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# EFFECTS OF BORON AND HUMIC SUBSTANCE TREATMENTS ON THE AVAILABLE BORON DISTRIBUTION IN THE SOIL PROFILE

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***Abstract***

*Boron (B) toxicity is a significant soil pollution in arid and semi-arid climate regions in the world. The management of boron nutrient in the soil is difficult because of the narrow range between its deficiency and toxicity levels which cause significant reduction in the plant yield. Humic substances are major components of organic matter in soil and have an important role improving soil fertility, increasing uptake of nutrients, cation exchange capacity, water-holding capacity and decreasing the negative effects of chemical fertilizers. In this study, we determined the distribution of B in soil profile of a field which had been provided with different concentrations of humic substances (HS) and different levels of B contained water for two consecutive years. These treatments were performed in cotton (Gossypium hirsutum L. Carmen) crop where four B contained irrigation water (0.6–1.8–5.4–16.2 mg B $l^{-1}$) and three humic substances (0–200–400 kg $ha^{-1}$) were applied in field in 2011 and repeated in 2012. The total amount of applied water by drip irrigation was 1039.9 mm. The current study was started after the second season of the cotton harvest. The soil samples were taken at 10 cm equal intervals up to 1 m soil depth. The different B treatments with irrigation increased the available B content in soil and showed an accumulation in the upper part of the soil profile. On the other hand, B leaching was dramatically decreased after plow layer. The humic substance treatments increased the available B contents particularly in the upper part of the soil profile in 5.4–16.2 mg B $l^{-1}$ treatments. The result of our study implied that humic substances do not play a role in the remediation of soil B toxicity.*

**Key words:** *boron toxicity, humic substances, remediation, accumulation, leaching.*

## INTRODUCTION

Boron (B) is an essential micronutrient for plant growth. The management of B in soil is difficult because of the narrow range between its deficiency and toxicity levels which cause significant reduction in the plant yield. B toxicity is a significant soil pollution in arid and semi-arid climate regions in the world. In arid and semi-arid regions, B toxicity could be derived from both high soil B contents and irrigation water with high B concentrations (Cartwright et al., 1984; Nable et al., 1997). Turkey is a rich country in terms of geothermal energy reserves but unfortunately, the high B contained geothermal wastewaters are discharged and drained to the Menderes River (Koç, 2011). The addition of B rich waste water to ground water increases the pollution of the water sources for agricultural purposes (Aydın and Seferoğlu, 1999). Boron has been accumulated in the plant over the requirement in the area (Koç, 2007). Aydın et al. (2010) determined that soil available B contents were changed between 0.43 to 2.34 mg B $kg^{-1}$ in the Aydın conditions.

Remediation of soils contaminated with boron was more difficult than the remediation of soil salinity. The leaching was a primary method of controlling salinity and B toxicity of soil by irrigation water. However, boron leaches more slowly than the salt and requires more irrigation water (Anapalı and Gemalmaz, 1992). The leaching of B from soil uses two or three times more water than saline soil (Çiftçi et al., 2004). In addition, the limited boron-free irrigation or ground water, more water usage and lack of drainage were limiting factors to the success of B remediation. The other conventional B remediation technique is liming, but this technique is insufficient process under the alkaline soil conditions. Due to the limitation on the conventional B remediation technique, new methods for B remediation are needed. Humic substances (HS) are major components of the natural organic matter in the soil. These may consist of physically and chemically heterogeneous mixtures of materials. HS affect physical and chemical properties of soil and improve soil fertility (Stevenson, 1994). HS positively affect the water-holding capacity, cation exchange capacity, fertilizer retention and microbial activity of the soil (Lobartini et al., 1997). Moreover, HS increase root vitality and nutrient uptake and contribute to improvement of yields. HS creates soluble or insoluble organic complexes with organic compounds, metals and minerals. Angin et al. (2008) reported that humic acid additions can be an effective way to remediation of B, but their optimum performance depends on degree of soil B contents. Santos and Rodella (2007) stated that humic substances can decrease contents of Zn, Cu, Pb, B, but cannot prevent toxicity in the soil conditions. Effect of humic substances on the soil B content is not well known and there is little research on the B remediation with humic substances.

