Effects of high boron concentration on boron uptake and growth of pistachio seedlings

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Abstract
Boron (B) is one of the important plant micronutrient elements and plays a significant role in physiological and biochemical processes. The poor drainage of saline soils maybe responsible for the excessive accumulation of B in the soil solution. Toxicity symptoms often occur because of additions of B via irrigation water and lack of drainage. The present study, as a pot experiment with pistachio plants was conducted to study the effect of increasing boron application on nutritional status and shoot growth under greenhouse conditions. Seven treatments consisted of B levels (0, 2.5, 5, 10, 20, 40 and 60 mg/kg soil as H_3BO_3) Treatments were arranged in a factorial manner in a completely randomized design with three replications. Results of this study clearly show that relatively high B content might reduce the adverse effects of B and consequently improve plant growth. It is suggested that this finding be verified under field conditions. Moreover, in future studies of boron stress should have attentions to soil pH, separation of young and old leaves, modeling of B adsorption by sorts of local soils and role of B in operative enzymes of oxin metabolism.

Key Words
Pistachio, salinity, boron.

Introduction
The role of macro and micronutrients is crucial in crop nutrition and thus important for achieving higher yields. Boron (B) is an essential micronutrient for vascular plants and diatoms (Marschner 1995). The role of B in plant is still the least well understood of all mineral nutrients (Mengel *et al* 2001). Several reports in the literature indicated that the supply of B in the substrate may affect the behavior of other micronutrients in plants, but the specific function of B on the behavior of other micronutrients is not well defined. Presumably, this is due to its complex chemistry in soil and little known physiological and biochemical functions in plants. A major constraint to cereal crop production is the element boron (B), which is often associated with marine argillaceous sediments (Erd 1980). Whilst B is a plant micronutrient at low concentrations, high concentrations are associated with phytotoxicity. Plant tolerance mechanisms associated with B toxicity are not well understood but thought to be related to the restriction of B uptake by the roots (Marschner 1995; Hayes and Reid 2004). Grain yield can be affected by concentrations above 1.9 mg/ml B in soil solution (Aitken and McCallum 1988), with yield reductions of 17% in barley (Cartwright *et al.* 1984). There are more than 420000 hectares of nonbearing and bearing pistachio trees (*pistacia vera* L.) mainly in Kerman province in Islamic Republic of Iran (Tajabadipour *et al.* 2005). Pistachio trees are known to grow and fruit under high drought and salt-stress conditions in the desert area of the I.R. of Iran (Spiegel-Roy *et al.* 1977). Despite the economic importance of this crop (LeBaron 1973), very little information is available on its nutritional requirements. The objectives of the present study were: (1) to determine uptake of B into pistachio leaves, stems, and roots from soil amended with various B levels (2) to determine toxicity level of B to pistachio trees (3) to evaluate effects of B toxicity on dry matter yield and to evaluate the effects of boron levels on chemical composition of pistachio seedlings

Methods
The experiment was conducted with a calcareous soil collected from the top 30 cm layer of a region 35 Km South of Sirjan, Kerman province, Islamic Republic of Iran.

The experiment was laid out in Randomized Complete Block design with three replications. Analysis of soil after air-drying and grinding to pass through a 2-mm sieve revealed the following chemical properties: This soil had a sandy loam texture, 27 % CaCO3, pH of 7.8, 2.34 % organic matter, 100 kg/ha exchangeable potassium (K), 5.5 kg/ha phosphorus (P) as measured by the standard methods given in Olsen. DTPA extractable Zn concentration was 0.7 mg/kg and Mannitol- CaCl extractable B concentration was 0.02 mg/kg. Seven different doses of B (0, 2.5, 5, 10, 20, 40 and 60 mg/kg as H_3BO_3) were applied to the plastic pots which filled with 5 kg of air-dried, <2 mm soil. 100 mg/kg N (urea form), 40 mg/kg P (in KH_2PO_4 form) were applied uniformly to each pot. Boron was added to bags based on experimental treatments. Each sample was mixed thoroughly and transferred to a plastic pot before planting. Pistachio seeds (*cv*. Badami) were placed in muslin sacks and pre-treated for 24 hours with 2 g/L Benomil solution. Eight germinated seeds were planted in each pot and irrigated with distilled water, after 25 days seedlings were thinned to four per pot. Seedlings grew for 185 days in a greenhouse with average daily temperature of 32°C. Pots were kept at field capacity by irrigating with distilled water every day. After the growth period, seedlings were cut at the soil surface and roots was separated and washed free of adhering soil particles. Leaf, stems, and root dry weights were recorded. Harvested plants dried at 70 °C for 72 h in an oven, weighed and ground for analysis. The ground plant samples were dry-ashed at 550 °C, dissolved in 2 N hydrochloric acid and made to volume with hot distilled water. Boron determination was made by the azomethin-H colorimetric method (Gupta 1983). Statistical analyses of all the data collected during investigations were performed by SPSS computer package and the means were compared by the LSD-test of significance.

