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Assessment of economic sulphur doses of soybean (*Glycine max merill* L.) in *Malwa* region of western M.P.

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Abstract
On farm trials (OFTs) were conducted for consecutive two years during 2011-12 and 2012-13 to assess the optimum sulphur levels of soybean with respect to growth, yield attributing characters, productivity, protein content and economics involved under Malwa plateau conditions of Central India. Soybean variety, JS 95-60 was taken to assess three levels of sulphur (0, 20 and 40 Kg S/ha). Treatment RDF+ 40 Kg S/ha found to be optimum level of sulphur as this treatment recorded significantly higher soybean root nodulation, yield and yield attributing characters, oil and protein content over 0 and 20 Kg sulphur/ha. This treatment also expressed its superiority over rest of the treatments in case of B: C ratio and net return. Thus, it may be concluded that application of RDF +sulphur @ 40 kg per ha was found economic feasible and beneficial for enhancing soybean productivity in Vertisols under rainfed conditions of Madhya Pradesh.

Keywords: Soybean, sulphur doses, root nodulation, yield, oil, protein content and economics

Introduction
Soybean [*Glycine max* (L.) Merrill], being an oil yielding leguminous crop, richest source of high quality protein, oil, calcium, iron and in amino acid like glycine, has established its potential as an industrially and economically viable oilseed crop in the world by virtue of its high nutritional value and myriad uses. In India, soybean has emerged as an important oilseed crop. One of the major constraints for low soybean productivity is provision of imbalanced nutrition (Joshi and Bhatia, 2003) [4]. Unless soybean is provided with required nutrient input to produce sufficient biomass, it may not yield high (Singh *et al*., 2003) [9].
Sulphur is an essential plant nutrient for crop production. For oil crop producers, sulphur fertilization is especially important because oil crops require more sulphur than cereal crops. For example, the amount of S required to produce one ton of seed is about 3-4 kg sulphur for cereals (range 1-6); 8 kg sulphur for legumes (range 5-13); and 12 kg sulphur for oil crops (range 5-20) (Jamal *et al*., 2010) [3]. In general, oil crops require about the same amount of sulphur as, or more than, phosphorus for high yield and product quality. The role of sulphur in soybean production has been reported by Srivastava *et al*. (2000) [10].
Application of sulphur improved nitrogenase activity, nitrogen fixation, plant dry matter and quality of soybean grain in sulphur deficient soil (Kandpal and Chandel, 1993) [5]. Sulphur fertilization significantly improves various quality parameters within plant system. Sulphur application @ 20 to 40 kg per ha in soybean produced maximum yield in various soils (Billore and Vyas, 2012). The present investigation was undertaken to assess the optimum economic sulphur levels of soybean in Malwa region of western M.P.

Materials and Methods
On Farm Trials (OFTs) were conducted in kharif seasons of 2012 and 2013 in the adopted village Rakoda by Krishi Vigyan Kendra, Ratlam. The soil of the experimental area was light black, loamy in texture, with low available nitrogen, medium in phosphorus and high in potassium status. This OFT was conducted at 5 farmer's fields with JS 95-60 variety during both the years. The treatments were farmers' practice T_1 (RDF+ No sulphur), T_2 (RDF+ sulphur @ 20 Kg/ha) and T_3 (RDF+ sulphur @ 40 Kg/ha). The recommended doses of nitrogen (20 kg N /ha), phosphorus (60 kg P_2O_5/ha) and potassium (20 kg K_2O/ha) were applied as basal to all the treatments. The different sulphur doses were also applied as basal dose. The sowing of soybean was carried out in the month of June and harvested in the first week of October. The recommended packages of practices were followed to raise the crop. The root nodules were counted by deep uprooting and washing of the root system with water

at 40 days after sowing. The observation of pods per plant, and test weight were taken at the time of harvesting. The seed samples were analyzed for assessing the protein content. For this, randomly drawn seed samples of known quantity from each treatment were utilized. Prior to seed protein content estimation, nitrogen content in seed was determined. The protein content was estimated by multiplying nitrogen content value of soybean seed by 6.25 (Sadasivam and Manickam, 1996) [7]. The total oil content of soybean seed was determined by analytical supercritical fluid extraction (SFE) with carbon dioxide as the extraction solvent and expressed as percent of total seed weight.

Results and Discussion

Effect on growth observation

The pooled data indicated that the application of increased levels of sulphur brought out substantial improvement in nodulation. The significantly higher root nodules per plant were recorded with treatment T_3 (RDF+ sulphur @ 40 Kg/ha). This may be due to better root development and profuse nodulation on account of increased rhizobial activity in the rhizosphere under sulphur and biofertilizers availability. This finally resulted in the formation of bolder and more number of root nodules. The positive response of sulphur on nodulation was also observed by workers like Ganeshmurthi and Reddy (2000) [2], and Watimongla and Gohain (2012) [13].

