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EFFECT OF PHOSPHORUS, SULPHUR AND PSB ON ENHANCING MUSTARD CROP PRODUCTIVITY AND ECONOMICS PROFITABILITY

Hari Shankar Singh*, Sarvesh Kumar, Anurag, Rohit Kumar Jaiswal, Roopak and Sumit
Department of Soil Science and Agricultural Chemistry, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur, Uttar Pradesh, India 208002
*Corresponding author E-mail: csaharisingh@gmail.com
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ABSTRACT

Field experiments were conducted to study the combined impact of phosphorus, sulphur and phosphate solubilizing bacteria in yield attributes with economics characters of mustard (*Brassica juncea* L.) during rabi season of 2024-25 and 2025-26 at student's instructional farm, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur under Central Plain Zone of Uttar Pradesh. The experiment consists of 13 treatments combinations in randomized block design with three replications and best performing treatment is T_{13} = (100%RDF + 25%P) +PSB+50 kg S ha^{-1} consistently produced maximum and T_1 (control) are minimum, yield and economics characters, The results revealed that the combined application phosphorus, sulphur along with PSB inoculation significantly improved yield parameters and economics characters over the control treatment i.e. Seed yield (25.42- 14.72), stover yield(63.57- 44.39), biological yield(88.95- 59.07) and harvesting index(28.72- 25.09) with economics characters i.e. cost of cultivation Rs. ha^{-1} (41262.2- 316.9.1), gross return Rs. ha^{-1} (136245.4- 73891.6), net return Rs. ha^{-1} (94983.2- 42282.5) and B:C Ratio(2.29- 1.33) maximum , minimum pooled mean respectively, compared to the control. The study concluded that the integrated use of phosphorus, sulphur, and PSB can effectively enhance mustard productivity and enhanced the economics value.

Keywords **:** Phosphorus, Sulphur, Phosphate Solubilizing Bacteria (PSB), Yield, Economics characters

Introduction

Rapeseed and mustard (*Brassica juncea* L.) are the major rabi oilseed in India and stand next to groundnut in the oilseed economy. Rapeseed and mustard are the most important edible oils of northern and eastern parts of India. The role of phosphorus (P) is critical in plant metabolism which plays an important role in energy transfer, respiration and photosynthesis. It is a key structural component of nucleic acids, co-enzymes, phosphoproteins and phospholipids.

Phosphorus fertilization is a major input in crop production (Blackshaw *et al*. 2004). It participates in metabolic activities as a constituent of nucleoprotein and nucleotides and play important role in the formation of energy rich bond like adenosine diphosphate (ADP) and adenosine triphosphate (ATP). Favourable response of mustard to applied P and S was reported by Gangwal *et al*. (2011) and Solanki *et al*. (2016). In areas where mustard is traditionally grown without P, poor growth and low yields are common features. Further, it improves seed size, stimulates proper seed filling and increases oil content. Rapeseed and mustard crop belong to Cruciferae family which favourably need sulphur (S) for their growth and development. Sulphur as the fourth major essential nutrient for plant.

Sulphur plays a multiple role for better oil production as well as quality of oilseeds (Biswas *et al*. 1995). Each unit of fertilizer S generates 3-5 units of edible oil. It is the major constituent of important amino acids like cystin, cysteine and methionine and helps in the development of chlorophyll. Sulphur application also has marked effect on soil properties and is used as soil amendment such as gypsum and pyrite to expand the accessibility of other nutrients in

soil. Between the two common sources of S, gypsum is available in India and is a poor source of S which may be used for oilseed crops. Rathore *et al*. (2015) reported the highest seed and oil yield in mustard (*Brassica juncea*) cv. Kranti, Varuna and Rohini with 20 kg S ha^{-1} applied through gypsum. Biofertilizers are known to play a vigorous role in soil fertility and crop productivity and considered as eco-friendly which can reduce the cost of chemical fertilizers to substantial amount. They supplement chemical fertilizers towards meeting the integrated nutrient demand of the crops. Phosphate solubilizing bacteria (PSB) promote seed germination and initial vigour of the plants by producing growth promoting substances. Application of PSB results in increased mineral and water uptake, root development, vegetative growth and nitrogen (N) fixation (Gangwal *et al*. 2011). Therefore, present study was taken up to study the combined effect of P, S and PSB on yield of mustard crop and soil properties.

