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Review/Overview

Grain yield, nutrient uptake, quality and economics of soybean (*Glycine max*) under different sulphur and boron levels in Punjab

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ABSTRACT

A 3-year field experiment was conducted at the Punjab Agricultural University, Ludhiana, during the rainy season of (*kharif*) 2006 to 2008, to study response of soybean [*Glycine max* (L.) Merrill] to different levels of sulphur and born. The experiment comprised of 13 treatments including all the combinations of 4 sulphur (S) levels (10, 20, 30 and 40 kg/ha) and 3 boron (B) levels (0.5, 1.0 and 1.5 kg/ha) and absolute control (no S; no B). The highest grain yield, protein, oil content, gross and net returns of soybean were recorded with 40 kg S/ha, which were statistically at par with 30 kg S/ha but significantly higher than other levels of sulphur. The productivity in 40 kg S/ha was enhanced 61.9% over the absolute control. The boron level of 1.5 kg/ha recorded the highest grain yield, gross and net returns, being statistically at par with 1.0 kg B/ha but significantly higher than 0.5 kg B/ha. The highest S and B uptake were recorded in 40 kg S/ha and 1.5 kg B/ha respectively. The highest grain yield recorded in 40 kg S/ha and 1.5 kg B/ha was statistically at par with 40 kg S/ha and 1.0 kg B/ha, 30 kg S/ha and 1.0 kg B/ha, 20 kg S/ha and 1.5 kg B/ha and 30 kg S/ha and 1.5 kg B/ha treatments but was significantly higher than all the other combinations of sulphur and boron.

Key words : Boron, Crop production, Economics, Grain-yield, Oil content, Soybean, Sulphur

Soybean, being a grain legume, has the ability to fix atmospheric nitrogen in the soil in association with *Bradyrhizobium* rhizobia. Soybean crop fixes 61–337 kg N/ha (Salvagiotti *et al.*, 2008). The succeeding crop requires 25% lesser amount of nitrogenous fertilizers. Thus cost on fertilizer for cropping system is reduced by about 5% (Mahindra, 2011).

Optimum nutrition is required for getting maximum seed yield and good quality of the grain. Several abiotic and biotic factors have been found to affect soybean yields. However, studies investigating the impact of sulphur and boron fertilization on grain yield of soybean remain scarce. Sulphur (S) is considered to be the fourth important essential nutrient after nitrogen, phosphorus and potassium for the plant growth. Due to increased cropping intensity in the Indo-Gangetic Plains (IGP), the deficiency of S is common in soybean. In soybean, S is present as sulphides, sulphites and inorganic combinations with carbon and nitrogen. Boron (B) is an essential micronutrient for higher plants. The widespread role of B within the plant includes cell-wall synthesis, sugar transport, cell-division and differentiation, membrane functioning, root elongation, regulation of plant hormone levels, and generative growth of plants. Boron is also recognized as one of the most commonly deficient micronutrients in agriculture. The quality of seeds deteriorated with low B as reflected in decreased content of B, starch, protein and oil along with stimulated concentrations of sugars and phenols. The present investigations were planned to study the effect of sulphur and boron on productivity, nutrient uptake and economics of soybean.

MATERIALS AND METHODS

The experiment was conducted at the Punjab Agricultural University, Ludhiana (36°56' N, 75°52' E and altitude 247 m), India, during the rainy seasons of 2006, 2007 and 2008. The experiment was comprised 13 treatments (12+1) which included all the combinations of 4 levels of S (10, 20, 30 and 40 kg/ha) and 3 of B (0.5, 1.0 and 1.5 kg/ha) and absolute control (no S; no B). The experiment was conducted in factorial randomized complete-block design with additional treatment as absolute control in 3 replications. Both S and B were applied at the time of sowing. During the whole crop season, the rainfall of