Effect on yield and yield attributing characters

Sulphur @ 40 kg per ha increased the number of pods per plant by 12.86 and 53 per cent over T_2 and T_1 treatments, respectively (Table 1).The increase in seed yield by 12.83 and 42.40 per cent was recorded with 40 kg S per ha over T_2 and T_1 treatments, respectively. Similarly, increased application of sulphur (T_3) exhibited the highest test weight of soybean. The increased yield under sulphur fertilization might be ascribed to increased pods per plant and seeds per pod with heavier seeds. Thus, significant improvement in yield obtained under sulphur fertilization seems to have resulted owing to increased concentration of sulphur in various parts of plant that helped maintain the critical balance of other essential nutrients in the plant and resulted in enhanced metabolic processes. Vyas *et al.* (2006) [12] also noticed increased yield of soybean with application of sulphur. Sulphur plays a vital role in improving vegetative structure for nutrient absorption, strong sink strength through development of reproductive structures and production of assimilates to fill economically important sink (Sharma and Singh, 2005) [8].

Quality parameters

The increasing levels of sulphur significantly improved the quality of soybean in terms of protein and oil content. There was increase in oil content with the application of 40 kg S per ha by 5.97 percentage and 10.87 percentage over T_2 and T_1 treatments. Similarly, increase in protein content with the application of 40 kg S per ha by 5.58 percentage and 4.37 percentage over T_2 and T_1 treatments was noticed (Table 2). Increase in oil content due to sulphur application can be attributed to the key role played by sulphur in biosynthesis of oil in oilseed plants. The increase in protein content may be accounted for the increase in synthesis of sulphur containing amino acids. Such beneficial effects of sulphur fertilization were also reported by Tandon *et al*. (2007) [11] and Nath *et al.* (2018) [6].

Economics

Among the S levels, maximum net returns was recorded with 40 kg S per ha, whereas benefit cost ratio 2.63 and 2.58 was mostly equal in 40 and 20 kg S per ha, respectively (Table 3). This behaviour of economic parameters due to S levels was change in marginal seed yield of the crop with successive increase in fertilizer nutrient and relative cost of inputs in relation to output.

Tandon *et al.* (2007) [11] also reported that S application is highly profitable as shown by value cost ratio in soybean under field condition.

Conclusion

Thus, it may be concluded that application of sulphur @ 40 kg per ha was found beneficial for enhancing soybean productivity in Vertisols under rainfed conditions of Madhya Pradesh.

Table 1: Effect of different levels of sulphur on yield attributing characters

Treatment	No. of Nodules/ plant			No. of pods/ plant			1000 seed weight (g)			Seed yield (q/ha)		
	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled	2011-12	2012-13	Pooled
T_1 (RDF + No Sulphur)	24	24	24	20.00	19.00	20.07	105	105	105	15.8	15.8	15.8
T_2 (RDF + S @ 20 Kg/ha)	30	29	29.5	26.29	26.00	27.21	109	108	108.5	20.5	20.1	20.3
T_3 (RDF + S @ 40 Kg/ha)	41	43	42	29.86	31.43	30.71	115	115	115	22.8	22.2	22.5
SEm ±	2.18	2.18	1.09	0.33	2.23	2.23	2.18	1.78	1.67	0.93	1.53	1.09
CD at 5%	6.72	6.72	3.36	1.02	6.89	6.89	6.72	5.49	5.14	2.86	4.71	3.36

Table 2: Effect of different levels of sulphur on quality parameters

Treatment	Oil %			Protein %		
	11-12	12-13	Pooled	2011-12	2012-13	Pooled
T_1 (RDF+ No Sulphur)	17.64	18.21	17.93	37.43	36.71	37.07
T_2 (RDF+ S @ 20 Kg/ha)	18.64	18.87	18.76	37.71	37.29	37.50
T_3 (RDF+ S @ 40 Kg/ha)	19.70	20.06	19.88	39.43	38.86	39.14
SEm ±	0.37	0.3	0.3	0.46	0.46	0.47
CD at 5%	1.15	0.78	0.85	1.43	1.43	1.45

Table 3: Effect of different levels of sulphur on pooled economic parameters

Treatment	Mean Cost of cultivation (Rs./ha)	Pooled Gross return (Rs./ha)	Pooled Net return (Rs./ha)	Pooled B:C Ratio
T_1 (RDF+ No Sulphur)	20200	49500	29300	2.45
T_2 (RDF+ S @ 20 Kg/ha)	20900	54000	33100	2.58
T_3 (RDF+ S@ 40 Kg/ha)	21800	57300	35500	2.63

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