Effect of exogenous application of Boron and Zinc with or without added urea on the yield and nutrient assimilation of cotton

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Abstract

A two year's field trial was conducted to investigate the impact of foliar by applied boron (B) and zinc (Zn) with or without added urea on plant nutrient content and seed cotton yield. The experimental site was situated at Central cotton Research Institute, Multan during the years 2008 and 2009. Treatments, laid out in RCBD with four replications, consisted of untreated check and foliar sprays of $B_{0.1\%}$, $Zn_{0.2\%}$, $B_{0.1\%}+Zn_{0.2\%}$, $B_{0.1\%}+urea_{2\%}$, $Zn_{0.2\%}+urea_{2\%}$ & $B_{0.1\%}+Zn_{0.2\%}+urea_{2\%}$. In foliar application the whole quantity was split into three equal doses and applied at day 30, 45 and 60 after planting. The basal dose of fertilizers was 150kg N, 50kg P_2O_5 and 50kg K_2O ha^{-1} in the form of urea, TSP and SOP, respectively. The whole quantity of P, K and 1/3rd N fertilizers was applied at planting whereas the remaining N was applied at first flower and peak flowering phases. cotton cv. CIM-534 was used as test crop. Results revealed that plant nutrient (N, B, Zn) content, fruit production per unit area, dry biomass production, boll number $plant^{-1}$, boll weight and seed cotton yield increased while fruit shedding decreased with all the treatments over control. The values of N, B, and Zn in leaves ranged from 40.2-55.3, 50.0-58.6 µg g^{-1} at 24 and 40.5-58.4, 50.2-65.5 µg g^{-1} at 72 hours, respectively. However, the maximum effects were observed where B, Zn and urea were applied in combined form. Application of $B_{0.1\%}+Zn_{0.2\%}+urea_{2\%}$ increased fruiting positions by 18.4%, intact fruit by 81.4%, boll number $plant^{-1}$ by 27.8%, boll weight by 6.9% and seed cotton yield by 27.8% over control plots. Thus addition of urea @ 2% in nutrient spray solution may be added to improve nutrient assimilation and seed cotton yield.

Introduction

cotton production in Pakistan based on per unit land area is quite low particularly due to biotic and abiotic stresses faced by the crop during the growing season. One of the prime factors is poor soil health that limits nutrient availability to the plant. In the soils of Pakistan, alkalinity and calcareousness dominate causing multiple nutrient deficiencies and disorders (Anonymous, 1998).

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Deficiencies of boron (B) have been reported in cotton grown areas of Punjab and Sindh (Rashid *et al.*, 2002) and other parts of the globe (Gupta, 1979; Shorrocks, 1997). Moreover, alkaline-calcareous soils in arid and semi-arid regions of the world, with low organic matter content, are conducive to Zinc (Zn) deficiency in plants (Lindsay, 1972; Rashid and Ahmad 1994; Rashid and Ryan, 2004). Furthermore, fertilizer use either without or with poor micronutrient contents aggravates the deficiency of micronutrients (Eguchi and Yamada, 1997; Rashid and Rafiq, 1997).

cotton crop is sensitive to deficiency of B and Zn nutrients and suffers yield losses due to increased shedding of squares and bolls. A positive response of cotton crop has been noticed due to B and Zn application within the country (Chaudhry and Hisbani, 1970; Malik *et al.*, 1990; Rashid and Rafiq, 1997) and specifically to B fertilization on sandy and silt loam soils in USA and Africa (Howard *et al.*, 1998; Abaye, 2000; Roberts *et al.*, 2000; Zhao and Oostershuis, 2000). Biological yield, yield contributing parameters and nutrient content in corn have also been reported to be positively affected by the addition of Zn and B (Ziaeyan and Rajaie, 2009).