Results

The effect of boron (B) applications on dry matter yield of pistachio seedlings

Analysis of variance indicated that dry matter yield of pistachio seedlings was significantly affected with the application of increasing rates B in the soil (p=0.05). With lower level of boron dry weight of leaf, stem and root of seedlings increased. But, high levels of boron leaf, stem, and root dry weights decreased significantly (Table 1). For instance, at the level of 60 mg/kg B, leaf, stem and root dry matter yield of seedlings decreased 52%, 53% and 65% respectively in comparison to control,. Maybe the positive effect of B with increasing dry weight is because of its impact on increasing activity of enzymes and supplying the products of photosynthesis, and its negative effect is because physiological problems and protoplasm injury due to boron toxicity (Gary *et al*. 1979). Eraslan *et al*. (2004) concluded that B uptake of plants increases in Zn deficient soils, therefore B toxicity develops and plant growth is adversely affected by this soil situation.

The effect of boron (B) applications on B concentrations of pistachio seedlings

Leaf, stem, and root B concentrations increased with increasing boron levels. For example, with application of 60 mg/kg B soil, leaf , stem and root B concentration increased by 8.2, 3.1 and 4 times relative to control. The increase of leaf B concentration was higher than that of stem and root (Figure 1). This tendency of B to accumulate at leaf indicates that B may prohibit movements of other nutrients from root to shoot. Result show that, B shifted to leaf and is sedentary in the phloem and cannot move to tissues (Eaton 1944). Boron in the phloem of some trees such as pistachio and orange is sedentary, therefore could not distribute and this can be a defensive mechanism of these trees against B toxicity. B concentration in all parts of plants increased with increasing level of B. The same results were obtained for various plants (Kamali and Childers 1970; Papadakis *et al*. 2003; Sotiropoulos *et al*. 1999; Shelp 1988).

Ca/B Ratios

Calcium and Boron concentration affect plant needs and availability of each other for normal growth of plants (Tisdale *et al*. 1985). Types of plant genotype also have effects on absorption of Ca and B (Huo-Yan *et al.* 2003). Gupta (1993) concluded that, maybe the Ca/B ratio can indicate the show boron situation of plants. Gupta (1984) reported that, with increasing boron concentration the Ca/B ratio reduces significantly. Increasing boron levels reduce the Ca/B ratio of leaf tissue of pistachio seedlings (Figure 2). The average of this ratio from 129/61 at level of 0 mg/kg B, comes to 8/98 at level of 60 mg/kg B. Ratios higher than 20/13 (0-10 mg/kg B) corresponded to little B toxicity in pistachio seedlings, but at lower ratios (20-60 mg/kg B) medium caused or high toxicity of boron reduced growth and caused leaf symptoms. The Ca/B ratio indicates that absorption of Ca depends on boron concentrations of plant (Shamsa *et al*. 2008). Gupta *et al.* (1985) reported that a Ca/B ratio of 10 to 45 is toxic for barley and a ratio of 185 is suitable for growth of barley. It seems that according to the salinity and high level of NaCl in soils of pistachio regions we cannot use this ratio as a suitable scale, because the effect of Na on Ca concentrations changes continuously.

