Original Research Article

Effect of level of sulphur and phosphorus on yield and quality of soybean grown in inceptisol

Abstract

The field experiment was conducted during *Kharif* 2017 at Post Graduate Research Farm,Rajarshee Chhatrapati Shahu Maharaj, College of Agriculture Kolhapur, with the view to study the effect of levels of sulphur and phosphorus on yield and quality of soybean grown in inceptisol.The soil of the experimental site was slightly alkaline in reaction,very low in available nitrogen, medium in available phosphorus and medium in available potassium and deficient in available sulphur. The field experiment was carried out inFactorial Randomized Block Design with three replications and sixteen treatments comprising four levels of sulphur (0, 20, 40, and 60 kg ha^{-1}) through elemental sulphur and four levels of phosphorus (0, 75, 100, and 125 kg ha^{-1}) through DAP.The result indicated that the significantly highest grain yield (27.20 q ha^{-1}, 25.04 q ha^{-1} respectively)was recorded by application of sulphur and phosphorus at 60 kg ha^{-1} (S_4) and100 kg ha^{-1} (P_3) than rest of the sulphur and the phosphorus levels. The application of (S_4, P_3) at 60 kg ha^{-1}and 100 kg P ha^{-1} showed significantly highest straw yield (38.85 q ha^{-1}, 35.50 q ha^{-1} respectively) than rest of thecombination of sulphur and Phosphorus levels.The quality parameterrecords highest percent of 1000 grain weight, oil content and oil yield were found in 60 kg S along with 100 kg P ha^{-1} while the lowest seed yield, 1000 grain weight and oil content were found in control. Therefore, application of 60 kg S with 100 kg P appeared as the promising practice for obtaining higher seed yield and better quality of Soybean.

Keywords: Soybean, DAP, Phosphorus.

1. Introduction

Soybean (*Glycine max* L. Merril)is a leguminous cropand belongs to the sub-family papilionaceae of the family Fabaceae.Soybean is native to China.It was introduced into northern India in 1000 AD from Central China.In India, the states of Madhya Pradesh and Maharashtra are major producers of soybean, accounting for 49.08 lakh hectors and 65.83 lakh tonns of the production. Soybean is nature's versatile plant; it supplies an abundant amount of protein (38-42 %), oil (18-22 %), and is enriched in unsaturated fatty acids and essential amino acids across a wide range of environmental condition. It gives 2-3 times more protein yield per hectare than other legumes or oilseed crops.

Kumar et. al. (2017) reported that "both seed and stover yield of soybean increased significantly due to individual as well as combined application of phosphorus and sulphur. The combined application of sulphur with phosphorusproduced the highest seed and stover yield of soybean".

Dhage et al. (2014) indicated that "grain and straw yield, as well as the uptake of phosphorus and sulphur, increased with the rate of application of phosphorusand Sulphur individually and in various combinations. The applicationof various levels of phosphorusand sulphur influenced the quality parameters of soybean, including protein content and test weight. Available phosphorusin the soil increased with increasing levels of phosphorus. Similarly, available sulphur in the soil increased with increasing levels of sulphur. Sulphur is recognized as the fourth major nutrient after nitrogen,phosphorusand potassium. Sulphur plays an important role in many physiological functions. Soybean is a source of sulphur containing amino acids such as cystein, cystine, methonine, which are essential forprotein synthesis and also promote oil and chlorophyll synthesis. Soybean seed yield was increased by sulphur application".

Chaousaria et al., (2009) recorded "an improvement in protein and oil content due to application of phosphorus and sulphur in soybean crop.Sulphur improves the nutrient use efficiency of other plant nutrients, particularly nitrogen (N)and phosphorus (P). Sulphur provids direct nutritive value".

Phosphorus is essential for the growth and development of root nodules, their multiplication, and the effectiveness of root nodule bacteria. Phosphorus is the second major plant nutrient and is an indispensible element that plays a unique role in several plant metabolic and energy transformation processes. It hastens maturity and improves the quality of grain.Phosphorus acts as an energy source (ATP) for plants.