Exogenous application of fertilizers is adopted to supplement nutrient needs of plants during the season. Foliar fertilization along with soil application of nutrients has been recommended since long to improve plant productivity and yield quality (Doring and Gericke, 1986; Tukey and Marczyñski, 1984). In cotton foliar spray up to two or three times has been found necessary to improve the B nutrition of the crop (Xie *et al.*, 1992). However foliar fertilization is only effective when soil nutrient availability is low, topsoil dry, and root activity during the reproductive stage is decreased (Wójcik, 2004). The efficacy of foliar applied nutrients may also depend on the rate of absorption of applied nutrient into the leaf and subsequent translocation to the fruiting bodies. Foliar applied urea, due to its smaller size (radii 0.44 nm) than the ectodesmata pores (radii 1.0 nm) on leaf surface (Schõnherr, 1976), is absorbed quickly up to 30% within one hour and translocated into the closest boll within 6 to 48 hours after application (Oosterhuis, 1999). Moreover, due to negative charge on cuticular membrane, cations like NH4+ in the spray solution are preferably absorbed by the leaf surface (Mengel, 2002; Tyree *et al.*, 1990). Œwietlik and Faust (1984) reported that the rate of nutrient absorption also varies with plant nutrient requirement. Since cotton plant has high demand for nitrogen, the addition of urea (NH4+) in the spray solution, along with B and Zn may facilitate the absorption of micronutrients by the leaves. Therefore, an experiment was laid out to investigate the efficiency of foliar applied B and Zn fertilizers with or without added urea fertilizer, on the nutrient assimilation and productivity of field grown cotton.

Materials and Methods

A two year's field study was carried out on cotton cultivar Cv. CIM-534 (*Goyypsium hirsutum* L.) during the crop seasons 2008-2009 at the experimental farm of Central Cotton

Research Institute, Multan. Treatments, laid out in RCBD with four replications, consisted of untreated check, and foliar sprays of $B_{0.1\%}$, $Zn_{0.2\%}$, $B_{0.1\%}$+$Zn_{0.2\%}$, $B_{0.1\%}$+$urea_{2\%}$, $Zn_{0.2\%}$+$urea_{2\%}$ and $B_{0.1\%}$+$Zn_{0.2\%}$+$urea_{2\%}$. The whole quantity of nutrient fertilizers for foliar spray was split into three equal doses and applied at day 30, 45 and 60 after planting. The basal dose of fertilizers was 150kg N, 50kg P_2O_5 and 50kg K_2O ha^{-1} was applied in the form of urea, TSP and SOP respectively. The whole quantity of P, K and 1/3rd N fertilizers was applied at planting. The remaining quantity of nitrogen was applied at first flower and peak flowering phases. Standard crop production practices were followed during the growth season. Composite soil samples from plough layer (0-15cm) were collected before imposition of treatments. Physical and chemical characteristics of the samples were determined using standard methods (Ryan *et al.* 2001). Analytical results indicated the soil is silt loam in texture, alkaline in reaction and free from excess salts, low in organic matter and nitrogen, moderate in phosphorus and potassium, deficient in AB-DTPA extractable-Zn and hot water extractable-B (Table 1).

Table-1 Physical and chemical characteristics of the experimental site at pre - planting

Characteristics	Units	Value
pH (1:5, H_2O)		8.24
ECe	dS m^{-1}	1.98
Organic matter content	%	0.54
NO_3-N	mg kg^{-1}	2.82
$NaHCO_3$-P	mg kg^{-1}	8.50
NH_4OAc-K	mg kg^{-1}	110
AB-DTPA-Zn	mg kg^{-1}	0.45
Hot water extractable-B	mg kg^{-1}	0.35
Textural class		Silt loam