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482.3, 409.5 and 886.3 mm was received during 2006, 2007 and 2008 respectively. The minimum temperature range was 15.2–35.2°C in 2006, 14.0–28.5°C in 2007 and 15.2–28.1°C in 2006. Similarly, the maximum temperature range was 29.1–40.3°C in 2006, 30.8–40.8°C in 2007 and 30.4–36.5°C in 2008. The source of S was gypsum (16% S) and for B it was borax (11% B). There were 4 replications in all the years of study. The soil was loamy sand, low in organic C (0.25%) and medium in available phosphorus (20.5 kg/ha) and potassium (220 kg/ha), but low in S (9.7 mg/kg) and B (9.8 mg/kg). The crop was raised by treating seed with captan @ 3 g/kg seed to control seed rot and seedling blight. Soybean variety 'PS 1042' was used in 2006 and 2007, whereas in 2008, the variety 'SL 525' was used. The recommended nutrient dose @ 30 kg N and 26.4 kg P/ha was applied in all the treatments including absolute control at the time of sowing using 50 kg urea and 130 kg diammonium phosphate (DAP). Pendimethalin (Stomp 30 EC) herbicide @ 0.45 kg/ha was applied using 500 litres water on the same day of sowing, followed by one hoeing (4 weeks after sowing) in all 3 years to control weeds. To raise a good crop, 3 irrigations in 2006, 4 irrigations in 2007 and only 2 in 2008, were applied. Thiodan (Endosulfan) 35 EC @ 2.5 litres/ha was sprayed twice to control pod-borer, and to control white-fly, 625 ml Rogor 30 EC (dimethoate)/ha was applied twice in the season.

Data on plant height and pods/plant were collected from random plants/plot at the time of harvesting. Twenty pods/plot were selected to record data on seeds/pod. From the total produce of each plot, 100 seeds were counted and weighed to express 100 seed weight. The crop was harvested when the pods were matured; the bundles were sun-dried for few days and then threshed manually. Data on biological and seed yield were collected at the time of harvest. The harvest index was calculated dividing seed yield by biological yield. The following formulae were used to calculate yield response and nutrient-use efficiency:

Yield response (%) = [(Treatment yield – Control yield)/Control yield] × 100

Nutrient-use efficiency [kg seed/kg nutrient (sulphur + boron)] = (Treatment yield – Absolute control yield)/ Amount of nutrient applied).

The uptake of nutrients, protein and oil content in soybean seed were determined by standard methods. The economics was computed using prevailing prices of inputs and output. The data were analysed in randomized complete-block design using standard procedures of ANOVA at 5% level of significance (Rangaswamy, 1995).

RESULTS AND DISCUSSION

Treatments versus absolute control

The treatments recorded significantly higher soybean characters like plant height, pods/plant, seeds/pod, seed yield, stover yield, total S and B uptake, protein, oil content, gross returns, net returns and benefit: cost ratio than the absolute control (Tables 1 and 2). This signifies the importance to conduct this experiment that sulphur and

Table 1. Effect of sulphur and boron nutrition on plant characters and yield attributes of soybean (mean data of 3 years)

Treatment	Plant height (cm)	Pods/ plant	Seeds/pod	100-seed weight (g)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index (%)	Yield response (%)
Sulphur (kg/ha)								
S_{10}	58.2	39.2	2.51	10.54	1.31	2.49	33.60	24.98
S_{20}	59.7	43.6	2.54	10.53	1.50	2.98	32.40	43.17
S_{30}	61.3	46.3	2.51	10.50	1.64	3.00	33.73	56.57
S_{40}	62.7	49.1	2.51	10.56	1.70	3.20	34.77	61.87
CD (P=0.05)	2.20	3.55	NS	NS	0.16	0.27	2.22	
Boron (kg/ha)								
$B_{0.5}$	59.5	42.5	2.48	10.53	1.43	2.82	32.78	36.14
$B_{1.0}$	60.5	44.7	2.53	10.51	1.57	2.91	34.07	49.57
$B_{1.5}$	61.5	46.4	2.54	10.56	1.62	3.02	34.04	54.24
CD (P= 0.05)	1.90	3.08	NS	NS	0.14	0.23	NS	
Treatments vs absolute control								
Treatments	60.5	44.5	2.52	10.53	1.54	2.92	33.63	46.65
Absolute control	56.3	31.6	2.39	10.20	1.05	2.16	32.93	24.98
SEm±	1.84	2.98	0.01	0.32	0.13	0.23	1.86	
CD (P= 0.05)	2.80	4.53	0.15	NS	0.20	0.34	NS	

boron nutrients had the ability to affect all the characters in soybean (Prakasha *et al.*, 2010a; Singh *et al.*, 2006). However, 100 seed weight and harvest index were not significantly influenced by these treatments.

