# Direct and residual effects of integrated sulphur fertilization in maize (Zea mays)-chickpea (Cicer arietinum) cropping system on typic ustochrept

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# Direct and residual effects of integrated sulphur fertilization in maize (*Zea mays*)- chickpea (*Cicer arietinum*) cropping system on Typic Ustochrept

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## ABSTRACT

A field experiment was conducted during the *kharif* and *rabi* season of 2000-04 at Indian Institute of Pulses Research, Kanpur to find out the performance of maize (*Zea mays* L.)-chickpea (*Cicer arietinum* L.) cropping sequence with sulphur fertilization along with farmyard manure (FYM). Inorganic S at 0 and 20 kg/ha was applied during *kharif* maize cultivation and in *rabi* season, three levels of S (0, 10 and 20 kg/ha) were applied with 2 levels of FYM (0 and 4 t/ha). Maize grain yield increased by 0.59 t with the application of 20 kg S/ha over control (1.99 t/ha). Significant positive effects of 20 kg/ha of S as manifested on growth, yield attributes, yield, S uptake, S utilization and economics of maize were not further carried over to following chickpea crop. However, in chickpea nodulation, grain and straw yield, protein content, and S uptake significantly increased due to application of sulphur along with FYM application. Higher mean nodule number (19.38), nodule dry weight (0.213 g/plant), grain yield (1.69 t/ha), straw yield (1.78 t/ha), and S uptake (15.6 kg/ha) was found with the 20 kg/ha of S fertilization. But utilization of added S decreased with increased S supply. Net return and return per rupee investment of the system also increased due to application of S and FYM to chickpea.

***Key words:*** Inceptisol, maize, chickpea, Sulphur utilization, Residual sulphur



Maize (*Zea mays* L.) is one of the important cereal crops next to wheat and rice in the world and maize-chickpea cropping system is most important food legume based system in the country. India is the world's largest producer as well as consumer of pulses. Chickpea (*Cicer arietinum*) is the most important among the pulse crops occupying largest area (6.4 m ha) and production (5.1 m t) in India. Adequate and balanced supply of plant nutrients is a prerequisite for achieving and sustaining the higher productivity (Srinivasarao *et al.,* 2003). Sulphur (S), a key element for higher pulse production is required for the formation of proteins, vitamins and enzymes. Sulphur is a constituent of amino acids cysteine, cystine and methionine. Besides, it is involved in various metabolic and enzymatic processes including photosynthesis, respiration and legume-rhizobium symbiotic nitrogen fixation. Indiscriminate use of high analysis fertilizers coupled with intensive cropping system has resulted in imbalance of soil nutrient reserves resulting in deficiency of S and that is becoming one of the major constraints for increasing productivity of pulses. Many reports indicate substantial yield increase in pulse crops due to S application (Srinivasarao *et al*., 2010). Continuous use of sulphur free fertilizers like di ammonium phosphate (DAP) in place of single super phosphate (SSP) under intensive cereal-pulse cropping systems and lack of addition of organic manures over the years resulted in the emergence of S deficiency. In the early 1990's S deficiency in Indian soils were estimated to occur in about 130 districts (Tandon, 1991). Among ten locations of pulse growing regions of India, characterized for S availability, soils of Kanpur, Faizabad, Delhi and Sehore were found to be low and rest were medium (Srinivasarao *et al*., 2002). Generally light textured soils with low organic carbon content have been found S deficient. The productivity of cropping system depends on efficient utilization of residual and cumulative nutrients. Recommendations for S nutrition in individual crops of maize and chickpea are available but information on S fertilization through sole application of inorganic fertilizer or integration with organic manure, its direct and residual effect in maize-chickpea system as a whole is lacking. Hence this experiment was carried out to study the effects of integrated S supply system on the performance of maize and chickpea grown in sequence on S deficient alluvial soils.

