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Effect of phosphorus and sulphur levels on growth and yield of summer sesame (*Sesamum indicum* L.)

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Abstract
A field experiment was conducted during *Zaid* season of 2021 at experimental field of the Crop Research Farm, Department of Agronomy, SHUATS, Prayagraj, (U.P.). The soil of experimental site was sandy loam in texture, nearly neutral in soil reaction (pH 7.2), EC (0.34 dS/m), available N (203.7 kg/ha), available P (17.2 kg/ha) and available K (208.8 kg/ha). The experiment was laid out in randomized block design with ten treatments consisting of 30 kg P/ha + 10 kg S/ha, 30 kg P/ha + 15 kg S/ha, 30 kg P/ha + 20 kg S/ha, 40 kg P/ha + 10 kg S/ha, 40 kg P/ha + 15 kg S/ha, 40 kg P/ha + 20 kg S/ha, 50 kg P/ha + 10 kg S/ha, 50 kg P/ha + 15 kg S/ha, 50 kg P/ha + 20 kg S/ha and RDF N:P:K 50:40:30 which replicated thrice and effect is observed on Pragati sesame variety. Application of 40 kg P/ha + 20 kg S/ha were recorded significantly higher in growth parameters *viz.*, Plant height (87.89 cm), Plant dry weight (22.23 g), Number of Branches per plant (6.52) and yield and yield attributes *viz.*, Number of Capsules per plant (41.38), Seeds per capsule (54.52), Seed yield (0.83 t/ha), Stover yield (2.24 t/ha),. These parameters were significantly influenced by application of 40 kg P/ha as SSP. Maximum Gross return (116399.00 ₹/ha), Net return (83173.4 ₹/ha) and B: C ratio (2.50/ha) were recorded in application of 40 kg P/ha + 20 kg S/ha.

Keywords: Sesame, phosphorus, sulphur, growth, yield and economics

Introduction

Oilseeds play a vital role in agricultural and industrial economics in world. Oilseeds are the main source of fats and protein particularly for vegetarians. Sesame is one of the most ancient crop grown for its oil rich seeds. It is a crop of tropical and subtropical areas. Bulk of the sesame in the world is grown in the semi-arid region with little rainfall which is an indication that sesame is drought tolerant crop. China is the world's higher producer of sesame followed by India and Myanmar. Sudan, Uganda and Nigeria ranked 4th, 5th and 6th in that order (Dey, 2016) [5].

Sesame (*Sesamum indicum* L.) belongs to family *pedaliaceae*, is an important edible oilseed crop. It is commonly known as til. Sesame is cultivated for its seed which contains 36-55% oil of very good quality and 17-24% protein. The seed contains all essential amino acids and fatty acids. It is a good source of vitamins and minerals such as calcium and phosphorus and the seed cake is also an important nutritious livestock feed (Balasubramaniyan and Palaniappan, 2001) [1]. About 80% of sesame produced in India is used for oil extraction. India exports sesame seeds to different countries.

Phosphorus, one of the major plant nutrients and an integral component of several important compounds in the plant cells including sugar-phosphate intermediates of respiration, photosynthesis and phospholipids that make up plant membranes (Lal, 2002; Taiz and Zeiger, 2003) [13, 24], helps in alleviating the yield and its attributes by supplying energy required for metabolic processes. It also enhances the quality and quantity of oil production as it plays important role in plant metabolism (Hemalatha *et al.*, 2013) [8]. The fertilization with phosphorus helps in improving the seed weight and also the development of deeper and proliferous root system it stimulates seed setting and hastens maturity. Phosphorus application not only increases the seed yield and oil content but also increases protein content and fatty acid synthesis of seeds it is necessary for maintaining a balance among other plant nutrients and ensuring the normal growth of the crop. Majority of soils contain substantial reserves of total phosphorus but most of it remains relatively inert with only less than 10 per cent of soil phosphorus enters the plant-animal cycle thereby reducing the effectiveness of phosphorus fertilization. In oilseeds, Sulphur plays significant role in increasing the yield and oil content of sesame (Deshmukh *et al.* 2010) [4]. Sulphur plays an important role in improving quality and boldness in seeds.

