INTERNATIONAL JOURNAL OF AGRICULTURE & BIOLOGY
ISSN Print: 1560–8530; ISSN Online: 1814–9596
15–587/2016/18–1–68–72
DOI: 10.17957/IJAB/15.0063
http://www.fspublishers.org

Full Length Article

Influence of Soil Applied Boron on the Boll Retention, Productivity and Economic Returns of Different Cotton Genotypes

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Abstract

Cotton is major contributor in fiber and edible oil production of Pakistan. However, its growth and development is severely hampered by boron (B) deficiency in semi-arid regions of the country. This experiment was conducted to determine the influence of soil applied B (0.5, 1.0, 1.5, 2.0 and 2.5 kg B ha^{-1}) on the performance of cotton genotypes FH-113, MNH-786 and CIM-496. Boron application significantly improved the boll retention, cotton seed yield, ginning out turn and net economic returns of cotton genotypes. In this regard, soil application at 1.5 kg B ha^{-1} was the most effective. Amongst the tested genotypes, FH-113 performed better than others. In conclusion, soil application of B at 1.5 kg ha^{-1} was the most cost effective in improving the yield and yield contributing traits of cotton and fetching the maximum net economic returns.

Keywords: Boron; Cotton; Boll retention; Seed cotton yield; Economic returns

Introduction

Cotton is the most important fiber crop of Pakistan. Besides its high valued fiber, it contributes 78% in domestic edible oil production (Govt. of Pakistan, 2014). Balanced fertilization and availability of all the macro and micronutrients are among the leading yield contributing factors. Increased cropping intensity in response to the high demand of food and fiber for ever increasing human population has badly affected the native supply of nutrients by the soils. Fertilizer application practices in Pakistan are predominantly for N, P and K. Boron (B) has become an important micro-nutrient for cotton production (Shorrocks, 1992) because its deficiency leads to poor performance of the crop for growth and development parameters especially in semi-arid regions like Pakistan. Low soil inherent B reduces the leaf photosynthetic rate, their translocation through petiole vascular bundles and thus causes stunted plant growth (Liu *et al*., 1986; Wang and Zhou, 1992) resulting in substantial decrease in lint yield (Zhao and Oosterhuis, 2003). There is evidently a connection between photosynthetic production of specific sugars and mobility of B from the xylem to the phloem and subsequent transfer to various plant parts and organs (Brown and Shelp, 1997). Boron deficiency in cotton affects both vegetative and reproductive growth. During the vegetative stage, B deficiency may lead to the retardation of growth, death of growing meristems and inhibition of vascular bundle development (Goldbach *et al*., 2007), while its deficiency during reproductive phase may cause poor flowers/fruits development (Asad *et al*., 2002) and poor boll retention (Dordas, 2006). As B helps in the transport of sugars and nutrients from leaves to fruits (Siddiky *et al*., 2007), cotton specifically requires an adequate supply of B especially during the boll development to harvest good yield.

In Pakistan, early cases of B deficiency were reported in cotton (Chaudhary and Hisbani, 1970); however, the research on this issue could not get due emphasis. Extensive soil sampling indicated B deficiency in 49% of soils from 20 different districts (Sillanpaa, 1982; Rashid, 1995) in Pakistan. Coarse soils are most likely to be B deficient because of leaching (Rashid, 1995), low organic matter, and semiarid to arid climatic conditions (NFDC, 2004). Since the countywide cotton growing soils and climate are of this typical nature so the growers face serious threats of premature shedding of cotton flowers, squares and bolls due to the B deficiencies along with heat stress. Most of the work on B nutrition has been done in acidic soils, which demand the research work in alkaline soils as well. This study was, therefore, conducted to monitor the influence of soil applied boron on the boll retention, productivity and economic returns of cotton genotypes.

To cite this paper: Saleem, M., M.A. Wahid, S.M.A. Basra and A.M. Ranjha, 2016. Influence of soil applied boron on the boll retention, productivity and economic returns of different cotton genotypes. *Int. J. Agric. Biol*., 18: 68–72

Materials and Methods

The study was carried out at Agronomic Research Area, University of Agriculture Faisalabad, Pakistan during 2009 and 2010. Seed of cotton genotypes FH-113, MNH-786 and CIM-496 was obtained from Cotton Research Institute, Faisalabad, Pakistan. Crop was planted on June 5, and May 29 during 2009 and 2010, respectively with single row cotton drill in 75 cm spaced rows using seed rate of 8 kg ha^{-1}. After the uniform stand establishment, plants were thinned to maintain plant to plant distance of 25 cm. Experiment was laid out in randomized complete block design in split plot arrangements having net plot size of 3 m × 5 m with four replications. Boron was soil applied at 0.5, 1.0, 1.5, 2.0 and 2.5 kg ha^{-1} using boric acid (17% B) as source of B at sowing. Physicochemical properties of the experimental soil are given in table 1.

