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SUNFLOWER CAN TAKE EXCESS BORON FROM DIFFERENT BORON SUPPLIES WITHOUT GROWTH LOSE AND NUTRITIONAL DISORDERS

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Abstract

One of the aims of this study was to determine the effect of different boron sources on boron nutrition and growth of sunflower plant. Also it was aimed to examine the sunflower response to the over leaf boron concentrations. For this, 7 boron sources; Anhydrate borax ($Na_2B_4O_7$), Boric acid (H_3BO_3), Etibor-48 (Powder; Borax pentahydrate, $Na_2B_4O_7$. 5 H_2O), Boron oxide (B_2O_3), Etidot-67 ($Na_2B_8O_{13}.4H_2O$), Borax ($Na_2B_4O_7.10H_2O$) and Etibor-48 (Granule; Borax pentahydrate, $Na_2B_4O_7.5H_2O$) were applied to 4 kg soil containing pots at the rates of: 0 (control), 5, 10 and 20 mg B kg^{-1}. Plants were grown under greenhouse condition until the flower bud period, and then plants were harvested and analyzed for nutrients. According to the results, leaf B concentration of sunflower increased up to 718 mg.$kg^{-1}$with the boron applications. All boron sources increased the leaf boron concentration and the means were recorded as 105, 170, 250 and 483 mg.kg^{-1} respectively. Sunflower growth and mineral nutrition were not affected negatively by the over leaf B concentrations.

***Key words**: boron sources, boron nutrition, boron toxicity, plant growth, sunflower.*

INTRODUCTION

Despite intensive researches have been made on the understanding of metabolic functions of boron (B) in plants for a long time, it is well known that B plays important roles on cell wall structure, lignification, carbohydrates metabolism, RNA metabolism, IAA metabolism, phenol metabolism, pollen germination, fruit set, structural and functional properties of biological membranes (Kacarand Katkat, 2010; Marschner, 2011).

Although, B has many functions on plant metabolism, many plants require quite low amount of B comparing the many other nutrients.

One of the most pronounced properties of B is that there is a narrow gap between the deficiency and toxicity levels in plants. It is true for B-sensitive plants, but it is not correct to generalize for all plants (Marschner, 2011).

Although, there is a little border between deficiency and toxicity levels in low-B requiring plants such as soybean, it is not valid for B-tolerant plants (Chepman et al., 1995). As in other nutrients, nutrient uptake and usage by the plants differs with many factors including genetically properties.

Nutrient uptake ability of plants can vary depending on the different plant species even they are grown in the same condition.

This variation can occur between the varieties of a plant species too.

In different studies these differences were emphasized and diversities of plants in terms of B uptakes were expressed (El-Sheikh et al., 1971; Paull et al., 1988; Paull et al., 1991; Taban and Erdal, 2000).

In a study conducted on the classification of plants demand in terms of B uptake capacity, plants were collected under 3 groups as: B demand is low (soil B:< 0.1 mg kg^{-1}), B demand is medium (soil B:0.1-0.5 mg kg^{-1}) and B demand is high (soil B:> 0.5 mg kg^{-1}) and sunflower took place in the high B demanding plants group (Berger, 1949; Kacarand Katkat, 2010; da Silva, 2016).

Asad et al. (2002) indicated that the youngest leaf B concentrations should be 25 mg kg^{-1} for 75 days sunflower plants to reach maximum shoot dry weight. In some other studies, it was implied that 32 - 35 mg kg^{-1} and 46 - 63 mg kg^{-1}

B is needed for maximum growth for different aged sunflower plants (Blamey et al., 1979; Rashid and Rafique, 2005).

According to the Bergman (1992), the youngest maturated leaf B concentrations should be 31-140 mg kg^{-1} for healthy sunflower growth. In a study worked on B toxicity in sunflower, it was found that B concentration of leaf increased up to 1870 mg $kg^{-1}$and the critical concentration of B toxicity was determined as 1130 mg kg^{-1}. Also in this study only 25% yield decrease was reported with 1870 mg kg^{-1} (Blamey et al., 1979).

In several studies, critical levels for B toxicity in sunflower leaves have been recorded as 100-700 mg kg^{-1}, >500 mg kg^{-1}, 925 mg kg^{-1} and 1150 mg kg^{-1} (Blamey, 1979; Aitken and McCallum, 1988; Cerda et al., 1981; Bergmann, 1992).

