International Meeting on Soil Fertility Land Management and Agroclimatology. Turkey, 2008. p:477-482

Differential Response of Cotton Cultivars to Boron Toxicity

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ABSTRACT

A greenhouse experiment was performed to study the effects of boron (B) on growth, and B distribution in the plant parts. The reactions of cotton varieties, grown in a mixture of sand and perlite medium, were investigated in point of boron doses. The experiment was conducted with four B doses (0.5, 7.5, 15, 22.5 mg B L^{-1}) and eight cultivars (Barut 2005, Gossipolsüz Nazilli, Gürel Bey, Nazilli 143, Nazilli 342, Nazilli 39, Nazilli-503, STN 8A) in factorial experiment design. Number of damaged leaf from boron toxicity, root, stem and leaf boron concentrations increased by boron application doses while fresh weight, dry weight and leaf numbers per plant decreased. In point of yield relations on boron doses, Gürel Bey and Gossipolsüz Nazilli cultivars were the most tolerant and Nazilli 39 cultivar was the most sensitive against boron toxicity.

Key words: *G. hirsutum* L, cultivars, leaf, stem, root, boron concentration

INTRODUCTION

Boron (B) toxicity, an important agricultural problem that limits crop productivity in different regions of the world, can occur in B-rich soils or in soils exposed to B-rich irrigation waters, fertilizers, sewage sludge, or fly ash (Nable *et al.*, 1997). Surface water rarely contains enough boron to be toxic but well water or springs occasionally contain toxic amounts, especially near geothermal areas and earthquake faults. For example, there are 20 geotermal areas in The Büyük Menderes River Basin which is one of the most important lands for cotton production in Turkey (Akar, 2007).

Furthermore, in recent years, B toxicity has attracted increasing interest owing to the greater demand for desalinated water, in which the B concentration may be too high for healthy irrigation (Parks and Edwards, 2005). A wide range of crops was tested for boron tolerance by using sand-culture techniques (Eaton 1944).

The typical symptoms shown by plants exposed to excess B are reduced vigour, delayed development, leaf burn (chlorotic and necrotic patches in older leaves), and decreased number, size and weight of fruits (Paull *et al.*, 1992; Nable *et al.*, 1997). However, despite the importance of this nutritional disorder, it is not understood why B is toxic to plants, or how tolerant plants avoid toxicity (Reid *et al.*, 2004). It has long been known that the optimum B level for one species could be either toxic or insufficient for other species (Blevins and Lukaszewski, 1998). Genetic variation in response to high B concentrations has prompted investigation into the mechanism operating in plants against B excess. In wheat (*Triticum aestivum*) and barley (*Hordeum vulgare*) cultivars, several possible tolerance mechanisms have been proposed, these operating mainly by exclusion (Paull *et al.*, 1992; Hayes and Reid, 2004). Tolerance to B toxicity operates not only at the whole-plant level but also at the organ and cellular level. For example, susceptibility to B toxicity is expressed among barley genotypes at either the whole plant or organ or cellular level (Kalayci et al., 1998; Torun et al., 2003).

These mechanisms are based on studies demonstrating an ability of plants to accumulate less B in shoots, although the transporters which participate in the exclusion process have not yet been identified. The objectives of this study were to investigate the differential response of eight cotton cultivars, developed for western part of Turkey, to boron toxicity and B distribution in the plant parts.

MATERIALS and METHODS

The eight cultivars of cotton plants (*Gossypium hirsutum* L.) used in the present study. Seeds were sown in 2:l of perlite-sand (1:2, v:v) mixture and grown for 43 days in a 3 l pot placed on benches in an experimental greenhouse in a nethouse. For 10 days after germination, pots were irrigated with ¼ strength Hoagland nutrient solution (Hoagland and Arnon, 1950). Then, following days, full strength Hoagland nutrient solution alone (control namly B1, 0.5 mg B L^{-1}) and Hoagland nutrient solution with three levels of boron doses (B2, B3, B4 as 7.5, 15, 22.5 mg B L-1) were applied. Cotton cultivars were Barut 2005, Gossipolsüz Nazilli, Gürel Bey, Nazilli 143, Nazilli 342, Nazilli 39, Nazilli-503, STN 8A) in factorial experiment design with 4 replication. There was one plant in each pot. The nutrient solution (pH 5.5-6.0) was supplied to the root zone as 250 ml day^{-1} per pot and drained solution was discarded to avoid nutrient accumulation.