Material and Method

A field experiment was conducted at student instructional research farm, Chandra Shekhar Azad University of Agricultural and Technology, Kanpur, during the Rabi seasons of 2024-25 and 2025-26. The experiment conducted at university campus at student's instructional farm in Chandra Shekhar Azad University of Agriculture & Technology, Kanpur under Central Plain Zone of Uttar Pradesh, Kanpur (U.P) under the sub-tropical condition plain zone. The experiment was designed as a randomized block design (RBD) with 13 treatment and 3 replications, involving different treatments of phosphorus (P), sulphur (S) and phosphorous solubilizing bacteria applied in soil. The treatments are T_{13} = (100%RDF + 25%P) +PSB+50 kg S ha^{-1} are best result. Each treatment was applied uniformly across the plots, and standard agronomic practices were followed for mustard cultivation. Meteorological data, including rainfall, temperature, relative humidity, wind speed, evaporation rate, and sunshine hours, were recorded daily during the crop period. These data were used to correlate the environmental conditions with crop growth and yield performance.

Mustard seeds were sown in well-prepared plots, and recommended agronomic practices were followed uniformly across all treatments. The crop was harvested at maturity and data were recorded on seed yield, straw yield and biological yield (total biomass). Seed yield was measured by threshing, cleaning and weighing seeds from each plot while straw yield was calculated by subtracting the seed weight from the total above-ground biomass. Biological yield was determined by the total biomass collected from each plot including both seed and straw.

Economic analysis of the experiment included the calculation of the cost of cultivation, gross returns, net returns and benefit-cost ratio (B:C). The cost of cultivation was assessed by expenses on inputs such as seeds, fertilizers, pesticides, labour and irrigation. Gross returns were calculated based on the market price of mustard seeds and straw while net returns were derived by subtracting the cost of cultivation from the gross returns. The benefit-cost ratio was computed as the ratio of gross returns to the cost of cultivation providing an economic assessment of each treatment's profitability.

The data were statistically analysed using ANOVA to evaluate the effects of different treatments on yield parameters and economic outcomes and the means were compared using the least significant difference (LSD) test at a 5% probability level. This approach provided insights into the most effective treatment combinations for enhancing yield and economic returns of mustard cultivation.

Result and Discussion

Results and Discussion The impact of phosphorus, sulphur and phosphate solubilizing bacteria in growth parameters, yield and yield attributes of mustard (*Brassica juncea* L.) in yield of mustard was assessed based on seed yield, straw yield, biological yield and harvesting index across the Rabi seasons of 2024-25 and 2025-26. The data reveal significant variations in mustard yield and straw production resulting from different nutrient and impact of PSB treatments.

Yield of mustard seed yield, stover yield, biological yield and harvesting index

The application of phosphorus, sulphur, and phosphate-solubilizing bacteria (PSB) significantly improved seed yield, stover yield, biological yield and harvest index of mustard during both years 2024- 2025, 2025- 2026 of the experiment and in the pooled analysis and they reported in table no.1. Among all the treatments, T_{13} (100% RDF + 25% phosphorus + PSB + 50 kg S ha^{-1} consistently produced the maximum yields. It recorded a seed yield of 25.38 q ha^{-1} in 2024-2025 and 25.46 q ha^{-1} in the 2025-2026 with a pooled mean of 25.42 q ha^{-1}. Similarly, the highest stover yield 63.95, 63.19 q ha^{-1} and pooled 63.57 q ha^{-1}, biological yield 89.33, 88.57 q ha^{-1} and pooled 88.95 q ha^{-1} and harvest index 28.78, 28.65% and pooled 28.72% were also obtained under T_{13} and the control treatment T_1 (control) recorded the minimum values for all parameters with pooled seed yield, stover yield,