Results and Discussion

Fully mature young leaves were collected at 24 and 72 hours after each foliar spray and analyzed for N, B and Zn contents. The concentrations of N, B and Zn in leaf tissues varied significantly ($p<0.01$) among different treatments both at 24 and 72 hours after foliar application. However, at 72 hours, the concentrations of B and Zn increased by 4% and 8%, respectively over 24 hours. The leaf tissue contents of N, B and Zn also increased with the application of these nutrients. Although, the combined application of $B_{0.1\%}$+$Zn_{0.2\%}$ promoted their absorption but more pronounced effect was observed when urea was added to $B_{0.1\%}$, $Zn_{0.2\%}$, and $B_{0.1\%}+Zn_{0.2\%}$ treatments. However, the maximum absorption of N, B and Zn was observed in the treatment $B_{0.1\%}+Zn_{0.2\%}$+Urea2% at both sampling times (Table-2). At 72 hours after spray, the concentrations of B in leaf tissues were 24% ($B_{0.1\%}$), 37% ($B_{0.1\%}$+$Urea_{2\%}$), 32% ($B_{0.1\%}+Zn_{0.2\%}$) and 44% ($B_{0.1\%}+Zn_{0.2\%}$+$Urea_{2\%}$) higher over control. Likewise, the leaf Zn content increased by 21% ($Zn_{0.2\%}$), 29% ($Zn_{0.2\%}$+$Urea_{2\%}$), 27% ($B_{0.1\%}+Zn_{0.2\%}$) and 31% ($B_{0.1\%}+Zn_{0.2\%}$+$Urea_{2\%}$) over control. A comparison among the treatments showed that the addition of urea2% to $B_{0.1\%}$ and $Zn_{0.2\%}$ caused 13% and 8% increase in the absorption of B and Zn, respectively. It is evident that the addition of urea in spray solution facilitated the absorption of B more than that of Zn. The evidence of increased leaf B content due to its foliar application and subsequent transportation to growing parts has been reported (Wang *et al.*, 2007). Foliar applied urea (15N) is rapidly absorbed up to 30% within one hour by leaves (Oosterhuis, 1999) and translocated into the adjacent boll within 6 to 48 hours after application (Zhu, 1989; Miley and Oosterhuis, 1989). Since the absorption by leaves and translocation of N to fruiting parts takes place rapidly, therefore N did not accumulate in leaf tissues from 24 to 72 hours of sampling. Increased absorption of nutrients applied in combined form were reported by Pi *et al.* (1989) who observed that the application of N K B Zn in cotton, N P B in oilseed rape, sesame and sunflower, and N P K B Zn in citrus significantly promoted the uptake of nutrients and increased crop yield.

Table-2 Effect of exogenous application of B and Zn fertilizers with or without added urea on N, B and Zn concentrations in leaf tissues at 24 and 72 hours after foliar spray

Treatment	Nutrient concentration ($\mu g\ g^{-1}$ dw)					
	N		B		Zn	
	24 hrs	72 hrs	24 hr	72 hr	24 hr	72 hr
Control	3.47	3.48	40.2	40.5	50.0	50.2
$B_{0.1\%}$	3.46	3.47	48.3	50.4	50.3	50.5
$Zn_{0.2\%}$	3.46	3.46	40.3	40.5	54.4	60.6
$B_{0.1\%}+Zn_{0.2\%}$	3.47	3.48	51.0	53.4	55.6	63.7
$B_{0.1\%}$+$Urea_{2\%}$	3.66	3.57	52.3	55.6	50.5	51.0
$Zn_{0.2\%}$+$Urea_{2\%}$	3.67	3.59	43.5	44.6	58.3	64.6
$B_{0.1\%}+Zn_{0.2\%}$+ $Urea_{2\%}$	3.70	3.61	55.3	58.4	58.6	65.5
$LSD_{p<0.01}$	**0.09****	**0.08****	**3.09****	**3.22****	**2.48****	**2.77****

Total fruiting positions and intact fruit ranged from 392 to 464 m^{-2} and 102 to 185 m^{-2}, respectively and fruit shedding percentage from 60.1 to 74.0 in different treatments (Table 3). Total fruiting positions and intact fruits per unit land area increased significantly ($p<0.01$) with the exogenous application of B and Zn fertilizers both with and without added urea.

The increase in number of fruiting positions ranged from 14.0 to 18.4% and in intact fruit from 52.9 to 81.4 % in different treatments over control. The maximum increase in fruiting positions and intact fruit per unit area was observed where combined dose of B, Zn and urea was applied. Fruit shedding percentage also decreased significantly ($p<0.01$) with the exogenous application of B and Zn nutrients either with or without urea over control. The decrease in fruit shedding remained in the range of 8.9 to 13.9% with maximum decrease being observed where B, Zn and urea were applied in combined form. It is known that B deficiency considerably decreases plant height, fruiting sites, leaf area, leaf net photosynthetic rate, and dry matter accumulation (Zhao and Oosterhuis, 2003). Therefore, fertilizing cotton crop with B and Zn nutrients promoted physiological as well as reproductive development resulting in increased fruit production per unit area. Similar results have been reported by Dordas (2006) who also found increase in number of bolls m^{-2} with the foliar application of B. Furthermore, the application of Zn promoted retention of squares and small bolls by the biosynthesis of IAA (Follet *et al.*, 1981; Oosterhuis *et al.*, 1991) and increased photosynthesis activity (Ohki, 1976; Welch, 1995) that enhanced flowering and boll retention by the cotton plants (Wang *et al*., 1985; Kler *et al.*, 1989).