Plants were harvested at the day of 43 from the sowing. Before the harvest, leaves per plant were counted as total and suffering from B toxicity which was defined as leaf having the spot necroses covered area was 30% of total leaf blade. The roots were cleaned from perlite and sand by washing. Roots and leaves were detached from stems. Roots, stems and leaves were rinsed in three times with distilled water after disinfecting with 10 g l^{-1} non-ionic detergent (decenoly-N-methyl-glucamide). Then they were blotted on filter paper and dried in a forced air over at 70°C for 24 h. Boron content was determined after digestion of dried and milled plant material with 6 M H_2SO_4 and H_2O_2 (Wolf, 1982).

To determine the B concentrations in the plant parts, the azomethine-H+ method was followed using spectro-photometry at 410 nm (Wolf, 1974). Standard analysis of variance techniques were used to assess the significance of treatment means. Differences between treatments were compared using LSD at the 0.05 probability level. Levels of significance are presented as follows:*P<0.05; **P<0.01; ***P<0.001; NS, not significant.

RESULTS and DISCUSSION

Symptoms of B excess caused by rising amounts of boron, developed as follows: A few brown necroses first developed at the leaf. B toxicity then resulted in brown marginal necroses and further spot necroses in the centre of the leaf. In treatment B4, some of the leaf tissue died from the leaf tip, which had a dirty-white discoloration, with marginal spot and larger necrotic areas developing towards the leaf base. B damage first occurred in older leaves and with increasing uptake in younger leaves as well.

Addition of B in the culture medium had a dramatic influence on number of leaf suffering from B toxicity (Table 1). The number of leaf suffering from B toxicity varied between 1.0-3.7, 2.7-5.0 and 3.7-5.3 plant^{-1} for B2, B3 and B4, respectively. It was the lowest for Gürel Bey in all excess B treatments. It was highest for Nazilli-39 in B2 and Nazilli 143 and Nazilli 503 in both B3 and B4 treatments.

Table 1. The effect of B applications on number of leaf suffering from B toxicity in the cotton cultivars

Cultivars	Suffering leaf number per plant			
	B0	B1	B2	B3
Barut 2005	0	2.3 b	4.0 b	4.3 b
Gossipolsüz Nazilli	0	2.0 bc	2.7 c	4.3 b
Gürel Bey	0	1.0 d	3.3 bc	3.7 c
Nazilli 143	0	3.3 a	5.0 a	5.3 a
Nazilli 342	0	2.3 b	4.0 b	5.0 a
Nazilli 39	0	3.7 a	4.0 b	4.3 b
Nazilli-503	0	1.7 d	5.0 a	5.3 a
STN 8A	0	2.0 bc	4.0 b	4.3 b
Mean	0	2.3	4.0	4.6

Addition of B in the culture medium had a dramatic influence on dry biomass (Table 2). Dry matter yield varied from 1.61 - 2.66, 1.18 - 1.92, 0.47 – 1.34 and 0.25-1.06 g plant^{-1} for B1, B2, B3 and B4, respectively. As B rate increased the dry matter yield decreased. Compearing the control the less decreases were in STN 8A, Gossipolsüz Nazilli and Barut 2005 for B2, B3 and B4, respectively. A reduction in growth and increase of B concentration in the plant tissues as a consequence of B toxicity has previously been observed in tomato (Güneş et al., 1999), sunflower (Ruiz *et al.*, 2003), barley (Karabal *et al.*, 2003) and Cervilla et al., 2007).

Applications of boron significantly increased B concentration in leaves, stems and roots of fig cultivars (Table 2). Boron concentrations ranged between 41-1409, 4.8-144, and 11.9-93.8 mg kg^{-1} for leaves, stems and roots, respectively (Table 3). Among the cultivars, Gürel Bey generally had the lowest B concentrations in the measured plant parts. Boron concentrations in the plant parts were in following order leaves>roots>stems for B1, B2 and B3 and leaves> >stems>roots for B4. This result corroborates the findings of Garate et al (1984); Subedi et al. (1999); Oyinlola (2005) who also reported that the B concentration in roots and stems were generally much lower than those in leaves. In a resant study, cotton plants were grown under greenhouse conditions in complete nutrient solution in order to determine for providing guideline values for estimating the boron status from deficiency to toxicity (El-Gharably and Bussler, 2007). The lower critical levels for boron in roots, young leaves and old leaves were 103, 61 and 78 ppm, while critical nutrient toxicity levels were 129, 80 and 91 ppm, respectively. For the Gossypium herbaceum-Etawa cultivar, the maximum growth was obtained when 1 ppm boron was applied as H_3BO_3 in the nutrient solution.