Therefore, oilseed crops require higher quantity of sulphur for proper growth and development to obtained higher yield. In case of sulphur, plays significant role in primary and secondary plant metabolism as a component of glucosinolates, proteins and other compounds that related to various parameters determine the nutritive quality of crops. The response of sulphur to oilseed is increasing due to increase in cropping intensity (Ghosh *et al.* 2000) [7]. Most of Indian soil is sulphur deficit and crop response also been reported to sulphur application.

Materials and Methods

The experiment was carried out during *Zaid* season of 2021 at Crop Research Farm, Department of Agronomy, Naini Agricultural Institute, SHUATS, Prayagraj (Allahabad) which is located at 25° 24' 42" N latitude, 81° 50' 56" E longitude and 98 m altitude above the mean sea level. This area is situated on the right side of the river Yamuna by the side of Allahabad Rewa Road about 5 km away from Prayagraj city. The soil samples were collected randomly from 0 to 15 cm depth from 5 spots of the experimental field just before layout of experiment. The soil texture of the experimental site was sandy loam having available N (225 kg/ha) P (21.50 kg/ha), potassium (87.00 kg/ha) and organic carbon of soil was of 0.28% with 7.4 available pH of soil. The experimental plot was layed out in randomized block design with ten treatments which replicated three times with a suitable plot size was of 3m×3m. There were ten treatments combination used for this experiment are T_1: 30 kg/ha Phosphorus + 10 kg/ha Sulphur, T_2: 30 kg/ha Phosphorus +15 kg/ha Sulphur, T_3: 30 kg/ha Phosphorus +20 kg/ha Sulphur, T_4: 40 kg/ha Phosphorus +10 kg/ha Sulphur, T_5: 40 kg/ha Phosphorus + 15kg/ha Sulphur, T_6: 40 kg/ha Phosphorus + 20kg/ha Sulphur, T_7: 50 kg/ha Phosphorus + 10kg/ha Sulphur, T_8: 50 kg/ha Phosphorus + 15kg/ha Sulphur, T_9: 50 kg/ha Phosphorus + 20kg/ha Sulphur and T_{10}: RDF (50:40:30) NPK kg/ha. Fertilizer was applied at the time of sowing in the form of urea, SSP and MOP. The growth parameters were recorded at periodic intervals 15, 30, 45, 60, 75, and 90 DAS from randomly selected plants from each treatment.

Results and Discussion

Growth attributes

Data presented in table 1 revealed the effect of Phosphorus and Sulphur levels on Growth and Yield of Summer Sesame (*Sesamum indicum* L.). The growth attributes that were considered in this experiment for observations were plant height (cm), number of branches per plant, dry weight (g/plant), Crop Growth Rate (CGR) (g/m²/day) and Relative Growth Rate (RGR) (g/g/day).

The results of the present investigation revealed that T_6 (40 kg/ha Phosphorus + 20 kg/ha Sulphur) recorded significantly higher plant height (87.89 cm) at harvest. However, T_5 (40 kg/ha Phosphorus + 15 kg/ha Sulphur), T_3 (30 kg/ha Phosphorus + 20 kg/ha Sulphur) and T_{10} (RDF 50:40:30 NPK kg/ha) is statistically at par with T_6 (40 kg/ha Phosphorus + 20 kg/ha Sulphur). No. of branches/plant (6.52) was observed in T_6 (40 kg/ha Phosphorus + 20 kg/ha Sulphur). However, T_2 (30 kg/ha Phosphorus + 15 kg/ha Sulphur), T_5 (40 kg/ha Phosphorus +15 kg/ha Sulphur) and T_8 (50 kg/ha Phosphorus + 15kg/ha Sulphur) was statistically at par with T_6 (40 kg/ha Phosphorus + 20 kg/ha Sulphur). Treatment T_6 (40kg/ha Phosphorus + 20kg/ha Sulphur) recorded significantly higher Dry weight (22.23 g). However, T_5 (40kg/ha Phosphorus + 15kg/ha Sulphur) and T_{10} (RDF (50:40:30) NPK kg/ha) is statistically at par with T_6 (40kg/ha Phosphorus +20kg/ha Sulphur). At 90DAS significantly higher Crop growth rate (2.9 g) was observed in T_7 (50 kg/ha Phosphorus +10 kg/ha Sulphur) and minimum Crop growth rate (1.28 g) was observed in T_2 (30 kg/ha Phosphorus + 15 kg/ha Sulphur). At 90 DAS maximum Relative growth rate (0.03g) was observed in T_8 (50 kg/ha Phosphorus + 15 kg/ha Sulphur) is higher than all other combinations and there is no significant difference among the treatments.

