Sulfur Management for Optimizing Oilseed and Pulse Production in Rain-fed Jharkhand

By Surendra Singh and A.K. Sarkar

Sulfur (S) deficiency in Indian soils is increasing due to extensive use of S-free fertilizers coupled with the increasing area under high S demanding crops such as oilseeds and pulses. On-farm experiments conducted on rain-fed upland soils of Jharkhand showed that S application could improve yield and quality of these crops. Significant direct and residual effects of S application on crop yields were found in mustard-black gram and groundnut-mustard cropping systems. Sulfur application was beneficial over existing recommendations that omit S for niger, mustard, groundnut, black gram, lentil, and soybean.

The state of Jharkhand, with an area of 795,000 ha, forms part of agro-climatic zone VII (Eastern plateau and hill region) of India. Of the total net sown area, 90% is rain-fed. Upland rain-fed soils are Alfisols, acidic in reaction, low in base saturation, high in P fixation capacity, poor in OM content and poor in water and nutrient retention capacities. Oilseeds and pulses grown on these soils have low average yields (less than 300 kg/ha).

A systematic evaluation of soil available S status was initiated in this region during the early 1990s. The S fertility status of oilseed- and pulse-growing areas were rated as low, which seemed to be one of the main causes of low productivity and quality in these crops. Analysis of a large number of surface samples revealed S deficiency in more than 50% of Jharkhand soils (Singh et al., 2000). The major reasons for S deficiency in these soils are: i) coarse-texture with low OM content, ii) leaching and erosion, iii) imbalanced use of S-free fertilizers, and iv) deficit application of S fertilizers in all crops, but mainly in oilseeds and pulses.

Field experiments on oilseed and pulse crop responses to S application were conducted in Dumka (sub-zone IV), Ranchi (sub-zone V), and East Singhbhum (sub-zone VI) districts of Jharkhand in *Kharif* and *Rabi* seasons from 1995 to 2006. Soils had pH values ranging from 5.5 to 6.4, OC from 0.26 to 0.47%, and soil available S (extracted with 0.15% $CaCl_2$) from 8.8 to 17.6 kg/ha.

Gypsum, phosphogypsum (PG) and single superphosphate (SSP) were evaluated as S sources. Gypsum contained 13% S, PG 15% S, and SSP contained 12% S plus 16% water-soluble P. Whenever SSP was used as S source, the P rate was adjusted accordingly. All sources were applied basally at the time of sowing and mixed uniformly with the soil. Recommended rates of N, P and K were applied to each crop as urea, triple superphosphate and potassium chloride (KCl). Rates of N, P, K and S applied to each crop are given in **Table 1**.

Table 1. Locations and nutrient application rates in major oilseed and pulse crops of Jharkhand.

		Rates of nutrient application, kg/ha			
Locations	Crops	N	P	K	S
Dumka (sub-zone IV)	Niger	20	20	20	15-60
Ranchi (sub-zone V)	Mustard	40	20	20	20-80
Ranchi (sub-zone V)	Groundnut	25	50	20	20-60
Ranchi (sub-zone V)	Black gram	20	40	20	12-36
East Singhbhum (sub-zone VI)	Lentil	20	40	20	10-40
East Singhbhum (sub-zone VI)	Soybean	20	60	20	20-60

Sulfur deficiency symptoms visible on groundnut (top) and black gram (right), which are initially expressed on the young, upper leaves that turn a pale green to yellow color.

Variable response to applied S was found in three oilseed and pulse crops compared to the NPK fertilizer recommendation (**Table 2**). Among oilseeds, niger grain, mustard grain

Table 2. Response of sulfur application to major oilseed and pulse crops of Jharkhand.

Crops	S sources	S rate, kg/ha	Yield with NPK, kg/ha	Yield with NPK + S, kg/ha	Response, %	Critical difference (p=0.05)
Oilseeds						
Niger	PG[1]	45	330	460	40	59
Mustard	PG	60	1,200	1,500	26	26
Pulses/legumes						
Groundnut	Gypsum	40	2,350	3,000	28	94
Black gram	PG	24	973	1,212	24	52
Lentil	PG	30	1,490	1,750	17	50
Soybean	PG	60	1,210	1,720	42	80

[1]PG = phosphogypsum
Sources: Singh et al., 2000; Singh and Singh, 1996; Singh et al., 1998; Singh et al., 2006.

Abbreviations and notes: N = nitrogen; P = phosphorus; K = potassium; OM = organic matter; OC = organic carbon; Kharif = rainy season; Rabi = dry season; ₹ = Indian rupee (US$1 = ₹54.17).

Table 3. Direct and residual effect of sulfur in oilseed-based cropping systems of Jharkhand.