2. Material and methods

The experiment was conducted during the kharif season in 2017 in an inceptisol at the Post Graduate Research Farm, Rajarshee Chhatrapati Shahu Maharaj College of Agriculture, Kolhapur, Maharashtra, India. The chemical composition indicates that the soil at the experiment site was medium deep (inceptisol) and deficient in available sulphur (7.42 kg ha^{-1}). Additionally, the soil was alkaline in reaction, very low in available nitrogen (137.98 kg ha^{-1}), medium in available phosphorus (15.33 kg ha^{-1}), and available potassium (181.30 kg ha^{-1}). The experiment was laid out in a factorial randomized block design with sixteen treatments and three replications. The treatments consisted of four levels of sulphur (0, 20, 40, 60 kg S ha^{-1}) and four levels of phosphorus (0, 75, 100, 125 kg P ha^{-1}). Sulphur and phosphorus were applied through elemental sulphur and diammonium phosphate (DAP). Plot-wise soil samples and treatment-wise plant samples were collected and analyzed as per standard procedures.

1. **Methods are used for soil analysis**

Table 1: Methods are used for soil analysis

Sr. No.	Parameters	Methods	Referances
1.	pH (1:2.5)	Potentiometry	Jackson(1973)
2.	EC	Conductivity	Jackson(1973)
3.	Organic Carbon (%)	Walkley and Black Wet Oxidation	Nelson and Sommer(1982)
4.	Available N (Kg ha-1)	Alkaline permanganate (Distillation)	Subbiah and Asija(1956)
5.	Available P (Kg ha-1)	0.5 M NaHCO3 extract at pH 8.5 (Colorimetry)	Olsen et.al (1965)
6.	Available K (Kg ha-1)	Neutral normal ammonium acetate using (Flame photometer)	Jackson(1973)
7.	Available S (Kg ha-1)	Turbidimetric	Williams and Steinbergs(1959)

2. **Methods are used for plant analysis and quality traits**

Table 2: Methods are used for plant analysis and quality traits

Sr. No.	Parameters	Methods	Referances
1.	Total N	Micro Kjekdahl (Diacid H2SO4:H2O2 digestion)	Parkinson and Allen (1975)
2.	Total P	Vanadomolybdate yellow color method (triacid H2SO4:HNO3:HCLO4 digestion)	Piper (1966)
3.	Total K	Flame photometer	Chapman and Pratt (1961)
4.	Total S	Turbidimetric	Tabatabai and Bremner (1970)
5.	Protein content	Micro Kjekdahl (Diacid H2SO4:H2O2 digestion)	Parkinson and Allen (1975)

6.	Oil content	Soxhlet extractor using ether as a solvent	Franz von Soxhlet. (1879)
7.	Germination Count	Quadratic method	-
8.	Chlorophyll	Spectrophotometer	Arnold O. Beckman (1940)

3. Results and discussion

Grain yield-

The data in relation to effect of levels of Sulphur and Phosphorus on grainyield is presented in table3. Sulphur application to soybean up to 60 kg S ha^{-1} increases the grain yield of soybean. Phosphorus application also successively and significantly increased grain yield of the crop over preceding levels up to 100 kg P ha^{-1}; however, the response at the higher level of 125 kg P $ha^{-1}$was found to be almost at par with 100 kg P ha^{-1}.The significantly highest grain yield (27.20 q ha^{-1}) was recorded with the application of sulphur at 60 kg ha^{-1} (S_4) compared to the other sulphur levels. The different levels of phosphorus application did not show much variation in grain yield. The application of Phosphorus at 100 kg ha^{-1} (P3) resulted in the significantly highest grain yield (25.04 q ha^{-1}). Decrease in yield (24.51 q ha^{-1}) at the P_4 level might be due to the higher concentration of phosphorus, which may cause toxic effect and nutrients imbalance.