The purpose of this research was to observe boron accumulation in soil profile due to different levels boron contained irrigation water and effect of humic substances on B leaching

## MATERIALS AND METHODS

### *The Previous Experiment*

This research was carried out at Adnan Menderes University Agricultural Faculty, Soil Science and Plant Nutrition Department, in 2011-2012. This experiment was designed in a split plot with three replications. Cotton (*Gossypium hirsutum* L. cv. Carmen) was used as test species in this experiment. The main plots had different levels of boron (B) contained irrigation water as B1: 0.6 (control)– B2: 1.8– B3: 5.4 –B4: 16.2 mg B $l^{-1}$ and the sub plots were humic substance (HS) treatments as HS1: 0 (control) – HS2: 200– HS3: 400 kg $ha^{-1}$. Second year experiment was designed over the same coordinates as of first year. Etidot67 (Sodium octaborate, 20.8% Soluble B) and Agrolig (65% total humic+fulvic acid) were used as sources of boron and Humic substances, respectively. During the two years' experiment, the total amount of applied water by drip irrigation was 1039.9 mm. Table 1 shows the amount of B by irrigation water into the soil during two years experiment. The total amount of B by irrigation water given into the soil were 6.3, 18.7, 56.1, 168.5 kg B $ha^{-1}$ for B1, B2, B3 and B4 respectively, as the total of two years.

Table 1. The amount of B by irrigation water into the soil during two years experiment (kg B $ha^{-1}$)

| Boron levels | 2011 | 2012 | Total |
|---|---|---|---|
| B1 | 3.0 | 3.3 | 6.3 |
| B2 | 8.7 | 10 | 18.7 |
| B3 | 26.3 | 29.8 | 56.1 |
| B4 | 79 | 89.5 | 168.5 |

B1: 0.6 mg B $l^{-1}$; B2 1.8 mg B $l^{-1}$; B3: 5.4 mg B $l^{-1}$; B4: 16.2 mg B $l^{-1}$

### *The Current Experiment*

This study was started after the second season of cotton harvest. The soil samples were taken at 10 cm equal intervals up to 1 m soil depth by using stainless steel rings (100 $cm^3$) with three replications in each plots (Figure 1). Air-dried and sieved soil samples were used to measure selected physico-chemical properties. Soil pH was alkaline as measured by distilled water (Kacar, 2008). Soil texture was found sandy loam as analyzed by Bouyoucos (1951). The soil available boron content was determined colorimetrically (420 nm) by the Azomethine-H method (Wolf, 1971).

Data collected from soil samples were analyzed with a completely randomized treatment structure. The statistical analysis was performed with the SPSS statistical software system (PASW Statistics, Ver.: 18.0). Mean separations were performed by the LSD-test at a significance level of 0.05.

Figure 1. Sampling points throughout the soil profile

## RESULTS AND DISCUSSIONS

The results indicated that the different levels of boron applications through irrigation water, humic substances treatments and soil depth had a statistically significant impact on the soil available boron contents (Table 2). B×HS, Bxdepth, HS×depth and B×HS×depth interaction was also found statistically significant (Table 2).

Table 2. The result of variance analysis for available B content of soil

| Variance Source | DF | Soil available B content |
|---|---|---|
| B | 3 | ** |
| HS | 2 | * |
| D | 9 | ** |
| B x HS | 6 | ** |
| B x D | 27 | ** |
| HS x D | 18 | * |
| B x HS x D | 54 | ** |
| Error | 232 | |
| $LSD_{0.05\ B}$ | | 0.52 |
| $LSD_{0.05\ HS}$ | | 0.37 |
| $LSD_{0.05\ D}$ | | 0.83 |
| $LSD_{0.05\ BxHS}$ | | 0.91 |
| $LSD_{0.05\ BxD}$ | | 1.65 |
| $LSD_{0.05\ HSxD}$ | | 1.43 |
| $LSD_{0.05\ BxHSxD}$ | | 2.86 |

* P<0.05, ** P<0.01, DF: degree of freedom, B: Boron application, HS: Humic substances application, D: Soil Depth.

Table 3 shows that effects of different levels of boron contained irrigation water and humic substances on available B contents in 0-100 cm soil depth with 10 cm increments. In terms of B application, the B3 and B4 treatments caused the available boron contents of soil reaching to the toxic level in the upper part of soil profile. The highest available boron content was recorded from the B4 application as 16.99 mg B $kg^{-1}$ in the 10-20 cm soil depth. Comparing with the control (B1), the available B content of soil increased at the high level B application (B4) by 1380 % in the 0-10 cm soil depth. On the contrary, in the control treatment, the maximum B content was obtained in the 90-100 cm soil depth.

