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Interaction Effect of Phosphorus and Sulphur on Yield and Quality of Soybean in a Vertisol

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ABSTRACT

A field experiment was carried out to evaluate the effect of sulphur and phosphorus application on yield and N, P and K contents of soybean grown on Vertisol. It was found that increasing application of sulphur and phosphorus, singly as well as in combination, significantly increased the grain yield and contents of N, P and K over control. The interaction of S x P exhibited a strong synergistic relationship in soybean nutrition grown on deficient soil. Result indicated that grain and straw yield, uptake of phosphorus and sulphur increased with increase in the rate of application of P and S individually as well as in various combinations. Applied various levels of P and S also influenced the quality parameters of soybean i.e. protein content and oil content. Available P in soil increased with increasing levels of phosphorus. Similarly available S in the soil increased with increasing levels of sulphur.

Introduction

Soybean is a well-known oilseed as well as pulses crop which is grown in various countries. Soybean, besides having excellent nutritional quality, contributes the highest to world oil production. Through, there has been a prodigious increase in the acreage (1.5 to 6.3 m ha) as well as production (1.0 to 6.1 mt) of soybean during last one and half decade, even then. The share of India in world soybean production is significantly (nearly 3.8%) attributed to low productivity (SOPA, 2015). Phosphorus, an important constituent of biochemical products in plant itself plays a key role in balance nutrition of the crop and affects productivity of soybean. Next most important emerging nutrient that is showing wide spread deficiency is sulphur. Sulphur is essential for synthesis of proteins, vitamins and sulphur containing essential amino acids and is also associated with nitrogen metabolism. The good yield of soybean can be achieved by balanced and adequate supply of phosphate, sulphur and other deficient, nutrients.

Sulphur interacts with phosphorus as phosphate ion is more strongly bound than sulphate (Choudhary and Das, 1996; Aulakh *et al.*, 1990). Phosphorus fertilizer application results increased of anion adsorption sites by phosphate, which releases sulphate ions into the soil solution (Chandra Deo and Khaldelwal, 2009). Thus, it may be subjected to leaching if not taken up by plant roots. Studies have indicated both synergistic and antagonistic relationship between sulphur and phosphorus but their relationship depends on their rate of application and crop species (Chaurasia *et al.*, 2009; Dwivedi and Bapat, 1998). Synergistic effect of applied P and S was observed by (Kumawat *et al.,* 2004), (Kumar and Singh, 1980) for soybean, (Islam *et al.*, 2006) for rice, (Pandey *et al.*, 2003) for linseed, (Chandra Deo and Khaldelwal, 2009) for chickpea.

Antagonistic relationship between P and S was observed in *moong* and wheat by (Islam *et al.*, 2006) and in lentil and chickpea by Hedge and Murthy (Aulakh *et al.*, 1990). The interaction of these nutrient elements may affect the critical levels of available P and S below which response to their application could be observed. Information on effect of combined application of P and S on yield, quality and content of each nutrient in soybean is rather limited. Therefore, the present investigation was undertaken to study interactive effects of P and S application on yield and quality of soybean.

Materials and Methods

The study was conducted in the All India Coordinated Research Project on Long Term Fertilizer Experiment (LTFE), Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh. The experimental sites (23°10″ N latitude and 79°57″ E longitude) have a semi-arid and sub-tropical climate with a characteristic feature of dry summer and cold winter.

