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Effect of Different Levels of Phosphorus and Sulphur on Seed & Stover Yield of Soybean (*Glycine max* L. Merill) under 'Eutrochrepts'

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Authors' contributions

This work was carried out in collaboration between all authors. Author SK designed the study. Author JAW performed the statistical analysis. Author BAL wrote the protocol and wrote the first draft of the manuscript. Authors PS and ZAD managed the analyses of the study. Authors SQ and AF managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted at KVK, Srinagar during two consecutive kharif seasons of 2010 and 2011 to study the "Effect of phosphorus and sulphur on yield and quality of soybean (*Glycine max* L. Merill) under Eutrochrepts". The experiment was laid down under 16 treatment combinations viz four levels of phosphorus (0, 30, 60, 90 kg P_2O_5 ha^{-1}) and four levels of sulphur (0,15, 30, 45 kg S ha^{-1}) in randomized complete block design with three replications .The soil of the experimental site was typic Eutrochrepts, silty clay loam in texture having pH 7.18, EC 0.18 dSm^{-1}, organic carbon 0.74 per cent, available N, P, K 250.52, 11.45, 120.62, kg ha^{-1}, respectively. Soil was sufficient in available Fe, Cu, Mn and deficient in available Zn and sulphur. Total and organic phosphorus content in soil was 345 and 173 ppm, respectively while as total and organic sulphur content was 232 and 162 ppm, respectively. Both seed and stover yield of soybean increased significantly due to individual as well as combined application of phosphorus and sulphur.

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Combined application of 45 kg S with 90 kg P_2O_5 produced highest seed (24.39 q ha^{-1}) and stover (43.51 q ha^{-1}) yield of soybean. Application of increasing levels of both phosphorus and sulphur resulted in a significant increase in macro and micronutrient content of soybean seed. With application of 90 kg P_2O_5 ha^{-1}, maximum nutrient content of N, P, K, Ca, Mg and S in seed was 6.42, 0.56, 1.876, 0.324 0.440, 0.466 per cent, respectively while as Fe, Cu, Mn was 100.01, 2.86 and 3.74 mg kg^{-1}, respectively.

Keywords: Phosphorus; sulphur; soybean; yield; nutrient content; quality.

1. INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] has become the miracle crop of the 21st century. It belongs to the family Leguminosae, sub-family Papilionaceae and the genus Glycine. It is a triple beneficiary crop, which contains about 40 per cent protein, possessing high level of essential amino-acids methionine and cystine, 20 per cent oil rich in poly unsaturated fatty acids especially omega-6 and omega-3 fatty acids, 6-7 per cent total minerals, 5-6 per cent crude fibre and 17-19 per cent carbohydrates [1]. Besides, it has good amount of iron, vitamin B-complex and isoflavones such as daidzein, genistein of clycitin. Presence of calcium and iron makes it highly suitable for women who suffer from osteoporosis and anaemia. The isoflavones of soybean have been found to possess health benefits, as they exhibited properties like cancer preventing, combating menopausal problem and helping to recover from diabetes [2].

Soybean was considered only as a food and fodder crop till World War-II when its potential as an oilseed crop was realized. Due to its multifaceted uses, soybean has since progressed by leaps and bounds as an oilseed crop. So much so that on the global scale it has come to the top of the list of oilseed crops and contributes over one-third of the total supply of the world vegetable oil pool. Indians as such, know soybean since ages as it was in cultivation in northern and north-eastern hills as food plant and is a part of routine diet of the people [3]. Black-seeded soybean has been grown since early times in the northern and north eastern hills and in scattered area in the central part of the country. Soybean was introduced in India probably as soon as it was domesticated in China [4]. India is also considered as a secondary centre of domestication for soybean [5].

Plant nutrition is a key input to increase the productivity of soybean seed crop. Out of several nutrients provided to plants, phosphorus is a major and essential nutrient for better plant growth and yield as this crop is exhaustive in nature and requires more energy. It is involved in wide range of plant processes from permitting cell division to development of good root system. It stimulates pod setting, seed formation and protein synthesis. The enhancement of symbiotic N-fixation by root nodules as a result of phosphorus nutrition is supported due to high phosphorus requirement of the bacteroides [6,7].