During the whole crop duration, nine irrigations were applied in each year at an approximate interval of 15 days depending on the crop need and rainfall occurrence. Crop was fertilized with 115-60-60 kg ha^{-1} of nitrogen (N), phosphorus (P), potassium (K), using urea, di-ammonium phosphate (DAP) and potassium sulphate (K_2SO_4). The whole amount of P and K along and one third of N were applied as basal dose. Remaining N was applied in two equal splits each at first irrigation (40 days after sowing (DAS)) and flowering stage (55 DAS). All other agronomic practices were kept uniform for all the experimental treatments during both growing seasons. Yield and yield contributing traits were taken at maturity. Plant height of five randomly selected plants from each plot was measured and then their average was worked out. Similarly, for number of bolls per plant, mature and effective bolls were counted by randomly selecting five plants form each plot. Moreover, twenty bolls were selected from each plot to calculate ball retention percentage, average boll weight and average seed cotton weight per boll. Ginning out turn (GOT) was calculated as:

$$Ginning\ out\ turn = \frac{Weight\ of\ the\ lint\ (g)}{Weight\ of\ the\ seed\ cotton} \times 100$$

To determine the leaf B concentration, middle leaves of uniform size were harvested at maturity. Boron concentration in leaves was determined following the protocol of John *et al*. (1975), using a spectrophotometer at 420 nm (Perkin Elmer, CA, USA). The collected data were analyzed statistically by using Fisher's analysis of variance technique and least significance difference (LSD) test at 5% probability level (Steel *et al*., 1997).

Results

Boron application improved the yield and yield contributing traits of cotton genotypes during both years (Table 2). Maximum plant height was recorded with application of 1.5 and 2 kg B ha^{-1} during both years (Table 2). Moreover, maximum number of bolls per plant was recorded with application of 2 kg B ha^{-1} during first year while soil fertilization of 1–2 kg B ha^{-1} improved the number of bolls per plant during the second year of study. Application of B improved the boll retention percentage of cotton genotypes during both the experiment year (Table 2). The application of 1.5 and 2 kg B ha^{-1} improved the boll retention percentage during both crop seasons (Table 2). Boron application did not improve the GOT during first year of study. However, maximum GOT was recorded with soil application of 1.5–2 kg B ha^{-1} during second year of study (Table 2). In relation to different B application rates, more B was accumulated when crop was fertilized with 2.5 kg ha^{-1} of B followed by 2 kg ha^{-1} during 2009. In 2010, maximum B was accumulated when crop was fertilized with 2 kg ha^{-1} but it was statistically similar to 2.5 kg ha^{-1} B application (Table 2). However, application of B beyond 2 kg ha^{-1} did not improve the plant height, number of bolls per plant, boll retention percentage and ginning out turn of cotton genotypes and was similar to control (Table 2). However, among cotton genotypes, maximum plant height, number of bolls per plant, boll retention percentage and leaf boron contents were recorded for FH-113 during both years (Table 2). Moreover, ginning out turn was maximum in FH-113 and MNH-786 during both study years (Table 2).

Maximum average boll weight per boll was noted when crop was fertilized with 1.5 and 2 kg ha^{-1} B by in all tested genotypes during both the years (Table 3). The minimum average boll weight was noted where no B was applied in genotype FH-113 during both years and in MNH-786 during 2010 at the B application rate of 2.5 kg ha^{-1} of B. However, B application beyond 2.5 kg ha^{-1} did not improve the plant height and was similar to control (Table 2). Nevertheless, minimum boll retention percentage was observed with application of 2.5 kg B ha^{-1} and it was similar to control (Table 2).

Average boll weight was maximum with 1.5 and 2 kg B ha^{-1} in all tested genotypes during both years of study except in CIM-496 fertilized with 2 kg B ha^{-1} (Table 3).

