

COMPARATIVE EFFICACY OF FOLIAR FEEDING VERSUS SOIL APPLICATION OF BORON AND ZINC FERTILIZERS FOR ECONOMIC SEED COTTON PRODUCTION

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Abstract

Studies were carried out in Soltanpur series (Typic Ustochrepts) to quantify the effects of boron and zinc fertilizers, applied through soil and foliar methods on fruit production, seed cotton yield and economic analysis. The trial was laid out at Central Cotton Research Institute, Multan during the year 2005-2007. The treatments consisted of soil application with three levels each of boron (B) [0, 2.5, 5.0 kg B ha⁻¹] and zinc (Zn) [0, 5, 10 kg Zn ha⁻¹] in comparison to foliar feeding with three levels each of B (0, 1.25, 2.5 kg B ha⁻¹) and Zn (0, 2.5, 5.0 kg Zn ha⁻¹). The design of the experiment was randomized complete block with three replications. In soil application, the whole quantity of B and Zn was applied at the time of planting. In foliar application method, the whole quantity was split into five equal doses and applied at day 30, 45, 60, 75 and 90 after planting. Cotton cv. CIM-496 was used as test crop. The basal dose of nitrogen, phosphorus and potassium was 150 kg N, 50 kg P₂O₅ and 50 kg K₂O ha⁻¹. The results revealed that fruit production per unit area increased whereas fruit shedding percentage decreased at all levels of B and Zn fertilization, irrespective of application methods. Seed cotton yield increased by 11%, boll number by 19%, boll weight by 4.3% and chlorophyll SPAD values by 16%, over control, irrespective of application method. Foliar application of B and Zn proved to be superior by producing, on an average, 4.5% higher seed cotton yield than the soil application method. The economic analysis revealed that foliar application, on an average, produced VCR value of 7.15:1 with a net profit of Rs. 8492/- as compared to 2.25:1 and net profit of Rs. 3437/- in soil application method.

Keywords: Boron, cotton, economic analysis, foliar feeding, soil application, yield, zinc.

INTRODUCTION

Cotton has attained now a major position in the economy of Pakistan and prosperity of teeming millions depend on its good production. There is down hill trend in cotton production for the last couple of years after realization of record yield during the year 2003-04. Thus there is a great need to arrest decline in cotton production and to achieve high level of productivity. This could only be attained by optimizing the use of available resources. Research work carried out so far has indicated usefulness of micro-nutrients especially boron and zinc in cotton crop. Almost all soils of Pakistan are alkaline and calcareous in nature, which limit the availability of micronutrients to plants. Multiple nutrient deficiencies are very common in alkaline soils of Pakistan [Anonymous 1998] and elsewhere [Takkur and Walker 1993]. Deficiencies of B and Zn in cotton grown areas of Punjab and Sindh have already been established [Rashid and Rafique 2002]. Continuous cropping, without complete nutrient replenishment, has gradually lowered the soil fertility. Resultantly, the crop yields are either stagnant or showing a downfall trend. The application of micronutrients along with macronutrient fertilizers is likely to arrest declining trend in cotton yields.

Among the essential plant micro-nutrients B deficiencies occur widely and have a significant agronomic impact throughout the world [Gupta 1979, Shorrocks 1997]. Boron fertilizer has been found beneficial in cotton production on sandy and silt loam soils in several parts of USA and Africa [Haoward *et al.* 1998, Abaye 2000, Roberts *et al.* 2000, Zhao and Oostershuis 2000]. Primary function of boron is related to cell wall formation, sugar transport, flower retention and pollen formation. Boron deficiency inhibits apical and extension growth, necrosis of terminal buds, cracking and breaking of stems and petioles, abortion of flower initials and shedding of fruits [Mozaffar 1993, Goldbach 1997]. Cotton response to boron has been found in Sindh and Punjab [Chaudhry and Hisbani 1970, Malik *et al.* 1990] whereas significant response to added boron fertilizer was not observed by Bhatti *et al.* [1988].

