Indian J. Plant Physiol., Vol. 14, No. 2, (N.S.) pp. 200-204 (April-June, 2009)

SHORT COMMUNICATION

BORON STRESS INFLUENCES ECONOMIC YIELD AND QUALITY IN CROP SPECIES

PRATIMA SINHA*, NEENA KHURANA AND NIRMALA NAUTIYAL

Botany Department, Lucknow University, Lucknow-226 007, (U.P.) India

Received on 10 Feb., 2009, Revised on 16 June, 2009

Boron plays an important role in improving the economic yield and quality of the produce. Studies conducted in refined sand at graded B levels (ranging from acute deficiency to excess) reveal that both deficiency and excess of B affect the seed quality of groundnut (*Arachis hypogea* L.) Var T3, sesame (*Sesamum indicum* L.) cv. T4, sunflower (*Helianthus annuus* L.) cv. NSFH-592, pigeonpea (*Cajanus cajan* L.) cv. UPAS, soybean (*Glycine max.* L.) cv. JS 80-21 , blackgram (*Vigna mungo* L.) cv. T-9, and quality of fruit in tomato (*Solanum lycoparsicum* L.) var. DL-3, tubers in potato (*Solanum tuberosum* L.) cv. TPS and carrot root (*Daccus carota* L.) cv.EN. At 0.3 µM B visible foliar symptoms of boron deficiency initiated in young leaves as interveinal chlorosis with marked reduction in growth. The affected leaves became thick, brittle and deshaped later turning to necrotic in prolonged deficiency. Boron toxicity symptoms initiated at > 30 µM B in old leaves as chlorotic spots along with the margins. These spots enlarged, coalesced and turned necrotic. Biomass, weight of pods and seeds were maximum at 30 µM B. Low (<30 µM B) as well as high (> 30 µM B) B reduced the economic yield and deteriorated the quality of the produce by lowering the concentration of starch, protein in seeds and storage organs, lycopene and ascorbic acid in tomato fruits and oil in oil seeds. The concentration of sugars and phenols was enhanced in B deficiency in all crops except in sunflower, potato and carrot where the of sugar content decreased in B stress (deficiency as well as excess B) condition whereas excess B reduced the sugar concentration in sesame and pigeonpea seeds. The concentration of boron in different parts paralleled with the increase in boron supply. Critical B concentration has been worked out in the edible and economically important plant part for each species.

Boron is an essential micro nutrient for higher plants has been established long back. B deficiency is a major problem in Indian soils. Deficiency of B ranges from 1-84% with mean of 33% being maximum in Teesta alluvial soil. Its deficiency has widely found in highly calcareous soils of Bihar, Tamil Nadu, eastern UttarPradesh, Saurashtra, sandy soil of Haryana and Rajasthan, Hill and sub mountaineous soils of north Himalayan and north eastern states and in red soils of Orissa, Karnataka and Andhara Pradesh (Singh 2006, Singh *et al*. 2009). In India certain pockets of agricultural land has been found to be high in B. Generally, B toxicity occurs in soils inherently high in B, over-fertilized with minerals high in B, receiving residues from fossil combustion, being used as disposal sites of B-containing waste materials, and irrigated with water high in B content (Keles *et al*. 2004). Boron stress not only affects the economic yield but also quality of the produce (Shorrocks 1991). It is essential for increasing the pollen producing capacity of anthers and pollen grain viability (Shen *et al*. 1995). However, the literature on the effect of B stress on yield and quality of various crops is rather scanty. Hence, in the present study, the values of deficiency, threshold of deficiency, threshold of toxicity and toxicity in seeds / fruits were

*Corresponding author, E-mail: pratimasinha2006@rediffmail.com

determined in some oil crops, legumes and vegetables. Furthermore, changes in quality of yield by variation in boron supply when grown in refined sand at graded levels of B were also determined.

Experiments were carried out in refined sand (Agawala and Sharma 1976) in glass house at ambient temperature (23-35^o C) at six levels of B (Boric acid), viz. 0.3, 1.5, 3.0, 30, 150 and 300 μM. Groundnut, sesame, sunflower, pigeonpea, soybean, blackgram, tomato, potato and carrot were grown in purified sand. There were 4 replications for each treatment. The composition of the nutrient solution was based upon the 'Long Ashton formula' described by Hewitt (1966) and modified by Agawala and Sharma (1976). Nutrient solution was supplied daily. A periodic record was made of visible symptoms of low as well as excess B. Plants were sampled for dry matter and tissue boron analysis (wolf 1971). The oven dried plant material was digested by wet digestion using HNO_3, $HClO_4$ (Piper 1942). In seeds, the estimation of sugars, starch, phenol and protein were made in fresh samples according to Sinha and Chatterjee (1994) and oil, lycopene and ascorbic acid concentration were estimated according to AOAC (1965). All determinations were carried out in triplicate and data were analysed statistically by ANOVA. Critical concentration of B in different plant part was estimated according to Marschner (2002).