Table 1: Physicochemical analysis of experimental soil

Characteristics	2009	2010
Sand (%)	67	66
Silt (%)	16	17
Clay (%)	18	17
Texture	Sandy Loam	
Saturation %	39	38
EC (dS m^{-2})	1.63	1.71
pH	8.05	8.0
Organic matter (%)	0.71	0.70
Total nitrogen (%)	0.050	0.052
Available P (ppm)	5.17	5.77
Available K (ppm)	178	171
Available B (ppm)	0.45	0.45

Table 2: Influence of soil applied boron on plant height, number of bolls per plant, boll retention, ginning out turn, and leaf B contents in different cotton genotypes

	Plant height (cm)		Number of bolls per plant		Boll retention (%)		Ginning out turn (%)		Leaf B contents (g m^{-2} DW)	
	2009	2010	2009	2010	2009	2010	2009	2010	2009	2010
Genotypes										
FH-113	117.1 a	122.6 a	24.92 a	26.61 a	37.94 a	38.62 a	40.65a	40.62a	0.99 a	1.01 a
MNH-786	105.4 b	112.63 b	14.85 b	16.75 b	33.83 b	32.45 b	40.78a	40.08a	0.91 b	0.95 b
CIM-496	100.4 b	109.99 c	14.38 b	16.52 b	32.45 b	33.74 b	37.49b	38.25b	0.84 c	0.89 c
LSD P 0.05	*4.23*	*1.87*	*4.25*	*2.12*	*1.71*	*1.52*	*0.56*	*1.82*	*0.02*	*0.04*
B levels (kg ha^{-1})										
Control	104.8 b	109.7 c	13.34 d	15.17 c	31.47 d	31.36 d	38.42	38.26c	0.63 f	0.67 f
0.5	106.9 ab	112.6 bc	17.00 c	19.37 b	34.07 bc	34.36 bc	40.23	39.52 b	0.76 e	0.80 e
1.0	108.1 ab	115.8 b	19.08 abc	21.31 a	35.55 ab	35.63 b	40.22	39.88 b	0.87 d	0.91 d
1.5	110.8 a	120.7 a	20.41 ab	22.52 a	37.30 a	37.68 a	39.92	40.08ab	1.01 c	1.04 c
2.0	110.1 a	121.0 a	20.83 a	22.70 a	37.05 a	37.57 a	39.55	40.91 a	1.09 b	1.15 a
2.5	105.1 b	110.7 c	17.65 bc	18.67 c	33.00 cd	33.00 c	39.48	39.25bc	1.12 a	1.12 b
LSD P 0.05	*4.56*	*1.86*	*3.12*	*1.55*	*1.95*	*1.49*	*NS*	*0.99*	*0.02*	*0.02*

Table 3: Influence of soil applied boron on average boll weight, seed cotton weight per boll and seed cotton yield of cotton genotypes

Treatment	Average boll weight (g)			Seed cotton weight per boll			Seed cotton yield (kg ha^{-1})		
	FH-113	MNH-786	CIM-496	FH-113	MNH-786	CIM-496	FH-113	MNH-786	CIM-496
Year 1									
Control	5. 19 c	4.42 d	4.30 d	2.67 c	2.54 e	2.38 d	2169 c	1703 c	1664 c
0.5	5.28 b	4.54 c	4.43 b	2.70 bc	2.60 d	2.43 c	2442 b	1815 b	1739 bc
1.0	5.30 b	4.62 b	4.44 b	2.73 b	2.64 c	2.51 b	2529 b	1857 ab	1816 ab
1.5	5.59 a	4.77 a	4.60 a	2.88 a	2.80 a	2.71 a	2644 a	1935 a	1870 a
2.0	5.60 a	4.78 a	4.62 a	2.89 a	2.70 b	2.70 a	2669 a	1931 a	1872 a
2.5	5.28 b	4.51 c	4.53 c	2.70 c	2.58 d	2.49 b	2258 c	1737 bc	1735 bc
LSD P 0.05	*Cultivars = 0.19, B levels = 0.02 Interaction = 0.04;*			*Cultivars = 0.02, B levels = 0.02, Interaction = 0.04;*			*Cultivars = 109, B levels = 58, Interaction = 101*		
Year 2									
Control	5.23 d	4.53 d	4.21 f	2.70 c	2.64 cd	2.28 e	2244 d	1761 d	1723 d
0.5	5.32 c	4.60 c	4.36 d	2.74 c	2.66 bc	2.36 d	2492 c	1882 b	1799 c
1.0	5.39 b	4.70 b	4.41 c	2.81 b	2.72 b	2.48 b	2590 b	1923 b	1881 b
1.5	5.61 a	4.83 a	4.54 a	2.91 a	2.85 a	2.65 a	2718 a	2003 a	1949 a
2.0	5.60 a	4.84 a	4.45 bc	2.90 a	2.77 b	2.53 b	2714 a	2000 a	1951 a
2.5	5.27 d	4.53 d	4.29 e	2.68 c	2.61 d	2.43 c	2300 d	1811cd	1794 c
LSD P 0.05	*Cultivars = 0.07, B levels = 0.03, Interaction = 0.04;*			*Cultivars = 0.06, B levels = 0.03, Interaction = 0.06;*			*Cultivars = 52, B levels = 37, Interaction = 65*		