biological yield and harvest index of 14.68,14.76 and14.72 q ha^{-1},43.89,44.89 and 44.39 q ha^{-1}, 58.57, 59.57 and 59.07 q ha^{-1} and 25.02, 25.12 and 25.09% respectively. The higher productivity achieved under T_{13} can be attributed to the combined effect of balanced phosphorus and sulphur with PSB, which enhanced phosphorus availability, improved nutrient uptake, promoted vigorous plant growth and increased photosynthetic efficiency with enhanced seed development, resulting in higher seed and stover yields. The increase in biological yield and harvest index further indicates improved both total biomass production and the efficient partitioning of assimilates towards the economic yield. Similar results have been reported by Singh *et al*. (2018), Kumar *et al*. (2020), Meena *et al*. (2021), Ameta *et al*. (2022), and Kumar and Meena (2023).

Table 1: Yield of mustard seed yield, stover yield, biological yield and harvesting index

Treatments	Seed Yield			Stover Yield			Biological Yield			Harvesting Index		
	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled
T1	245.7	249.6	247.64	3.18	3.37	3.28	9.84	9.87	9.85	3.6	3.7	3.63
T2	253.0	257.0	254.97	3.57	3.67	3.62	10.65	10.69	10.67	3.8	3.9	3.82
T3	258.9	263.0	260.98	3.77	3.87	3.82	11.32	11.35	11.33	4.0	4.1	4.07
T4	266.6	270.8	268.70	3.97	4.07	4.02	11.82	11.86	11.84	4.2	4.3	4.27
T5	254.7	258.7	256.68	3.67	3.77	3.72	11.00	11.03	11.02	3.9	4.0	3.94
T6	262.3	266.5	264.41	3.87	3.97	3.92	11.59	11.62	11.61	4.2	4.2	4.18
T7	268.3	272.5	270.42	4.07	4.17	4.12	12.02	12.06	12.04	4.3	4.4	4.36
T8	271.7	276.0	273.85	4.07	4.27	4.17	12.21	12.25	12.23	4.4	4.5	4.44
T9	278.5	282.9	280.72	4.47	4.57	4.52	12.47	12.50	12.48	4.6	4.6	4.59
T10	281.9	286.4	284.15	4.76	4.86	4.81	12.64	12.68	12.66	4.7	4.8	4.72
T11	277.7	282.1	279.86	4.37	4.47	4.42	12.37	12.41	12.39	4.5	4.6	4.53
T12	279.4	283.8	281.58	4.57	4.66	4.62	12.53	12.56	12.55	4.6	4.7	4.66
T13	283.6	288.1	285.87	4.86	4.96	4.91	12.85	12.89	12.87	4.8	4.9	4.82
C.D	0.281	0.243	0.214	0.011	0.009	0.009	0.017	0.012	0.018	0.056	0.053	0.006
SE(m)	0.096	0.083	0.073	0.004	0.003	0.003	0.006	0.004	0.006	0.019	0.018	0.002
C.V.	0.062	0.053	0.047	0.165	0.129	0.122	0.086	0.059	0.088	0.781	0.727	0.089

Economics

The economic analysis of mustard cultivation, focusing on cost of cultivation, gross return, net return and benefit-to cost (B: C) ratio is detailed in table no. 2. This overview provides insights into the financial aspects of the different treatment combinations used in the study, including variations in expenses, revenue, profitability and overall economic efficiency.