In winter season i.e. from November to February the temperature ranges from 8.9°C to 34.5°C and the relative humidity varies from 70% to 90%. Dry and warm weather usually persists during the month of March to June. The temperature may rise as high as 46^0C during these summer months. Monsoon season extends from mid-June to mid-September. The temperature during this period varies between 22°C and 38°C and the relative humidity ranges from 70 to 80%. The total annual rainfall varies from 1200 to 1500 mm. The soil of the experimental sites falls under Vertisol and belongs to Kheri-series of fine montmorillonite, Hyperthermic family of Typic Haplusterts popularly known as “medium black soil”. At the inception of this experiment in 1972, pooled soil sample were drawn from the surface layers (0-20 cm) of the experimental field has pH (7.6), electrical conductivity (0.18), organic carbon (0.57%), available N (193.0 kg ha-1) available P (7.60 kg ha-1) and available K (370 kg ha-1) and available sulphur (17.47 kg ha-1). The treatments consist of T1-50% NPK, T2-100% NPK, T3-150% NPK, T4-100% NP, T5-100% N, T6-100% NPK + FYM, T7-100% NPK-S and T8-Control, and replicate with four times in randomized block design.

Experimental details

Design used: Randomized block design
Replication: 04
Treatments: 8
Plot size: 17x10.8 m (183.6 m^2)
Space between replications: 2m
Space between plots: 1 m
Experimental area: 146X58 m
Cropping sequence: Soybean-wheat

Results and Discussion

Grain and straw yield

With increasing level (Table 3) of both phosphorus and sulphur grain and straw yield of soybean were increased significantly. The percent increase in grain yield due to phosphorus and sulphur varied from 12.31 to 20.8% and 6.9 to 12.1%, respectively, whereas the straw yield was increased from 10.6 to

15.9% and 6.3 to 12.9%. The magnitude of response was more in case of phosphorus as compared to sulphur. Synergistic effect of phosphorus and sulphur interaction on grain and straw yield was highest at 80 kg P_2O_5 and 20 kg S ha^{-1}. The magnitude of increase in grain and straw yield was 12.4 and 16.2% due to combined application of phosphorus and sulphur 80 kg P2O5 and 20 kg S ha^{-1} over control, respectively. The synergistic effect of P and S may be due to utilization of high quantities of nutrients through their well-developed root system and nodules which might have resulted in better growth and yield at soil.

These results confirm the earlier findings of (Nagar *et al.*, 1993) in soybean, (Sinha *et al.*, 1995) in winter maize, (Choudhary and Das, 1996) in black gram, (Shankaralingappa *et al.*, 1999) in cowpea, (Randhawa and Arora, 2000) in wheat, (Teotia *et al.*, 2000) in moong bean, (Kumawat *et al.*, 2004) in *taramira* and (Islam *et al.*, 2006) in rice. (Kumar and Singh, 1980) with soybean reported a suitable balance between P and S for producing increased yield. (Aulakh *et al.*, 1990) and (Singh *et al.*, 1995) have shown that nature of P and S interaction depends on their rates of application.

Nitrogen and protein content

Nitrogen content (Table 2) was significantly increased with the increase in level of P and S. (Dwivedi and Bapat, 1998) reported that nitrogen content in soybean increased significantly by P and S application up to 50 kg $ha^{-1}$of each nutrient. The interaction of P and S was significant and maximum nitrogen content was recorded at 80 kg P_2O_5 and 20 kg S ha^{-1}.Protein content in soybean grain was increased significantly with application of P and S individually as well as in combination (Table 2). The maximum increase in protein content (43.20%) was obtained with 40 kg P_2O_5 and 20 kg S ha^{-1} together. Protein was increased by 53.29% over control. The response to applied P with respect to protein content in soybean is attributed to more nitrogen fixation. Similar results were also reported by (Shankaralingappa *et al.*, 1999) in cowpea and (Kumawat *et al.*, 2004) in *taramira*.

Increasing doses of sulphur application resulted in a significant increase in protein content of soybean. The positive response to added sulphur is assigned to low status of available S of soil or due to stimulating effect of applied sulphur in the synthesis of chloroplast protein resulting in greater photosynthetic efficiency which in turn translated in term of increased yield. (Dwivedi and Bapat, 1998) reported significant increase in the protein content of soybean with application of P and S up to 50 kg ha^{-1} over control. The findings are similar to (Jogendra-Singh *et al.*, 1997) in summer *moong* and (Srinivasan *et al.*, 2000) in black gram.