Table 1. Influence of boron on leaf, stem and root dry weights (g/pot) of pistachio seedlings.

parameters	B level (mg/kg soil)							Lsd (0.05)
	0	2.5	5	10	20	40	60	
Leaf	2.39	2.48	2.55	2.23	2.15	1.59	1.15	0.26
Stem	2.49	2.71	2.82	2.39	1.86	1.69	1.17	0.54
root	3.95	4.25	4.96	4.35	3.62	2.09	1.38	0.64

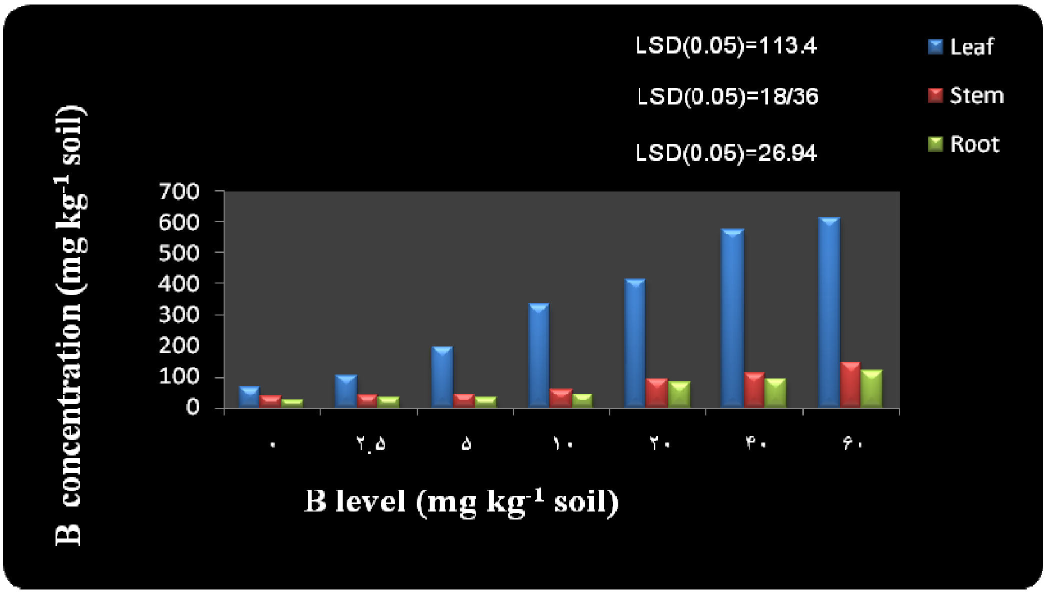

Figure 1. Influence of boron application on B concentrations (mg/kg) of leaf, stem and root.

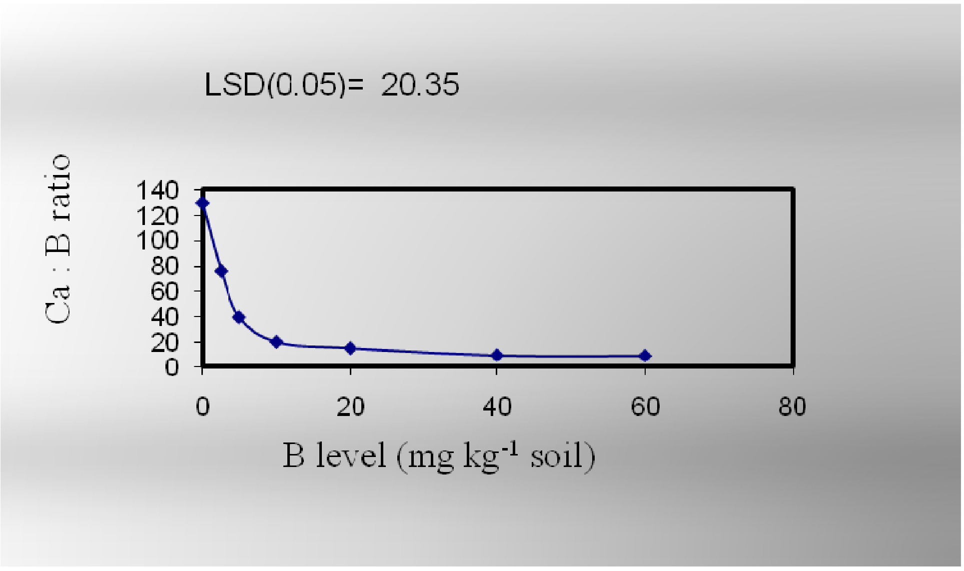

Figure 2. Influence of boron application on the Ca/B ratio of leaf tissue of pistachio seedlings

Conclusion

Results of this study, show that pistachio yields increase with appropriate application of B. The establishment of optimal nutritional regimes will be an important contribution to the determination of pistachio reactions to soil boron.