As B fertilizer, different B sources can be used. Although, borax ($Na_2B_4O_7 \cdot 10H_2O$), sodiumpentaborate ($Na_2B_4O_7$ 5 H_2O), boric acid (H_3BO_3) are the most used B fertilizer, some other B containing materials such as anhydrite borax (Na2B4O7) are used for fertilization purposes on different plants (Demirtaş, 2006; Kacar, 2013).

One of the aims of this study was to determine the effect of different B sources on B nutrition and growth of sunflower plant.

Also it was aimed to examine the sunflower response to the over leaf B concentrations.

MATERIALS AND METHODS

Study was conducted under greenhouse condition. As plant material, sunflower was growth until the flower bud period in 4 kg soil containing pots as 4 replications. Seven B sources were tested to see and compare the effects on plant growth, B nutrition and some other nutrient concentrations. B sources and some properties were given in Table 1 (Anonymous, 2016).

Four levels of B as: 0 (control), 5, 10 and 20 mg B kg^{-1} were given to the pots before sowing together with the 300 mg kg^{-1} N (as ammonium nitrate), 200 mg kg^{-1} P (as triple-superphosphate) and 150 mg kg^{-1} K (potassium sulphate) basal fertilizers.

The experimental soil was loamy (Bouyoucos, 1951) having pH 8.0 (1:2.5 soil to water ratio), 1.5 % $CaCO_3$, 1.1 % organic matter (Jackson, 1962), 13.6 mg kg^{-1} $NaHCO_3$ extractable P (Olsen et al., 1954), 115, 684, 37.5 mg kg^{-1} 1N NH_4OAC exchangeable K and Ca and Mg (Knudsen et al., 1982).

DTPA extractable Fe, Cu, Zn and Mn concentrations (Lindsay and Norwell, 1978) were 3.1, 0.64, 1.39 and 12.3 mg kg^{-1}, respectively. Soil B concentration extracted with 0.01M $CaCl_2$ was 1.1 mg kg^{-1}. Soil P concentration was determined with a spectrophotometer; K, Ca, Mg, Fe, Cu, Zn and Mn concentrations were measured with AAS and B concentration was determined with ICP (Kacar, 2009).

At the flower bud period, experiment was ended. Before harvesting, leaf samples were taken from the upper mostly developed leaves (Bergman 1992).

Then, whole plant was harvested above the soil. Samples were washed with top water and pure water than dried at 65^0C until the stable weight and weighted. Also, leaf samples were washed, dried and grinded for analysis.

Leaf samples were wet digested for mineral analysis. Leaf P concentrations were determined with a spectrophotometer (Shimadzu UV-1208) at 430 nm according to the vanadomolybdo phosphoric acid method. Potassium, Ca, Mg, Fe, Cu, Zn, and Mn concentrations were determined using AAS. Boron concentration of the leaf was measured with ICP (Kacarand İnal, 2008).

Analysis of variance (ANOVA) and Duncan's Multiple Range Test were conducted and least significant differences at the 5% level of probability estimated by COSTAT (CoHort Software, Washington, DC, USA) statistical program

Table 1. Some properties of B sources used for the experiment

Content	Unit	Amount
Anhydrate borax ($Na_2B_4O_7$)		
Content	Unit	Amount
B_2O_3	%	68 min.
Na_2O	%	30.27min.
SO_4	mg kg^{-1}	300max.
Cl	mg kg^{-1}	105max.
Fe	mg kg^{-1}	50max.
Boric acid (H_3BO_3)		
Content	Unit	Amount
B_2O_3	%	56.25min.
SO_4	mg kg^{-1}	500max
Cl	mg kg^{-1}	10max.
Fe	mg kg^{-1}	10max.
Etibor-48, powder (Borax pentahydrate, $Na_2B_4O_7.5H_2O$)		
Content	Unit	Amount
B_2O_3	%	47.76 min.
Na_2O	%	21.25 min.
SO_4	mg kg^{-1}	135 max.
Cl	mg kg^{-1}	70 max.
Fe	mg kg^{-1}	5 max.
Boron oxide (B_2O_3)		
Content	Unit	Amount
B_2O_3	%	98 min.
SO_4	mg kg^{-1}	500 max.
Cl	mg kg^{-1}	10 max.
Fe	mg kg^{-1}	35 max.
Etidot-67 ($Na_2B_8O_{13}.4H_2O$)		
Content	Unit	Amount
B_2O_3	%	67 min.
Na_2O	%	14 min.
Borax ($Na_2B_4O_7.10H_2O$)		
Content	Unit	Amount
B_2O_3	%	36.47 min.
Na_2O	%	16.24 min.
SO_4	mg kg^{-1}	135 max.
Cl	mg kg^{-1}	70 max.
Fe	mg kg^{-1}	10 max.
Etibor-48, granule (Borax pentahydrate, $Na_2B_4O_7.5H_2O$)		
Content	Unit	Amount
B_2O_3	%	48 min.
Na_2O	%	21.37 min.
SO_4	mg kg^{-1}	200 max.
Cl	mg kg^{-1}	70 max.
Fe	mg kg^{-1}	3 max.

