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Response of a Cotton Cultivar to Sulphur Fertilization

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Field experiments on sulphur fertilization in cotton cultivar CIM-109 were carried out at Central Cotton Research Institute Multan, Pakistan, in silty loam soils. The treatments consisted of four sulphur doses (0, 7, 14, 28 kg ha^{-1}) and two sulphur sources (gypsum and ammonium sulphate). Sulphur fertilization showed significant increase in seed cotton yield, boll number and boll weight. The addition of 7 kg S ha^{-1} seemed sufficient to overcome deficiency in silty loam soils for optimum cotton production. There were no differences in seed cotton yield due to sulphur sources. The petiole sulphate-sulphur concentration increased with increasing doses of sulphur fertilizer. The concentration of SO_4–S > 2000 ppm seemed sufficient for normal cotton growth and optimum seed cotton yield.

Key words: Sulphur fertilization, Fruit production, Petiole NO_3–N, Petiole SO_4–S, Fibre quality, Seed cotton yield.

Indroduction

Sulphur deficiency is increasing due to the adoptation of high yielding varieties, intensive cultivation and use of high analysis sulphur free fertilizer throughout the world. The increased occurrence of sulphur deficiency is attributed to the exhaustive cultivation of oilseed crops. In general, soils in the Punjab have enough sulphur to cater for plant needs, but 25% of cultivated area has SO_4–S less than 10 mg kg^{-1} of soil, which is critical threshold for most crops (Ahmad *et al* 1992).

Total sulphur requirements of cotton may approach the level of phosphorus. Cotton absorbed 12-15 kg ha^{-1} of sulphur and for adequate nutrition 0.2% SO_4–S was desired in cotton petioles and leaves during mid-season (Mitchell and Baker 1997). Cotton requires a continuous supply of external sulphur for normal growth. Proteolysis hardly occurs during sulphur starvation of cotton plant (Mengel and Kirkby 1978). Experiments conducted in Malawi (Mathews 1972) and elsewhere (Makhdum *et al* 2001) showed significant increase in seed cotton yield due to sulphur fertilization. A sulphur dose of 22 kg ha^{-1} gave higher seed cotton yield than control. Cotton growers in South Carolina invariably add 11 kg ha^{-1} of sulphur to obtain maximum cotton yield (Messick 1992).

Fertilizers which contain sulphur as a combining ingredient are being replaced with high analysis fertilizer that are low in sulphur. Crop intensity has increased and determined cotton cultivars which develop nutrient demands more rapidly are common in culture. Taking into account these factors sulphur deficiency is likely to occur in context of prevailing cropping systems. Experiments, therefore, were conducted to test cotton response to sulphur fertilization on its growth yield and fibre qualities.

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Materials and Methods

Experiments were conducted on silty loam soils for two seasons 1998-2000 at Central Cotton Research Institute, Multan, Pakistan. Soil samples were collected before sowing from the plough layer of experimental sites and analysis carried out as per methods described by Klute (1986) and Page *et al* (1982). These soils have pH of 8.37, organic matter 0.4% $NaHCO_3$ extracted phosphorus 14 mg kg^{-1} of soil and NH_4OAc extracted potassium 220 mg kg^{-1} of soil.

Sulphur from soil was extracted using 0.001M $CaCl_2 \cdot 2H_2O$ solution as an extraction agent. Plant leaf samples were washed with distilled water, dried at 70°C, ground and digested in acid mixture (HNO_3 and $HClO_4$). Analyses were conducted by the turbidimetric method with $BaCl_2.2H_2O$; readings were taken using a spectrophotometer at 470 mm (Verma *et al* 1977). Sulphate values in experimental plots ranged from 11 to 13 mg kg^{-1} of soil at the time of planting cotton.

