spot on leaf tips and margins. The spots initially turned into chlorotic areas and eventually necrotic areas. The necrotic areas spread out from leaf tips and margins to the blade of leaf and the leaves showed scorched appearance. These symptoms appeared first among the cultivars Akçakum (Figure 1). The similar symptoms were reported by (Bergmann, 1992).

Figure 1. The boron toxicity symptoms on Akçakum cv.

It was determined that the B toxicity had a statistically significant impact on the all analyzed properties in the figs in Table 1 (ANOVA).

Table 1. The result of variance analysis for all measured parameters of nine fig cultivars under control and boron toxicity conditions

Variance Source	DF	Calculated of mean square						
		B concentration	Plant height	Internodal length	Leaf numbers	Shoot diameters	Root length	Total dry matter
B	2	**	*	*	*	*	*	*
C	1	*	*	*	*	*	*	*
BxC	2	*	*	*	*	*	*	*

*P<0.05, **P<0.01, DF: degree of freedom, B: Boron application, C: Cultivars.

Table 2 shows boron distribution in the basal-older leaves of figs cultivars under normal and toxic B conditions. Boron concentrations in all of the leaf parts increased significantly by increasing the B supply. Leaf tips were the dominant sites of B accumulation compared to the other leaf parts. Boron concentration in the leaf tips was at least 4 and 6 times higher than in leaf blade and petiole respectively. Boron concentration in the leaf tips was lowest (2477 mg kg^{-1}) in Halebi cv. and highest (3933 mg kg^{-1}) in Bardakçı cv. The order was Halebi < Koca ana < Akçakum < Göklop < Mor incir < Morgöz < Siyahkuş < Sarılop < Bardakçı with the values (mg kg^{-1}) of 2477, 2517, 2595, 2629, 2950, 3095, 3216, 3343 and 3933, respectively. Comparing with the normal level B condition, leaf tips B concentration was increased significantly with high B application. The highest increase of leaf tips boron concentration obtained from Mor incir cv. (2683%) while Koca ana cv. had the lowest increase by 994% under B toxicity.

Table 2. Boron distribution in the basal-older leaves of figs cultivars under normal and toxic B conditions

Cultivars	Normal 0.46 mg B kg^{-1}			Toxic B 8 mg B kg^{-1}		
	Tip	Blade	Petiole	Tip	Blade	Petiole
Akçakum	133	91	34	2595	135	35
Bardakçı	178	98	23	3933	255	44
Göklop	158	92	19	2629	904	60
Halebi	106	38	21	2477	791	44
Koca ana	230	89	40	2517	793	41
Mor incir	106	106	45	2950	962	48
Morgöz	153	53	40	3095	870	52
Sarılop	250	109	30	3343	1279	45
Siyahkuş	228	121	29	3216	693	40
Average	171	89	38	2973	722	46

The fig cultivars showed differential response in terms of some plant morphological properties against the B toxicity. Under the toxic B condition, plant height, internodal length, leaf numbers, shoot
diameter and total dry weight were decreased significantly. However, root length was showed a decreasing response to the toxic B condition (Table 3).

Comparing with the normal level B, plant height, internodal length, leaf numbers, shoot diameter and total dry weight were decreased with toxic level B application Among the measured morphologic parameters reduction in the total dry weight was highest (40.0%). It was followed by internodal length, leaf numbers, plant height and shoot diameter with the values of 38.8%, 29.4%, 19.1 and 17.5, respectively (Table 4). Unlike, root length was observed tends to increase under toxic boron condition. Bardakçı cv. was showed the lowest reduction, in terms of plant height and total dry weight, while it was the highest in Akçakum cv. Root length was increased in Bardakçı cv., Koca ana cv., Mor incir cv., Morgöz cv. and Siyahkuş cv. whereas it was decreased Akçakum cv., Göklop cv., Halebi cv. and Sarılop cv.