RESULTS AND DISCUSSIONS

Effects of B sources and doses on plant growth

Different B sources and application doses did not affect plant growth, although some proportional increases or decreases were determined from B sources. Dry weight of above ground part of sunflower did not vary significantly with the B sources and their increasing levels. Plant dry weights showed variation between 44.1 pot-^{1} and 55.9 g pot-^{1} (Table 2).

Table 2. Effects of B sources and application doses on plant dry weights

B sources	B doses (mg kg^{-1})				
	0	5	10	20	Means
	Dry weights (g pot^{-1})				
Anhydrate borax	49.4	52.0	52.0	55.0	53.3
Boric acid	49.4	50.3	55.1	54.6	52.4
Etibor-48 (powder)	49.4	48.4	45.3	43.9	47.4
Boron oxide	49.4	47.5	44.1	45.0	45.5
Etidot-67	49.4	44.8	51.2	47.7	47.4
Borax	49.4	49.7	48.8	51.8	49.3
Etibor-48 (granule)	49.4	55.9	52.2	53.6	53.6
Means	49.4	49.8	49.8	50.2	49.9

Effects of B sources and doses on leaf B concentration

The individual effects of B sources and application doses and source x dose interactions affected leaf B concentration of sunflower significantly. Looking at the interactions, leaf B concentration showed a big variation between 105 and 718 mg kg^{-1}. Leaf B concentrations obtained from the all B sources showed increase with the doses. This tendency reflected to the means and leaf B concentrations determined from the each dose significantly varied from the others. While the lowest B concentration was measured from the control treatment, this value increased linearly with the increasing B doses. Under control treatment, leaf B concentration was found as 105 mg kg^{-1}, but this value and 20 mg kg^{-1} application doses, respectively. According to the means, significant variations were found among the B sources (Table 3). While the lowest B concentrations were increased 1.60, 2.38 and 4.60 times with 5,10 determined from the Anhydrate borax ($Na_2B_4O_7$) and Boric acid (H_3BO_3), the most effective source was the granule form of Etibor-48 ($Na_2B_4O_7.5H_2O$)

Table 3. Effects of B sources and application doses on leaf B concentrations

B sources	B doses (mg kg^{-1})				
	0	5	10	20	Means
	Leaf B concentrations (mg kg^{-1})				
Anhydrate borax	105 I*	130 GHI	191 FGH	387 BCD	203 c**
Boric acid	105 I	135 GHI	205 FGH	369 CDE	203 c
Etibor-48 (powder)	105 I	194 FGH	219 FGH	529 B	262 b
Boron oxide	105 I	187 FGH	206 FGH	438 BC	234 bc
Etidot-67	105 I	153 FGH	256 DEF	482 BC	249 bc
Borax	105 I	155 FGHI	243 DEFG	460 BC	241 bc
Etibor-48 (granule)	105 I	235 EFGH	428 BC	718 A	372 a
Means	105 *D****	170 *C*	250 *B*	483 *A*	

* Interaction effect; **source effect; ***dose effect. There is not significant difference between the values sharing the same letters.

Effects of B sources and doses on leaf mineral nutrition

The effects of different B sources and their application doses on P, K, Ca and Mg concentrations of sunflower were presented in Table 4. Boron sources and source x dose interaction significantly affected leaf P levels. Looking at the interaction leaf P concentrations were collected under two groups with the values between 0.19% and 0.28%. Similarly, also B sources were collected in two groups in terms of their effect on leaf P. On leaf K and Mg concentrations, only B sources had significant effect. Leaf K concentrations changed between 4% - 5% and Mg concentrations changed between 0.23% – 0.30%. Individual effects of sources and levels were found to be significant on leaf Ca concentrations. Leaf Ca concentrations obtained from the highest B doses (10 mg kg^{-1}) significantly decreased comparing to obtained from the other B levels. Calcium concentrations in leaves of sunflower showed significant variations between 2.11% - 2.90% under different B sources. While the highest Ca concentration was measured from the boric acid applied plants, the lowest was determined from the Etidot-67 applied parcels.