Phosphorus and sulphur content

With increasing in level of S from 0 to 40 and 40 to 80 kg ha^{-1}, P and S content in grain and straw were increased significantly. Similarly P and S contents were increased significantly with increasing levels of phosphorus from 0 to 10 and 10 to 20 kg P_2O_5 ha^{-1}. The combined application of 40 kg P_2O_5 and 20 kg S ha^{-1} significantly increased P and S content in grain and straw (Table 2).

Phosphorus content in soybean ranged from 0.23 to 0.37% in grain and 0.12 to 0.26% in straw, while S content ranged from 0.30 to 0.40% in grain and 0.10 to 0.13% in straw. Similar results were reported by (Teotia *et al.*, 2000) and (Islam *et al.*, 2006) in mungbean, (Singh and Singh) in black gram and (Chandra Deo and Khaldelwal, 2009) in chickpea.

Nutrient sources

i.	**Nitrogen**	**Urea (46% N)**
ii.	Phosphorus	Single superphosphate (16% P_2O_5) while, Di-ammonium – phosphate (46% P_2O_5) in T_7
iii.	Potassium	Muriate of potash (60% K_2O)

Table.1 Physico-chemical properties of soil (0-20 cm depth) at the start of the Long-Term Fertilizer Experiment (1972)

S. No.	Soil Properties	Unit	Value
1.	Mechanical composition		
	i. Sand	%	25.27
	ii. Silt	%	17.91
	iii. Clay	%	56.82
2	Textural class	-	Clay
3.	Bulk density	Mg m^{-3}	1.3
4.	Particle density	Mg m^{-3}	2.5
5.	Cation exchange capacity	C mol $(P^+)kg^{-1}$	49.0
6.	pH (1:2.5)	--	7.6
7.	Electrical conductivity (1:2.5)	dSm^{-1}	0.18
8.	Organic carbon	g kg^{-1}	5.70
9.	Calcium carbonate	%	4.60
10.	Available nitrogen	kg ha^{-1}	193.0
11.	Available phosphorus	kg ha^{-1}	7.60
12.	Available potassium	kg ha^{-1}	370.0
13.	Available sulphur	kg ha^{-1}	17.47
14.	Available zinc	mg kg^{-1}	0.33

Source: Annual report (2014) of AICRP on Long-Term Fertilizer Experiment, JNKVV, Jabalpur.

Table.2 Effect of continuous addition of fertilizers and manure on distribution of available nutrients

Treatments	Available nutrients status							
	N (kg ha^{-1})		P (kg ha^{-1})		K (kg ha^{-1})		S(kg ha^{-1})	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
50% NPK	217.00	182.00	22.61	20.16	243	234	24.17	22.34
100% NPK	275.00	238.00	33.18	28.95	275	253	34.98	32.64
150% NPK	291.00	260.00	40.55	39.15	296	275	39.30	37.21
100% NP	240.00	215.00	30.75	28.88	225	180	30.82	27.40
100% N	198.00	180.00	11.26	10.80	207	172	15.08	14.63
100% NPK + FYM	310.00	280.00	42.88	40.81	328	297	42.66	38.47
100% NPK (S FREE)	248.00	217.00	30.15	27.86	255	245	15.94	14.63
CONTROL	182.00	165.00	10.01	9.80	208	165	13.95	12.72
SEm±	12.18	12.90	2.20	2.05	11.14	11.51	0.81	0.97
CD (P=0.05)	35.35	37.44	6.40	5.94	32.34	33.39	2.39	2.85

Table.3 Effect of continuous application of fertilizers and manure on grain and straw yield of soybean

Treatments		Soybean yield (kg ha^{-1})	
		Grain	Straw
T_1	50% NPK	600	1413
T_2	100%NPK	725	1900
T_3	150%NPK	1075	2463
T_4	100%NP	665	1788
T_5	100%N	538	1356
T_6	100%NPK+ FYM	1113	2713
T_7	100%NPK-S	963	2350
T_8	Control	450	1100

