
**Journal of Plant Nutrition**
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713597277

# INCREASING SAR OF IRRIGATION WATER AGGRAVATES BORON TOXICITY IN MAIZE (*ZEA MAYS* L.)

Muhammad Imran[a]; Muhammad Aamer Maqsood[a]; Rahmatullah[a]; Shamsa Kanwal[a]
[a] Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan

Online publication date: 15 June 2010

**To cite this Article** Imran, Muhammad , Maqsood, Muhammad Aamer , Rahmatullah and Kanwal, Shamsa(2010) 'INCREASING SAR OF IRRIGATION WATER AGGRAVATES BORON TOXICITY IN MAIZE (*ZEA MAYS* L.)', Journal of Plant Nutrition, 33: 9, 1301 — 1306

**To link to this Article: DOI:** 10.1080/01904167.2010.484091
**URL:** http://dx.doi.org/10.1080/01904167.2010.484091

*Journal of Plant Nutrition*, 33:1301–1306, 2010

ISSN: 0190-4167 print / 1532-4087 online
DOI: 10.1080/01904167.2010.484091

Taylor & Francis
Taylor & Francis Group

# INCREASING SAR OF IRRIGATION WATER AGGRAVATES BORON TOXICITY IN MAIZE (*ZEA MAYS* L.)

**Muhammad Imran, Muhammad Aamer Maqsood, Rahmatullah, and Shamsa Kanwal**

*Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad, Pakistan*



□ *We evaluated the effect of boron (B) application on shoot growth and shoot B concentration and uptake by two maize cultivars ('FHY-396' and 'Sonari') on a loam soil irrigated with water of different sodium absorption ratio (SAR) values [control, 5 and 15 (mmol$_c$ L$^{-1}$)$^{1/2}$]. Plants were harvested after forty days of growth. Shoot dry matter decreased significantly (P $<$ 0.05) with B application due to toxicity marked by leaf injury. Toxic effect of B was further aggravated by increasing SAR of irrigation water. In both cultivars concentration and uptake of B was significantly (P $<$ 0.05) increased over control with B application and SAR of irrigation water. Shoot Ca concentration decreased with increasing SAR and B application. The phenomena of B toxicity and low Ca marked by reduction in shoot dry matter of plants irrigated with high SAR water could be important in management of brackish water used for irrigating crops on arid and semiarid region soils.*

**Keywords:** boron toxicity, calcium deficiency, brackish water, maize cultivars, SAR

## INTRODUCTION

Boron (B) is an essential micronutrient. It has narrow range of sufficiency for plant growth between deficiency and toxicity. Several soil, plant and climatic factors influence its availability and uptake by crops (Moraghan and Mascagni, 1991). Crops are generally produced by artificial irrigation on relatively young soils of arid and semiarid regions of the world. Availability of good-quality irrigation water in sufficient quantities is becoming a serious threat to world crop production in these areas. Hence farmers in these areas are forced to use brackish water, either recycled municipal or poor underground water, for crop production (Qadir and Oster, 2004). Salt injury including B by using brackish water for crop production had been reported

Received 29 September 2008; accepted 23 June 2009.
Address correspondence to M. A. Maqsood, Institute of Soil and Environmental Sciences, University of Agriculture, Faisalabad 38040, Pakistan. E-mail: mohamgill@hotmail.com

(Grieve and Poss, 2000). High sodium adsorption ratio (SAR) of irrigation water inhibits the growth and yield of crops in arid and semiarid regions of the world. Research has revealed that application of B at $\geq$4 mg kg$^{-1}$ soil causes B toxicity to many crops (Gupta, 1972; Rashid and Qayyum, 1991). Excessive B application under saline conditions restricted growth by causing B toxicity in wheat (Holloway and Alston, 1992). But the effect of salinity on B toxicity is still contradictory (Wimmer et al., 2001). For example Ca reduces B toxicity in many crops (Eck and Cambell, 1962) and its excessive amount in growth medium increases B requirement of plants (Havlin et al., 2005). Numerous studies have shown that many agronomic plant species are seriously injured by high $Na^+/Ca^{2+}$ ratios characteristic of high SAR (Kent and Lauchli, 1985). Genotypic variation in crop species and cultivars has been reported with respect to B and Ca uptake (Huo-yan et al., 2003). Keeping this scenario in view, an experiment was designed to study the effect of B on two maize cultivars irrigated by water of different SAR values.