The effects of individual factors and their interaction were not significant on leaf Mn and Zn concentrations. However, source x dose interaction affected leaf Fe and Cu concentrations, significantly. When looked at the Fe and Cu values depending on the interactions, it was seen that Fe and Cu concentrations varied between 71 mg kg^{-1} - 115 mg kg^{-1} and 7.6 mg kg^{-1} - 11.4 mg kg^{-1} respectively. These variations were 104 mg kg^{-1} – 130 mg kg^{-1} and 35 mg kg^{-1} – 55 mg kg^{-1} for Mn and Zn (Table 5).

Table 4. Effects of B sources and application doses on P, K, Ca and Mg concentrations

B sources	B doses (mg kg^{-1})				
	0	5	10	20	Means
			P (%)		
Anhydrate borax	0.19 E*	0.20 DE	0.24 A-E	0.24 A-E	0.22 b
Boric acid	0.27 AB	0.27 AB	0.26 ABC	0.28 A	0.27 a
Etibor-48 (powder)	0.27 AB	0.26 ABC	0.25 A-E	0.24 A-E	0.26 a
Boron oxide	0.23 A-E	0.23 A-E	0.20 DE	0.20 DE	0.22 b
Etidot-67	0.20 DE	0.20 DE	0.20 DE	0.22 A-E	0.21 b
Borax	0.21 CDE	0.23 A-E	0.26 ABC	0.24 A-E	0.25 a
Etibor-48 (granule)	0.21 CDE	0.24 A-E	0.20 DE	0.22 A-E	0.22 b
			K (%)		
Anhydrate borax	4.2	4.6	4.6	4.9	4.60 bc**
Boric acid	5.2	5.1	4.8	4.9	5.00 a
Etibor-48 (powder)	5.0	4.8	4.8	4.4	4.75 ab
Boron oxide	4.3	4.3	4.1	4.1	4.20 cd
Etidot-67	3.9	4.0	4.0	4.0	4.00 d
Borax	4.3	4.3	5.0	4.6	4.55 bc
Etibor-48 (granule)	4.4	4.4	4.2	4.2	4.30 cd
			Ca (%)		
Anhydrate borax	2.60	2.77	2.74	2.64	2.69 bc
Boric acid	3.10	2.80	2.90	2.83	2.90 a
Etibor-48 (powder)	2.83	2.72	2.74	2.60	2.72 ab
Boron oxide	2.50	2.53	2.45	2.06	2.39 d
Etidot-67	2.08	2.14	2.09	2.14	2.11 e
Borax	2.50	2.38	2.68	2.34	2.46 cd
Etibor-48 (granule)	2.59	2.46	2.42	2.26	2.43 d
Means	2.6 *A****	2.54 *AB*	2.57 *A*	2.41*B*	
			Mg (%)		
Anhydrate borax	0.28	0.28	0.28	0.27	0.28 ab
Boric acid	0.32	0.29	0.3	0.29	0.30 a
Etibor-48 (powder)	0.29	0.28	0.29	0.26	0.28 ab
Boron oxide	0.26	0.25	0.24	0.22	0.24 cd
Etidot-67	0.23	0.23	0.23	0.23	0.23 d
Borax	0.27	0.25	0.30	0.28	0.28 ab
Etibor-48 (granule)	0.27	0.27	0.25	0.25	0.26 bc

* Interaction effect; **source effect; ***dose effect. There is not significant difference between the values sharing the same letters.

Table 5. Effects of B sources and application doses on Fe, Cu, Mn and Zn concentrations

B sources	B doses (mg kg^{-1})			
	0	5	10	20
	Fe (mg kg^{-1})			
Anhydrate borax	109 ABC*	84 E-K	87 E-K	109 ABC
Boric acid	95 C-G	100 A-D	98 B-E	90 E-J
Etibor-48 (powder)	84 E-K	89 E-K	78 G-K	71 K
Boron oxide	76 H-K	76 H-K	83 E-K	80 F-K
Etidot-67	77 G-K	83 E-K	74 I-K	115 A
Borax	87 E-K	87 E-K	113 AB	86 E-K
Etibor-48 (granule)	91 D-I	87 E-K	73 JK	94 C-G
	Cu (mg kg^{-1})			
Anhydrate borax	8.4 BCD	8.3 BCD	8.7 A-D	10.9 AB
Boric acid	10.2 A-D	11.4 A	11.1 AB	10.1 A-D
Etibor-48 (powder)	10.9 AB	10.7 AB	8.9 A-D	8.6 A-D
Boron oxide	9.6 A-D	9.4 A-D	7.9 CD	8.3 B-D
Etidot-67	8.8 A-D	9.2 A-D	8.7 A-D	8.6 A-D
Borax	7.6 D	8.6 A-D	9.9 A-D	10.5 ABC
Etibor-48 (granule)	10.2 A-D	10.4 ABC	8.8 A-D	8.9 A-D
	Mn (mg kg^{-1})			
Anhydrate borax	112	105	112	122
Boric acid	121	118	122	130
Etibor-48 (powder)	125	125	114	104
Boron oxide	117	123	104	106
Etidot-67	106	104	114	110
Borax	107	117	126	125
Etibor-48 (granule)	125	125	119	117
	Zn (mg kg^{-1})			
Anhydrate borax	40	47	45	45
Boric acid	55	47	46	43
Etibor-48 (powder)	40	43	40	35
Boron oxide	41	47	46	35
Etidot-67	42	39	36	44
Borax	45	36	47	42
Etibor-48 (granule)	49	46	43	35