The progressive increase in levels of phosphorus i.e. 40 kg P/ha and 20 kg S/ha significantly increased the growth attributing characters of sesame *viz*., plant height, number of branches was reported by Jahan *et al.* (2019) [9], Shelke *et al.* (2014) [22], and Chakraborty (2013) [2]. As effect of Phosphorus found too slow and concern is only that Phosphorus should be available through all the growth stages of life. This may be due to availability of phosphorus slowly during different growth stages. Application of phosphorous and Sulphur with irrigation water as per requirement ensures steady availability of soil moisture to crop, which consequently improve uptake of Phosphorus, fertilizer use efficiency, growth and development. It ultimately reflects on accumulation of higher dry matter in aerial parts. Results found similar with Sarkar *et al.* (2005) [20] and Vani *et al.* (2017) [26]. Application of higher doses of sulphur might have increased the uptake of nitrogen, phosphorus and potassium which in turn reduced the sulphur deficiency ultimately increased the crop growth rate and relative growth rate of sesame. Similar results were found by Shelke *et al.* (2014) [22].

Table 1: Effect of Phosphorus and Sulphur levels on Growth Parameters of Summer Sesame (*Sesamum indicum* L.)

Treatments	Plant height (cms) at 90 DAS	No. of branches at 90 DAS	Dry weight (g/plant) at 90 DAS	Crop Growth Rate (g/m²/day) at 75-90 DAS	Relative Growth Rate (g/g/day) at 75-90 DAS
T_1-30kg/ha Phosphorus + 10kg/ha Sulphur	82.32	5.84	17.56	1.84	0.002
T_2-30kg/ha Phosphorus + 15kg/ha Sulphur	82.77	6.31	17.80	1.28	0.001
T_3-30kg/ha Phosphorus + 20kg/ha Sulphur	85.02	5.89	18.36	1.47	0.001
T_4-40kg/ha Phosphorus + 10kg/ha Sulphur	83.47	5.65	19.20	1.87	0.001
T_5-40kg/ha Phosphorus + 15kg/ha Sulphur	84.82	6.39	22.13	2.19	0.002
T_6-40kg/ha Phosphorus + 20kg/ha Sulphur	87.89	6.52	22.23	2.46	0.002
T_7-50kg/ha Phosphorus + 10kg/ha Sulphur	81.43	5.67	19.06	2.90	0.001
T_8-50kg/ha Phosphorus + 15kg/ha Sulphur	82.05	6.13	20.10	2.82	0.003
T_9-50kg/ha Phosphorus + 20kg/ha Sulphur	82.93	5.89	20.70	2.16	0.001
T_{10}-RDF (50:40:30) NPK kg/ha	85.30	5.94	21.96	1.70	0.002
F-Test	S	S	S	S	NS
S.Em (±)	1.24	0.17	0.15	0.63	0.01
C. D (5%)	3.67	0.52	0.46	1.89	-

Yield attributes

Data presented in table 2 indicated the effect of Phosphorus and Sulphur levels on Growth and Yield of Summer Sesame (*Sesamum indicum* L.). The yield characters that were considered in this experiment are seeds/capsule (No.), capsules/plant (No.), test weight (g), seed yield (t/ha), stover yield (t/ha) and harvest index (%)