Cost of cultivation (Rs. /ha) and Gross Return (Rs./ha)

The economic analysis showed that the application of phosphorus, sulphur and phosphate-solubilizing bacteria (PSB) had a noticeable influence on the cost of cultivation and gross return of mustard during both years 2024-2025, 2025- 2026 of the study and they reported in table no. 2. The maximum cost of cultivation was recorded under T_{13} (100% RDF + 25% phosphorus + PSB + 50 kg S ha^{-1} with values of Rs. 40,058 ha^{-1} during the 2024- 2025, Rs. 42,466 ha^{-1} during 2025- 2026 and Rs. 41,262.2 ha^{-1} on a pooled mean basis. The increase in cultivation cost under this treatment was mainly due to the additional application of phosphorus, sulphur, and PSB. In contrast, the treatment T_1 (control) recorded the minimum cost of cultivation Rs. 30,515 ha^{-1} and Rs. 2,703 ha^{-1} during the 2024- 2025 and 2025-2026 respectively, with a pooled mean value of Rs. 31,609.1 ha^{-1}. In gross return the maximum was achieved with T_{13}, which recorded Rs. 135,278 ha^{-1} in the 2024- 2025, Rs. 137,213 ha^{-1} in the 2025- 2026 and a pooled mean value of Rs. 136,245.4 ha^{-1} and the minimum gross return was observed under the T_1 (control) with values of Rs. 73,544 ha^{-1} in the 2024- 2025, Rs. 74,239 ha^{-1} in 2025-2026 and Rs. 73,891.6 ha^{-1} on a pooled mean basis. Overall, although T_{13} involved a comparatively higher asset, the increase in crop productivity resulted in substantially maximum gross returns indicating that the combined application of phosphorus, sulphur, and PSB is economically beneficial for mustard cultivation. Similar enhancements in yield of mustard, seed yield, stover yield, biological yield and harvesting index with economic returns have also been reported and who observed that balanced fertilization combined with biofertilizers enhanced crop productivity and profitability in Indian mustard by Singh *et al*. (2020), Solanki *et al*. (2020) and Chauhan *et al*. (2021).

Net Return (Rs./ha) and Benefit-to-Cost Ratio (B: C Ratio)

The integrated application of phosphorus, sulphur and phosphate-solubilizing bacteria (PSB) significantly influenced the economic returns of mustard, as reflected by the net return and Benefit: Cost (B:C) ratio they reported in table no. 2. In the treatments, T_{13} (100% RDF + 25% phosphorus + PSB + 50 kg S ha^{-1}) recorded the maximum net return Rs. 95,219 ha^{-1} during the 2024- 2025, Rs. 94,747 ha^{-1} during the 2025- 2026 and Rs. 94,983.2 ha^{-1} on a pooled mean. The maximum net return under this treatment was mainly due to its higher seed yield and gross return. In contrast, treatment T_{1} (control) recorded the minimum net return values of Rs. 43,029 ha^{-1} and Rs. 41,536 ha^{-1} during the 2024- 2025 and 2025- 2026 respectively and pooled mean Rs. 42,282.5 ha^{-1}. Similarly, the observed maximum Benefit: Cost (B:C) ratio was recorded under T_{13} 2.36 in the 2024- 2025, 2.21 in the 2025-2026 and 2.29 in pooled mean and the minimum B:C ratio was observed under the T_1 (control) with values of 1.40, 1.26 and 1.33 during the 2024- 2025, 2025-2026 and pooled data analysis, respectively. Overall, the pooled results clearly proved that the integrated application of phosphorus, sulphur, and PSB under T_{13} was the most economically profitable treatment, producing the maximum net return and B:C ratio despite its relatively higher cultivation cost. These findings also report of Mahapatra *et al*. (2024), Naik *et al*. (2024), Chahar *et al*. (2024) and Bhargav (2024) who also observed that balanced fertilization combined with biofertilizer application significantly improved the profitability of Indian mustard through enhanced yield and resource-use efficiency.