Plants at low (< 30 μM B) as well as high (> 30 μM B) boron showed growth reduction as compared to normal (30 μM) B. Plants at deficient B developed visible symptoms of boron deficiency as chlorosis of young leaves which later became necrotic and withered. The stem of the affected plants were short and leaf size was reduced significantly. These effects were similar to other B deficiency symptoms described in other crop plant species (Camacho-Cristobal *et al*. 2005). Boron toxicity symptoms appeared at >30 μM B as depression in growth, development of marginal chlorosis and reduction in size of older leaves. These chlorotic areas later coalesced and became necrotic (Marschner 2002). At low and excess boron flowering was delayed and flowers failed to mature and shed prematurely. Boron toxicity stress led to retarded seed/fruit formation. Poor seed / fruit formation in B deficiency is attributed to a role of boron in anther development and pollen tube growth and fertilization. In acute boron deficiency or excess, pods/seeds and fruits formation were reduced significantly (Table 1). The concentration of boron

Table 1. Influence of boron stress on economic yield and tissue B concentration of produce in some plant species (SE ±).

Crops	Plant part	Economic / Seed yield (g plant^{-1})			B concentration (μg g^{-1} dw)		
		C	L	H	C	L	H
Groundnut	Kernel	12.08±0.09	3.68 (-95)±0.06	0.90 (-93)±0.001	20.0±0.03	2.0 (-90)±0.05	80.0 (+300)±0.09
Sesamum	Seeds	6.20±0.06	2.00 (-67)±0.001	3.80 (-38)±0.11	8.9±0.02	2.8 (-68)±0.001	24.7 (+177)±0.21
Sunflower	Seeds	7.20±0.01	1.01(-86)±0.002	5.20 (-28)±0.05	22.0±0.05	1.0 (-95)±0.0	59 (+168)±0.11
Pigeonpea	Seeds	30.90±0.09	8.34 (-73)±0.03	5.20 (-83) ±0.01	9.2±0.01	3.2 (-66)±0.01	18.5 (+101)±0.10
Soybean	Seeds	7.41±0.0	2.10 (-72)±0.006	5.20 (-30)±0.07	22.9±0.07	5.7 (-75)±0.01	45.3 (+198)±0.17
Blackgram	Seeds	2.31±0.03	0.12 (-95) ±0.04	1.16 (-50)±0.002	22.0±0.09	2.9 (-87)±0.02	40.5 (+84)±0.19
Tomato	Fruits	66.23±0.02	20.53 (-69)±0.16	25.80 (-61)±0.09	29.6±0.18	3.0 (-90)±0.02	160.0 (+441)±0.12
Potato	Tubers	20.00±0.07	12.8 (-36)±0.11	4.40 (-78)±0.02	20.5±0.11	5.1 (-75)±0.04	485.2 (+1367)±0.20
Carrot	root	5.30±0.10	1.15 (-78)±0.06	1.91 (-64)±0.001	10.0±0.12	3.7 (-63)±0.07	24.3 (+143)±0.0

C = Control, L = low B (0.3-3.0 μM B),H = high B (300- 600 μM B), Data in parenthesis represent % decrease (-) / increase (+) over control .

Table 2. Influence of boron stress on some quality parameters in edible part of some plant species (SE ±).

