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*Full Length Research Paper*

# Research on weed species for phytoremediation of boron polluted soil

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**This research was aimed to investigate the application of weed species for** phytoremediation **of soil polluted with boron. A greenhouse experiment was conducted to study the effect of increasing boron (B) application on the growth and B uptake of common weed species, *Sorghum halepense* L. Pers., *Cyperus rotundus* L., *Cynodon dactylon* L. Pers., *Amaranthus retroflexus* L., *Echinochloa Cruss-gali* L. and *Chenopodium album* L. Four levels of B (0, 10, 20 and 30 mg kg$^{-1}$ soil) were applied to six weed species. Results revealed that, shoot and root dry weight of species decreased with increasing B application. There was a considerable variation among weed species in terms of their responses to B applications. The species having rhizomes such as S*. halepense*, *C. rotundus* and *C. dactylon* Pers. were more tolerant to the B toxicity than species growing from the seeds of *A. retroflexus*, *E. Cruss-gali* and *C. album*. The shoots contained higher concentration of B than the roots. Boron content of weed species was notably different and was affected by B applications. The high aboveground biomass and B accumulation in the shoot of any of weed species used in the experiment cannot be considered a potential parameter for the phytoextraction of B.**

**Key words:** Boron toxicity, tolerance, dry weight, hyperaccumulator.

## INTRODUCTION

Boron (B) is an essential trace element required for normal growth of plants, and plants vary in their B requirement. The range between deficient and toxic concentrations for B is smaller than for any of other nutrient element. In arid and semi-arid areas, B toxicity results from high levels of B in soils and from additions of B via the irrigation water (Ryan et al., 1998; Gemici and Tarcan, 2002; Akar, 2007). Toxic effects are more obvious in dry seasons, when roots penetrate deeper into the soil.

Boron occurs in many rocks and soils at total concentrations of 5 - 50 mg kg$^{-1}$, and is normally present in plant leaf tissue at concentrations of 10 - 50 mg kg$^{-1}$. However, many species are quite sensitive to elevated B levels in their tissues, showing severe toxicity symptoms at tissue levels of about 50 mg kg$^{-1}$. Such levels can be found in tissues when the available soil B exceeds 3 mg kg$^{-1}$ (Hakki et al., 2007).

The term hyperaccumulator was first used in relation to plants containing more than 1000 µg g$^{-1}$ (0.1%) Ni in dry tissue (Jaffre et al., 1976; Brooks et al., 1977). A later publication extended the use of the term to include plants containing more than 1% Zn or Mn, or more than 0.1% Cu, Co, Cr and Pb (Baker and Brooks, 1989). The ability of *Thlaspi caerulescens* L. to accumulate Zn to more than 10,000 µg g$^{-1}$ in dry tissue has been known since the 1860s. Recently, Babaoglu et al. (2004) reported that *Gypsophila sphaerocephala Fenzl ex Tchihat* var. *G. sphaerocephala* contained considerably higher B concentrations in its above-ground parts (2093 mg kg$^{-1}$ seeds; 3345 mg kg$^{-1}$, leaves).

The potential of hyperaccumulator plants is often hindered by the slow growth and aboveground biomass, since the majority of the metal hyperacculator plants are poor yielding and slow growing (Salt et al., 1995 and Ebbs and Kochian, 1997). Plants suitable for phytore-

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mediation should possess (a) an ability to accumulate the targeted metal(s), preferably in the aerial parts, (b) tolerance to the metal concentrations accumulated, (c) fast growth of the metal accumulating biomass, and (d) ease of cultivation and harvesting (Baker and Brooks, 1989). Chaney et al. (1997) have argued that metal tolerance and hyper accumulation are more important factors than high biomass production. A recent list of hyperaccumulators for several metals (Zn, Cd, Pb, Ni, Cu, Se and Mn) has been published (Reeves and Baker, 2000). This work did not consider several other elements, such as B, As and Al. But very little is known to date about abnormal accumulation of B by plants.