Effect of sulphur

On the basis of 3 years mean, the taller plants, higher number of pods/plant and higher seed yield were recorded under 40 kg S/ha (S_{40}) which was statistically at par with S_{30} but was significantly higher than S_{20} and S_{10} treatments (Table 1). Seeds/pod and 100 seed weight were not significantly influenced by any of the sulphur treatments. The seed yield under S_{40} was 29.8% higher than S_{10}. The higher seed yield under this treatment might be due to favourable effects of better plant nutrition on growth attributes, which further got translated to yield attributes like higher pods/plant and finally on seed yield. The similar results with S dose of 40 kg/ha were also recorded by Gokhale *et al.* (2005). Highest soybean seed yield was recorded with 40 kg S/ha by Prakasha *et al.* (2010b) also. Mandal and Sikder (1999) reported that seed yield was greater with 30 kg S/ha, but further increase up to 60 kg/ha did not improve the yield any more. The stover yield and harvest index were again the highest under S_{40} treatment, being significantly higher than S_{10} treatment. However, the highest harvest index under S_{40} treatment was significantly higher than S_{20} treatment but was statistically at par with rest of the treatments. The yield response recorded under S_{40} was 36.9, 18.7 and 5.3% higher than S_{10}, S_{20} and S_{30} treatments respectively. It might be owing to higher yield recorded with higher doses of sulphur fertilizer.

Different nutritional treatments showed a significant effect on nutrient-use efficiency by soybean (Table 2). The highest S-use efficiency was recorded under S_{10} treatment which was 7.9 kg/kg higher than that recorded under S_{40} treatment. It might be due to lower nutrients used and comparatively lower seed yield recorded under S_{10} than under S_{40} treatment.

The highest total S uptake was recorded under S_{40} which was statistically on par with S_{30} but significantly higher than all other treatments (Table 2). This may be ascribed to better fertilization, resulting in better growth and higher grain and stover yields under these treatments that activated the greater absorption of nutrients from soil and resulted in higher S uptake. The minimum S uptake was recorded under treatment S_{10} which was significantly lower than all the rest of the treatments. Moreover, adequate availability of S in these treatments with their application helped in enhanced nutrient uptake. Najar *et al.* (2011) also reported highest S uptake with 40 kg S/ha in soybean.

Seed protein and oil content are important parameters which govern the quality of soybean. The quality of soybean was significantly influenced by sulphur treatments only (Table 2). The protein content of 2.8% and oil content of 1.8% were higher under S_{40} treatments than S_{10}. The highest protein and oil content recorded under S_{40} treatment were statistically at par with S_{30} treatment but significantly higher than S_{10} and S_{20} treatments. It may be be-

Table 2. Effect of sulphur and boron nutrition on plant characters and yield attributes of soybean (mean data of 3 years)

Treatment	Nutrient use efficiency (kg seed/kg nutrient)	Total S uptake (kg/ha)	Total B uptake (g/ha)	Protein content (%)	Oil content (%)	Returns (× 10^3 ₹/ha)		Benefit: cost ratio
						Gross	Net	
Sulphur (kg/ha)								
S_{10}	23.8	12.3	132.1	35.9	18.4	23.9	10.3	1.75
S_{20}	21.6	16.3	157.5	36.6	19.1	27.4	13.7	1.99
S_{30}	19.2	21.2	161.3	37.7	19.7	29.9	16.1	2.16
S_{40}	15.9	22.9	170.8	38.7	20.2	31.0	17.0	2.20
CD (P= 0.05)	-	3.7	10.4	1.9	0.76	3.4	3.5	0.17
Boron (kg/ha)								
$B_{1.0}$	15.6	17.3	139.8	37.2	19.3	26.1	12.7	1.96
$B_{1.5}$	20.9	18.3	155.4	37.2	19.4	28.6	14.8	2.07
$B_{0.5}$	23.9	18.9	171.2	37.3	19.4	29.5	15.2	2.06
CD (P= 0.05)	-	NS	9.6	NS	NS	3.2	3.1	0.06
Treatments vs absolute control								
Treatments	20.1	18.2	155.4	37.2	19.3	28.1	14.2	2.03
Absolute control	-	9.1	37.3	35.2	18.1	19.1	6.6	1.53
SEm±	-	2.5	4.7	1.0	0.4	2.0	2.6	0.11
CD (P= 0.05)	-	4.6	10.3	1.9	0.9	5.6	5.8	0.25

cause sulphur is the key constituent of essential amino acids like methionine, cysteine and cystine which are the pre-cursors for protein synthesis. Singh *et al.* (2006) also reported similar results of effect of sulphur on soybean quality.