Cotton cultivar CIM-109 was planted in early June at a spacing of 75 cm between rows and 30 cm between plants. The layout of experiment was randomized complete block design with four repeats. The area of each plot was 105 m^2. Sulphur was applied in the form of gypsum and its doses consisted o 0, 7, 14 and 28 kg S ha^{-1}, all broadcasted and incorporated in the soil at the time of seed bed preparation. An additional treatment of ammonium sulphate was included for gypsum comparison and its dose consisted of 28 kg S ha^{-1}. All experimental units received nitrogen and phosphorus. Nitrogen was

Table 1
Effect of sulphur fertilization on development of plant shape (mean of 2 seasons)

Treatments: Sulphur ($kg\ ha^{-1}$)	Treatments: Source	Plant height (cm)	Number of nodes on main stem	Inter-nodal length (cm)
00	--	102	35	2.94
07	Gypsum	107	36	3.01
14	-do-	109	36	3.04
28	-do-	111	36	3.09
28	Ammonium	114	37	3.14
LSD ($p < 0.05$)		4.26*	1.11**	0.16^{ns}

ns, non significant at 0.05 levels; **, highly significant at 0.01 level.

Table 2
Effect of sulphur fertilization on fruit production (mean of 2 seasons)

Treatments: Sulphur ($kg\ ha^{-1}$)	Treatments: Source	Fruiting positions/ m^2	Intact fruit/ m^2	Fruit shedding (%)
00	--	516	121	76.30
07	Gypsum	534	133	75.30
14	-do-	535	133	75.10
28	-do-	540	134	75.00
28	Ammonium	539	133	75.10
LSD ($p < 0.05$)		20.75*	7.09**	1.25^{ns}

ns, non significant at 0.05 levels; **, highly significant at 0.01 level.

applied in the form of urea at the rate of 150 kg N ha^{-1} and phosphorus in the form of diammonium phosphate at the rate of 50 kg P_2O_5 ha^{-1}. Crop production practices were the standard ones of the cotton growing area.

Five consecutive plants in each plot were harvested at maturity and measurements were taken on plant height, fruiting positions and intact fruit. Seed cotton yield and its components were determined by harvesting whole plot and calculations made on area basis. Data obtained were subjected to statistical analysis as per methods described by Gomez and Gomez (1984).

Results and Discussion

Plant height is a good measure of overall growth and development. Field application of sulphur showed significant increase in cotton plant height and its node number (Table 1). Internodal length also increased, but to a non-significant level. These data demonstrate that role of sulphur seemed to be more pronounced in terms of node differentiation than that of elongation of internodal lengths in cotton plant.

Cotton plant requires continuous supply of sulphur for its normal growth. Sulphur deficiency causes accumulation of nitrates and organic nitrogen compounds in cotton plant (Mengel and Kirkby 1978). The slow utilization of nitrogen compounds is likely to reduce plant size in sulphur deficient soils. Sulphur deficient cotton plants, in general, were short and showed abnormal growth and development. Mitchell *et al* (1992) stated that plants deprived of sulphur showed some visible effects which resemble those caused by nitrogen deficiency. The plants show marked decrease in growth and canopy size besides being abnormal in appearance.

Fruiting positions provide indication of potential yield whereas, intact fruits represent actual yield. Data provided in Table 2 indicate significant differences in fruiting positions and intact fruit due to sulphur fertilization. However, there were no differences in fruit shedding. Sulphur fertilization increased plant

Table 3
Effect of sulphur fertilization on seed cotton yield and other characters (mean of 2 seasons)

Treatments: Sulphur ($kg\ ha^{-1}$)	Treatments: Source	Seed cotton yield ($kg\ ha^{-1}$)	Number of bolls per plant	Boll weight (g)	Lint (%)
00	--	2095	22	2.57	35.50
07	Gypsum	2242	24	2.60	35.50
14	-do-	2255	24	2.62	35.60
28	-do-	2255	24	2.62	35.60
28	Ammonium sulphate	2257	24	2.63	35.60
LSD ($p < 0.05$)		31.37**	0.51**	0.03**	0.48^{ns}

ns, non significant at 0.05 levels; **, highly significant at 0.01 level.