References

Marschner H (1995) Mineral Nutrition of Higher Plants. Academic Press, London.

Mengel K, Kirkby EA, Kosegarten H, Appel T (2001) Principles of plant nutrition, 5th ed. (Klwer Academic publisher, Dordrecht).

Erd RC (1980) The minerals of boron. In 'Mellor's Comprehensive Treatise on Inorganic and Theoretical

Chemistry'. (Ed R Thompson) pp. 7-71. (Longman, New York).

Aitken RL, McCallum LE (1988) Boron toxicity in soil solution. *Australian Journal of soil Research* **26,** 605-610.

Tajabadi pour A, Sepaskhah AR, Maftoun M (2005) Plant water relations and seedling growth of three pistachio cultivars as influenced by irrigation frequency and applied potassium. *Journal of plant nutrition* **28,** 1413-1425.

LeBaron AD (1973) Projecting Iranian agricultural supply and demand. *Iranian Journal of Agricultural Research* **2,** 2-11.

Gary OK, Sharma AN, Kona, GRSS (1979) Effect of boron on the pollen vitaly and yield of rice plants (*Oryza sativa* L. Var. Jaya). *Plant Soil* **52,** 591-594.

Eraslan F, içek N, Güneri E (2004) The effect of boron toxicity and gypsium application on growing ant nutrient element contents of pepper. Turkey 3th National Fertilizer Congress, Agriculture- Industry- Environment, 343- 350, 11- 13 October, Tokat, Turkey (in Turkish).

Mengle K, Kirekby EA (1987) Principles of plant nutrition. 4th ed. International potash Institue, Bern, Switcherland. p. 559-572.

Tisdale SL, Nelson WL, Beaton, JD (1985) Soil fertility and fertilizers. 4th ed. Macmillan Publishing Co, NewYork. 754p.

Huo-Yan W, Yan-hua W, Chang-Wen D, Fang-Sen X, Yu-Hua Y (2003) Effect of boron and calcium supply on calcium fractionation in plants and suspension cells of rape cultivars with different boron deficiency. *Soil Sci. Plant Nutr*. **26,** 789-806.

Gupta SP, Gupta VK (1984) Influence of zinc on calcium, magnesium, sodium, potassium and phosphorous nutrition of soybean (*Glycine max*) in sodic soils. *Indian J. Ecol*. **11,** 236-242.

Gupta UC (1993) Deficiency, sufficiency, and toxicity levels of boron in crops. In 'Boron and its role in crop production'. (Ed UC Gupta) pp.137- 145. (CRC Press, Boca Raton, FL).

Shamsa K, Aziz RT, Magsood MA, Abbas N (2008) Critical ratio of calcium and boron in maize shoot for optimum growth. *Soil Sci. Plant Nutr*. **31,** 1535-1542.

Gupta UC, James YW, Campbell CA, Leyshon AJ, Nicholaichuk W (1985) Boron toxicity and deficiency: A review. *Can. J. Soil Sci.* **65,** 381-409.

Kamali A, Childers NF (1970) Growth and fruiting of peach in sand culture as affected by boron and fritted form of trace elements. *J. Am. Soc. Hort. Sci*. **95,** 652-656.

Papadakis IE, Dimassi KN, Therios, IN (2003) Response of two citrus genotypes to six boron concentrations: concentration and distribution of nutrients, total absorption, and nutrient use efficiency. *Aust. J. Agric. Res.* **54,** 571-580.

Shelp BJ (1988) Boron mobility and nutrition in broccoli (*Brassica oleracea* var. italica). *Ann. Bot.* **61,** 83-91.

Sotiropoulos TE, Therios IN, Dimassi KN (1999) Calcium application as a means to improve tolerance of kiwi fruit *(Actindia deliciosa L.)* to boron toxicity. *Scientia Horticulturae* **81,** 443-449.