Table-3 Effect of exogenous application of B and Zn fertilizers with or without added urea on fruit production per unit area at maturity

Treatment	Number of fruiting positions m^{-2}	% increase over control	Number of intact fruits m^{-2}	% increase over control	Fruit shedding percentage	% decrease over control
Control	392	--	102	--	74.0	--
$B_{0.1\%}$	447	14.0	156	52.9	65.1	8.9
$Zn_{0.2\%}$	450	14.8	159	55.9	64.7	9.3
$B_{0.1\%}+Zn_{0.2\%}$	455	16.1	172	68.6	62.2	11.8
$B_{0.1\%}+urea_{2\%}$	459	17.1	175	71.6	61.9	12.1
$Zn_{0.2\%}+urea_{2\%}$	460	17.3	179	75.5	61.1	12.9
$B_{0.1\%}+Zn_{0.2\%}+urea_{2\%}$	464	18.4	185	81.4	60.1	13.9
LSD$p<0.01$	15.6	4.45ns	14.6	14.8	3.17	3.77

The plants collected at maturity were partitioned into leaf, stalk and fruit portions. The material was oven dried for biological yield estimation. Data indicated that biomass yield of leaf, stalk and fruit portions and also total biomass increased significantly ($p<0.01$) with the foliar application of B and Zn fertilizers with or without added urea (Table-4). Maximum biomass production was observed where combined dose of B, Zn and urea fertilizers was applied. Leaf biomass increased by 41.2%, stalk biomass by 28.8%, fruit biomass by 21.9% and total biomass by 26.6% in the treatment $B_{0.1\%}+Zn_{0.2\%}+Urea_{2\%}$ (Table

4). Plant dry matter yield is the product of vegetative and reproductive development. The combined application of B, Zn and urea was found to be the best combination as it produced the maximum growth and development resulting in greater biomass yields over all other treatments. Previous studies have also revealed that the application of Zn significantly improved growth and dry matter yield of cotton and wheat plants (Sawan *et al.*, 2001; Khoshgoftarmanesh *et al.*, 2004). Cakmak *et al.* (1989) also observed that growth of plants, especially of shoot is badly impacted by Zn deficiency. Similarly, growth promotion by B application in wheat due to increased nutrient uptake (Reinbott *et al.*, 1997), through membrane stability (Blaster-Grill *et al.*, 1989) and enhanced ATPase activity (Lawrence *et al.*, 1995) is well documented.

Table-4 Effect of exogenous application of B and Zn fertilizers with or without added urea on dry mater production at maturity

Treatment	Dry biomass (gm^{-2})			
	Leaves	Stalk	Fruit	Total
Control	85	170	342	596
$B_{0.1\%}$	90	179	352	622
$Zn_{0.2\%}$	92	182	358	631
$B_{0.1\%}$+$Zn_{0.2\%}$	103	205	397	705
$B_{0.1\%}$+$Urea_{2\%}$	97	195	373	665
$Zn_{0.2\%}$+$Urea_{2\%}$	101	200	390	692
$B_{0.1\%}$+$Zn_{0.2\%}$+ $Urea_{2\%}$	120	219	417	756
$LSD_{p<0.01}$	**20.3**	**22.7**	**20.4**	**33.5**