## MATERIALS AND METHODS

Bulk surface (0–15 cm) soil sample was collected from the Research Farm of University of Agriculture, Faisalabad, Pakistan, and air-dried and ground to pass through a 2.0 mm sieve. A sub-sample of the prepared soil was analyzed for various physico-chemical properties. Soil texture as determined by hydrometer method was loam (Gee and Bauder, 1986). Soil had pH 7.98 which was measured in saturated soil paste by Calomel glass electrode assembly using a Beckman pH meter (Beckman Coulter, Brea, CA, USA). Electrical conductivity of saturated soil paste extract was 1.75 dS m$^{-1}$. Sodium adsorption ratio (SAR) of the soil was 9.5 (mmol$_c$ L$^{-1}$)$^{1/2}$. Plant-available B in soil extracted by 0.05 M hydrochloric acid (HCl) was 0.62 mg B kg$^{-1}$ soil. It was determined with a spectrophotometer.

Each of total 36 pots was filled with 5 kg prepared soil. Various treatments comprising of B rates (0 and 4 mg kg$^{-1}$ soil), maize cultivars (hybrid FHY-396 and variety Sonari) and irrigation water having SAR levels of control, 5 and 15 (mmol$_c$ L$^{-1}$)$^{1/2}$ were imposed in triplicate to pots according to completely randomized design (CRD). Waters of different SAR were prepared (Haider and Ghafoor, 1992). Uniform basal dose of 60 mg nitrogen (N), 45 mg phosphorus pentoxide ($P_2O_5$) and 30 mg potassium oxide ($K_2O$) kg$^{-1}$ soil was applied to all pots in solution form. Urea, ammonium dihydrogen phosphate and potassium sulfate were used to apply N, phosphorus (P), and potassium (K), respectively. Boron was applied as boric acid in solution form. After fertigation of NPK fertilizers and B, the soil in each pot was thoroughly equilibrated for one week before its remixing.

Five seeds of each cultivar were sown per pot. Thinning was done after 10 days of sowing to allow two plants per pot to grow. Soils in various pots were kept at field capacity for 40 days with waters of different SAR values. The plants were harvested after forty days of sowing. Those were washed with distilled water. Dry weights of plant samples were recorded after oven drying them to a constant weight at 70°C in a forced air oven. The samples were then ground to 40 mesh with a Wiley mill fitted with stainless steel blades and chamber. The ground samples of shoot were dry-ashed in a muffle furnace at 550°C for 6 hours (Chapman and Pratt, 1961). After dry ashing, samples were digested in sulfuric acid ($H_2SO_4$), filtered and analyzed for B concentration by azomethine- H on a UV- Visible Spectrophotometer (Shimadzu, UV-1201, Shimadzu, Columbia, MD, USA) at 420 nm wavelength. Calcium concentration in plant digest was determined by atomic absorption spectrophotometer (Perkin Elmer Analyst 100; Perkin Elmer, Waltham, MA, USA).

Data were statistically analyzed for significant effect of various treatments on growth, concentration and uptake of B by plants according to three-factor CRD using PC based statistical package (Statistix 8.1, Analytical Software, Tallahassee, FL, USA). Significant treatment means were compared using least significance difference (LSD) method (Steel and Torrie, 1980).