Table 4: Effect of soil applied B on economic analyses of three cotton genotypes during 2009-2010

Treatments (Cultivar × B levels)	Seed cotton yield kg ha^{-1}	Value $Rs.ha^{-1}$	Cotton sticks value	Gross income $Rs.ha^{-1}$	Total cost Rs. ha^{-1}	Net return $Rs.ha^{-1}$	Benefit cost ratio
FH-113 × 0 kg B ha^{-1}	2207	193538	10000	203538	142526	61012	1.42
FH-113 × 0.5 kg B ha^{-1}	2467	216175	10000	226175	144516	81659	1.56
FH-113 × 1.0 kg B ha^{-1}	2560	224338	10000	234338	145529	88809	1.61
FH-113 × 1.5 kg B ha^{-1}	2681	235050	10000	245050	146686	98364	1.67
FH-113 × 2.0 kg B ha^{-1}	2691	235750	10000	245750	147286	98464	1.66
FH-113 × 2.5 kg B ha^{-1}	2279	199675	10000	209675	145776	63899	1.44
MNH-786 × 0 kg B ha^{-1}	1732	151913	10000	161913	138516	23397	1.17
MNH-786 × 0.5 kg B ha^{-1}	1849	162163	10000	172163	139786	32377	1.23
MNH-786 × 1.0 kg B ha^{-1}	1890	165788	10000	175788	140544	35244	1.25
MNH-786 × 1.5 kg B ha^{-1}	1969	172713	10000	182713	141489	41224	1.29
MNH-786 × 2.0 kg B ha^{-1}	1966	172413	10000	182413	142021	40392	1.28
MNH-786 × 2.5 kg B ha^{-1}	1774	155688	10000	165688	141614	24074	1.17
CIM-496 × 0 kg B ha^{-1}	1694	148550	10000	158550	137324	21227	1.15
CIM-496 × 0.5 kg B ha^{-1}	1769	155163	10000	165163	138389	26774	1.19
CIM-496 × 1.0 kg B ha^{-1}	1849	162150	10000	172150	139336	32814	1.23
CIM-496 × 1.5 kg B ha^{-1}	1910	167575	10000	177575	140191	37384	1.27
CIM-496 × 2.0 kg B ha^{-1}	1912	167750	10000	177750	140751	36999	1.26
CIM-496 × 2.5 kg B ha^{-1}	1765	154763	10000	164763	140566	24197	1.17

Moreover, minimum average boll weight was recorded where no B was applied in genotypes MNH-786 and CIM-496 during first year and CIM-496 during second year (Table 3). Application of boron 1.5 kg ha^{-1} in FH-113, MNH-786 and 2.0 kg ha^{-1} in FH-113 gave maximum seed cotton weight per boll during both years. The minimum seed cotton weight per boll was noted in genotypes FH-113 and MNH-786 by application of 2.5 kg ha^{-1} B also exhibited minimum seed cotton weight at B application rate of in both years and was similar to control (Table 3). All the cotton genotypes gave maximum seed cotton yield in response to B application at 1.5 kg ha^{-1} and 2.0 kg ha^{-1} during both crop years (Table 3). However, the minimum seed yield was noted in plots where no B was applied in 2009 and in the plots where B was applied at the rate of 2.5 kg ha^{-1} during 2010. Different B application rates increased the net benefits compared to no B application in all the three cotton genotypes (Table 4). Maximum field benefits or net returns were obtained when 1.5 and 2 kg ha^{-1} of B was applied to genotype FH-113 during both study years (Table 4); whereas the minimum benefit cost ratio was noticed where no B was applied in CIM-496 during both years of experimentation (Table 4).