Soybean plays a vital role in agricultural economy of India. The low productivity of the crop is due to several constraints, one among the important is unbalanced nutrition [8]. For its optimum yield realization, it is necessary to optimize the nutrient inputs. Fertilizer application is very important practice and at present the most baffling as well. Soybean shows inconsistent response to application of phosphorus and sulphur. High soybean yield demands high fertilizer dosage, applied directly to the crop or accrued through preceding crops.

2. MATERIALS AND METHODS

The experiment was laid out in randomized complete block design with 4 levels of each sulphur and phosphorus and replicated thrice. The corresponding doses of sulphur and phosphorus were applied as per the treatment schedule and mixed thoroughly in the soil. A basal dose consisting of uniform recommended dose of nitrogen and potassium was applied through urea and muriate of potash to all plots. At harvest, plants were removed along with pods and the harvested crop of each plot was placed separately on canvas tarpaulin on the concrete floor, sundried and beaten with the stick. The stover was removed and seed winnowed to make it clean. Seed samples were collected treatment wise for analysis. The seed yield obtained from each plot was cleaned, sundried and weighted separately. After harvesting the plants from each plot were tied into separate bundles. The weight of each bundle was recorded and then the stover yield was converted into q ha^{-1}.Seed samples were dried in oven at 65℃ for 48 hours, ground in a Willey Mill and the processed samples were analysed separately for their nitrogen, phosphorus and potassium content. The Kjeldahl method for total nitrogen content was analysed using micro-Kjeldahl's method [9]. For estimation of total phosphorus, potassium and sulphur content, using blue filter [10]. Total potassium determination in the digest was done by Flame photometer and sulphur by turbidimetric method [11], respectively. For estimation of calcium and magnesium, total iron, manganese, zinc and copper content in seed was determined using AAS.

3. RESULTS AND DISCUSSION

Seed yield increased significantly with the increasing levels of sulphur and/or phosphorus (Table 1, Fig. 1). A significant increase in seed yield was recorded at 90 kg P_2O_5 ha^{-1} (23.26 q ha^{-1}). The increase in seed yield due to phosphorus application might be due to improvement in plant growth and vigour as P plays important role in plant metabolism, finally leading to enhanced seed yield. Similar results were also earlier reported by [12]. Maximum seed yield of 22.25 q ha^{-1} was recorded with the application of 45 kg S ha^{-1}, which was significantly higher over other levels of sulphur. The increase in soybean seed yield by sulphur application might be due to the effect of sulphur in utilizing large quantities of nutrients through their well developed root system, which resulted in better plant development and ultimate yield [13]. The response of sulphur and phosphorus application on stover yield was similar to that of seed yield. Increasing levels of phosphorus application from 0 to 90 kg ha^{-1} increased the stover yield of soybean at harvest significantly from 31.32 to 41.53 q ha^{-1} (Table 1 Fig. 2). Similar beneficial effect of P application on yield was also observed by. The stover yield of soybean at harvest increased significantly from 33.73 to 39.36 q ha^{-1} with increase in sulphur levels from 0 to 45 kg ha^{-1}. Soybean seed at harvest revealed a significant variation in nitrogen content due to varying levels of phosphorus and sulphur applied (Table 1). Application of phosphorus showed a significant increase in nitrogen content over the control. The increase in the nitrogen content due to phosphorus application might be attributed to the increased availability of nitrogen as well as fixation [14] in Taramirra. Nitrogen in presence of P which enhances rhizobial activity. However higher levels of P had antagonistic effect on nitrogen content. Sulphur application also increased significantly the nitrogen content of soybean seed at harvest.