## RESULTS AND DISCUSSION

### Shoot Growth

There was a significant ($P < 0.05$) main and interactive effect of maize cultivars, B application and SAR of irrigation water on shoot dry matter production by plants. Shoot dry matter ranged from 6.37 to 5.13 g plant$^{-1}$ (Table 1). Significantly ($P < 0.05$) more dry matter was produced by hybrid (FHY-396) than variety (Sonari). Shoot dry matter of both maize cultivars decreased significantly ($P < 0.05$) by B application and SAR of irrigation water. Application of B at 4 mg kg$^{-1}$ soil was toxic to plants. It conforms to Gupta (1972). Reduction in shoot dry matter due to B toxicity was further aggravated by increasing SAR (sodicity) of irrigation water. Maize plants are seriously affected by B toxicity (Marcar et al., 1999). Interactive effect of NaCl

**TABLE 1** Shoot dry matter (g) of two maize cultivars irrigated with water of different SAR values with or without boron application. (Means of 3 replications)

| | SAR of Irrigation Water | | | | | |
|---|---|---|---|---|---|---|
| Maize cultivar | Control | | 5 (mmol$_c$ L$^{-1}$)$^{1/2}$ | | 15 (mmol$_c$ L$^{-1}$)$^{1/2}$ | |
| | −B | +B @ 4 mg kg$^{-1}$ | −B | +B @ 4 mg kg$^{-1}$ | −B | +B @ 4 mg kg$^{-1}$ |
| FHY-396 | 6.28 | 6.15 | 6.37 | 5.75 | 5.73 | 5.37 |
| Sonari | 6.19 | 5.47 | 5.66 | 5.34 | 5.35 | 5.13 |

LSD$_{(0.05)}$ (SAR × B level × cultivars) = 0.09.

**TABLE 2** Shoot boron concentration (mg B $kg^{-1}$) of two maize cultivars irrigated with water of different SAR values with or without boron application. (Means of 3 replications)

| Maize cultivar | Control | | SAR of Irrigation Water 5 $(mmol_c\ L^{-1})^{1/2}$ | | 15 $(mmol_c\ L^{-1})^{1/2}$ | |
|---|---|---|---|---|---|---|
| | −B | +B @ 4 mg $kg^{-1}$ | −B | +B @ 4 mg $kg^{-1}$ | −B | +B @ 4 mg $kg^{-1}$ |
| FHY-396 | 24.95 | 73.22 | 33.58 | 78.88 | 37.62 | 88.86 |
| Sonari | 32.32 | 84.28 | 36.54 | 97.52 | 42.48 | 110.09 |

$LSD_{(0.05)}$ (SAR × B level × cultivars) = 3.02.

salinity and excess B on growth and yield had been previously reported by earlier investigators (Wimmer et al., 2003; Sotiropoulos and Dimassi, 2004). Aggravated toxic effect of B on maize plants irrigated with high SAR (low Ca) water was evident from present study.



## Boron Uptake

There was a significant ($P < 0.05$) main and interactive effect of maize cultivars, B application and SAR (sodicity) of irrigation water on concentration and uptake of B by plants. Boron concentration in both cultivars increased significantly ($P < 0.05$) by B application and SAR of irrigation water (Table 2). These results are in agreement with Ismail (2003). Shoot B concentration was significantly ($P < 0.05$) more in variety (Sonari) than in hybrid (FHY-396). The effect was more pronounced with increasing SAR of irrigation water. Similarly increased B concentration in plants was observed by Sotiropoulos et al. (2006) and Alpaslan and Gunes (2001) using NaCl salinity. Irrigation with high SAR water increased sodium relative to calcium in root medium, which decreased calcium availability to plants (Table 3) which is in accordance with Mass and Grieve (1987).

Calcium has negative functional relationship with B in plants (Carpena et al., 2000; Kanwal et al., 2008; Gupta, 1979). Increasing SAR reduced calcium in plants, thereby increasing B concentration and uptake in shoot. Gupta (1972) also reported similar results about Ca and B in plant. Figure

**TABLE 3** Shoot calcium concentration (mg $g^{-1}$) of two maize cultivars irrigated with water of different SAR values with or without boron application. (Means of 3 replications)

| Maize cultivar | Control | | SAR of Irrigation Water 5 $(mmol_c\ L^{-1})^{1/2}$ | | 15 $(mmol_c\ L^{-1})^{1/2}$ | |
|---|---|---|---|---|---|---|
| | −B | +B @ 4 mg $kg^{-1}$ | −B | +B @ 4 mg $kg^{-1}$ | −B | +B @ 4 mg $kg^{-1}$ |
| FHY-396 | 5.57 | 5.08 | 4.82 | 4.78 | 4.39 | 4.24 |
| Sonari | 4.87 | 4.70 | 4.72 | 4.42 | 4.44 | 3.66 |

$LSD_{(0.05)}$ (SAR × B level × cultivars) = 0.35.