The highest grain yield was recorded by treatment T_{15} (S_4P_3) (29.65 q ha^{-1}). Yield attributes of the plant due to sulphur application are well known, considering the physiological role of sulphur in the plant body. Sulphur enhances cell multiplication, elongation, expansion, and imparts a deep green colour to leaves due to better chlorophyll synthesis, resulting in increased food supply, essential replacement of amino acids, and relatively greater amount of dry matter accumulation. The supply of phosphorus to the soil might have accelerated cell division and enlargement, carbohydrate, fat metaboilism, and respiration in the plant favouring increased growth and yield. The similar results were also recorded by Kumar *et.al.* (2017), Dhage *et al*. (2014), Mahmoodi *et al.* (2013).Deshbhratar et al. (2013),The yield components and seed yield of soybean were significantly influenced by phosphorus and sulphur application, as noted by Barman et. al. (2022)

Straw yield-

The results indicated that the increase in levels of 'S' significantly increased the straw yield of soybean. The application of S at 60 kg ha^{-1} (S_4) showed a significantly higher straw yield (38.85 q ha^{-1}) than the rest of the sulphur levels. Among the different levels of phosphorus, the highest straw yield was observed with $P_{3,}$i.e 100 kg P ha^{-1} yielding 35.50 q ha^{-1}.

Considering the interaction effects of levels of S & P, it was observed that the straw yield of soybean was significantly influenced by the interaction effect of S & P levels. Treatment T_{15} (S_4P_3) and T_{14} (S_4P_2) recorded the highest straw yield (42.00 and 41.96 q ha^{-1} respectively) and were found to be statistically at par with each other and significantly superior to the over rest of the treatments. Application of sulphur might have increased the availability of nutrient to the soybean plant due to an improved nutritional environment, which in turn favourably influenced energy transformation, activation of enzymes, chlorophyll synthesis, and increased carbohydrate metabolism. Similar results were also obtained by Kumar *et.al.* (2017)Dhage *et al.* (2014) and Mahmoodi *et al.* (2013).

Table 3 : Effect of sulphur and phosphorus and their interaction on yield of soybean ($q\ ha^{-1}$).

Levels of sulphur ($kg\ ha^{-1}$)	Levels of phosphorus ($kg\ ha^{-1}$)					Treatments		
	P_1 (0)	P_2 (75)	P_3 (100)	P_4 (125)	Mean		S.E±	C.D. at 5%
Grain								
S_1 (0)	15.68	18.09	17.73	18.27	**17.44**			
S_2 (20)	16.97	24.50	25.09	24.66	**22.81**	**S**	0.37	1.07
S_3 (40)	20.24	27.26	27.68	27.24	**25.61**	**P**	0.37	1.07
S_4 (60)	22.67	28.60	29.65	27.87	**27.20**	**SxP**	0.74	2.14
Mean	**18.89**	**24.61**	**25.04**	**24.51**	**23.26**			
Straw								
S_1 (0)	18.90	24.10	25.00	26.32	**23.58**			
S_2 (20)	24.13	35.96	36.00	35.27	**32.84**	**S**	0.49	1.43
S_3 (40)	27.73	36.99	39.00	36.62	**35.09**	**P**	0.49	1.43
S_4 (60)	32.32	41.96	42.00	39.11	**38.85**	**SxP**	0.99	2.87
Mean	**25.77**	**34.75**	**35.50**	**34.33**	**32.59**			