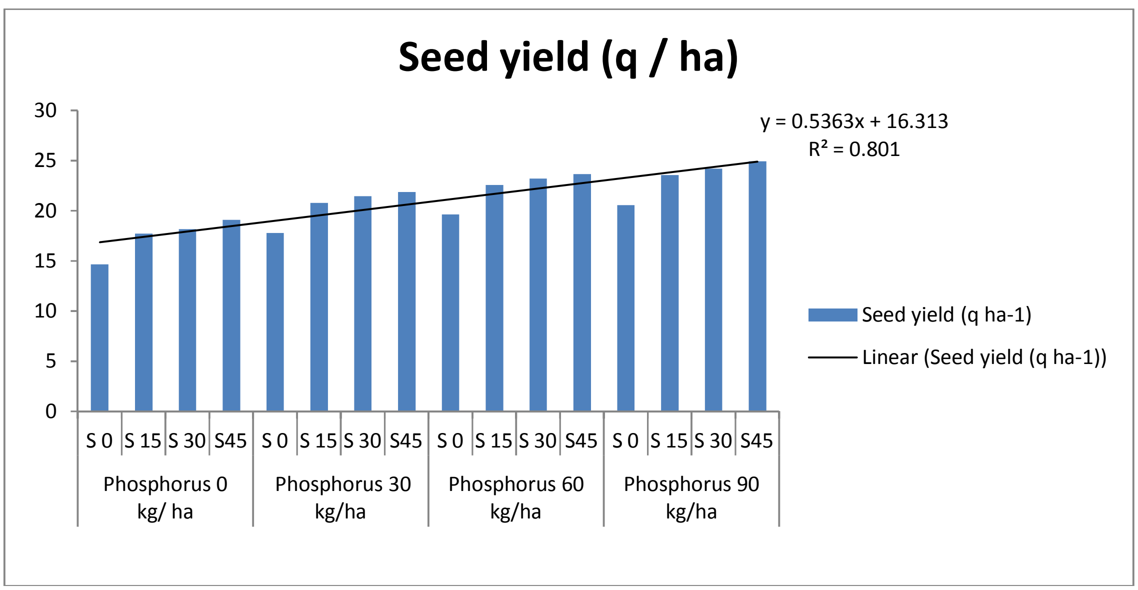

Fig. 1. Effect of phosphorus and sulphur on seed yield in soybean

Table 1. Effect of phosphorus and sulphur on yield and nutrient content in soybean. (Pooled data)

Treatment		Seed yield (q ha^{-1})	Stover Yield(q ha^{-1})	N content (%)	P content (%)	K content (%)	Ca content (%)	Mg content (%)	S content (%)
Phosphorus 0 Kg/ha	S_0	14.66	27.60	5.63	0.519	1.813	0.230	0.380	0.401
	S_{15}	17.74	31.40	5.87	0.529	1.832	0.267	0.399	0.429
	S_{30}	18.18	32.90	6.08	0.534	1.841	0.290	0.407	0.458
	S_{45}	19.10	33.30	6.23	0.536	1.861	0.298	0.412	0.490
Phosphorus 30 Kg/ha	S_0	17.8	32.80	5.94	0.535	1.822	0.260	0.395	0.407
	S_{15}	20.80	35.63	6.17	0.545	1.854	0.291	0.415	0.436
	S_{30}	21.44	38.10	6.39	0.538	1.871	0.317	0.423	0.467
	S_{45}	21.88	38.50	6.54	0.553	1.869	0.325	0.428	0.498
Phosphorus 60 Kg/ha	S_0	19.65	36.45	6.10	0.544	1.849	0.273	0.410	0.415
	S_{15}	22.57	40.28	6.363	0.554	1.860	0.312	0.431	0.442
	S_{30}	23.21	41.73	6.54	0.559	1.880	0.335	0.439	0.475
	S_{45}	23.65	42.13	6.70	0.563	1.891	0.343	0.445	0.505
Phosphorus 90 Kg/ha	S_0	20.56	37.87	6.11	0.551	1.867	0.288	0.423	0.421
	S_{15}	23.55	41.60	6.34	0.559	1.872	0.320	0.439	0.449
	S_{30}	24.22	43.10	6.56	0.564	1.889	0.344	0.447	0.483
	S_{45}	24.93	43.51	6.70	0.568	1.898	0.352	0.452	0.513
$CD_{(p\leq 0.05)}$ (P)		0.32	0.33	0.12	0.0016	0.002	9.89	0.001	0.002
(S)		0.39	0.39	0.09	0.002	0.002	11.13	0.003	0.003