Tables.4 Effect of continuous application of fertilizers and manure on protein and oil yield of soybean

Treatments		Soybean yield (kg ha^{-1})	
		Protein	Oil
T_1	50% NPK	1658	993
T_2	100%NPK	2758	1281
T_3	150%NPK	4627	1993
T_4	100%NP	2396	1109
T_5	100%N	1168	640
T_6	100%NPK+ FYM	4800	2322
T_7	100%NPK-S	2671	1515
T_8	Control	1084	494
	SEm±	**294.51**	**155.54**
	CD	**854.65**	**451.39**

Table.5 Effect of continuous application of fertilizers and manure on protein, carbohydrate and oil content (%) in soybean seed

Treatments		Protein (%)	Oil (%)	Carbohydrate (%)
T_1	50%NPK	28.09	16.57	13.41
T_2	100%NPK	38.22	17.59	18.34
T_3	150%NPK	43.11	18.53	20.13
T_4	100%NP	36.11	16.65	16.51
T_5	100%N	23.23	12.72	12.09
T_6	100%NPK+FYM	43.20	20.74	20.25
T_7	100%NPK – S	27.67	15.73	17.18
T_8	Control	23.53	10.95	11.56
SEm±		**1.415**	**0.310**	**0.574**
CD (p=0.05)		**4.107**	**0.900**	**1.666**

Available phosphorus and sulphur

The results presented in Table 4 showed that the available P was increased consistently with increasing in level of phosphorus; P content in soil increased from 22.3 kg ha^{-1} in control to 32.9 kg P_2O_5 ha^{-1} with application of 40 kg P_2O_5 ha^{-1}. Similar results were also reported by Balaguravaish *et al.*, and Chandra Deo and Khaldelwal (2009). Application of S did not affect the available P significantly in the soil but it tends to increase with sulphur was increased with increasing levels of sulphur application. Phosphorus application had no effect on sulphur content of the soil. The findings are similar to Chandra Deo and Khaldelwal (2009), reported that application of 60 kg P_2O_5 ha had no effect on sulphur content of the soil.

Effect of P and S on quality parameters of soybean

Protein and Oil content

The data presented in Table 5 revealed that increase in oil content was to the tune of 18.53% to 20.54% due to application of 40 to 80 kg P over control, while 2.32 to 4.79% increase in oil content was due to application of 10 to 20 kg S ha^{-1}. There was improvement in quality parameters (protein content, carbohydrate and oil content) due to P and S application. The improvement of protein and oil content through P and S fertilizer form application to the soybean crop. The Chaousaria *et al.*, (2009) recorded improvement in protein and oil content due to application of phosphorus and sulphur in soybean crop. Further, Dwivedi and Bapat (1998), Majumdar *et al.*, (2001) and recently Kumar *et al.*, (2009) also reported that improvement in protein and oil content due to phosphorus and sulphur application. On an average, 60 kg P_2O_5 ha^{-1} increased protein and oil content by 7.03 and 15.24% respectively over the control. The increase in oil content with P application could be due to the fact that P helped in synthesis of fatty acids and their esterification by accelerating biochemical reactions in glyoxalate cycle (Dwivedi and Bapat, 1998). The increase in protein and oil content due to 20 kg S ha^{-1} was 11.26 and 24.17% respectively. The increase in oil content with S application might be due to the fact that S helped in oil synthesis by enhancing the level of thioglucosides (Dwivedi and Bapat, 1998). Soybean responded more to S in increasing oil and protein content of seed, as also reported by Kumar and Singh (1981). The interaction between P and S was significant. All the S levels increased both oil and protein contents significantly at every level of P. The maximum protein and oil content were recorded with a treatment combination of 80 kg P_2O_5 and 40 kg S ha^{-1}.

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