With soil pH being more than 7.0, the availability of Zn to plants is low since the availability of soil Zn to plants decreases by a factor of 100 for each unit pH increase [Lindsay 1979]. Alkaline-calcareous soils in arid and semi-arid regions of the world are conducive to Zn deficiency in plants [Rashid and Ahmad 1994]. Low Zn availability in these soils is attributed to Zn fixation by free CaCO_3 , Zn precipitation in alkaline soil solution environment and low Zn replenishment in soil solution is because of low soil organic matter content (generally < 1%) [Lindsay 1972, Rashid and Ryan 2004]. Zinc is an essential components of various enzymes for energy production, protein synthesis and growth regulation. Zinc (Zn) deficient cotton plants have small cupped leaves with interveinal chlorosis. The most visible Zn deficiency symptoms are short internodes, decrease in leaf size and loss of fruiting bodies.

Due to financial constraints and sharp increase in fertilizer prices, specifically DAP, farmers are focusing only on the nitrogenous fertilizers to raise cotton crop. This practice may lead to further yield losses and a major set backs in the country's agricultural based economy. Undoubtedly, soil application of fertilizers is the appropriate means of nutrient supply to the plants but foliar fertilization is gaining popularity among the farming community due to being more cost effective. Foliar application also helps the farmer to timely replenish the crop requirement of nutrients during the growing season. However the efficacy and economic use of micronutrient application through foliage, in comparison to soil application, needs to be carefully evaluated.

Therefore, an experiment was conducted to determine the best combination of boron and zinc fertilizer doses and appropriate method of application for profitable seed cotton production to cope with the rapidly increasing cost of production.

MATERIALS AND METHODS

Studies were carried out on cotton cultivar Cv. CIM-496 (*Goyypsiium hirsutum* L) during the crop season 2005-2007 at the experimental farm of Central Cotton Research Institute, Multan. Treatments consisted of (a) soil application with three levels of boron plus zinc (0, 2.5, 5.0 kg B ha⁻¹) and three levels of zinc (0, 5.0, 10.0 kg Zn ha⁻¹), (b) Foliar application with three levels of boron (0, 1.25, 2.5 kg B ha⁻¹) and three levels of zinc (0, 2.5, 5.0 kg Zn ha⁻¹). The design of the experiment was randomized complete block with three replications. In soil application, the whole quantity of boron and zinc was applied at the time of planting. In foliar application method, the whole quantity was split into five equal doses and applied at 30, 45, 60, 75 and 90 days after planting. The basal dose of nitrogen, phosphorus and potassium was 150 kg N, 50 kg P₂O₅ and 50 kg K₂O ha⁻¹. The whole quantity of phosphorus, potassium and 1/3rd nitrogen fertilizers was applied at planting. The remaining quantity of nitrogen was applied at first flower and peak flowering phases. Standard production practices were followed during the season. Composite soil samples (0-30cm depth) were collected before planting crop and the analysis was carried out using appropriate methods [Ryan *et al.* 2001]. Soil samples were analyzed for physical and chemical characteristics. Chlorophyll meter (Minolta SPAD-502) was used to record SPAD values (chlorophyll meter readings) of the intact fully expanded leaves (the 4th from the apex) at peak flowering stage. The chlorophyll meter readings were taken avoiding mid-rib of each leaf blade. Thirty SPAD readings were averaged to represent the mean SPAD value of each plot.

Results show that soil is alkaline in reaction and free from excess of salts. It is low in organic matter with medium supply of phosphorus and potassium. These soils are deficient in zinc and boron contents (Table 1).

Table 1: Physical and chemical characteristics of the experimental site before imposition of treatments.