The HS treatments increased the available B contents particularly in the upper part of the soil profile. The highest available B content was obtained from HS3 application as 8.01 mg B $kg^{-1}$ in the 10-20 cm soil depth. HS treatments significantly increased soil available B content by 77.75 % in the 0-10 cm soil depth in comparison with control. The lowest B content was recorded from the HS3 treatments in the 90-100 cm soil depth (Table 3).

BxHS interactions were more prominent in B3 and B4 treatments. It was determined that the highest difference occurred between 10-20 cm and 20-30 cm soil depth in the B3 and B4 levels. The highest available boron content was obtained from B4HS3 applications as 23.59 mg B $kg^{-1}$ in 10-20 cm soil depth. The second highest available boron content was recorded from same application but in the 0-10 cm soil depth (Table 3).

Table 3. Effects of different levels of boron contained irrigation water and humic substances on available B contents in different soil depths (mg B $kg^{-1}$)

| Applications | Depth (cm) | B1 | B2 | B3 | B4 | means |
|---|---|---|---|---|---|---|
| HS1 | 0-10 | 0.96 | 2.97 | 3.05 | 10.10 | 4.27 |
| | 10-20 | 1.32 | 1.53 | 7.62 | 11.16 | 5.41 |
| | 20-30 | 1.11 | 1.42 | 2.33 | 4.08 | 2.23 |
| | 30-40 | 1.02 | 1.16 | 1.52 | 3.12 | 1.71 |
| | 40-50 | 1.13 | 1.06 | 0.49 | 2.66 | 1.33 |
| | 50-60 | 1.25 | 1.17 | 0.34 | 2.19 | 1.24 |
| | 60-70 | 1.38 | 1.01 | 0.33 | 2.25 | 1.24 |
| | 70-80 | 1.25 | 0.80 | 0.18 | 2.12 | 1.09 |
| | 80-90 | 1.35 | 0.71 | 0.08 | 1.56 | 0.92 |
| | 90-100 | 1.70 | 0.56 | 0.34 | 1.50 | 1.02 |
| Means | | 1.25 | 1.24 | 1.63 | 4.07 | 2.05 |
| HS2 | 0-10 | 1.00 | 1.29 | 7.37 | 12.25 | 5.48 |
| | 10-20 | 1.41 | 1.13 | 6.98 | 16.23 | 6.44 |
| | 20-30 | 0.87 | 1.20 | 1.65 | 5.35 | 2.27 |
| | 30-40 | 0.83 | 1.21 | 1.39 | 3.24 | 1.67 |
| | 40-50 | 0.85 | 0.96 | 1.51 | 2.94 | 1.57 |
| | 50-60 | 1.01 | 0.86 | 1.45 | 1.86 | 1.29 |
| | 60-70 | 1.05 | 0.57 | 1.30 | 1.47 | 1.10 |
| | 70-80 | 1.34 | 0.33 | 1.01 | 1.41 | 1.02 |
| | 80-90 | 1.29 | 0.32 | 0.60 | 0.83 | 0.76 |
| | 90-100 | 0.95 | 0.28 | 0.65 | 1.19 | 0.77 |
| Means | | 1.06 | 0.81 | 2.39 | 4.68 | 2.24 |
| HS3 | 0-10 | 0.94 | 1.25 | 7.44 | 20.73 | 7.59 |
| | 10-20 | 0.79 | 1.11 | 6.56 | 23.59 | 8.01 |
| | 20-30 | 0.81 | 1.08 | 4.64 | 12.44 | 4.74 |
| | 30-40 | 0.51 | 1.13 | 1.50 | 3.16 | 1.58 |
| | 40-50 | 0.64 | 1.10 | 1.50 | 1.88 | 1.28 |
| | 50-60 | 0.58 | 1.14 | 1.44 | 1.04 | 1.05 |
| | 60-70 | 0.57 | 1.14 | 0.70 | 0.55 | 0.74 |
| | 70-80 | 0.68 | 1.02 | 0.51 | 0.83 | 0.76 |
| | 80-90 | 0.44 | 0.98 | 0.45 | 0.93 | 0.70 |
| | 90-100 | 0.59 | 0.95 | 0.52 | 0.34 | 0.60 |
| Means | | 0.66 | 1.09 | 2.53 | 6.55 | 2.71 |

B: Boron application, HS: Humic substances

Figure 2 depicts the distribution of soil available B content in terms of boron applications with irrigation water in the soil profile. B1 and B2 treatments showed almost no difference throughout soil profile. The soil B contents were followed by a course in straight line under the B1 and B2 applications. However, soil B contents increased slightly in all depth in B1 and B2 treatments.