			Yield, kg/ha					
			Direct			Residual		
Cropping systems	S source	S rate, kg/ha	With NPK and S	With NPK	Response, %	With NPK and S	With NPK	Response, %
Mustard-black gram	PG[1]	60	1,520	1,280	19	1,080	880	23
Critical difference (p=0.05)				41			26	
Groundnut-mustard	SSP	45	1,510	1,290	17	1,040	800	30
Critical difference (p=0.05)				65			93	

[1]PG = phosphogypsum; SSP = single superphosphate.

kg S/ha as PG significantly increased mustard grain yield by 240 kg/ha and that of the succeeding black gram crop by 200 kg/ha. Application of 45 kg S/ha added through SSP also significantly increased the yield of groundnut pods by 220 kg/ha, and the yield of the succeeding mustard grown on residual S increased by 240 kg/ha. For both cropping systems, the direct effect of S application contributed about 17 to 19% more yield while crops grown on residual S showed a greater response that ranged between 23 to 30%.

Table 4. Effect of sulfur on quality of oilseed and pulse crops of Jharkhand.

Crops	S rate, kg/ha	Content	Quality parameters, % With N, P and K	With N, P, K and S	Response, %	Critical difference (p=0.05)
Niger	60	Oil	39	44	11	0.9
Mustard	80	Oil	38	41	7	0.6
Groundnut	40	Oil	36	40	11	0.4
Black gram	36	Protein	15	18	14	0.2
Lentil	40	Protein	17	18	6	0.3
Soybean	60	Protein	35	37	6	1.4

Table 5. Economics of sulfur application in oilseeds and pulses of Jharkhand.

Crop	S rate, kg/ha	S response, kg/kg	S response, ₹/ha	Value: cost ratio	Benefit: cost ratio
Niger	45	2.9	67	9.2	8.2
Mustard	60	9.0	165	22.6	21.6
Groundnut	40	16.3	342	46.9	45.9
Black gram	24	10.0	275	37.6	36.6
Lentil	30	8.7	256	35.0	34.0
Soybean	60	8.5	189	25.8	24.8

Prices/costs per kg were: ₹23.2 (niger), ₹18.3 (mustard), ₹21 (groundnut), ₹27.6 (black gram), ₹29.5 (lentil), ₹22.5 (soybean); ₹7.3/kg S in gypsum/phosphogypsum.

and groundnut pod yields were significantly increased by 130 (40%), 300 (26%) and 650 (28%) kg/ha with added S levels of 45, 40 and 60 kg/ha, respectively, over the recommended rate of NPK application. Similarly among pulses, application of 24, 30 and 60 kg S/ha significantly increased black gram, lentil and soybean yields by 239 (24%), 260 (17%) and 510 (42%) kg/ha. Since these fields were deficient in available S status (less than 10 kg/ha), an increase in crop yield may be expected due to external application of S.

Results on direct and residual effects of S sources are presented in **Table 3**. In general, application of S benefits more than one crop grown in sequence and produces a significant residual response. Residual response depends on rate of S application, nature of S source, and the crop being grown. Data of two field experiments revealed significant direct and residual response of added S in mustard–black gram and groundnut–mustard cropping systems. Application of 60

Sulfur applied to these low S soils not only increased crop yields, but also affected crop quality such as oil content of oilseeds and protein content of pulses (**Table 4**). As S is an important constituent of some essential amino acids (e.g., cysteine, cystine and methionine), soil S deficiency can lower protein quality. Cruciferous crops contain S in secondary plant substances such as oils, whose synthesis is inhibited in S deficient soil. Application of S through gypsum and PG resulted in a significant increase of oil content in niger (11%), mustard (7%) and groundnut (11%); and also a significant increase in protein content in black gram (14%), lentil (6%) and soybean (6%).

Data in **Table 5** provides the value-to-cost ratios (VCR) for S application, which are indicators of gross return. The rate of net return (benefit-to-cost ratio or BCR) is calculated by subtracting 1 from the VCR. The rate of return from S application varied between crops and was generally higher in the groundnut, black gram and lentil crops that required less S (between 24 and 40 kg/ha) compared to the niger, mustard and soybean crops that required 45 to 60 kg S/ha. The highest BCR of 45.9 was obtained in groundnut.

Conclusions

It is recommended that the S-deficient, rain-fed upland soils of Jharkhand should receive S application through gypsum, PG or SSP along with the recommended rates of N, P and K fertilizers. The economic optimum S rate was found to be 40 to 80 kg S/ha for the major oilseeds and 24 to 40 kg S/ha for pulse crops that are extensively grown within the region. BC

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