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## MATERIALS AND METHODS

Field experiments were conducted during 2000-04 on fixed site in research farm of Indian Institute of Pulses Research, Kanpur (26°28' N and 80°24' E). Profile soil samples up to the depth of 90 cm were collected from experimental site during the initiation of the experiment. Processed soil samples were analyzed for various physico-chemical properties and various fractions of sulphur. Total S was determined by digestion of the soil with diacid mixture of perchloric acid and nitric acid in the ratio of 1:1. Plant available S was determined in 0.01 M $CaCl_2$ extract. Adsorbed S was calculated by subtracting available S from S extracted with 500 mg/kg P solution. Organic S was calculated by subtracting S extracted in 500 ppm P solution from total S. Sulphur in all the extracts was determined by the turbidimetric procedure. Experimental soil belongs to Typic Ustochrept and profile mean pH, EC, organic carbon and $CaCO_3$ was 7.54, 0.38 dS/m, 3.2 g/kg and 1.19%, respectively and having sand, silt and clay content of 30.3, 35.9 and 22.8%, respectively. Profile soil of the experimental site contained a mean of 7.1 mg/kg of plant available S, 12.9 mg/kg of adsorbed S, 265 mg/kg of organic S and 285 mg/kg of total S. Chickpea was grown in *rabi* season after the harvest of *kharif* maize. Experiment was laid out in split plot design. Treatments consisted of two levels of inorganic sulphur (0 and 20 kg/ha) in *kharif* as main plots. In *rabi*, three levels of S (0, 10 and 20 kg/ha) as a sub plot and two levels of FYM (0 and 4 t/ha) as a sub sub plot. Each treatment was replicated thrice. Inorganic S was applied in the form of elemental S where as FYM was used as organic form of sulphur. Other nutrients such as nitrogen, phosphorus and potassium were applied at the rate of 20, 60 and 20 kg/ha in the form of diammonium phosphate and muriate of potash. Weeding and other management practices were followed as per the recommendations. At 50 days of age, nodule number was counted after carefully lifting the plants along with roots after thorough washing. Collected nodules were oven dried and taken dry weights. Total N and S content in the plant were estimated by standard methods and protein content was computed from total N in the grain. Per cent utilization of added S by maize and chickpea were calculated using the formula:

$$\frac{\text{(S uptake (kg/ha) in treated plot – S uptake (kg/ha) in control plot)}}{\text{Amount of S added}} \times 100$$

## RESULTS AND DISCUSSION

### *Maize*

Mean maize grain yield was increased by 29.7% when 20 kg S/ha was applied as compared to control (Table 1). Higher yield due to S application was owing to higher plant height, dry matter production, and higher values of yield attributes, viz. cob length, cob girth, cob weight, seed weight and shelling per cent. Ram *et al.* (2006) reported response of maize to S fertilization upto 60 kg/ha. Harvest index and crude protein content also followed similar trend as grain yield. Sulphur applied to chickpea during *rabi* season through elemental S upto 20 kg/ha significantly and positively affected the yield attributes, grain

**Table 1.** Effect of S fertilization on growth parameters, yield attributes, yield and protein content of maize in maize-chickpea cropping sequence (pooled data of 4 years)