The Number of capsule per plant of sesame was recorded significantly higher in the treatment combination of T_6 (40 kg/ha Phosphorus + 20 kg/ha Sulphur) was 41.38. However, T_3 (30 kg/ha Phosphorus + 20 kg/ha Sulphur) and T_5 (40 kg/ha Phosphorus +15 kg/ha Sulphur) is statistically at par with T_6 (40 kg/ha Phosphorus + 20 kg/ha Sulphur). In number of seeds per capsule of sesame was recorded significantly higher in the treatment combination of T_6 (40 kg/ha Phosphorus + 20 kg/ha Sulphur) was 54.52. However, T_3 (30 kg/ha Phosphorus +20 kg/ha Sulphur) and T_5 (40 kg/ha Phosphorus + 15 kg/ha Sulphur) is statistically at par with T_6 (40 kg/ha Phosphorus +20 kg/ha Sulphur). The test weight was recorded significantly higher in the treatment combination T_6 (40 kg/ha Phosphorus + 20 kg/ha Sulphur) was 3.56. However, T_1 (30 kg/ha Phosphorus +10 kg/ha Sulphur), T_3 (30 kg/ha Phosphorus +20 kg/ha Sulphur), T_8 (50 kg/ha Phosphorus +15 kg/ha Sulphur) and T_9 (50 kg/ha Phosphorus +20 kg/ha Sulphur) is statistically at par with T_6 (40 kg/ha Phosphorus +20 kg/ha Sulphur). The seed yield of sesame was observed significantly higher in the treatment combination of T_6 (40kg/ha Phosphorus +20kg/ha Sulphur) 0.83 t/ha is significantly higher among all the treatment combinations. However, T_3 (30kg/ha Phosphorus +20kg/ha Sulphur) and T_5 (40kg/ha Phosphorus +15 kg/ha Sulphur) is statistically at par with T_6 (40kg/ha Phosphorus +20kg/ha Sulphur). The Stover of sesame was observed significantly higher in the treatment combination of T_6 (40kg/ha Phosphorus + 20kg/ha Sulphur) 2.24 t/ha is significantly higher among all the treatment combinations However, T_3 (30kg/ha Phosphorus + 20kg/ha Sulphur) is statistically at par with T_6 (40kg/ha Phosphorus + 20kg/ha Sulphur). The Harvest index of sesame was observed significantly higher in the treatment combination of T_5 (40kg/ha Phosphorus + 15kg/ha Sulphur) 27.81% and minimum Harvest index of sesame was observed in the treatment combination of T_9 (50kg/ha Phosphorus + 20kg/ha Sulphur) was 19.38%.

The more number of capsules per plant under higher Phosphorus doses might be due to proper availability of Phosphorus at reproductive phase when plant needs more energy. As well as it might be due to favorable temperature and adequate moisture during their growth period resulting in better growth and beneficial effect on flowering, better capsule setting. These findings are similar with Pagal *et al.* (2007) and Thentu *et al.* (2014) [25]. Higher uptake of nutrients *viz.*, Phosphorus and Sulphur and higher dry matter accumulation and translocation might be attributed to reproductive plant parts. These results are found similar with the results of Choudhari and Patel (2007) [3] in sesame. The synergistic relationship of Phosphorus and Sulphur in plant metabolism and the maximum yield response to these elements is achieved when the supply of them are balanced in oilseed crops Salame *et al.*, 2020 [18]. Seed yield is the function of several yield attributing characters *viz.*, number of capsules/plant, number of seeds/capsule and test weight of seed. Increase in number of capsules/plant and number of seeds/capsule due to adequate nutrition of phosphorus might have resulted in the production of higher seed yield. The cumulative effect of all these growth and yield components was reflected on seed yield and effect of adequate phosphorus supply was well marked. Higher seed yields at higher levels of phosphorus were also reported by Sarkar and Mallick (2010) [19].

Table 2: Effect of Phosphorus and Sulphur levels on Yield attributes of Summer Sesame (*Sesamum indicum* L.)