* Interaction effect. There is not significant difference between the values sharing the same letters.

If an evaluation was made depending on the results obtained, there was not significant differences between the values weather obtained from the under control (–B) conditions or obtained from the B applied conditions. Because plants could take enough B from the soil and that was sufficient for sunflower growth. So, un-application of B did not result any B deficiency in plant. When considered that sufficiency range of sunflower in this period was between 35 - 150 mg kg^{-1}, plant managed to take sufficient B from the soil even under –B conditions (Jones and Wolf, 1996). In a study conducted by Aquino et al. (2013), it was indicated that sunflower leaf B concentration under –B condition reached up to 126 mg kg^{-1}, and the reason for this was explained with the high available soil B content. As seen from the soil analysis, experimental soils contain high amount of available B (1.1 mg kg^{-1}) and sunflower took the enough B for its growth (da Silva, 2016). In different studies, it is implied that sunflower takes place among the plants that are capable of higher B uptake capacity (Tanaka, 1967; Shorrocks, 1992; Souza, 2004). In a study conducted for a long time ago, it was indicated that soil should contain over than 0.5 mg kg^{-1}available B for optimum sunflower growth (Berger, 1949). Similarly, Silva and Ferreyra (1998) stated that soil B concentration should be more than 0.45 mg kg^{-1} for health sunflower growth. So, not applying of B did not border plant growth. In a study, application of 0, 1, 2, 3 and 4 kg ha^{-1} B to the B sufficient soil, did not affect sunflower growth and yield (Bonacin et al., 2009). Also, Marchetti et al. (2001) informed that B sources and doses did not affect plant height and stem diameter and this was related to B concentration of experimental soil.

Here in this study, the most attractive situation rather than B deficiency is the extreme increases of leaf B concentration with the B doses. As seen from the results, leaf B concentrations of sunflower so increased that these levels can be accepted as toxic for most of the plants. But sunflower growth were not affected negatively from these B concentrations. Demirtaş (2005) states that some of the plants don't show characteristic B toxicity symptoms, and sunflower is one them. Blamey et al. (1997) informed the critical B toxicity level in sunflower leaves as 1130 mg kg^{-1}. In different studies, sunflower plants were indicated as high B requiring plants, so they were not affected by the high soil B (Gomez Rodriguez et al.,1981; da Silva, 2016).

Most of the other nutrients were not affected from the B levels and doses. Although, in the highest B doses leaf Ca concentrations decreased (Dechenand Nachtigall, 2006; Turan et al., 2009), all the nutrients determined in the leaf were sufficient for the optimum sunflower growth (Prado and Leal, 2006; Zobiolevd, 2010). If general evaluations were made in terms all B sources had effect on the increment of leaf B concentration. Also, plant growth was not effected negatively from the all B sources. At the same time, other nutrient concentrations obtained from the B sources were between the sufficiency ranges. As indicated previous studies some B sources such as anhydrate borax, borax pentahydrate, sodium pentaborate, solubor, boric acid etc. can be used for fertilization (Demirtaş, 2006; Gupta, 2007; Kacar, 2013).

CONCLUSIONS

As a result, all B sources increased leaf B concentrations even there were some differences among them. Sunflower took sufficient B from the soil even no fertilization was made, and the B concentration of plant increased up to 718 mg kg^{-1} with B applications. Despite the high B concentrations, sunflower growth was not affected, and the other nutrient concentrations kept their ideal concentrations. So, it can be said that all B sources can be used for B fertilization. And sunflower can be growth under high B containing soils. Also it can be said that there is not a narrow range between B deficiency and toxicity levels for sunflower.

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