There are many geothermal fields and thermal springs in the Small and Big Meander valleys in Western Turkey. Fluids emerging from some of these areas contain high boron concentrations and cause environmental problems for cold waters in agricultural areas where boron contaminates aquifers and soils (Kasap, 1984; Karamanderesi, 1997; Gemici and Tarcan, 2002). Boron has been accumulated in the plant over the requirement in the area (Koç, 2007). Accordingly, strategies should be developed either by breeding B-tolerant genotypes or by phytoremediation with B accumulating species. Soil amendments by conventional techniques such as leaching or increasing pH by liming (Nable et al., 1997) for increased B adsorption on soil seem not to suit for Western Turkey conditions due to its low annual rainfall and water shortages, and the high lime content of the soils. Therefore, this experiment was carried out to investigate using weed species for phytoremediation of soil polluted with boron.

## MATERIALS AND METHODS

A greenhouse experiment was conducted in Aydın province of Turkey between 13th May to 22nd July, 2008. *Amaranthus retroflexus* L. (AMARE), *Echinochloa Cruss-gali* L. (ECHCG), *Chenopodium album* L. (CHEAL), *Cynodon dactylon* (L.) Pers. (CYNDO), *Cyperus rotundus* L. (CYPRO) and *Sorghum halepense* (L.) Pers. (SORHA) were used in the experiments as model weeds which are the most common summer weed species for the region as well as worldwide. Seeds and rhizomes of annual, respectively perennial weeds were sown in pots containing air dried 4 kg soil and weeds were further grown under greenhouse conditions. The soil were used in the experiment has loam in texture, 2.6% $CaCO_3$, pH of 7.87, organic matter 1.2%, total N 0.15%. The concentrations of $NH_4OAc$-extractable K, Ca and Na were 175, 3244 and 30 mg $kg^{-1}$ respectively. $NaHCO_3$ -available P was 12.7 mg $kg^{-1}$, DTPA-extractable Zn was 0.76 mg $kg^{-1}$ and NaOAc-extractable B was 1.1 mg $kg^{-1}$.

Four boron rates were (0, 10, 20 and 30 mg B $kg^{-1}$ soil) applied with 6 replications in a randomized complete block design. $H_3BO_3$ was used as boron source. Species planted to the pots using rhizomes (SORHA, CYPRO and CYNDO or seeds (AMARE, ECHCG and CHEAL). A basal dose of N, P and K were applied as 200, 100 and 100 mg $kg^{-1}$, respectively and mixed thoroughly with soil before the sowing. After 5 weeks growing period plants were harvested, dried at 65°C, and root and shoot weights were determined. Root and shoot samples were ground for analysis. Boron was determined as described by Wolf (1974).

Variance (ANOVA) analysis was used for statistical evaluation of the obtained data and means were compared by LSD test ($p < 0.05$) using the SPSS package programme (Version 13.0, Chicago, USA).

## RESULTS AND DISCUSSION

### Plant biomass and height

The application of 20 and 30 mg B $kg^{-1}$ soil induced visible B toxicity symptoms such as necrotic spots in the tips and margin of leaf blades which were more severe in ECHCG and AMARE. The biomass of weed species decreased with increasing B rates. The maximum shoot and root dry weight was obtained from the control treatment (Table 1). The shoot dry weight decreased by about 68, 61, 58, 48, 45 and 42%, in SORHA, CYPRO, CYNDO, CHEAL, ECHCG and AMARE, respectively as compared to control with 30 mg B $kg^{-1}$ soil application (Table 1). Root dry weight decreased by about 65, 64, 57, 43, 34 and 32% in CYPRO, SORHA, CYNDO, AMARE, CHEAL and ECHCG, respectively as compared with control, as well. The reduction in both shoot and root dry weights were less in species having rhizomes (SOR HA, CYPRO, CYNDO). The ratio of root dry weight/shoot dry weight remained similar at all B treatments.