As a result, fig cultivars produced more leaves, higher plant height, longer internodal length, wider shoot diameter and more dry weight per plant with 0.46 mg B kg^{-1} of B application in comparison to toxic B level. However, 8 mg B kg^{-1} of B application showed characteristic B toxicity symptoms, reduction in growth and increasing root length. It could be considered in present research that affected leaf B concentrations and plant height, internodal length, leaf numbers, shoot diameter and total dry weight under toxic boron application due to slow development and growth (Cervilla et al., 2007), decreasing the photosynthetic leaf area (Lee and Aronoff, 1966; Bergmann, 1992; Bennett, 1993), decreasing of water use efficiency (Sotiropoulos et al., 1999), especially, steadily leaf necrosis, beginning at the tip or margins and gradually covering the whole leaf (Sotiropoulos et al., 2002; Apostol and Zwiazek, 2004; Reid et al., 2004). Reduction of total dry weight due to toxic boron concentration was reported by Kaya et al., (2009). On the other hand, effect of boron toxicity on root length of fig cultivars was found differently. Similar findings were reported by Reid, (2010), who pointed out that there is a unusual response of root growth to boron tolerance. All of fig cultivars showed differential response in the amount of both leaf B concentration and the after exposure to toxic boron application. Among the cultivars Akçakum cv. was identified as the most sensitive cultivar as judged from the severity of toxicity symptoms on leaves and level of plant height and internodal length, while because of the least reduction in total dry matter yield and plant height Bardakçı can be classified as tolerant cultivar amount of fig cultivars.

Table 3. The effects of toxic B, on some morphological properties of nine figs cultivars

Cultivars	Plant height, cm	Internodal length, cm	Leaf numbers	Shoot diameter, mm	Root length, cm	Total dry weight, g
Normal (0.46 mg B kg^{-1})						
Akçakum	33.5	10.5	7.3	11.6	39.3	11.2
Bardakçı	21.8	6.8	5.5	9.6	25.0	8.2
Göklop	26.1	7.5	6.0	11.0	36.0	10.1
Halebi	25.3	7.3	6.5	11.1	32.0	6.4
Koca ana	27.8	9.9	8.5	8.8	37.0	6.1
Mor incir	19.0	9.0	6.0	7.8	47.3	10.5
Morgöz	30.3	13.3	7.7	10.1	28.0	5.5
Sarılop	34.0	8.0	7.0	10.5	41.0	12.7
Siyahkuş	31.0	7.0	7.0	9.8	36.0	7.4
Average	26.2	8.5	6.8	9.7	35.7	8.5
Toxic B (8 mg B kg^{-1})						
Akçakum	20.5	1.1	2.5	7.0	26.0	3.8
Bardakçı	19.2	6.2	3.7	7.8	40.3	6.7
Göklop	22.0	6.2	5.7	9.2	34.0	5.6
Halebi	22.3	6.8	5.5	6.4	26.5	4.2
Koca ana	22.5	5.8	7.8	8.7	38.7	4.5
Mor incir	13.0	1.0	2.0	6.8	60.0	5.5
Morgöz	25.0	7.5	5.0	7.9	52.0	4.3
Sarılop	24.0	3.0	5.0	9.3	28.0	4.6
Siyahkuş	22.5	4.0	6.0	8.6	36.5	5.8
Average	21.2	5.2	4.8	8.0	38.4	5.1

Table 4. The changing on some morphological properties of nine figs cultivars

Cultivars	Plant height %	Internodal length %	Leaf numbers %	Shoot diameter %	Root length %	Total dry weight %
Akçakum	38.8	89.5	65.8	39.7	33.8	65.7
Bardakçı	11.9	8.8	32.7	18.8	-61.2	17.5
Göklop	15.7	17.3	5.0	16.4	5.6	44.7
Halebi	11.9	6.8	15.4	42.3	17.2	34.4
Koca ana	19.1	41.4	8.2	1.1	-4.6	26.0
Mor incir	31.6	88.9	66.7	12.8	-26.8	47.4
Morgöz	17.5	43.6	35.1	21.8	-85.7	22.6
Sarılop	29.4	62.5	28.6	11.4	31.7	63.4
Siyahkuş	27.4	42.9	14.3	12.2	-1.4	21.5
Average	19.1	38.8	29.4	17.5	-7.6	40.0

CONCLUSIONS

Boron, which is essential nutrient for plant growth, affects plant growth and yield quality due to toxicity and deficiency. The excessive accumulation of B leads to necrosis on leaf margins or blade. Thus, it is observed that this process reduces plant growth (decreasing the photosynthetic leaf area or decreasing of water use efficiency).

On the basis of percent reduction consistently in analyzed properties, Bardakçı cv. showed minimum percentage of reduction among the fig cultivars under boron toxicity condition. However, differences in morphological characters measured among all fig cultivars may also be related to differences in photosynthetic capacity (leaf area) or their tolerance mechanism under boron toxicity condition. As a result of general conclusion, among the cultivars, Bardakçı cv. was affected the least under boron toxicity and all of fig cultivars showed different response against boron toxicity. Similar researches should be carried out in field conditions to get more reliable results.

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