| Treatment | Plant height at harvest (cm) | Drymatter production at harvest (kg/ha) | Cob length (cm) | Cob girth (cm) | Cob Weight (g) | 100 grain weight (g) | Shelling % | Seed yield (t/ha) | Stover yield (t/ha) | Harvest index (%) | Crude protein content (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| *S application to maize (kg/ha)* | | | | | | | | | | | |
| 0 | 179.8 | 5,937 | 13.09 | 11.20 | 176.2 | 26.60 | 68.11 | 1.99 | 4.05 | 32.95 | 10.11 |
| 20 | 182.1 | 6,493 | 13.94 | 11.28 | 188.1 | 28.12 | 70.14 | 2.58 | 4.26 | 37.70 | 10.91 |
| SEm± | 0.6 | 37 | 0.09 | 0.04 | 2.1 | 0.40 | 0.50 | 0.05 | 0.08 | 0.80 | 0.10 |
| CD(P=0.05) | 1.9 | 118 | 0.29 | NS | 6.7 | 1.30 | 1.60 | 0.14 | NS | 2.50 | 0.30 |
| *S application to chickpea (kg/ha)* | | | | | | | | | | | |
| 0 | 179.9 | 5,830 | 13.10 | 10.99 | 175.6 | 26.14 | 68.05 | 1.99 | 3.93 | 33.68 | 10.07 |
| 10 | 180.1 | 5,979 | 13.40 | 11.05 | 179.8 | 26.87 | 68.66 | 2.19 | 3.99 | 35.36 | 10.43 |
| 20 | 182.8 | 6,448 | 14.05 | 11.14 | 186.4 | 27.31 | 69.11 | 2.51 | 4.24 | 37.18 | 10.84 |
| SEm± | 0.7 | 36 | 0.11 | 0.06 | 1.9 | 0.30 | 0.40 | 0.04 | 0.06 | 0.70 | 0.10 |
| CD(P=0.05) | 2.0 | 102 | 0.32 | NS | 5.4 | 0.90 | NS | 0.11 | 0.17 | 2.00 | 0.30 |
| *FYM application (t/ha)* | | | | | | | | | | | |
| 0 | 179.8 | 6,122 | 13.46 | 11.13 | 178.9 | 26.52 | 68.12 | 2.18 | 4.14 | 34.45 | 10.22 |
| 4 | 182.1 | 6,271 | 13.58 | 11.19 | 184.2 | 27.68 | 68.93 | 2.48 | 4.17 | 37.35 | 10.97 |
| SEm± | 0.7 | 29 | 0.08 | 0.04 | 1.6 | 0.21 | 0.50 | 0.05 | 0.08 | 0.90 | 0.20 |
| CD (P=0.05) | 2.1 | NS | NS | NS | 4.7 | 0.62 | NS | 0.15 | NS | NS | 0.60 |

yield, stover yield, harvest index and protein content in maize. Jaggi and Raina (2008) reported significant positive effects of 30 kg/ha of applied S to garlic were further carried over to following maize crop. Anil Kumar *et al*. (2005) also reported that application of FYM either to maize or both maize and *gobhi sarson* (*Brassica napus* ssp *oleifera* var. *annua*) increased the system productivity by 7.7%. Residual effect of FYM was also reflected on the grain yield, cob weight, seed weight and protein content of maize.

### *Chickpea*

Sulphur applied to previous maize crop did not affect significantly the nodulation, seed, stover yield and harvest index of succeeding chickpea. But significant increase in number of nodules was observed with the application of S as well as FYM in *rabi* season (direct effect). Mean nodule number and nodule weight were increased by 5.4 and 0.014 g/plant with the application of 20 kg S/ha over control (Table 2). Significantly higher nodules/plant of chickpea (19.85) were observed with the application of 4 t FYM/ha compared to no FYM. The effects were very conspicuous with FYM application over inorganic S. This could be due to low level of organic carbon content of soil (0.32%). Addition of FYM could have resulted in increase in organic matter content and corresponding increase in microbial population in soil. In alluvial soils of North India, increasing level of S upto 40 kg/ha significantly increased the nodule number/plant, nodule dry weight and nitrogenase activity in urdbean (Tandon, 1991). However, residual effect of S applied to *kharif* maize did not show significant increase in nodulation even in absence of S in *rabi*.