Number of bolls plant^{-1}, boll weight and seed cotton yield increased significantly ($p<0.01$) with the application of B and Zn through foliar sprays either applied individually or in combination with or without added urea (Table 5). The increase in number of bolls plant^{-1} ranged from 11.1 to 27.8%, in boll weight from 1.2 to 6.9% and in seed cotton yield from 10.9 to 27.8% in different treatments over control. The maximum number of bolls plant^{-1}, boll weight and seed cotton yield were however, observed where B, Zn and urea were applied in combined form. The increase in yield in different treatments over control was 10.9% ($B_{0.1\%}$), 14.1% ($Zn_{0.2\%}$), 22.3% ($B_{0.1\%}$ + $Zn_{0.2\%}$), 14.2% ($B_{0.1\%}$ + $Urea_{2\%}$), 18.2% ($Zn_{0.2\%}$ + $Urea_{2\%}$) and 27.8% ($B_{0.1\%}$ + $Zn_{0.2\%}$ + $Urea_{2\%}$). The increase in seed cotton yield resulted due to increase in number of bolls pant^{-1} and boll weight. The soils in cotton grown areas are usually deficient in B and Zn nutrients which result in enhanced fruit shedding. Furthermore, the deficiency of these nutrients particularly B in cotton results in small, deformed bolls, poor fruit retention and reduced lint yields (Roberts *et al.*, 2000). Zinc is reported to be involved in the synthesis of IAA (Oosterhuis *et al.*, 1991), a hormone that reduces fruit shedding. In the current studies, the application of both B and Zn lowered the shedding of fruit (Table-3) that resulted in ultimate increase in seed cotton yield. Sawan *et al.* (2008) also found that Zn application increased seed cotton yield by increasing number of opened bolls and boll weight. Similarly foliar applications of boron have been found to increase seed cotton yield by 14% (Roberts *et al.*, 2000). It is well known that B plays a key role in water and nutrients transportation from root to shoot (Rehem *et al.*, 1998). Hence an adequate supply of B and Zn would result in increased boll weight due to accumulation of the photosynthates in the developing boll (Oosterhuis *et al.*, 1991; Khandgave *et al.*, 1996; Sawan *et al.*, 2001). Previous studies showed an increase in yield in the range of 6 to 11% (Rashid and Rafiq, 1997; Makhdum *et al.*, 2002) due to soil application of B and Zn and up to 8% by foliar application of B (Howard *et al.*, 1998). In the present studies increase in yield levels was quite higher (up to 27.8%) which might be attributed to the combined effect of B, Zn and urea application through foliar sprays. Hence addition of urea to foliar sprays of B and Zn could be adopted to achieve better yields in cotton crop.

Table-5 Effect of exogenous application of B and Zn fertilizers with or without urea on seed cotton yield and its components

Treatment	Number. of bolls plant^{-1}	Boll weight (g)	Seed cotton yield (kg ha^{-1})
Control	18	2.60	1828
$B_{0.1\%}$	20	2.65	2028
$Zn_{0.2\%}$	21	2.63	2085
$B_{0.1\%}$+$Zn_{0.2\%}$	22	2.70	2236
$B_{0.1\%}$+$Urea_{2\%}$	21	2.72	2087
$Zn_{0.2\%}$+$Urea_{2\%}$	22	2.66	2160
$B_{0.1\%}$+$Zn_{0.2\%}$+$Urea_{2\%}$	23	2.78	2337
LSD	**1.28****	**0.26***	**92.9****

* Significant at $p<0.05$

** Significant at <0.01

Conclusions and Recommendations

Present study revealed that foliar application of B and Zn nutrients to cotton crop were beneficial. The addition of urea along with B and Zn improved nutrient absorption, promoted plant growth and development and increased cotton productivity under nutrient limited soil conditions. Therefore, it is recommended that urea @ 2% in spray solution of B and Zn may be added to improve nutrient assimilation and seed cotton yield.

References

Abaye, A.O. 2000. cotton response to boron and nitrogen fertilization. Proc. Beltwide Cotton Conf. National cotton Council, Memphis, T.N. USA, pp. 1446-1447.

Anonymous. 1998. Micronutrients in Agriculture: Pakistan Perspective, Status Report 4/98. National Fertilizer Development Centre, Islamabad. Pakistan.

Blaster-Grill, J., D. Knoppik, A. Amberger and H. Goldbach. 1989. Influence of boron on the membrane potential in *Elodea densa* and *Helianthus annus* roots and H+ extrusion of suspension cultured *Daucus carota* cells. Plant Physiol., 90:280-284.

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

Cakmak, I., H. Marschner, and F. Bangerth. 1989. Effect of zinc nutritional status on growth, protein metabolism and levels of Indole-3-acetic acid and other phytohormones in beans (*Phaseoluss vulgaris* L.). J. Exp. Bot., 40:405-412.

Dordas, C. 2006. Foliar boron application affects lint and seed yield and improves seed quality of cotton grown on calcareous soils, Nutr. Cycl. Agroecosys., 76, 19-28.

