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Influence of sulphur level on yield, uptake and quality of soybean (*Glycine max*) under temperate conditions of Kashmir valley

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ABSTRACT

A field experiment was conducted during 2004 and 2005 to study the influence of sulphur levels on yield, uptake and quality of soybean (*Glycine max* L. Merr) under temperate conditions of Kashmir valley. Increasing levels of sulphur significantly increased growth, nodulation, yield, uptake and quality of soybean up to the application of 30 kg S/ha but maximum growth, nodulation, yield and quality of soybean was recorded under 40 kg S/ha which was at par with 30 kg S/ha. Stover and grain yield of soybean increased in the tune of 66.0 and 53.4% over the control due to addition of 40 kg S/ha, respectively. Application of 40 kg S/ha recorded highest total N, P, K, S, Ca and Mg nutrients uptake by soybean over the rest of the treatments. However, highest sulphur-use efficiency and apparent sulphur recovery was recorded with 10 kg S/ha, followed by 20 kg S/ha. The maximum N: S, K: S, Ca: S and Mg: S ratio were recorded under control, whereas minimum with the application of 40 kg S/ha in stover and seed of soybean. The available S at harvest soil increased significantly with S level.

Kew words: Nodulation, Quality, Soybean, Sulphur levels, Uptake, Yield

Soybean (*Glycine max* L. Merr.) is an important leguminous crop of economic and dietary value in India. Summer season of Kashmir valley is most favourable for its cultivation. The earlier studies were confined mainly to N, P and K requirement to this important crop. However, no attention was paid to sulphur nutrient. Sulphur deficiency is reported in Inceptisols of Kashmir valley and identified as yield-limiting factor, particularly in production of pulses and oilseed crops (Shrivastava *et al*. 2000). Sulphur is an important secondary nutrient which helps in synthesis of cystein, methionine, chlorophyll, vitamins (B, biotin and thiamine), metabolism of carbohydrates, oil content, protein content and also associated with growth and metabolism, especially by its effect on the protolytic enzymes. Sulphur response has been observed for several legume crops including soybean and its application to sulphur deficient soils has been found to increase the crop yield and improve the quality of crop produce (Sarkar *et al*. 2002, Singh *et al*. 2006). The magnitude of sulphur removal is much higher due to intensive cropping therefore it is important to carry out detailed investigation to understand the uptake pattern in different crops. Therefore, an attempt has been made in the present investigation to find out optimal levels of sulphur for soybean crop under temperate conditions of Kashmir valley.

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MATERIALS AND METHODS

A field experiment was conducted at Regional Research Station, SKUAST-K, Wadura for two consecutive years during rainy *(kharif)* 2004 and 2005 on soybean. The experimental soil was silty clay loam in texture having *p*H (1:2.5) 7.20, EC 0.39 dS/m, organic carbon 7.8 g/kg and available N, P, K and S contents were 283.7, 15, and 210 and 8.5 kg/ha, respectively. The experiment was laid out with four replications in a randomized block design with five treatments, i e control (S_0), 10 (S_{10}), 20 (S_{20}), 30 (S_{30}) and 40 (S_{40}) kg S/ha in fixed plot. Sulphur was applied through gypsum in moist soil three days prior to sowing as per treatments. A uniform recommended dose of N, P and K 20, 17.5 and 25 kg/ha were applied as basal through urea, diammonium phosphate and muriate of potash, respectively. ‘Shalimar Soy 1’ soybean seeds were sown on 5 and 7 June in 2004 and 2005, respectively. All the cultural practices were followed as per package of practice. Nodules number, fresh and dry weight was observed after 65 days of crop. The data was recorded on different parameters and pooled as the difference between the years was not significant. The initial soil samples were analyzed for its various physico-chemical parameters by the standard methods (Jackson 1973). The stover and grain samples were collected at harvest analyzed for P, K Ca, Mg and S by vanadomolbedophosphoric yellow colour method, flame photometer, EDTA titration method and turbidimetric method (Chesnin and Yien 1951), respectively. Available S in soils at harvest was extracted with 0.15% $CaCl_2$ and estimated by turbidimetric method. The N in soybean seed was determined by modified Kjeldahl method and used for computation of crude protein by multiplying the N content (%) with a factor of 5.71 as given by Sadasivam and Manickam (1992). The oil content in soybean seed was determined using Soxhlet apparatus in petroleum ether (40–60°C). Sulphur containing amino acids such as methionine and cystein content were analyzed by adopting procedure as given by Horn *et al*. (1946) and Leach (1966). The sulphur-use efficiency and apparent sulphur recovery was worked as follows:

Sulphur-use efficiency (kg grain/ kg S applied) = (yield in treated plot– yield in control plot)/amount of S applied

Apparent sulphur recovery (%) = [(uptake in treated plot– uptake in control plot)/ amount of S applied] × 100

RESULTS AND DISCUSSION

Data presented in Table 1 revealed that plant growth, nodulation and yield attributes of soybean increased significantly with the increasing levels of sulphur when compared with control. However, maximum plant height, pods/plant and seeds/pod were recorded with the application of 40 kg S/ha which was at par with 30 kg S/ha. The improvement in crop growth and yield attributes with S application could be observed to its pivotal role in regulating the metabolic and enzymatic processes including photosynthesis and respiration which resulted in yield increase (Singh *et al*. 2000). Number, fresh and dry weight of nodules also significantly increased with successive increasing of S up to the application of 30 kg S/ha, beyond which a plateau was reached. This might be due to sulphur being the integral component of nitrogenase enzyme which improved the nodulation and fixation of N_2 in legume-*Rhizobium* symbiosis. Similar results were reported by Ganeshamurthy and Reddy (2000). Increasing levels of sulphur significantly increased the stover and grain yield of soybean over control. The significantly higher stover (1.89 tonnes/ha) and grain (1.80 tonnes/ha) yield was recorded with the application of 40 kg S/ha over rest of the treatments but was at par with the application of 30 kg S/ha during both the years. Application of 40 kg S/ha increased stover and grain yield of soybean in the tune of 66.0 and 53.4% more over the control, respectively. These results are in close conformity with the findings of Nasreen and Farid (2006). The sulphur-use efficiency (SUE) and apparent sulphur recovery (ASR) significantly decreased with increasing levels of sulphur in soybean. SUE and APR decreased from 28.1 to 15.7 and 24.3 to 18.9 from the application of 10 to 40 kg S/ha. The highest SUE (28.1 kg/kg) and APR (24.3%) were recorded under 10

Table 1 Effect of different levels of S on nodulation, yield and fertilizer-use efficiency of soybean (pooled data of two years)

S level (kg/ha)	Plant height (cm)	Nodules/ plant	Fresh weight/ plant (g)	Dry weight/ plant (mg)	Pods/ plant	Seeds/ plant	Stover yield (tonnes/ha)			Seed yield (tonnes/ha)			SUE (kg grain/ kg S)	ASR (%)	Available S in soil at harvest (kg/ha)
							2004	2005	Mean	2004	2005	Mean			
S_0	56.1	18.1	0.61	102	55.0	92.7	1.11	1.17	1.14	1.09	1.26	1.17			6.9
S_{10}	63.4	24.0	1.02	193	61.1	98.8	1.42	1.64	1.53	1.31	1.60	1.45	28.1	24.3	9.1
S_{20}	68.8	29.2	1.28	336	67.2	103.0	1.62	1.83	1.73	1.57	1.71	1.64	23.4	23.9	13.8
S_{30}	73.2	33.5	1.42	411	74.3	106.1	1.81	1.91	1.86	1.67	1.83	1.75	19.2	21.5	16.7
S_{40}	74.4	34.6	1.46	420	76.6	107.0	1.82	1.96	1.89	1.70	1.90	1.80	15.7	18.9	21.5
CD (P=0.05)	4.02	1.95	0.05	14.4	4.62	1.90	0.98	1.10		0.91	1.04				0.74

Table 2 Effect of different levels of S on concentration of macro and secondary nutrients in soybean (pooled data of two years)

S level (kg/ha)	N content (%)		P content (%)		K content (%)		S content (%)		Ca content (%)		Mg content (%)	
	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed	Stover	Seed
S_0	1.80	5.68	0.032	0.68	2.21	2.40	0.20	0.38	0.78	0.86	0.38	0.40
S_{10}	1.93	5.77	0.042	0.70	2.28	2.44	0.22	0.41	0.81	0.90	0.42	0.43
S_{20}	2.00	5.81	0.045	0.71	2.32	2.49	0.24	0.45	0.81	0.94	0.44	0.46
S_{30}	2.05	5.84	0.047	0.72	2.34	2.54	0.25	0.48	0.82	0.96	0.46	0.49
S_{40}	2.07	5.88	0.048	0.73	2.34	2.55	0.26	0.49	0.82	0.96	0.47	0.51
CD (P=0.05)	0.05	0.12	0.002	0.01	NS	NS	0.20	0.38	NS	NS	0.013	0.02