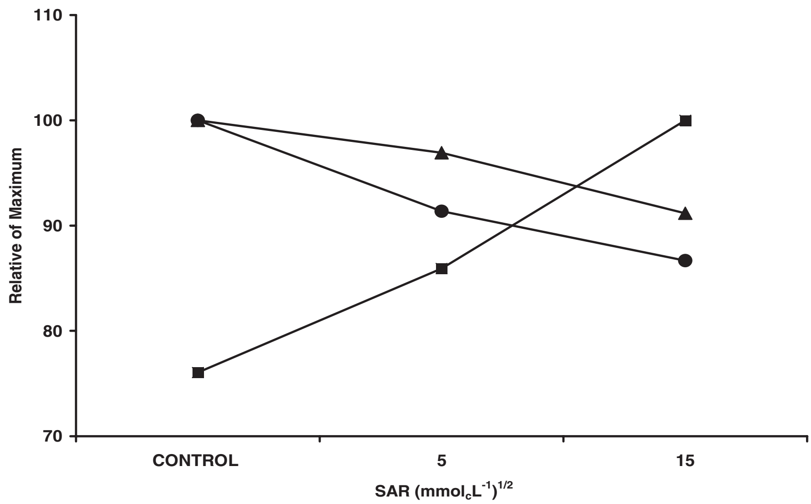


**FIGURE 1** Relative change as percent of maximum in shoot dry matter (•) and shoot B (■) and Ca (▲) concentration in maize variety (Sonari) treated with 0 mg B kg$^{-1}$ soil.

1 shows simultaneous influence of increasing SAR of irrigation water to decrease Ca in plants and increasing B concentration on shoot dry matter. This could be of vital concern for crop production under arid and semiarid climatic conditions where irrigation waters are brackish. Therefore further investigations under field conditions are warranted to fully appreciate the situation.

## REFERENCES

Alpaslan, M., and A. Gunes. 2001. Interactive effects of boron and salinity on the growth, membrane permeability and mineral composition of tomato and cucumber plants. *Plant and Soil* 236: 123–128.

Carpena, R. O., E. Esteben, M. J. Sarro, J. Penalosa, A. Garata, J. J. Lucena, and P. Zornoza. 2000. Boron and calcium distribution in nitrogen-fixing pea plants. *Plant Science* 151: 163–170.

Chapman, H. D., and P. F. Pratt. 1961. *Method of Analysis for Soil, Plants and Waters.* Berkeley, CA: University of California Division of Agricultural Science.

Eck, P., and F. J. Cambell. 1962. Effect of high calcium application on boron tolerance of carnation (*Dianthus caryophyllus* L.). *Journal of American Society of Horticultural Science* 81: 510–517.

Gee, G. W., and J. W. Bauder. 1986. Particle-size analysis. In: *Methods of soil analysis, Part 1: Physical and mineralogical methods*, ed. A. Klute, pp. 383–409. Madison, WI: Soil Science Society of America.

Grieve, C. M., and J. A. Poss. 2000. Wheat response to interactive effects of boron and salinity. *Journal of Plant Nutrition* 23: 1217–1226.

Gupta, U. C. 1972. Interaction effects of boron and lime on barley. *Soil Science Society of America Journal* 36: 332–334.

Gupta, U. C. 1979. Boron nutrition of crops. *Advances in Agronomy* 31: 273–307.

Haider G., and A. Ghafoor. 1992. *Manual of Salinity Research Methods.* Lahore, Pakistan: International Water Logging and Salinity Research Institute.