Table 4

Effect of sulphur fertilization on fibre characteristics (mean of 2 seasons)

Treatments: Sulphur ($kg\ ha^{-1}$)	Treatments: Source	Fibre length (mm)	Fibre uniformity ratio (%)	Fibre fineness ($\mu g\ inch^{-1}$)	Fibre strength (000 lbs $inch^{-2}$)
00	--	25.60	46.20	4.60	92.50
07	Gypsum	25.80	46.40	4.50	93.10
14	-do-	25.50	46.40	4.60	93.60
28	-do-	25.70	46.20	4.50	93.10
28	Ammonium sulphate	25.80	46.70	4.50	93.70
LSD ($p < 0.05$)		0.45^{ns}	0.88^{ns}	0.23^{ns}	1.70^{ns}

ns, non significant at 0.05 levels.

growth and this led to more fruiting positions and intact fruit. Sulphur fertilization per season did not significantly reduce fruit shedding. Cotton plant has in built capacity to maintain vegetative-reproductive balance called relative fruitfulness (Guinn 1998). Cotton plant due to nutrient deficiency tends to curtail vegetative expansion and thus reduces overall plant size and boll load. This phenomenon is fully exhibited from data on plant size and fruit load obtained in control and sulphur receiving treatments.

The benefit of vigorous plant growth and higher number of intact fruit was reflected in seed cotton yield. Sulphur fertilization caused significant increase in seed cotton yield, boll number and boll weight (Table 3).

Increase in yield occurred with the first level of sulphur application (7 kg ha^{-1}) and no further increase occurred at the second and third sulphur level. Increase in yield was similar irrespective of fertilizer sources viz gypsum and ammonium sulphate. Results obtained in this experiment fully demonstrate sulphur need for cotton crop in soils having SO_4–S in the range of 11-18 mg kg^{-1} of soils. More increase in yield due to sulphur fertilization has been obtained in several cotton growing areas of the world (Matthews 1972; Mascagni *et al* 1991; Tandon 1995; Makhdum *et al* 2001).

Lint samples analyzed for quality showed a little variation due to sulphur fertilization (Table 4).

The reason being that genetic and climatic factors exert so much influence on fibre quality that a little direct effect from sulphur can be elucidated (Mullins 1996; Makhdum *et al* 2001).

Sulphate-sulphur concentration in leaf petioles collected during mid-season increased with sulphur addition in soil (Table 5). The control plots showed a level of 1355 ppm SO_4–S, which increased to 3089 ppm with increased sulphur fertilization.

Table 5

Effect of sulphur fertilization on SO_4–S concentration in leaf petioles

Treatments: Sulphur ($kg\ ha^{-1}$)	Treatments: Source	Leaf petiole: NO_3–N ppm	Leaf petiole: SO_4–S ppm	NO_3–N/ SO_4–S
00	--	15582	1355	11.5
07	Gypsum	12700	2045	6.20
14	-do-	128520	2567	5.00
28	-do-	12550	3089	4.00
28	Ammonium sulphate	12570	3120	4.00

The concentration of 1355 ppm SO_4–S in petioles of control plot confirmed sulphur deficiency, since 2000 ppm value is considered as a critical level in cotton leaves (Mascagni *et al* 1991). Furthermore, the ratio of NO_3–N to SO_4–S was wide engough to indicate sulphur deficiency problem. A ratio of 10 or more is thought to represent sulphur deficiency (Mitchell and Baker 1998).

Conclusions

Cotton yield increased due to application of sulphur at the rate of 7 kg ha^{-1} in soils having alfkaline pH and low organic matter. The critical level of SO_4–S was 11 mg kg^{-1} of soil for the purpose of soil fertilization. Plant analysis indicated 2045 ppm SO_4–S in cotton leaf tissues for harvesting good yield.

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