On the other hand, soil available B contents decreased dramatically by both B3 and B4 treatments from 20 cm soil depth. The highest decrease was observed at B4 treatment.

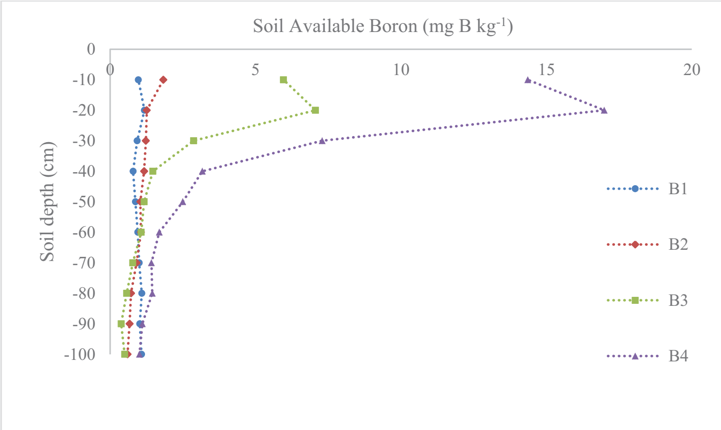


Figure 2. The distribution of soil available B content in terms of boron applications with irrigation water in soil profile

The distribution of soil available B content in terms of humic substances treatments in the soil profile has been given in Figure 3. The soil available B content decreased throughout soil profile by all of HS applications. However, the available B content reduction was apparently different from surface to 40 cm soil depth. The decrease in available B contents was similar in deeper part of soil profile. The highest decrease on the soil available B content was observed in HS3 treatment.

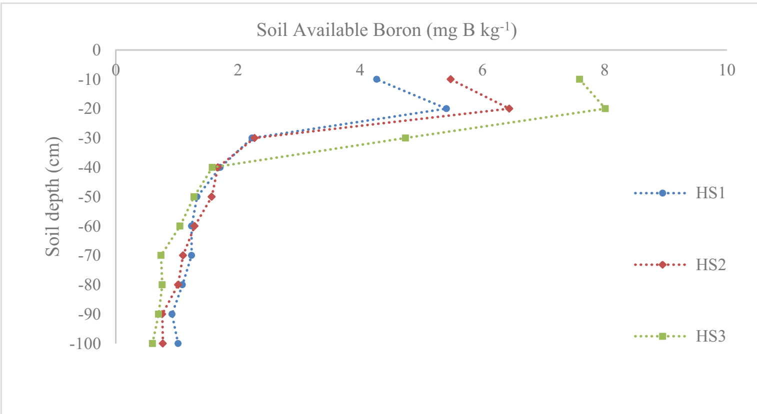


Figure 3. The distribution of soil available B content in terms of humic substances treatments in soil profile

In general assessment, increasing B and HS applications increased soil available B content in the upper part of soil both individually and their interactions. As expected, B addition greatly enhanced available B contents beyond levels in the control soil. Soil available B levels were increased from 0.99 to 16.99 mg B $kg^{-1}$ upon B addition which indicates there B has reached to toxic levels in the soil (Jones, 1999; Choi et al., 2006).

Humic substances are considered to play an important role in B adsorption (Parks and White, 1952; Yermiyahu et al., 1995; Goldberg, 1997). Moreover, humic substances enhanced solubilisation and availability of nutrients in the soils positively. Therefore, they increased B availability in the soils account for its a chelation effects (Milap Chand et al., 1980; Zhang et al., 2003 Turan and Angin, 2004; Sarwar et al., 2012).

High level boron treatments (5.4 and 16.2 mg B $l^{-1}$) showed a boron accumulation in the upper part of the soil profile. On the other hand, B leaching was dramatically decreased after the plow layer. Effects of humic substances on the soil available B contents were more prominent at the B3 and B4 levels in the plow layer. When humic substances use efficiency on the B remediation in the soils were considering that HS treatments cannot remediate soil B content contrarily showed enhancing effect on the soil B content. The findings are consistent with Kaptan (2013), however, these are in conflict with Turan and Angin (2004); Angin et al. (2008).

## CONCLUSIONS

Boron is an essential micronutrient for plant growth. But the excessive accumulation of B in the soils leads to toxicity for plants. This study showed that B application by irrigation water and humic substances addition can increase soil available B content. Humic substances enhanced the retention and availability of B in the soil, hence, their application for B toxicity remediation seems a false practise. The current B levels in the soil and the amount of HS can impact the remediation process. Further research is needed to investigate B toxicity remediation with substances other than HS on different soil types.

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