Doring, H.W. and R. Gericke. 1986. The efficiency of foliar fertilization in arid and semiarid regions. In: A. Alexander (ed.), Foliar fertilization. Kluwer Acad. Publishers, Dordrecht, The Netherlands, pp. 2935.

Eguchi, S. and Y. Yamada, 1997. Long term field experiment on the application of slow-release boron fertilizer. Part 2. Behaviour of Boron in the soil. *In:* Bell, R.W. and Revkasem, B. (eds). *Proc. Int.Symp. on B in soils and plants*, pp: 49–56. *Chiang Mai, Thailand*, Sep. 1997.

Follet, R.H., L.S. Murphy and R.L. Donahue. 1981. Fertilizers and Soil Amendments, Prentice Hall, Englewood Cliffs, NJ, USA.

Gupta, U.C. 1979. Boron nutrition of crops, Adv. Agron., 31:273-307.

Howard, D.D., C.O. Gwathmey, and C.E. Sams. 1998. Foliar feeding of cotton: Evaluating potassium sources, potassium solution buffering, and boron. Agron. J., 90:740-746.

Khandagave, R.B., R.V. Koraddi, and T.H. Chandranath. 1996. Effect of sulphur and zinc on growth and yield of rainfed cotton (*Gossypium hirsutum* L.). Farming Syst., 19(3, 4), 11-14.

Khoshgoftarmanesh, A. H., H. Shariatmadari, N. Karimian, M. Kalbasi and M.R. Khajehpour. 2004. Zinc efficiency of wheat cultivars grown on a saline calcareous soil. J. Plant Nut., 27(11):1953–1962.

Kler, D.S., D. Raj and G.S. Dhillon. 1989. Modification of microenvironment with cotton canopy for reduced abscission and increased seed yield, Environ. Ecol., 7(4), 800-802.

Lawrence, K., P. Bhalla and P.C. Misra. 1995. Changes in NAD(P)H-dependent redox activities in plasmalemma-enriched vesicles isolated from boron-and zinc-deficient chickpea roots. J. Plant Physiol., 146:652-657.

Lindsay, W.L. 1972. Zinc in soil and plant nutrition, Adv. Agron., 24:147-186.

Makhdum, M.I., Shabab-ud-Din, F. Ahmad and F.I. Chaudhry. 2002. Zinc and boron fertilizer requirement for cotton grown in a calcaric cmbisol. Balochistan J. Agri. Res. 3(2):11-14.

Malik, M.N.A., M.I. Makhdum, S.I.H. Shah, and F.I. Chaudhry. 1990. cotton response to boron nutrition in silt loam soils, The Pakistan Cottons, 34: 133-140.

Miley, W.N. and D.M. Oosterhuis 1989. cotton nitrogen and carbohydrate nutrition. University of Arkansas, Coop. Ext. Ser. Fact sheet No. 2045.

Mengel, K. 2002. Alternative or complementary role of foliar supply in mineral nutrition. ACTA HORTIC. 594: 3348.

Ohki, K. 1976. Effect of zinc nutrition on photosynthesis and carbonic anhydrase activity in cotton, Physiol. Plant., 38:300-304.

Oosterhuis, D.M. 1999. Foliar Fertilization. Proc. Beltwide Cotton Conf. 1:26-29. Natl. cotton council. Memphis, TN.

Oosterhuis, D.M., K. Hake and C. Burmester. 1991. Foliar feeding. Cotton Physiol Today. 2:1-7. Cotton Council of America. Memphis, TN., USA.

Pi, M.M., W.D. Liu, L.S. Wu and Y.H. Wang. 1989. Effect of combined application of boron and nitrogen, phosphorous, or potassium on yield and nutrient uptake of cotton. In Proceedings of the International Symposium on Balanced Fertilization, pp. 361–369. Press of Agricultural, Beijing, China.

Rashid, A. and N. Ahmad. 1994. Soil Testing in Pakistan, In: FADINAP Regional Workshop on Cooperation in Soil Testing for Asia and the Pacific 16-18 August 1993, Banghok, Thailand, United Nations, New York, pp. 39-53.

Rashid, A. and E. Rafique (1997). Annual Report "Micronutrients /nutrient management in cotton in relation to Cotton leaf curl virus (CLCV)". NARC, Islamabad.