Table 2. The effect of B applications on dry matter yield of cotton cultivars

Cultivars	-----Dry matter yield (g pot^{-1})-------				----Decreases, %-----		
	B0	B1	B2	B3	B1/B0	B2/B0	B3/B0
Barut 2005	2.27 b	1.94 ab	1.21 a	1.06 a	15	47	53
Gossipolsüz Nazilli	1.93 bc	1.59 ab	1.11 ab	0.83 ab	17	42	57
Gürel Bey	1.99 b	1.18 b	1.01 ab	0.74 ab	41	49	63
Nazilli 143	2.16 b	1.83 ab	1.08 ab	0.60 b	15	50	72
Nazilli 342	1.61 c	1.39 b	0.47 b	0.42 b	14	71	74
Nazilli 39	2.66 a	1.92 a	0.81 b	0.33 b	28	69	88
Nazilli-503	2.71 a	1.80 ab	1.34 a	0.96 ab	33	50	65
STN 8A	1.61 c	1.47 b	0.55 b	0.25 b	9	66	85
Mean	2.12	1.64	0.95	0.65	21	56	69

Table 3. The effect of B applications on B concentrations (mg B kg-1) in leaves, stems and roots of cotton cultivars

Cultivars	B concentrations (mg B kg^{-1})			
	B0	B1	B2	B3
Leaves				
Barut 2005	70 a	181 c	668 c	1004 c
Gossipolsüz Nazilli	43 a	291 b	649 c	793 d
Gürel Bey	41 a	144 c	449 d	604 e
Nazilli 143	53 a	166 c	267 e	518 e
Nazilli 342	72 a	238 bc	787 b	1409 a
Nazilli 39	48 a	234 bc	822 bc	1181 b
Nazilli-503	97 a	161 c	733 bc	1225 b
STN 8A	73 a	307 a	106 a	1355 a
Mean	62	203	679	1011
Stems				
Barut 2005	13.1 a	16.5 b	35.0 e	56.8 e
Gossipolsüz Nazilli	10.8 b	23.4 b	24.9 f	61.1 e
Gürel Bey	20.1 a	23.7 b	36.3 e	44.3 f
Nazilli 143	4.8 b	32.1 ab	97.1 a	123.7 b
Nazilli 342	13.4 a	40.7 a	69.1 b	89.2 c
Nazilli 39	6.6 b	11.6 c	51.7 c	75.4 d
Nazilli-503	13.8 a	24.3 b	35.1 e	60.1 e
STN 8A	12.2 a	22.5 b	41.7 d	144.3 a
Mean	11.9	24.3	48.9	81.9
Roots				
Barut 2005	12.0 b	27.8 c	36.9 d	51.8 d
Gossipolsüz Nazilli	15.7 ab	70.3 a	72.9 ab	93.8 a
Gürel Bey	20.4 ab	42.3 bc	64.1 b	66.7 c
Nazilli 143	17.8 ab	33.4 c	56.8 b	78.1 b
Nazilli 342	25.1 a	51.7 b	54.2 bc	60.3 cd
Nazilli 39	12.0 b	35.1 c	46.9 c	52.0 d
Nazilli-503	15.8 ab	45.4 b	59.6 b	85.4 b
STN 8A	11.9 b	41.4 c	74.5 a	81.1 b
Mean	16.3	43.4	58.2	71.2

Relationship between B rates and dry matter yield and its parameters were given in Table 4. Dry matter yields were negatively correlated by applied B rates. The slope figures in this relations ranged from -0.108 to -0.050. Cultivars which were affecded by excess B treatments were in following order Nazilli 39> Nazilli-503> Nazilli 143> STN 8A> Nazilli 342> Barut 2005> Gürel Bey> Gossipolsüz Nazilli.

Table 4. Relationship between B rates and dry matter yield and its parameters

Cultivars	Slope	Intercept	R^2
Barut 2005	-0.058	2.276	0.94
Gossipolsüz Nazilli	-0.050	1.929	0.99
Gürel Bey	-0.052	1.820	0.88
Nazilli 143	-0.072	2.228	0.98
Nazilli 342	-0.060	1.645	0.88
Nazilli 39	-0.108	2.645	0.98
Nazilli-503	-0.076	2.560	0.95
STN 8A	-0.067	1.720	0.92

The results presented here indicate that shoot and leaf concentrations of B can be used in screening cotton cultivars under greenhouse conditions for B tolerance. Plant biomass was also very significantly correlated B doses, suggesting that plant biomass under B toxicity can also be a reliable criterion in distinguishing genotypes for their tolerance to B toxicity.

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