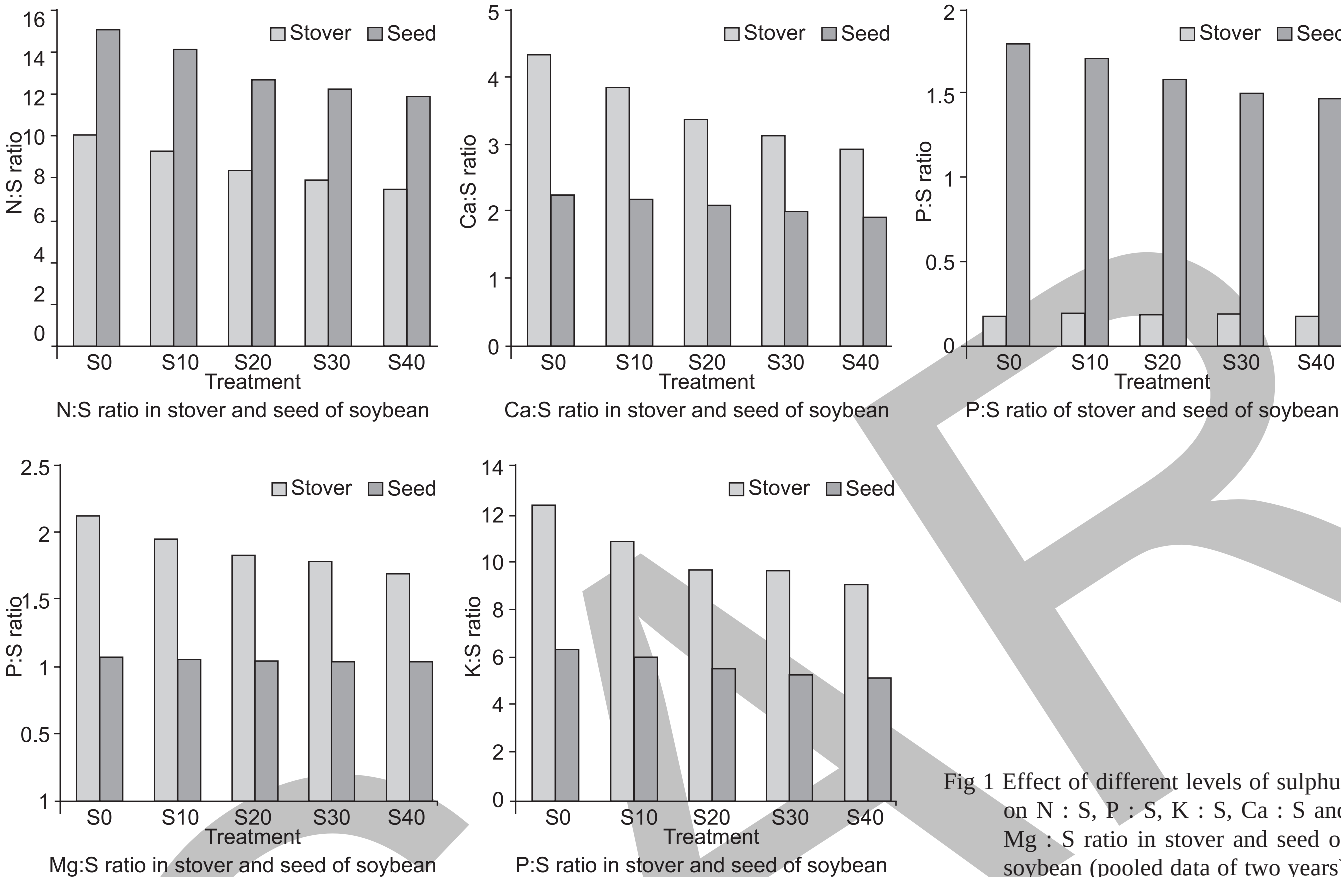

Fig 1 Effect of different levels of sulphur on N : S, P : S, K : S, Ca : S and Mg : S ratio in stover and seed of soybean (pooled data of two years)

kg S/ha. The available S in the post-harvest soil increased significantly with S level.