Havlin, J. L., S. L. Tisdale, J. D. Beaton, and W. L. Nalson. 2005. *Soil Fertility and Fertilizers: An Introduction to Nutrient Management*, 7th ed. New Delhi: Dorling Kinderson (India).

Holloway, R. E., and A. M. Alston. 1992. The effects of salt and boron on growth of wheat. *Australian Journal of Agricultural Research* 42: 987–1001.

Huo-yan, W., W. Yun-hua, D. Chang-wen, X. Fang-sen, and Y.Yu-hua. 2003. Effects of boron and calcium supply on calcium fractionation in plants and suspension cells of rape cultivars with different boron deficiency. *Journal of Plant Nutrition* 26: 789–806.

Ismail, A. M. 2003. Response of maize and sorghum to excess boron and salinity. *Biologia Plantarum* 47: 313–316.

Kanwal, S., Rahmatullah, T. Aziz, M. A. Maqsood, and N. Abbas. 2008. Critical ratio of calcium and boron in maize shoot for optimum growth. *Journal of Plant Nutrition* 31: 1535–1542.

Kent, L. M., and A. Lauchli. 1985. Germination and seedling growth of cotton: Salinity- calcium interactions. *Plant, Cell and Environment* 8: 155–159.

Marcar, N. E., J. Guo, and D. F. Crawford. 1999. Response of *Eucalyptus camaldulensis* Dehnh., *E. globlus* Labill. ssp. globulus and *E. grandis* W. Hill to excess boron and sodium chloride. *Plant and Soil* 208: 251–257.

Mass, E. V., and C. M. Grieve. 1987. Sodium-induced calcium deficiency in salt-stressed corn. *Plant, Cell and Environment* 10: 559–564.

Moraghan, J. T., and H. J. Mascagni. 1991. Environmental and soil factors affecting micronutrient deficiencies and toxicities. In: *Micronutrients in Agriculture*, 2nd ed, eds. J. J. Mortvedt, F. R. Cox, L. M. Shuman, and R. M. Welch, pp. 371–425. Madison, WI: Soil Science Society of America.

Qadir, M., and J. D. Oster. 2004. Crop and irrigation management strategies for saline-sodic soils and water aimed at environmentally sustainable agriculture. *Science of the Total Environment* 323: 1–19.

Rashid, A., and F. Qayyum. 1991. Micronutrients status of Pakistan soils and its role in crop production. Final Report of Cooperative research programme 1983–90. Islamabad: National Agricultural Research Centre.

Sotiropoulos, T. E., and K. N. Dimassi. 2004. Response to increasing rates of boron and NaCl on shoot proliferation and chemical composition of *in vitro* kiwifruit shoot cultures. *Plant Cell, Tissue and Organ Culture* 79: 285–289.

Sotiropoulos, T. E., S. Fotopoulus, K. N. Dimassi, V. Tsirakoglou, and I. N. Theiros. 2006. Response of the pear rootstock to boron and salinity in vitro. *Biologia Plantarum* 50: 779–781.

Steel, R. G. D., and J. H. Torrie. 1980. *Principles and Procedures of Statistics.* New York: McGraw-Hill.

Wimmer, M. A., K. H. Muehling, A. Lauchli, P. H. Brown, and H. E. Goldbach. 2001. Interaction of salinity and boron toxicity in wheat (*Triticum aestivum* L.). In: *Developments in Plant and Soil Science (Plant Nutrition)*, eds. W. J. Horst, M. K. Schenk, A. Bürkert, N. Claassen, H. Flessa, W. B. Frommer, H. Goldbach, H. W. Olfs, V. Römheld, B. Sattlemacher, U. Schmidhalter, S. Schubert, N. V. Wirén, and L. Wittenmayer, pp. 426–427. Amsterdam: Springer.

Wimmer, M. A., K. H. Muehling, A. Lauchli, P. H. Brown, and H. E. Goldbach. 2003. The interaction between salinity and boron toxicity affects the subcellular distribution of ions and proteins in wheat leaves. *Plant, Cell and Environment* 26: 1267–1274.