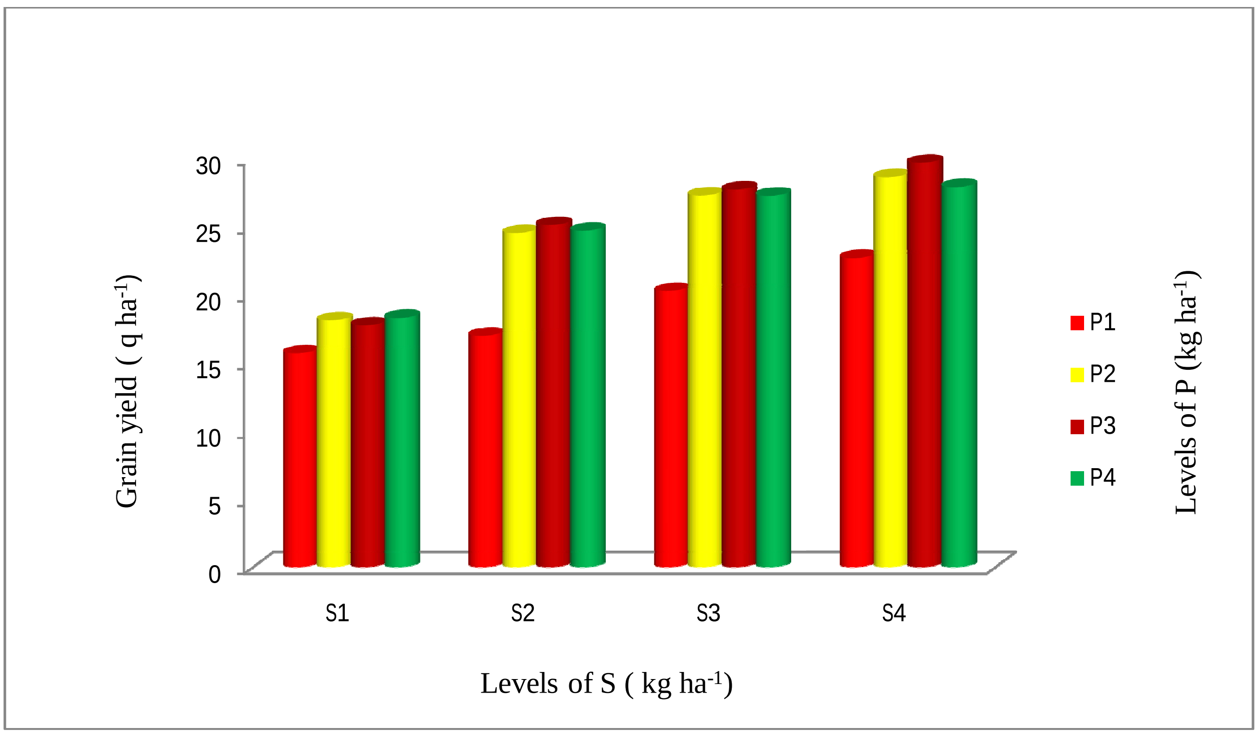

Fig. 1.Effect of different levels of sulphur and phosphorus interaction on grainyield ofsoybean