S_0 = Control; S_{15} = 15 kg Sulphur ha^{-1}; S_{30} = 30 kg Sulphur ha^{-1}; S_{45} = 45 kg Sulphur ha^{-1}

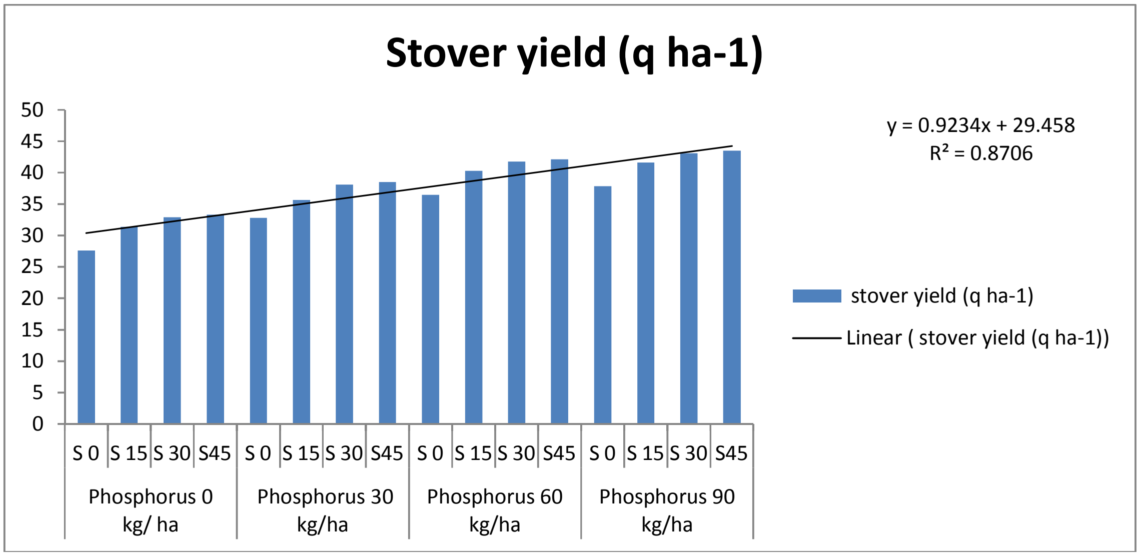

Fig. 2. Effect of phosphorus and sulphur on stover yield in soybean

Concentration of phosphorus in soybean seed (Table 1) recorded a significant variation due to varying levels of phosphorus might be attributed due to increased root growth resulting in the increase foraging capacity of plant roots to absorb more of the relatively less mobile phosphorus [15]. The increase in phosphorus content with sulphur application might be because of the mobilization of soil phosphorus into available form due to action of acid produced by the added sulphur resulting in better uptake by the plants. Such effect was mainly due to the action of acid produced by added sulphur which may have rendered the potassium available to plant.

Calcium content in soybean seed at harvest increased significantly with the application of phosphorus and, It could be attributed to the antagonistic effect between sulphur and calcium at higher levels. Similar results were obtained by [16]. The magnesium content of soybean seed at harvest (Table 1) increased significantly with the increasing levels of phosphorus and sulphur. Application of 45 kg S ha^{-1} significantly increased the magnesium content by the soybean seed. The increased magnesium content by soybean crop with sulphur application might be ascribed to the increased biomass yield as well as its synergistic effect.

Application of 90 kg P_2O_5 ha^{-1} recorded sulphur content of 0.466 per cent in soybean seed at harvest. The addition of phosphorus increases the adsorption of PO_4 resulting in concurrent desorption of SO_4 from colloidal surface which may lead to increased sulphur mobilization and availability for plant uptake. Similar results were also reported by [17]. Due to its rapid absorption and translocation by the plants having adequate supply of sulphur in the soil application of sulphur also resulted in a significant increase in its content.