Crops Plant parts	Sugars (% fw)			Starch (% fw)			Phenols (% fw)			Protein (% fw)			Oil (% fw)			Lycopene (% fw)			Ascorbic acid (% fw)		
	C	L	H	C	L	H	C	L	H	C	L	H	C	L	H	C	L	H	C	L	H
Groundnut Kernel	12.08 ±0.03	3.68 ±0.05 (-95)	0.90 ±0.001 (-95)	-	-	-		-	-	28.90 ±0.91	24.40 ±0.03 (-16)	22.0 ±0.051 (-24)	49.0 ±0.23	29.3 ±0.14 (-40)	34.0 ±0.1 (-31)	-	-	-	-	-	-
Sesamum Seeds	4.90 ±0.02	6.00 ±0.04 (+22)	4.60 ±0.61 (-6)	4.40 ±0.11	2.86 ±0.21 (-35)	2.68 ±0.11 (-39)	0.017 ±0.004	0.02 ±0.001 (+19)	0.006 ±0.0 (-68)	-	-	-	42.0 ±0.22	31.0 ±0.11 (-27)	34.4 ±0. 09 (-18)	-	-	-	-	-	-
Sunflower Seeds	0.024 ±0.005	0.016 ±0.001 (-31)	0.023 ±0.007 (-4)	5.30 ±0.041	3.66 ±0.03 (-31)	4.56 ±0.002 (-14)	0.016 ±0.001	0.023 ±0.003 (+46)	0.009 ±0.0 (-44)	-	-	-	31 ±0.31	6.82 ±0.10 (-88)	21.4 ±0.56 (-31)	-	-	-	-	-	-
Pigeonpea Seeds	1.34 ±0.01	1.90 ±0.11 (+42)	1.10 ±0.013 (-18)	50 ±0.01	40 ±0.01 (-20)	45 ±0.01 (-10)	0.012 (+82)	0.022 ±0.031 (+64)	0.019 ±0.0	22.8 ±0.38 (-39)	13.90 ±0.22 (-43)	13.0 ±0.31	-	-	-	-	-	-	-	-	-
Soybean Seeds	0.16 ±0.03	0.21 ±0.021 (+33)	0.18 ±0.011 (+11)	4.20 ±0.09	2.90 ±0.11 (-31)	3.28 ±0.21 (-22)	0.009 ±0.0	0.013 ±0.001 (+54)	0.014 ±0.002 (+64)	8.30 ±0.42	3.90 ±0.31 (-40)	5.60 ±0.41 (-60)	18.9 ±0.09	14.5 ±0.11 (-23)	-	-	-	-	-	-	-
Black-gram Seeds	0.08 ±0.004	0.130 ±0.021 (+63)	0.113 ±0.101 (+41)	4.0 ±0.061	2.68 ±0.02 (-33)	3.16 ±0.041 (-21)	0.006 ±0.0	0.009 ±0.001 (+45)	0.008 ±0.001 (+32)	24.88 ±0.41	9.0 ±0.21 (-64)	12.6 ±0.51 (-49)	-	-	-	-	-	-	-	-	-
Tomato Fruits	2.02 ±0.11	1.40 ±0.07 (+42)	1.65 ±0.101 (+17)	0.051 ±0.008	0.015 ±0.002 (-71)	0.050 ±0.0 (-2)	0.006 ±0.0	0.0086 ±0.002 (+43)	0.011 ±0.001 (+84)	-	-	-	-	-	-	7.19 ±0.0	2.60 ±0.01 (-64)	5.84 ±0.02 (-19)	0.18 ±0.001	0.12 ±0.0 (-34)	0.29 ±0.02 (-59)
Potato Tubers	0.27 ±0.001	0.21 ±0.061 (-22)	0.022 ±0.003 (-92)	21.49 ±0.54	6.27 ±0.09 (-71)	6.22 ±0.07 (-71)	0.014 ±0.001	0.020 ±0.004 (+43)	0.016 ±0.002 (+14)	-	-	-	-	-	-	-	-	-	-	-	-
Carrot root	0.97 ±0.08	0.097 ±0.001 (-35)	0.85 ±0.21 (-12)	2.52 ±0.011	0.40 ±0.081 (-84)	1.01 ±0.06 (-60)	0.0018 ±0.0	0.0034 ±0.0 (+89)	0.0032 ±0.001 (+78)	-	-	-	-	-	-	-	-	-	-	-	-

C = Control , L = low B (0.3-3.0 µM B), H = High B (300- 600 µM B). Data in parenthesis represent % decrease (-) / increase (+) over control .

increased with an increase in boron supply. The higher concentration of boron was found in leaves than in seeds and fruits might be due to higher loss of water from shoots resulting in uneven distribution in various plant parts (Marschner 2002).

The growth and yield of plant was best at 30 μM B which is usually the normal boron supply for several crop plants in sand culture and at levels lower and higher than this the growth and yield were lowered variably. This might be due to low protein synthesis and disturbed carbohydrate metabolism as has been suggested by Mengel and Kirkby (2001) for several plant species. In excess boron the decrease in biomass is most probably due to greater accumulation of B and inhibition in growth and development due to excess boron.

The accumulation of sugars in seeds/fruits in boron deficient as well as excess B might be due to improper utilization of sugars (Table 2) in seeds/fruits. This might be partially responsible for deterioration of produce quality under low and excess boron supply. A marked reduction in starch concentration in boron stress plants might be due to disturbed synthesis of enzyme involved in starch production. These observations are in accordance with some of the earlier reports (Zhao and Oosterhuis 2003). The accumulation of phenols (Table 2) in low and high boron treated plants might be due to enhanced synthesis and inhibited utilization of phenols in cell wall synthesis which is responsible for deterioration of quality of produce (Cakmak and Romheld 1997). The reduction in oil content in seeds of some oil crops (Table 2) might explain the indirect involvement of boron in fat synthesis (Marschner 2002). The decreased concentration of sugars in low and excess sunflower seeds, potato tubers and carrot root, might be due to low sink activity of shoots suffering from boron stress (Dugger1985). The reduction in concentration of lycopene (Table2) and ascorbic acid in tomato fruits is also responsible for deteriorating the quality of the produce. The values of deficiency, threshold of deficiency, threshold of toxicity and toxicity differ with plant species (Table 3).