Effect of integrated S supply on grain and straw (Table 2) showed that chickpea yields were improved significantly. Significant increase in grain yield (1.65 t/ha) and straw yield (5.69 t/ha) was observed due to application of 20 kg S. There was a significant increase in seed yield (1.64 t/ha) and straw yield (5.74 t/ha) due to the application of 4 t FYM/ha. Residual effect of S application during *kharif* season was also realized with higher grain yield of chickpea (1.51 t/ha). Pulses response to S varies widely due to differences in location, crop species, soil type, available S status in soil, genotypes, growth conditions and management level. Based on green house studies, Tandon (1991) reported significant response of chickpea (12.2%) to S application. In different pulse crops, response to S application generally varied from 5-70% (Srinivasarao *et al*., 2001). The response of chickpea to S application varied from 9% on alluvial soils of Kanpur to 47% on alluvial soils of Punjab. The increase in yield parameters might be due to involvement of S in synthesis of S containing amino acids, carbohydrates metabolism, protein synthesis, energy transformation and chlorophyll synthesis. In another experiment, 15% grain yield increase of chickpea was reported at 120 kg S/ha as pyrites with the corresponding increase in S uptake from 10.09 kg/ha in control to 18.07 kg/ha at 120 kg S/ha (Nambiar, 1988).

Protein content of chickpea was significantly influenced by the S fertilization along with FYM (Table 2). Highest protein content (21.4%) was observed with the addition of 20 kg S and with 4 t FYM/ha (21.0%). Sulphur applied in *kharif* maize (residual effect) also significantly influenced protein content. Sulphur application not only increases grain yield but also improves the quality of pulse crops. This is mainly attributed to its association with S-containing amino acids and quality of proteins. Several studies have concluded that lack of S-amino acids is the main factor limiting the biological value of proteins (Singh, 2008). The increase in protein content was reported in chickpea, greengram, blackgram, pigeonpea and lentil. Singh (2008) reported an increase in cystine (50%) and methionine (29%) contents of greengram due to S application. On vertisols, maximum protein content (19.7%), methionine (1.69 g/16g N) and cysteine (1.68g/16g N) were recorded where 50% RDF was applied to chickpea and 100 % RDF + FYM was applied to previous soybean crop.

### *S uptake and utilization*

Significant increase in S uptake in maize (10.95 kg/ha) and chickpea (15.6 kg/ha) due to direct effect of 20 kg S/ha was observed (Table 3). Due to residual effect also in both crops S uptake increased significantly. Application of 4 t FYM/ha also increased S uptake in both the crops. But utilization of applied S decreased at higher S level in case of direct application. Pulse crops in general need as much quantity of S as they require phosphorus. As a thumb rule, the S uptake/tonne of grain production can be taken as 3-4 kg for cereals, 8 kg for pulses. Apart from continuous removal of S from soil, the incidental supply of S to the soil through SSP and ammonium sulphate has been curtailed by the replacement of these fertilizers with DAP and urea (Srinivasarao *et al*., 2003). Use of organic manure and crop residue that used to add some quantity of S has also declined. The wide gap between S removal and addition has drastically reduced the S reserves of the soil and thus the magnitude and extent of its deficiency and crop response to its application is increasing. The extent of S removal by chickpea was 35% more than maize. Sulphur use efficiency in chickpea was found at 18% which increased to 28% with addition of 4 t FYM/ha at 10 kg S/ha application. However, with increasing S application to 20 kg S/ha, the use efficiency came down (Srinivasarao *et al*.,

**Table 2.** Effect of S fertilization on nodulation, yield and protein content of chickpea in maize-chickpea cropping sequence (pooled data of 4 years)