Discussion

Application of B improved the yield and yield contributing traits of cotton genotypes. Soil fertilization with B improved plant height of cotton, possibly due to involvement of boron in meristematic growth of plant (Bohnsack and Albert, 1977), which might have enhanced the cell division and elongation (Shelp, 1993; Rerkasem and Jamjod, 2004), resulting in increased plant height. Moreover, application of B improved the number of bolls and boll retention of cotton genotypes which is possibly due to role of B during reproductive growth and assimilate translocation (Dear and Lipsett, 1987; Noppakoonwong *et al.*, 1997), germination and growth of pollen tube (Mozafar, 1993), while dearth of B diminishes the germination of pollen and growth of pollen tube (Bergmann, 1984).

The B level of 1.5 and 2.0 kg ha^{-1} improved seed cotton yield more obviously than other application rates during both years. Boron improved the number of bolls, average boll weight and seed cotton weight per boll of cotton genotypes ultimately yielding more seed cotton. As cotton has high B requirement and is very sensitive to soil boron deficiency (Shorrocks, 1992), so low response in control and lower B levels due to B deficiency could have considerably decreased leaf net photosynthetic rate, plant height, fruiting sites and dry matter accumulation during squaring and fruiting, because of depressed photosynthesis and plant growth (especially fruits and roots) resulting in increased fruit abscission and changes in dry matter partitioning among plant tissues (Zhao and Oosterhuis, 2003). Even temporary B deficiency, reduces cotton shoot dry matter yields, plant height and flower and fruit set, and these could not be prevented by foliar application of B (Rosolem and Costa, 2000). Application of B increased the leaf B concentration owing to increase uptake of B from soil to plant. Moreover, increase in B concentration in leaves of cotton was as a result of prompt response of cotton to applied nutrients.

Application of B improved the seed cotton yield and yield related traits of cotton (Rashidi and Golami, 2011) as has been observed in this study (Tables 2–3). Boron application improved the yield related traits of all cotton genotypes owing to role of B in reproduction, particularly flowering and fruit setting resulting in improved yields (Dear and Lipsett, 1987; Noppakoonwong *et al.*, 1997). Improvement in yield contributing traits is due to application of B resulted in better seed cotton yield which is possible outcome of more number of bolls, increased boll weight and increased seed cotton weight per boll.

Application of B improved the average boll weight and seed cotton weight per boll due to increase in boll size, which is possible outcome of B involvement in assimilate supply (Reddy *et al.*, 2003). Findings of this study showed that B applications not only increased the yield and improved the quality but also increased the net benefits from the field (Table 4). Increase in yield due to B fertilization resulted in more economic return. Although B application treatments took more cost to produce maximum seed cotton yield but at the end these returned more net benefits that compensated their cost and gave more benefits than others. Benefit cost ratio is important to farmers because they are interested in net returns. Different B application levels significantly affected the benefit cost ratio (Table 4). Maximum benefit cost ratio was achieved with application of 1.5–2 kg B ha^{-1} due to more seed cotton yield than any other treatment (Table 4).

Conclusion

Boron application significantly improved the growth, boll retention and lint yield of cotton. Cotton genotype FH-113 showed best results than MNH-786 and CIM-496. Boron application at 1.5 kg ha^{-1} was the most cost effective treatment for improving the cotton yield and quality.

References

Asad, A., F.P.C. Blamey and D.G. Edwards, 2002. Dry matter production and boron concentrations of vegetative and reproductive tissues of canola and sunflower plants grown in nutrient solution. *Plant Soil*, 243: 243–252

Bergmann, W., 1984. *The Significance of Micronutrient Boron in Agriculture.* Symposium held by the Borax Group in the International Trade Centre of the GDR, Berlin, Germany, 20 December, 1984

Bohnsack, C.W. and L.S. Albert, 1977. Early effects of boron deficiency on indole acetic acid oxidase levels of squash root tips. *Plant Physiol.*, 59: 1047–1050

Brown, P.H. and B.J. Shelp, 1997. Boron mobility in plants. *In*: *Boron in Soils and Plants*, pp: 85–101. Bell, R.W. and B. Rerkasem (eds.). Kluwer Academic Publishers, Dordrecht, The Netherlands

Chaudhry, T.M. and G.R. Hisbani, 1970. Effect of boron on the yield of seed cotton. *Pak. Cottons*, 15: 13–15

Dear, B.S. and J. Lipsett, 1987. The effect of boron supply on the growth and seed production of subterranean clover (*Trifolium subterraneum* L.). *Aust. J. Agric. Res.*, 38: 537–546