The higher gross and net returns were recorded under S_{40} which were statistically at par with S_{30} and S_{20} but significantly higher than S_{10} treatment (Table 2). It might be due to higher seed yield recorded in these treatments. The highest benefit: cost ratio recorded with S_{40} was statistically on a par with S_{30} treatment but significantly higher than S_{10} and S_{20} treatment. These observations are in agreement with the findings of Parkasha *et al.* (2010b), who also reported higher gross returns, net returns and benefit: cost ratio with application of 40 kg S/ha.

Effect of boron

Boron treatments significantly influenced the plant height, pods/plant and seed yield (Table 1). Seeds/pod, 100 seed weight, stover yield and harvest index were not significantly influenced by boron treatments. The highest plant height, pods/plant and seed yield were recorded under $B_{1.5}$ treatment which was statistically at par with $B_{1.0}$ but was significantly higher than $B_{0.5}$ treatment. Positive response of pulses to B application (0.5 to 2.5 kg B/ha) have been largely reported from Bihar, Odisha, West Bengal, Asom, and Punjab (Takkar *et al.*, 1997). The stover yield and harvest index were not significantly influenced by any of the treatments. However, the maximum harvest index was obtained in $B_{1.0}$ which was 2.71% higher than $B_{0.5}$. The highest yield response with application of B was recorded in $B_{1.5}$ which was 4.7–18.1% higher than lower levels of B (Table 2).

Ross *et al.* (2006) suggested that application of 0.28–1.12 kg B/ha during early vegetative or reproductive growth was found to be sufficient to produce near maximal yields. Singh *et al.* (2006) reported that the seed and stover yields of soybean were significantly influenced by graded levels of S and B application and reported maximum seed yield with 60 kg S + 2.0 kg B/ha. Crak *et al.* (2006) reported that increasing B rates applied either as soil or foliar improved first pod height (17%). Different nutritional treatments showed a significant effect on nutrient-use efficiency by soybean (Table 2). The highest B nutrient-use efficiency was recorded under $B_{1.5}$ treatment, which was 8.3 kg/kg nutrient higher than that recorded under $B_{0.5}$ treatment, but the results were non-significant. It might be due to lower nutrients used and comparatively higher seed yield than in lower level of boron. Seed protein and oil content were not significantly influenced by boron treatments (Table 2).

The highest gross and net returns were recorded with $B_{1.5}$, which was statistically on a par with $B_{1.0}$ but significantly higher than $B_{0.5}$ treatment (Table 2). It might be owing to higher seed yield recorded under these treatments. The highest benefit: cost ratio recorded under $B_{1.0}$ was statistically on a par with $B_{1.5}$ but significantly higher than $B_{0.5}$ treatment.

Interaction

The grain yield was significantly increased with the increase in sulphur level from 10 to 30 and 40 kg S/ha at all the levels of boron (Table 3). The increase in grain yield with boron levels only recorded at 40 kg S/ha. It signifies the importance of boron application at 40 kg S/ha. The highest grain yield recorded with $S_{40}B_{1.5}$ was statistically at par with $S_{40}B_{1.0}$, $S_{30}B_{1.0}$, $S_{20}B_{1.5}$, $S_{30}B_{1.5}$ treatments but was significantly higher than all other combinations of sulphur and boron.

Table 3. Interactive effect of sulphur and boron on grain yield (t/ha) of soybean

Boron (kg/ha)	Sulphur (kg/ha)				
	10	20	30	40	Mean
0.5	1.22	1.42	1.54	1.54	1.43
1.0	1.29	1.54	1.74	1.72	1.57
1.5	1.44	1.56	1.65	1.84	1.62
Mean	1.31	1.50	1.64	1.70	
CD (P=0.05)	0.28				

Based on 3 years study, it may concluded that in S-and B-deficient soils, S dose of 30 kg/ha and B dose of 1.0 kg/ha are sufficient for getting good grain yield, better quality and higher returns.

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