Each crop responded differently to rates of boron, phenomenon also reported for barley (Rahman et al., 2006), for barley grass (Choi et al., 2006), for *Brassica rapa* (Kaur et al., 2006) and for rice (Ochiai et al., 2008). Reducing in the shoot and root dry matter can be attributed due to the toxic effects of B, resulting in reduced size and weight of plants. It can be also concluded that species having rhizomes were the more tolerant to the B toxicity than species growing from the seeds.

Plant height of weed species significantly affected with the B applications except in ECHCG, AMARE in CYPRO. Plant height decreased with increasing rate of B applications. Among the weed species SORHA was the highest while ECHCG was the smallest in all B treatments (Table 2). Kalayci et al (1998), Sotiropoulos et al (2003) and El-Gharably and Bussler (2007) were also reported that plant height was reduced by excess B rates.

### Boron accumulation

Boron concentrations in the roots and shoots of weeds increased with the B levels, registering the lowest concentration in control (0 mg B $kg^{-1}$ soil) treatment and highest in 30 mg B $kg^{-1}$ soil application (Table 3). The B concentration in shoots also increased with B concentrations and significant differences were determined between B rates.

**Table 1.** Effects of B application on the dry weight of some weed species.

| B (mg $kg^{-1}$ soil) | CYNDO | ECHCG | AMARE | SORHA | CHEAL | CYPRO |
|---|---|---|---|---|---|---|
| **Shoot dry weight (g $pot^{-1}$)** | | | | | | |
| 0 | 11.76a (100) | 12.55a (100) | 5.14a (100) | 9.42a (100) | 11.48a (100) | 11.84a (100) |
| 10 | 9.72b (83) | 10.20b (81) | 4.35b (84) | 8.58b (91) | 9.50b (83) | 10.66b (90) |
| 20 | 8.06c (69) | 7.87c (63) | 2.36c (45) | 7.06c (75) | 7.36c (64) | 8.70c (74) |
| 30 | 6.76d (58) | 5.68d (45) | 2.14c (42) | 6.44d (68) | 5.52d (48) | 7.24d (61) |
| **Root dry weight (g $pot^{-1}$)** | | | | | | |
| 0 | 3.78a (100) | 8.25a (100) | 4.10a (100) | 9.14a (100) | 2.82a (100) | 8.17a (100) |
| 10 | 3.26b (87) | 7.67b (93) | 3.06b (75) | 8.22b (90) | 1.64b (58) | 7.17b (88) |
| 20 | 2.69c (71) | 4.75c (58) | 2.35c (57) | 6.43c (70) | 1.22c (43) | 6.50c (80) |
| 30 | 2.14d (57) | 2.65d (32) | 1.75d (43) | 5.82d (64) | 0.95d (34) | 5.29d (65) |
| **Root dry weight/shoot dry weight ratio** | | | | | | |
| 0 | 0,321 (100) | 0,657 (100) | 0,797 (100) | 0,970 (100) | 0,246 (100) | 0,690 (100) |
| 10 | 0,335 (104) | 0,752 (114) | 0,702 (88) | 0,957 (99) | 0,173 (70) | 0,672 (97) |
| 20 | 0,334 (104) | 0,603 (92) | 0,994 (125) | 0,911 (94) | 0,165 (67) | 0,747 (108) |
| 30 | 0,316 (98) | 0,467 (71) | 0,815 (102) | 0,903 (93) | 0,171 (70) | 0,731(106) |

CYNDO = *Cynodon dactylon* (L.) Pers., ECHCG = *Echinochloa Cruss-gali* L., AMARE = *Amaranthus retroflexus* L., SORHA = *Sorghum halepense* (L.) Pers., CHEAL = *Chenopodium album* L., and CYPRO = *Cyperus rotundus* L.
Values in the parentheses are the relative to the control plants. Different letters following the values show the significant difference between the B treatments by the LSD test ($P < 0.05$). Two-way ANOVA was carried out the data at 0, 10, 20 and 30 g $B^{-1}$ soil treatments using B concentrations and the species.