It is concluded from that low as well as excess boron deteriorated the yield as well as quality of the produce. The critical values of boron in edible parts will be helpful in predicting the deficiency and toxicity of boron and for intensifying agronomic practices for optimizing in economic yield of these crop species.

Table 3. Values of deficiency, threshold of deficiency, threshold of toxicity and toxicity in some plant species.

Crops	Plant part	Days after sowing	Deficiency	Threshold of deficiency	Threshold of toxicity	Toxicity
			μg B g^{-1} dw			
Groundnut	Kernal	141	6.2	11.5	50.0	72.0
Sesame	Seeds	77	3.5	5.4	15.5	42.0
Sunflower	Seeds	110	3.2	12.0	30.0	58.0
Pigeonpea	Seeds	139	3.8	8.2	52.8	102.0
Soybean	Seeds	101	6.4	10	34	89.0
Blackgram	Seeds	73	9.0	25.0	58.0	102.0
Tomato	Fruits	145	5.0	10.5	70.0	110.0
Potato	Tubers	76	5.0	8.6	24.0	52.0
Carrot	root	86	4.2	10.6	34.0	69.0

REFERENCES

Agarwala, S.C. and Sharma, C.P. (1976). Pot sand culture technique for the study of mineral nutrition element deficiencies under Indian conditions. *Geophytology* **6:** 356-367.

AOAC. (1965). Official and Tentative Methods of Analysis of the Association of official Agricultural chemists, (edn. 11). Washington DC, USA.

Cakmak, K. and Romheld, V. (1997). Boron deficiency induced impairments of cellular functions in plants. *Plant and Soil* **193:** 71-83.

Camacho-Cristobal, J.J., Maldonado, T.M. and Gonzalez-Fontes, A. (2005). Boron deficiency increase putrescine levels in tobacco plants. *J. Plant Physiol.* **162:** 921-928.

Dugger, W.M. (1983). Boron in plant metabolism. In : A. Lauchli and R.L. Bieleski (eds.), Encyclopedia of Plant Physiology, Vol 15 B, pp. 626-650. Springer-Verlag Berlin.

Hewitt, E.J. (1966). Sand and Water Culture Methods Used in the Study of Plant Nutrition. Tech. Commun. 22. Com. Bur. Hort. Plantn. Crops, England.

Keles, Yüksel, Öncel, Isil and Yenice, Nilgün (2004). Relationship between boron content and antioxidant compounds in *Citrus* leaves taken from fields with different source. *Plant and Soil* **265:** 345-353.

Marschner, H. (2002). Mineral Nutrition of Higher Plants. Academic Press, New York.

Mengel, K and Kirkby, E.A. (2001). Principles of Plant Nutrition, (4th Edition). Int. Potash Inst, Bern, Switzerland.

Piper, C.S. (1942). Soil and Plant Analysis: Monograph. Waite Agricultural Research Institute, The University, Adelaide. Australia

Shen, Z , Zhang, X., Wang, Z. and Shen, K. (1995). On the relationship between boron nutrition and development of anther (pollen) in rapeseed plant. *Zhongguo Nougye Kexue* (Beijing) **27:** 51-56.

Shorrocks, V.M. (1991). Thialand-boron first amongst micronutrients. *Micronutr. News Inform.* **11:** 4-6.

Sinha, P. and Chatterjee, C. (1994). Influence of boron on yield and grain quality of pearlmillet. *Indian J. Agric. Sci.* **64:** 836-840.

Singh, M.V. (2006). Emerging boron deficiency in soils and crops in India and its management. 18th World Congress Soil Science July 9-15, Philadelphia, Pennsylvania. USA.

Singh, M.V., Wanjari, R.H., Sharma, S.P., Singh, A.P., Patel, K.P. and Bhupalraj, G. (2009). Relative efficiency of boron sources in improving Cauliflower(*Brassica oleracea* L.) yield and its uptake in Indian soils. In: Proceedings. XVI International Plant Nutrition Colloq. University of California, Davis. Department of Plant Science.

Wolf, B. (1971). The determination of boron in soil extracts, plant materials, composts, water and nutrient solutions. *Soil Sci. Plant Anal.* **2:** 363-374.

Zhao, D. and Oosterhuis, D.M. (2003). Cotton growth and physiological responses to boron deficiency. *J. Plant Nutr.* **26:** 855-867.