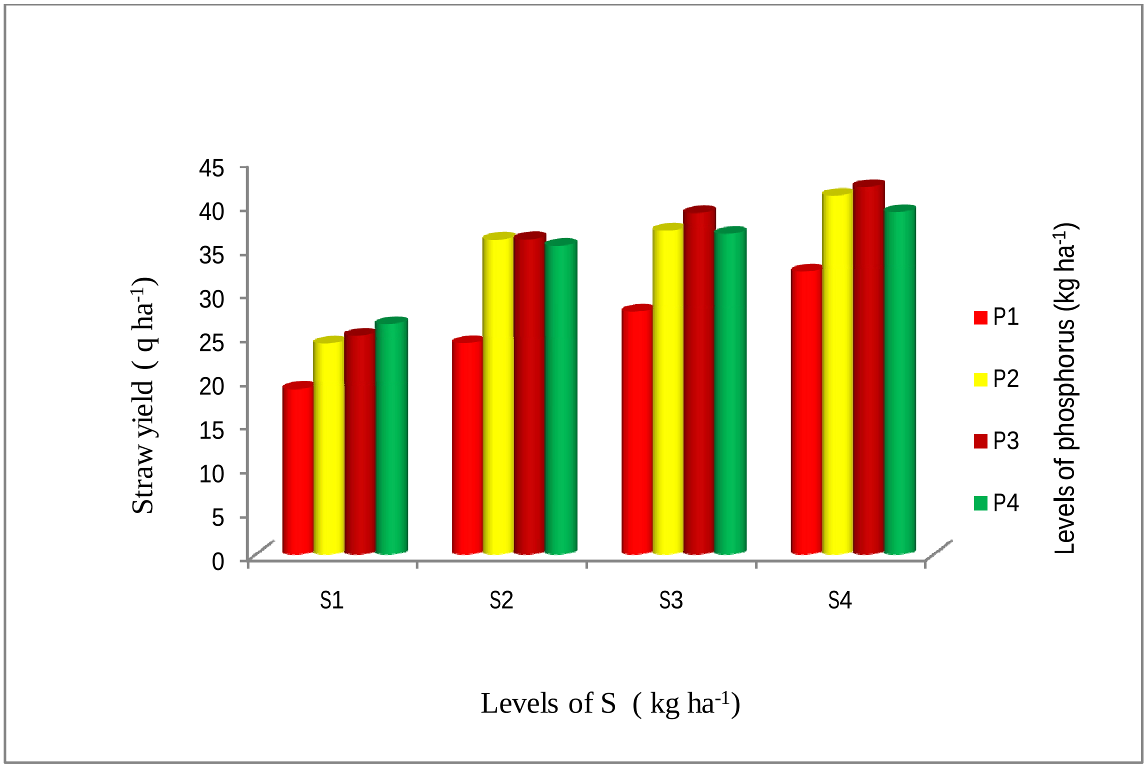

Fig. 2. Effect of different levels of sulphur and phosphorus interaction on straw yield of soybean.

Effect of S and P on quality parameters of soybean

1. 1000 Grain Weight

The different levels of S & P and their interaction showed a significant effect on thousand grain weight. Application of sulphur at 60 kg ha^{-1} recorded highest thousand grain weight (150.58 g), which was significantly superior to rest of the S levels. The application of different levels of phosphorus i.e. P_2, (146.12g) P_3 (147.54g) and P_4 (145.84g) did not showmuch variation in thousand grain weight and were found statistically at par with each other,but significantly superior to P_1 (140.64g) i.e. 0 k ha^{-1} P.

The interaction effect of sulphur and phosphorus indicated that the highest thousand grain weight of soybean was observed in treatment T_{15} (S_4P_3) (155.00g) which was significantly superior to the rest of the treatment except T_{14} (S_4P_2) and T_{16} (S_4P_4), which recorded 151.51g and 153.08g, respectively. Sulphur plays an important role in growth by attributing metabolic and synthesis activities of oil, starch, and protein. The increase in thousand grain weight may be due to these result activities. Similar findingswere reported by Mahmoodi *et al.* (2013) and Dhage *et al.* (2014).

2. Oil Per cent

The oil percentage in soybean grainincreased with higher levels of sulphur. However,the highest oil percentage was observed at the in S_4 level (21.10%), i.e. application of sulphur at 60 kg ha^{-1}, which was significantly superior to the other sulphur levels. The application of phosphorus at 100 kg ha^{-1} (P_3) recorded the highest oilpercentage (19.96 %) in soybean and was significantly superior to the control (P_1) (19.10 %) i.e. 0 kg ha^{-1} P. But, P_2 (19.85 %) and P_4(19.79 %) levels are statistically at par with the P_3 level. Further, oil per

This might be due to the higher concentration of P causingnutrientimbalance. Application of 60 kg S and 100 kg P ha^{-1} recorded the highest oil percentage (21.41%) over all other treatments except treatment T_{14} i.e. (21.35 %), i.e. application of 60 kg S and 75 kg P ha^{-1}. There was an improvement in quality parameters due to S and P application. Similar findings were reported by Harendra, Kumar and Das, (2007).Furthermore, the interaction between P and S was significant. All the S levels increased oil content significantly at every level of P. The maximum oil content was recorded with a treatment combination of P2O5 and S. by Jarupula et. al. (2018). The oil content of soybean was significantly influenced by phosphorus and sulphur application. As reported by Barman et. al. (2022)

3. **Oil Yield**

The oil yield of soybean was enhanced due to different levels of sulphur and phosphorus. The highest oil yield (574.66 kg ha^{-1}) was obtained at 60 kg sulphur per hectare,which was significantly superior to the other sulphur levels (0, 20, and 40 levels). The application of phosphorus at 100 kg ha^{-1} showed highest oil yield (504.69 kg ha^{-1}), significantly superior to the control i.e. P_1 (365.79 kg ha^{-1}) 0 kg P ha^{-1}. However, the application of phosphorus at 75 kg ha^{-1} (P_2) (493.27 kg ha^{-1}) and 125 kg ha^{-1} (P_4) (487.59 kg ha^{-1}) was statistically at par with 100 kg ha^{-1} phosphorus (P_3). The interaction effect of different sulphur and phosphorus levels found to be significant among the various treatment combinations.The treatment T_{15} which involved the application of sulphur at 60 kg ha^{-1} with 100 kg ha^{-1} phosphorus, recorded the highest oil yield (634.80 kg ha^{-1}), followed by treatment T_{14} (S_4P_2), which involved 60 kg S ha^{-1} with 75 kg ha^{-1} P (610.60 kg ha^{-1}) these treatments were statistically at par with each other and significantly superior to the other treatments.