**Table 2.** Effects of B application on the plant height of some weed species.

| B (mg $kg^{-1}$ soil) | CYNDO | ECHCG | AMARE | SORHA | CHEAL | CYPRO | Average |
|---|---|---|---|---|---|---|---|
| 0 | 94.0a B | 61.5a C | 41.0a E | 118.0a A | 55.0a CD | 53.8a D | 70.5 |
| 10 | 74.7b B | 48.6a C | 40.1a D | 95.1b A | 40.8ab D | 48.9a C | 58.0 |
| 20 | 69.1bc B | 47.7a D | 32.3a E | 88.4b A | 40.6ab D | 57.4a C | 55.9 |
| 30 | 45.9c BC | 48.7a B | 30.7a E | 88.0b A | 38.0b C | 42.5a B | 49.0 |
| Average | 70.9 | 51.6 | 36.0 | 97.4 | 43.6 | 50.6 | |

CYNDO = *Cynodon dactylon* (L.) Pers., ECHCG = *Echinochloa Cruss-gali* L., AMARE = *Amaranthus retroflexus* L., SORHA = *Sorghum halepense* (L.) Pers., CHEAL = *Chenopodium album* L., and CYPRO = *Cyperus rotundus* L.
Small letters indicate the statistical differences between the B treatments by the LSD test ($P < 0.05$. Capital letters indicate the statistical differences between the species by the LSD test ($P < 0.05$).

Maximum B concentrations were determined as 432, 398, 329, 323, 321 and 268 mg $kg^{-1}$ for ECHCG, CYNDO, CYPRO, AMARE, SORHA and CHEAL, respectively. The values were lower than B content of *Gypsophila sphaerocephala* Fenzl ex Tchihat var. *G. Sphaerocephala*, weed species grown in Turkey, reported by Babaoglu et al., (2004). Our results revealed that the shoots contain a higher concentration of B than roots, suggesting translocation through the xylem stream and transpiration involved in the accumulation of B in leaves. Results of this study corroborates the report of Garate et al. (1984); Subedi et al. (1999); Wojcik et al. (2003) and Oyinlola (2005) who also reported that the B concentrations in roots were generally much lower than shoots. Weed species used in the experiment are the most common summer weed species for the region as well as worldwide (Doğan and Boz, 2005). They were also grown in B toxic soil. However these species did not match the criterion of Baker et al. (2000) for a hyperaccumulator plant containing high levels of B.

## Conclusion

According to the results of the research, boron negatively influenced the biomass of weed species and the B accumulation positively correlated with the B application to the soil. Species having rhizomes were the more tolerant to the B toxicity than species growing from the seeds. The maximum shoot B content was 432 mg $kg^{-1}$ in ECHCG.

**Table 3.** Effect of B application on shoots and roots B concentrations of some weed species.

| B (mg $kg^{-1}$ soil) | CYNDO | ECHCG | AMARE | SORHA | CHEAL | CYPRO | Average |
|---|---|---|---|---|---|---|---|
| **Shoots B (mg $kg^{-1}$)** | | | | | | | |
| 0 | 75d A | 95d A | 64d A | 68d A | 78c A | 105d A | 81 |
| 10 | 133c BC | 235c A | 148c BC | 128c C | 174b B | 193c AB | 169 |
| 20 | 202b C | 303b A | 225b B | 233b BC | 187b C | 287b AB | 240 |
| 30 | 398a A | 432a A | 323a B | 321a B | 268a C | 329a B | 345 |
| Average | 202 | 266 | 190 | 188 | 177 | 229 | 209 |
| **Roots B (mg $kg^{-1}$)** | | | | | | | |
| 0 | 29c A | 27b A | 28b A | 23b A | 34c A | 36b A | 30 |
| 10 | 75b A | 42b B | 55b B | 47ab B | 61bc AB | 70a A | 58 |
| 20 | 124a A | 48b D | 76ab BC | 67a C | 75ab BC | 82a B | 79 |
| 30 | 151a A | 77a C | 87a BC | 69a C | 98a B | 95a B | 96 |
| Average | 95 | 49 | 62 | 52 | 67 | 71 | |
| **Root/shoot ratio** | | | | | | | |
| 0 | 0,32 | 0,66 | 0,80 | 0,97 | 0,25 | 0,69 | 0,61 |
| 10 | 0,33 | 0,75 | 0,70 | 0,96 | 0,17 | 0,67 | 0,60 |
| 20 | 0,33 | 0,60 | 0,99 | 0,91 | 0,17 | 0,75 | 0,63 |
| 30 | 0,32 | 0,47 | 0,82 | 0,90 | 0,17 | 0,73 | 0,57 |
| Average | 0,33 | 0,62 | 0,83 | 0,94 | 0,19 | 0,71 | |