Characteristics	Values
pH	8.3
ECe (dS m ⁻¹)	1.49
Organic matter (%)	0.50
Na HCO ₃ -P (mg kg ⁻¹)	8.0
NH ₄ O Ac-K- (mg kg ⁻¹)	133
AB-DTPA-Zn (mg kg ⁻¹)	0.45
Hot water soluble B (mg kg ⁻¹)	0.32
Textural class	Silt loam

RESULTS AND DISCUSSION

Fruit production capacity was influenced positively by the application of B and Zn fertilizers. Increasing levels of B and Zn fertilizers, irrespective of application method, caused increase in number of total fruiting positions and intact fruit per unit land area. However, foliar application produced higher intact fruit as compared to soil application. Fruit shedding decreased with the increasing levels of B and Zn fertilizers (Table 2). Fertilizing cotton crop with B and Zn nutrients promoted physiological as well as reproductive development resulting in increased fruiting per unit area. Dordas [2006] also reported that foliar application of B @ 0, 400, 800 and 1,200 mg l⁻¹ increased the number of bolls per square meter. The deficiency of B has been reported to considerably decreased leaf net photosynthetic rate, plant height, leaf area, fruiting sites, and dry matter accumulation during squaring and fruiting. Depressed photosynthesis and plant growth (especially fruits and roots) resulted in increased fruit abscission and changes in dry matter partitioning among plant tissues [Zhao *et al.* 2003]. Follet *et al.* [1981] and Oosterhuis *et al.* [1991] stated that Zn is involved in the biosynthesis of IAA which favours, in cotton, the retention of squares and small bolls. Similarly, Ohki [1976] and Welch [1995] reported that higher concentration of plant Zn increased the photosynthesis activity by increasing the activity of carbonic anhydrase. Increased photosynthetic activity in turn, enhanced flowering and boll retention by the cotton plants [Wang *et al.* 1985, Kler *et al.* 1989].

Seed cotton yield, number of bolls per plant and boll weight increased significantly with the addition of boron and zinc fertilizers irrespective of application method (Table 3). However, foliar application produced a better yield response causing an increase of 10% (B_{1.25}, Zn_{2.5}) and 16.6% (B_{2.5}, Zn_{5.0}) in yield over control as compared to 6% (B_{2.5}, Zn_{5.0}) and 11% (B_{5.0}, Zn_{10.0}) increase in case of soil application. On overall basis, irrespective of fertilizer doses and application methods, seed cotton yield increased by 11%, boll numbers by 19%, boll weight by 4.3% and chlorophyll SPAD values by 16% due to B and Zn fertilization. The results

are in conformity to those of Howard and Gwathmey [1998] who reported that soil-applied B at $0.56 \text{ kg B ha}^{-1}$ increased yields by 6% and four foliar applications of $0.11 \text{ kg B ha}^{-1}$ increased yields by 8% compared with untreated check yields. The increase in seed cotton yield resulted due to increase in number of bolls per plant and boll weight. The increase in boll weight is attributed to the favorable effect of Zn fertilization on photosynthetic activity and plant metabolism, resulting in higher accumulation of the photosynthetic products in the bolls [Oosterhuis *et al.* 1991, Khandgave *et al.* 1996, Sawan *et al.* 2001]. Similar interpretations were extended by Jyung *et al.* [1975] and Glass [1989]. The chlorophyll content (SPAD values) also increased from 15.8% ($B_{1.25}, Zn_{2.5}$) to 23.7% ($B_{2.5}, Zn_{5.0}$) by foliar application and from 13.2% ($B_{2.5}, Zn_{5.0}$) to 18.4% ($B_{5.0}, Zn_{10.0}$) in soil application method. The increased chlorophyll content in leaves due to better Zn nutrition of cotton plants may be attributed to enhanced nutrient uptake, utilization, and metabolism [Li *et al.* 1991]. In sunflower leaves, content of chlorophyll 'a' as well as of chlorophyll 'b' was reduced with Zn deficiency [Khurana and Chatterjee 2001]. Kaya and Higgs [2001] also reported that at low Zn concentration (i.e., 0.01 mg L^{-1}) in solution culture chlorophyll content in tomato leaves decreased significantly.

Table 2: Fruit production at maturity as affected by foliar feeding vs soil application of B and Zn fertilizers.