Rashid, A., E. Rafique and J. Ryan. 2002. Establishment and management of boron deficiency in field crops in Pakistan: A country report, In: Boron in Plant and Animal Nutrition, Goldbach et al. (Eds), Kluwer Academic/Planum Publishers, New York., pp. 339-348.

Rashid, A. and J. Ryan. 2004. Micronutrient constraints to crop production in soils with Mediterranean type characteristics: A Review, J. Plant Nutr., 27: 959-75.

Rehem, G.W., W.E. Fendter and C.J. Overdahi. 1998. Boron for Minnesota soils. University of Minnesota Extension Service. Available online at http://www.Extansion Umn.Edv.

Reinbott, T.M., D.G. Blevins and M.K. Shcon. 1997. Content of boron and other elements in main stem and branch leaves and see of soybean. J. Plant Nutr., 20:831-843.

Roberts, K.R., J.M. Gersman, and D.D. Howard. 2000. Soil- and Foliar-Applied Boron in cotton Production: An Economic Analysis. J. cotton Sci., 4:171-177.

Ryan, J., G. Estefan and A. Rashid. 2001. Soil and plant analysis laboratory manual, 2nd Ed. International Centre for Agriculture Research in the Dry Areas (ICARDA). Aleppo, Syria, p 172.

Sawan, Z.M., S.A. Hafez, A.E. Basyony. 2001. Effect of phosphorus fertilization and foliar application of chelated zinc and calciumon seed, protein and oil yields and oil properties of cotton. J. Agric. Sci. Camb. 136:1918.

Sawan, M.Z., M.H. Mahmoud and A.H. El-Guibali. 2008. Influence of potassium fertilization and foliar application of zinc and phosphorus on growth, yield components, yield and fiber properties of Egyptian cotton *(Gossypium barbadense L.)*. J. Plant Ecology, 1(4):259270.

Schõnherr, J. 1976. Water permeability of isolated cuticle membranes: The effect of pH and cations on diffusion, hydrodynamic permeability and size of polar pores in the cutin matrix. PLANTA, 128: 113126.

Shorrocks, V.M. (1997). The occurrence and correction of boron deficiency, Plant and Soil, 193:121-148.

Œwietli, K.D. and M. Faust. 1984. Foliar nutrition of fruit crops. Hort. Rev. 6:287355.

Tukey, H.B., S, Marczyñski. 1984. Foliar nutrition old ideas rediscovered. Acta Hort. 145: 205-212.

Tyree, M.T., T.D. Scherbatskoy and C.A. Tabor. 1990. Leaf cuticles behave as asymetric membranes. Evidence from the measurement of diffusion potentials. Plant Physiol. 92: 103109.

Wang, Y., L. Shi, X. Cao and F. Xu. 2007. Plant Boron Nutrition and Boron Fertilization in China. In Xu et al. (eds.), Advances in Plant and Animal Boron Nutrition, p. 93101.

Wang, J.X., W.H. Chem and Y.L. Yu. 1985. The yield increasing effect of growth regulators on cotton and their application. China cottons, 3:32-33.

Welch, R.M. (1995). “Micronutrient nutrition of plants”, Critical Rev. Plant Sci., 14:49-82.

Wójcik, P. 2004. Uptake of mineral nutrients from foliar fertilization. J. Fruit Ornam. Plant Res. Special ed.12:201-218.

Xie, Q., W.X. Wei and Y.H. Wang. 1992. Studies on absorption, translocation and distribution of boron in cotton. Acta Agron. Sinica, 13(1):3137.

Zhao, D., and D.M. Oosterhuis. 2000. Nitrogen application effect on leaf photosynthesis, nonstructural carbohydrate concentrations and yield of field-grown cotton. Spec. Rep. 198. Arkansas Agric. Exp. Stn., Fayetteville, AR.

Zhao, D. and D.M. Oosterhuis. 2003. “cotton growth and physiological responses to boron deficiency”, J. Plant Nut., 26: 855-867.

Zhu, B. 1989. Absorption and translocation of foliar applied nitrogen in cotton. M.S. Thesis University of Arkansas, Fayetteville.

Ziaeyan, A.H. and M. Rajaie. 2009. Combined effect of Zinc and Boron on yield and nutrients accumulation in corn. Int. J. Plant Product., 3 (3): 35-44.