| Treatment | Nodules/plant | Nodule weight (g/plant) | Seed yield (t/ha) | Stover yield (t/ha) | Harvest index (%) | Protein content (%) |
|---|---|---|---|---|---|---|
| *S application to maize (kg/ha)* | | | | | | |
| 0 | 16.56 | 0.205 | 1.45 | 1.81 | 44.5 | 20.5 |
| 20 | 16.68 | 0.207 | 1.57 | 1.90 | 47.0 | 21.1 |
| SEm± | 0.20 | 0.009 | 0.04 | 0.04 | 0.3 | 0.1 |
| CD (P=0.05) | NS | NS | NS | NS | NS | 0.3 |
| *S application to chickpea (kg/ha)* | | | | | | |
| 0 | 13.78 | 0.197 | 1.29 | 1.57 | 45.1 | 20.4 |
| 10 | 16.72 | 0.210 | 1.51 | 1.74 | 46.4 | 20.7 |
| 20 | 19.38 | 0.213 | 1.69 | 1.78 | 48.7 | 21.4 |
| SEm± | 0.39 | 0.003 | 0.04 | 0.05 | 0.4 | 0.1 |
| CD (P=0.05) | 1.14 | 0.008 | 0.11 | 0.14 | 1.1 | 0.2 |
| *FYM application (t/ha)* | | | | | | |
| 0 | 13.40 | 0.180 | 1.32 | 1.60 | 45.3 | 20.6 |
| 4 | 19.85 | 0.233 | 1.64 | 1.81 | 47.5 | 21.0 |
| SEm± | 0.34 | 0.002 | 0.05 | 0.05 | 0.31 | 0.1 |
| CD (P=0.05) | 1.01 | 0.005 | 0.14 | 0.15 | 1.0 | 0.3 |



**Table 3.** Sulphur uptake and utilization of added S as affected by S fertilization in maize-chickpea cropping sequence

| Treatment | S uptake by maize (kg/ha) | S utilization (%) | S uptake by chickpea (kg/ha) | S utilization (%) | Total uptake (kg/ha) |
|---|---|---|---|---|---|
| *S application to maize (kg/ha)* | | | | | |
| 0 | 7.85 | | 13.9 | | 21.7 |
| 20 | 10.95 | 14.8 | 15.1 | 6.0 | 26.0 |
| SEm± | 0.29 | | 0.2 | | |
| CD (P=0.05) | 0.92 | | 0.6 | | |
| *S application to chickpea (kg/ha)* | | | | | |
| 0 | 7.71 | | 12.3 | | 20.0 |
| 10 | 8.65 | 9.4 | 14.2 | 19.0 | 22.9 |
| 20 | 10.80 | 15.4 | 15.6 | 16.5 | 26.4 |
| SEm± | 0.21 | | 0.1 | | |
| CD (P=0.05) | 0.60 | | 0.4 | | |
| *FYM application (t/ha)* | | | | | |
| 0 | 8.85 | | 12.4 | | 21.3 |
| 4 | 9.98 | 17.6 | 15.6 | 34.4 | 25.6 |
| SEm± | 0.22 | | 0.1 | | |
| CD (P=0.05) | 0.65 | | 0.2 | | |

**Table 4.** Economics as influenced by S fertilization in maize-chickpea cropping sequence

| Treatment | Cost of cultivation (Rs/ha) | Net return (Rs/ha) | Net return per Re investment |
|---|---|---|---|
| *S application to maize (kg/ha)* | | | |
| 0 | 20,533 | 21,268 | 1.04 |
| 20 | 22,933 | 25,900 | 1.13 |
| *S application to chickpea (kg/ha)* | | | |
| 0 | 20,533 | 18,500 | 0.90 |
| 10 | 21,733 | 22,786 | 1.05 |
| 20 | 22,933 | 27,388 | 1.19 |
| *FYM application (t/ha)* | | | |
| 0 | 20,533 | 20,615 | 1.00 |
| 4 | 21,733 | 27,471 | 1.26 |

2004).

### *Economics*

Net return (Rs. 25,900/ha) and return per rupee investment (1.13) of the system increased from Rs. 21,268/ha and 1.04, respectively with the application of 20 kg S/ha in the maize crop. Application of S to chickpea crop also increased net return and return per rupee investment. Higher economic benefits were also obtained with FYM application.

Results suggest that in sulphur deficient regions, yield levels of maize-chickpea system could be improved by sulphur application at 20 kg/ha in *kharif* maize and 20 kg/ha to *rabi* chickpea. Integration of FYM along with inorganic sulphur fertilizer improves yields of the system further.

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