This improvement in oil yield is attributed to the enhancement in quality parameters (1000 grain weight, protein and oil content) due to application of sulphur and phosphorus. The improvement of sulphur and phosphorus through the growing media to the soybean crop is also noted. Additionally, the enzyme acetic thiokinase, which is involved in the conversion of acetyl Co-A to malonyl Co-A and this activity of thiokinase is governed by sulphur, potentially resulting in increased oil yield. Similar findings were reported by Harendra Kumar and Das, (2007)The maximum oil content, oil yieldwere recorded with a treatment combination of P2O5 and S, as reported by Jarupula et. al. (2018)

4. **Protein Content (%)**

"The different levels of sulphur, phosphorus and their interactions did not showed much more variation in protein content and were found non significant in protein per cent. Similar results were obtained" by Dhage *et al.* (2014).

5. **Total Chlorophyll Content.**

The different levels of S and P and their interaction showed a significant effect on chlorophyll content. The level of S_3 i.e. application of sulphur at 40 kg ha^{-1} recorded the highest chlorophyll content (0.210 mg g^{-1}) and was found to be significantly superior over the rest of the sulphur levels. The application of phosphorus (P_4) at 125 kg ha^{-1} showed the highest chlorophyll content (0.191 mg g^{-1}) and was found to be statistically at par with P_3 (0.180 mg g^{-1}) and significantly superior over the control i.e. P_1 0 kg P ha^{-1}.

The interaction effect of sulphur and phosphorus indicated that the highest chlorophyll content of soybean was observed in treatment T_{12} (S_3P_4) (0.236 mg g^{-1}), which was significantly superior over the rest of the treatments. The chlorophyll content of the leaf is influenced by both N and S nutrition of the crop. Application of 40 kg S ha^{-1} significantly increased the chlorophyll content of the leaves. Higher rates of applied sulphur did not further increase the chlorophyll content of the leaves. Similar results were obtained by Reddy and Ganeshamurthy (2000).

6. **Germination Per cent**

The different levels of sulphur, phosphorus and their interactions were found non significant in germination per cent.

Table. 4 Effect of sulphur and phosphorus on quality parameter of soybean.

Treatment	1000 grain weight	Oil Per- cent	Oil yield	Protein content	Chlorophyll content	Germination count
	(g)	%	Kg ha^{-1}	%	mg g^{-1}	%
S_1	140.52	17.79	310.99	39.91	0.133	97.17
S_2	143.58	19.62	448.15	40.02	0.170	97.67
S_3	145.47	20.19	517.53	40.05	.0210	97.25
S_4	150.58	21.10	574.66	40.57	0.195	96.92
SE ±	0.62	0.08	8.17	0.20	0.002	0.8
CD at 5%	1.81	0.23	23.61	NS	0.005	NS
P_1	140.64	19.10	365.79	40.27	0.168	97.33
P_2	146.12	19.85	493.27	40.11	0.169	97.25
P_3	147.54	19.96	504.69	40.33	0.180	97.08
P_4	145.84	19.79	487.59	39.85	0.191	97.33
SE ±	0.62	0.08	8.17	0.20	0.002	0.8
CD at 5%	1.81	0.23	23.61	NS	0.005	NS

Conclusion

The application of sulphur at 60 kg ha^{-1} and phosphorus at 100 kg ha^{-1} showed a significant effect in increasing the grain yield (27.20 q ha^{-1}) and straw yield (25.04 q ha^{-1}) of soybean.The quality parameter records highest percent of 1000 grain weight, oil content and oil yield were found in 60 kg S along with 100 kg P ha^{-1} while the lowest seed yield, 1000 grain weight and oil content were found in control. Therefore, application of 60 kg S with 100 kg P appeared as the promising practice for obtaining higher seed yield and better quality of Soybean.

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