Nutrient levels (kg ha^{-1})		Fruiting positions m^{-2}	Intact fruits m^{-2}	Fruit shedding (%)
Soil application				
B_0	Zn_0	520	142	73
$B_{2.5}$	$Zn_{5.0}$	532	162	69.5
$B_{5.0}$	$Zn_{10.0}$	537	168	68.7
LSD($p < 0.05$)		6.13*	5.31*	2.06*
Foliar application				
B_0	Zn_0	520	142	73
$B_{1.25}$	$Zn_{2.5}$	502	165	67
$B_{2.5}$	$Zn_{5.0}$	510	175	65.7
LSD($p < 0.05$)		10.27*	8.39*	3.75*

Table 3: Impacts of foliar feeding vs soil application of B and Zn fertilizers on seed cotton yield and its components.

Nutrient levels (kg ha^{-1})		Seed cotton yield (kg ha^{-1})	Bolls plant^{-1}	Boll weight (g)	Chlorophyll content (SPAD values)
Soil application					
B_0	Zn_0	2253	18	3.12	38
$B_{2.5}$	$Zn_{5.0}$	2385	20	3.20	43
$B_{5.0}$	$Zn_{10.0}$	2502	22	3.27	45
LSD($p < 0.05$)		115.0*	2.62*	0.07*	2.09*
Foliar application					
B_0	Zn_0	2253	18	3.12	38
$B_{1.25}$	$Zn_{2.5}$	2479	21	3.25	44
$B_{2.5}$	$Zn_{5.0}$	2628	23	3.34	47
LSD($p < 0.05$)		205.8*	2.50*	0.12*	2.24*

Economic analysis (Table 4) showed that VCR values of 2.3:1 ($B_{2.5}, Zn_{5.0}$) and 2.2:1 ($B_{5.0}, Zn_{10.0}$) with net returns of Rs. 2456/- and Rs. 4417/- respectively were obtained in soil application whereas higher values of VCR i.e. 7.9:1, 6.4:1 with net returns of Rs. 6508/- and Rs. 10475/- respectively were obtained in foliar application method.

Hence, the results confirm that B and Zn nutrition of cotton, in soils deficient of these nutrients, may be beneficial in terms of agricultural productivity and net returns to the farmers either applied through soil or foliar application method. The soil application is however low productive and less economic due to alkaline soil conditions. Foliar application of B and Zn, therefore, seems to be more appropriate by being agronomically more productive and economically more fruitful. The response however, may vary at different locations due to soil fertility status and environmental conditions. The optimum doses of foliar spray may therefore, vary at different locations of the cotton growing areas. In Multan conditions, foliar sprays of 2.5 kg B and 5.0 kg Zn per hectare in five splits provided the best economic returns.

Table 4: Economic analysis

Nutrient levels (kg ha ⁻¹)	Increase in yield over control (kg ha ⁻¹)	Cost of B and Zn fertilizer (Rs. ha ⁻¹)	Value of seed cotton (Rs. ha ⁻¹)	Net profit (Rs. ha ⁻¹)	Value cost ratio (VCR)
Soil application					
$B_0 Zn_0$	-	-	-	-	-
$B_{2.5} Zn_{5.0}$	132	1900	4356	2456	2.3:1
$B_{5.0} Zn_{10.0}$	249	3800	8217	4417	2.2:1
Foliar application					
$B_0 Zn_0$	-	-	-	-	-
$B_{1.25} Zn_{2.5}$	226	950	7458	6508	7.9:1
$B_{2.5} Zn_{5.0}$	375	1900	12375	10475	6.4:1

CONCLUSIONS

Following conclusions may be drawn from the above study:

1. The results indicated that cotton crop responded positively to B and Zn fertilization either applied through soil or foliar methods.
2. Foliar application @ $B_{2.5}, Zn_{5.0}$ yielded maximum fruit production, chlorophyll contents (SPAD values), seed cotton production, highest value of VCR (6.4:1) and net profit.

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