The concentration of macro and secondary nutrients in stover and seeds of soybean significantly affected due to the application of sulphur (Table 2). Application of S significantly increased the concentration of N, P, S and Mg in stover and seed of soybean over the control. However, K and Ca concentration did not increase significantly. The maximum content of N (2.08 and 5.88%), P (0.47 and 73%), S (0.28 and 0.50%) and Mg (0.47 and 0.51%) in stover and seed were recorded with 40 kg S/ha. The increase in nitrogen content might be attributed to the increase in number and size of nodules and thereby increasing the fixation of N_2 by the plant and also due to utilization of carbohydrates for protein synthesis (Ganeshamurthy and Reddy 2000). The significant increase in the P and Mg content in the seed and stover may be due to favourable effects of S fertilizers on absorption of other elements. Such effect may be due to the action of acid produced by the added sulphur (Singh *et al.* 2006). Increased sulphur content in stover and seed may be due to rapid absorption and translocation of it by plant with adequate supply of sulphur from the soil (Shrivastava *et al.* 2000).

The application of sulphur in soybean significantly affected various nutrient ratios in stover and seed of soybean. The N:S and P:S ratio recorded maximum in seed than stover of soybean, whereas K:S, Ca:S and Mg:S ratio were recorded maximum in stover with different treatments (Fig 1). Increasing levels of S significantly decreased the entire ratio except P: S ratio which increased with increasing levels of S up to 20 kg S/ha thereafter decreased. The maximum N:S, K:S, Ca:S and Mg:S ratio were recorded under control whereas minimum with the application of 40 kg S/ha in stover and seed. However, P:S ratio in stover recorded maximum under 20 kg S/ha. Decreasing various nutrient ratios in stover and seeds of soybean with increasing levels of sulphur may indicate the S requirement for higher productivity of soybean in S-deficient soil. Moreover, adequate availability of S may also help in mineralization of nutrients as S is the integral part of S-contain amino acids which is essential for growth and development of microorganisms resulted increased the concentration and uptake of macro and secondary nutrients by soybean (Saini *et al.* 2005).

Total uptake of N, P, K, S, Ca, and Mg by soybean was recorded maximum with the application of 40 kg S/ha over rest of the treatments but at par with 30 kg S/ha, although the increasing levels of sulphur increased the uptake of these elements significantly when compared to control (Table 3). This may be owing to high production of stover and seed yield and increase in the content of these elements in stover

Table 3 Effect of different levels of S on uptake of macro and secondary nutrients and quality of soybean (pooled data of two years)

S level (kg/ha)	Total nutrient uptake (kg/ha)						Quality of soybean			
	N	P	K	S	Ca	Mg	Protein content (%)	Oil content (%)	Methionine (g/16 g N)	Cystein (g/16 g N)
S_0	83.7	8.39	53.3	6.74	19.08	9.22	34.02	15.7	1.50	1.42
S_{10}	113.4	10.8	70.4	9.17	25.47	12.68	35.43	17.5	1.57	1.48
S_{20}	132.3	12.4	80.9	11.52	29.38	15.13	36.94	18.3	1.62	1.52
S_{30}	140.0	13.5	88.0	13.20	32.07	17.14	37.66	19.1	1.65	1.54
S_{40}	144.6	14.1	91.7	14.29	32.87	18.07	37.74	19.2	1.67	1.55
CD (P=0.05)	7.35	0.72	4.43	0.72	1.90	1.01	1.37	0.75	0.06	0.05

and seed due to S application at 40 kg/ha. These results are in agreement with those of Shrivastava *et al*. (2000) and Nasreen and Farid (2006).

Protein, oil content and amino acid content in soybean seed increased with successive increase of S levels (Table 3). The protein content increased from 34.02 to 37.74% with the application of 40 kg S/ha which was markedly higher over the control. Oil content in soybean seed increased with increasing levels of S when compared with control. Oil content increased from 15.7 to 19.2% at 40 kg S/ha which was significantly superior over other treatments but at par with 30 kg S/ha. An increase in oil content in oilseeds due to S application was also earlier reported by Singh *et al.* (2006). The methionine and cysteine content increased from 1.50 to 1.67 and 1.42 to 1.55 g/16 g N with the application of sulphur levels from 0 to 40 kg/ha, respectively. Application of S in sulphur-deficient soil enhances the amount of these amino acids and protein content in seed. Sulphur nutrition affects the amino acid composition in seeds which determines their nutritive value. The same trend in sulphur containing amino acids in soybean seed was also reported by Kiyoko *et al.* (2004).

From these studies it is concluded that application of S 30 kg/ha was found to be beneficial in terms of obtaining high crop productivity, fertility and quality of soybean grown on S-deficient soils (Inceptisols) of Kashmir valley.

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