Zinc content of seed increased significantly upto 30 kg of phosphorus and with 45 kg S ha^{-1} applied and beyond which it decreased. It may be attributed to the antagonistic effect of phosphorus on zinc uptake at higher levels (Table 2). The increase in the zinc content could be attributed that application has shown synergistic effect on Zinc indicating significant increase in zinc content with sulphur application (Ravi et al., 2008). Increase in iron content due to combined application of phosphorus and sulphur at harvest was observed. The iron content of soybean seed at harvest increased significantly from 6.38 mg $100g^{-1}$ in the control to 10.85 mg $100g^{-1}$ with the application of $S_{45}P_{90}$. Sreemannarayana et al. (1995) have reported a significant combined effect of phosphorus and sulphur on the iron content in soybean seed.

Copper content in soybean with increase in levels of sulphur and phosphorus. Application of 90 kg P_2O_5 ha^{-1} and 45 kg S ha^{-1} also significantly recorded higher content of copper (2.82 ppm) over other lower levels of sulphur which may be attributed to the change of pH resulting in more absorption of copper.

Table 2. Effect of phosphorus and sulphur on micro nutrient content in soybean. (Pooled data)

Treatment		Zn content (mg/ kg)	Fe content (mg / kg)	Cu content (mg / 100g)	Cu content (mg kg $_{-1}$%)	Mn content (mg kg $_{-1}$)
Phosphorus 0 Kg/ha	S_0	76.44	6.38	0.72	0.72	1.81
	S_{15}	85.75	7.69	1.55	1.55	2.52
	S_{30}	91.12	8.39	1.89	1.89	2.86
	S_{45}	94.07	8.61	1.99	1.99	2.99
Phosphorus 30 Kg/ha	S_0	100.24	7.63	1.51	1.51	2.52
	S_{15}	109.55	8.91	2.35	2.35	3.21
	S_{30}	114.92	9.61	2.69	2.69	3.56
	S_{45}	117.87	9.83	2.79	2.79	3.69
Phosphorus 60 Kg/ha	S_0	94.46	8.36	1.90	1.90	2.89
	S_{15}	103.77	9.64	2.76	2.76	3.60
	S_{30}	109.14	10.34	3.10	3.10	3.93
	S_{45}	112.09	10.56	3.00	3.00	4.06
Phosphorus 90 Kg/ha	S_0	90.32	8.66	2.03	2.03	3.00
	S_{15}	99.63	9.93	2.87	2.87	3.73
	S_{30}	105.00	10.63	3.30	3.30	4.06
	S_{45}	107.95	10.85	3.21	3.21	4.19
$CD_{(p\leq0.05)}$ (P)		1.86	0.22	0.08	0.08	0.13
(S)		1.86	0.41	0.09	0.09	0.11

S_0 = Control; S_{15}= 15 kg Sulphur ha^{-1}; S_{30}= 30 kg Sulphur ha^{-1}; S_{45}= 45 kg Sulphur ha^{-1}

An increase in crude protein content (Table 2) with the increasing levels of phosphorus might be due to increase in amino acids as well as improved nitrogen nutrition of crop resulting the better root growth and more efficient utilization of other nutrients and water by plant and the protein content in seed increases. Such positive effect of P application on pulses in acidic soil has also been reported by Awomi et al. (2012). Sentimenla and Singh (2012) also observed significant increase in protein content of soybean in acid soil of Nagaland. A significant increase in crude protein content due to sulphur application might be attributed to higher nitrogen utilization by the crop along with adequate supply of sulphur, thereby, enhancing the protein synthesis in the plant and its higher concentration in the seed.

4. CONCLUSION

Highest soybean seed and stover yield at 90 kg P_2O_5 ha^{-1} with 45 kg S ha^{-1} recorded highest seed and stover. Phosphorus and sulphur application resulted in a significant increase in the nutrient concentration of macro as well as micronutrients in seed. On the application of 90 kg P_2O_5 ha^{-1}, highest nutrient content of N, P, K. Ca, Mg. At higher levels of phosphorus application, Zn content of seed decreased and it was highest at 30 kg P_2O_5 ha^{-1} .With application of 45 kg S ha^{-1}, the content of N, P, K, Ca, Mg and S was increased.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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