Treatments	Capsules/plant	Seeds/capsules	Test weight (g)	Seed yield (t/ha)	Stover yield (t/ha)	Harvest index (%)
T_1-30kg/ha Phosphorus +10kg/ha Sulphur	36.11	45.34	3.46	0.51	1.87	21.52
T_2-30kg/ha Phosphorus +15kg/ha Sulphur	35.37	41.56	3.22	0.70	1.91	26.85
T_3-30kg/ha Phosphorus +20kg/ha Sulphur	38.25	49.43	3.40	0.82	2.20	27.22
T_4-40kg/ha Phosphorus +10kg/ha Sulphur	36.92	48.37	3.22	0.53	1.99	21.06
T_5-40kg/ha Phosphorus +15kg/ha Sulphur	38.75	49.26	3.11	0.82	2.15	27.81
T_6-40kg/ha Phosphorus +20kg/ha Sulphur	41.38	54.52	3.56	0.83	2.24	27.15
T_7-50kg/ha Phosphorus +10kg/ha Sulphur	36.47	48.68	3.3	0.61	2.08	22.69
T_8-50kg/ha Phosphorus +15kg/ha Sulphur	36.70	47.92	3.42	0.64	2.10	23.45
T_9-50kg/ha Phosphorus +20kg/ha Sulphur	36.55	46.75	3.37	0.52	2.16	19.38
T_{10}-RDF (50:40:30) NPK kg/ha	37.13	45.82	3.30	0.71	1.87	27.47
F-test	S	S	S	S	S	NS
S.Em (+)	1.06	1.84	0.08	0.00	0.00	0.31
C. D (0.05)	3.15	5.47	0.24	0.01	0.01	-

Economic attributes

Data presented in table 3 shown the economics performance of different treatment combination which evaluation was based on cost of cultivation (INR/ha), gross return (INR/ha), net return (INR/ha) and benefit cost ratio (B:C). Highest cost of cultivation (34225.8 INR/ha), gross return (116399 INR/ha), net return (83173.4 INR/ha) and benefit cost ratio (2.50) were found with the application of T_6 (40kg/ha Phosphorus +20kg/ha Sulphur).

Table 3: Effect of Phosphorus and Sulphur levels on Economics of Summer Sesame (*Sesamum indicum* L.)

Treatments	Cost of cultivation (INR /ha)	Gross returns (INR /ha)	Net returns (INR /ha)	B: C ratio
T_1-30kg/ha Phosphorus +10kg/ha Sulphur	31955.4	79713.9	47758.5	1.49
T_2-30kg/ha Phosphorus +15kg/ha Sulphur	32090.0	78429.9	46339.9	1.44
T_3-30kg/ha Phosphorus +20kg/ha Sulphur	32225.8	105112.0	72886.5	2.26
T_4-40kg/ha Phosphorus +10kg/ha Sulphur	32955.4	87360.7	54405.3	1.65

T_5-40kg/ha Phosphorus +15kg/ha Sulphur	33090.0	92385.5	59295.5	1.79
T_6-40kg/ha Phosphorus +20kg/ha Sulphur	33225.8	116399.0	83173.4	2.50
T_7-50kg/ha Phosphorus +10kg/ha Sulphur	33955.4	94180.5	60225.1	1.77
T_8-50kg/ha Phosphorus +15kg/ha Sulphur	34090.0	86654.9	52564.9	1.54
T_9-50kg/ha Phosphorus +20kg/ha Sulphur	34225.8	78220.9	43995.1	1.29
T_{10}-RDF (50:40:30) NPK kg/ha	33840.5	84100.6	50260.1	1.49

Conclusion

On the basis of one season experimentation, application with 40 kg/ha Phosphorus + 20 kg/ha Sulphur was found to be higher production (836.44 kg grains/ha) and economically viable with higher B:C ratio (2.50). The above conclusion is a result of one season's work and may be considered for recommending to the farmers, after at least one more season's field trial.

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