CYNDO = *Cynodon dactylon* (L.) Pers., ECHCG = *Echinochloa Cruss-gali* L., AMARE = *Amaranthus retroflexus* L., SORHA = *Sorghum halepense* (L.) Pers., CHEAL = *Chenopodium album* L., and CYPRO = *Cyperus rotundus* L.
Small letters indicate the statistical differences between the B treatments by the LSD test (P < 0.05. Capital letters indicate the statistical differences between the species by the LSD test (P < 0.05).

Considering the high aboveground biomass and B accumulation in the shoot of any of weed species used in the experiment cannot be accepted a potential parameter for the phytoextraction of B. Using other local weed species, further investigations are necessary for phytoremediation of soil polluted with boron.

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## REFERENCES

Akar D (2007). Potential boron pollution in surface water, crop and soil in the lower Buyuk Menderes Basin. Environ. Eng. Sci. 24(9): 1273-1279.

Babaoglu M, Gezgin S, Topal A, Sade B, Dural H (2004). *Gypsophila sphaerocephala Fenzl ex Tchihat.*: A boron hyperaccumulator plant species that may phytoremediate soils with toxic B levels. Turk. J. Bot. 28: 273-278.

Baker AJM, Brooks RR (1989). Terrestrial higher plants which hyperaccumulate metallic elements: a review of their distribution, ecology and phytochemistry. Biorecovery, 1: 81-126.

Baker AJM, McGrath SP, Reeves RD, Smith JAC (2000). Metal hyperaccumulator plants: A review of the ecology and physiology of a biological resource for phytoremediation of metal-polluted soils. In: Terry N & Banuelos G (Eds.) Phytoremediation of Contaminated Soil and Water. CRC Press LLC, USA, pp. 85-107.

Brooks RR, Lee J, Reeves RD, Jaffre T (1977). Detection of nickeliferous rocks by analysis of herbarium specimens of indicator plants. J. Geochem. Exploration, 7: 49-57.

Chaney RL, Malik M, Li YM, Brown SL, Angle JS, Baker AJM (1997). Chaney RL, Phytoremediation of soil metals. Curr. Opin. Biotechnol. 8: 279-284.

Choi EY, McNeill A, Coventry D, Stangoulis J (2006). Whole plant response of crop and weed species to high subsoil boron. Aust. J. Agric. Res. 57(7): 761-770.

Doğan MN, Boz Ö (2005). Comparison of Weed Problems in Main and Second Crop Maize (Zea mays L.) Growing Areas in Turkey, Asian J. Plant Sci. 4(3): 220-224.

Ebbs SD, Kochian LV (1997). Toxicity of zinc and copper to *Brassica species*: Implications for phytoremediation. J. Environ. Qual. 26: 776-781.

El-Gharably GA, Bussler W (2007). Critical levels of boron in cotton plants. J. Plant Nutr. Soil Sci. 148(6): 681-688.

Garate A, Carpena-Ruiz RO, Ramon AM (1984). Effect of boron and manganese and other nutrients in fluids of vascular tissues. An Edafology Agrobiologia, 43: 146-177.

Gemici Ü, Tarcan G (2002). Distribution of boron in thermal waters of western Anatolia, Turkey, and examples of their environmental impacts. Environ. Geol. 43: 87-98.