Dordas, C., 2006. Foliar boron application affects lint and seed yield and improves seed quality of cotton grown on calcareous soils. *Nut. Cycl. Agroecosyst*., 76: 19–28

Goldbach, H., L. Huang and M. Wimmer, 2007. Boron functions in plants and animals: recent advances in boron research and open questions. *In*: *Advances in Plant and Animal Boron Nutrition*. pp: 3–25. Xu, H.E., P.H. Goldbach, R.W. Brown, T. Bell, C.D. Fujiwara, S. Hunt, Goldberg and L. Shi (eds.). Springer, Dordrecht, The Netherlands

Govt. of Pakistant (GOP), 2014. *Economic Survey of Pakistan 2012–2013*. Ministry of Food, Agriculture and Livestock, Federal Bureau of Statistics, Govt. of Pakistan

John, M.K., H.H. Chuah and J.H. Neufeld, 1975. Application of improved azomethine-H method to the determination of boron in soils and plants. *Anal Lett*., 8: 559–568

Liu, W.D., M.M. Pi and Y.H. Wang, 1986. Diagnosis of boron deficiency in cotton plant. *Chin. J. Soil Sci*., 17: 132–135

Mozafar, A., 1993. Role of boron in seed production. *In*: *Boron and its Role in Crop Production*, pp: 185–206. Gupta, U.C. (ed.). CRC Press, Inc.: Boca Raton, Florida, USA

NFDC, 2004. *Annual Fertilizer Report*, p: 18. National fertilizer development center, Islamabad, Pakistan

Noppakoonwong, R.N., B. Rerkasem, R.W. Bell, B. Dell and J.F. Loneragan, 1997. Diagnosis and prognosis of boron deficiency in black gram (*Vigna mungo* L. Hepper) in the field by using plant analysis. In: *Boron in Soils and Plants. Developments in Plants and Soil Sciences*, Vol. 76, pp: 89–94. Bell, R.W. and B. Rerkasem (eds.)

Rashid, A., 1995. Nutrient indexing of cotton and micronutrient requirement of cotton and grandaunt. *In*: *Micronutrient Project Annual Report*, 1993–1994. NARC Islamabad, Pakistan

Rashidi M. and M. Gholami, 2011. Interactive effect of nitrogen and boron fertilizers on yield and yield components of cotton (*Gossypium hirsutum* L.). *Libyan Agric. Res. Center J. Int.*, 1: 33–38

Reddy, N.Y.A., R.U. Shaanker, T.G. Prasad and M.U. Kumar, 2003. Physiological approaches to improving harvest index and productivity in sunflower. *Helia*, 26: 81–90

Rerkasem, B. and S. Jamod, 2004. Boron deficiency in wheat: a review. *Field Crop Res.*, 89: 173–186

Rosolem, C.A. and A. Costa, 2000. Cotton growth and boron distribution in the plant as affected by a temporary deficiency of boron. *J. Plant Nutr*., 23: 815–825

Shelp, B.J., 1993. Physiology and biochemistry of boron in plants. *In*: *Boron and its Role in Crop Protection*, pp: 53–85. Gupta, U.C. (ed.)

Shorrocks, V.M., 1992. A global appraisal of the occurrence, diagnosis and correction of boron deficiency. *In*: *Proc. Int. symptoms on the role of sulphur, Magnesium and Micronutrients in Balanced Plant Nutrition*, pp: 39–53. Portech, S. (eds.). The Sulphur Institute, Washington DC. USA

Siddiky, M.A., N.K. Halder, K.U. Ahammad, K. Anam and M. Rafiuddin, 2007. Response of brinjal to zinc and boron fertilization. *Int. J. Sustainable Agric. Tech*., 3: 40–45

Sillanpaa, M., 1982. *Micronutrients and Nutrients Status of Soils, a Global Study, FAO Soils.* Bull. No. 48.Food and Agri. Department, Rome

Steel, R.G.D., J.H. Torrie and D.A. Dickey, 1997. *Principles and Procedures of Statistics: A Biometrical Approach*, 3rd edition, pp: 352–358. McGraw Hill, Book Co. Inc., New York, USA

Wang, Y.H. and X.F. Zhou, 1992. The effects of boron on the anatomical structures of cotton petioles. In: *Proc. Int. Symposium on the Role of Sulphur, Magnesium and Micronutrients in Balanced Plant Nutrition*, pp: 70–80. Portch, S. (ed.). The Sulphur Institute, Washington DC, USA

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

(Received 02 June 2015; Accepted 22 June 2015)