Hakki EE, Atalay E, Harmankaya M, Babaoglu M, Hamurcu M, Gezgin S (2007). Determination of suitable maize (*Zea mays* L.) genotypes to be cultivated in boron-rich Central Anatolian soil. In Xu F, Goldbach HE, Brown PH, Bell RW, Fujiwara T, Hunt CD, Goldberg S and Shi L (eds.) Advances in Plant and Animal Boron Nutrition. Springer, pp. 231-247.

Jaffre T, Brooks RR, Lee J, Reeves RD (1976). Sebertia acuminata: a hyperaccumulator of nickel from New Caledonia. Science, 193: 579-580.

Karamanderesi IH (1997). Geology and hydrothermal alteration processes of the Salavatlı-Aydın Geotermal field. (Ph.D. dissertation)

Dokuz Eylül University, Izmir, Turkey.
Kasap I (1984). Geotermal resource evaluation of Germencik-Ömerbeyli (Western Anotolia) geotermal field of Turkey. Seminar on Utilization of Geotermal Energy for Electric Power Production and Space Heating, 14-17 May, Florence.
Kalayci M, Alkan A, Cakmak I, Bayramoglu O, Yilmaz A, Aydin M, Ozbek V, Ekiz H, Ozberisoy F (1998). Studies on differential response of wheat cultivars to boron toxicity. Euphytica, 100: 123-129.
Kaur K, Nicolas ME, Ford R, Norton RM, Taylor PWJ (2006). Physiological mechanisms of tolerance to high boron concentration in *Brassica rapa.* Functional Plant Biol. 33(10): 973-980.
Koç C (2007). Effects on environment and agriculture of geothermal wastewater and boron pollution in great Menderes basin. Environ. Monit. Assess, 125(1-3): 377-388.
Nable RO, Banuelos GS, Paull JG (1997). Boron toxicity. Plant Soil, 193: 181-198.
Ochiai K, Uemura S, Shimizu A, Okumoto Y, Matoh T (2008). Boron toxicity in rice (*Oryza sativa* L.). I. Quantitative trait locus (QTL) analysis of tolerance to boron toxicity. Theor. Appl. Genet. 117(1): 125-133.
Oyinlola EY (2005). Distribution of boron and its uptake in the plant parts of two tomato varieties. Chem. Class J. 2: 77-80.
Reeves RD, Baker AJM (2000). Metal accumulating plants. In: I Raskin, B Ensley (Eds.) Phytoremediation of Toxic Metals: Using Plants to Clean up the Environment. New York: Wiley, pp. 193-229.
Rahman S, Park TI, Kim YJ, Seo YW, Yun SJ (2006). Invers relationship between boron toxicity tolerance and boron contents of barley seed and root. J. Plant Nutr. 29: 1779-1789.
Ryan J, Singh M, Yau SK (1998). Spatial variability of soluble boron in Syrian soils. Soil Tillage Res. 45: 407-417.
Salt DE, Blaylock M, Kumar PBN, Dushenkov V, Ensley BD, Chet I, Raskin I (1995). Phytoremediation: a novel strategy for the removal of toxic metals from the environment using plants. Biol. Technol. 13: 468-474.
Sotiropoulos TE, Therios IN, Kortessa N, Dimassi KN (2003). Boron toxicity in kiwifruit plants (*Actinidia deliciosa*), treated with nitrate, ammonium, and a mixture of both. J. Plant Nutr. Soil Sci. 166(4): 529-532.
Subedi KD, Budhathoki CB, Subedy M, Yubak GC (1999). Respons of wheat genotypes to sowing date and boron fertilisation aimed at controlling sterility in a rice-wheat rotation in Nepal. Plant Soil, 188: 249-256.
Wojcik P, Wojcik M, Treder W (2003). Boron absorption and translocation in apple rootstocks under conditions of low medium boron. J. Plant Nutr. 26(5): 961-968.
Wolf B (1974). Improvements in the azomethine-H method for the determination of boron. Comm. Soil Sci. Plant Anal. 5: 39-44.