Table 2 : Cost of cultivation (Rs./ha), Gross Return (Rs./ha), Net Return (Rs./ha) and Benefit-to-Cost Ratio (B: C Ratio)

Treatments	Cost of cultivation (Rs./ha)			Gross Return (Rs./ha)			Net Return (Rs./ha)			Benefit Cost Ratio (B: C Ratio)		
	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled	2024-25	2025-26	Pooled
T1	30515	32703	31609.1	73544	74239	73891.6	43029	41536	42282.5	1.40	1.26	1.33
T2	38154	40546	39349.6	95702	96397	96049.2	57548	55851	56699.5	1.50	1.37	1.43
T3	39105	41512	40308.4	115279	117189	116234.2	76174	75677	75925.8	1.94	1.81	1.87
T4	39174	41582	40377.9	126320	127710	127015.2	87146	86128	86637.3	2.20	2.05	2.13
T5	38223	40615	39419.1	105081	106396	105738.5	66858	65781	66319.3	1.74	1.61	1.67
T6	38247	40655	39450.9	117884	119174	118529.3	79637	78520	79078.4	2.06	1.92	1.99
T7	38316	40724	39520.4	120589	121854	121221.5	82272	81130	81701.1	2.13	1.98	2.05
T8	39011	41403	40207.2	98382	99672	99026.7	59370	58805	59087.5	1.51	1.41	1.46
T9	39081	41473	40276.6	94685	95950	95317.2	55604	54477	55040.6	1.41	1.30	1.35
T10	39989	42397	41192.7	101483	102823	102153.1	61494	60426	60960.3	1.53	1.42	1.47
T11	39896	42287	41091.5	107761	109150	108455.4	67865	66863	67364.0	1.69	1.57	1.63
T12	39965	42357	41161.0	111483	113418	112450.3	71518	71061	71289.3	1.78	1.67	1.72
T13	40058	42466	41262.2	135278	137213	136245.4	95219	94747	94983.2	2.36	2.21	2.29
C.D	42.427	43.454	4305.39	272.746	277.548	12164.87	246.636	249.982	7900.602	0.007	0.006	0.19
SE(m)	14.45	14.8	1466.33	92.891	94.527	4143.097	83.999	85.138	2690.779	0.002	0.002	0.065
C.V.	0.065	0.063	6.408	0.149	0.15	6.605	0.21	0.216	6.752	0.232	0.208	6.49

Conclusion

The findings of the present study indicate that the combined application of phosphorus, sulphur and phosphate-solubilizing bacteria (PSB) had a significant positive effect on the yield attributes and economic of mustard (*Brassica juncea* L.) under the Central Plain Zone of Uttar Pradesh. Treatments, T_{13} (100% RDF + 25% phosphorus + PSB + 50 kg S ha^{-1}) constantly recorded the maximum performance during both years as well as in the pooled data analysis. This treatment produced the maximum yield attributes which resulted in the maximum seed yield, stover yield, biological yield and harvest index. In addition, T_{13} recorded the maximum gross return, net return and Benefit: Cost ratio representing that the further investment in phosphorus, sulphur, and PSB was economically satisfying. The balanced nutrient supply favourable conditions for resulting in improved yield and higher economic returns compared with the other treatments. Based on the results obtained over two years, it can be concluded that the application of 100% RDF + 25%phosphorus + PSB + 50 kg S ha^{-1} is an effective strategy for mustard cultivation in the Central Plain Zone of Uttar Pradesh. Adoption of this practice can enhance crop productivity, improve profitability and contribute to the sustainable production of mustard in the region

References

Bhargav, S., Pal, R. L., Mubeen, Khan, N., Ahmad, M., Ahmad, S., Kumar, S., Bahadur, R., & Khan, F. (2024). Plant growth and nutrient uptake of mustard (*Brassica juncea* L.) as influenced by application of phosphorus and sulphur. *Journal of Research*, **26**(4), 567–574. https://doi.org/10.5958/2349-297X.2024.00063.7

Biswas, D. R., Ali, S. A., and Khera, M. S. (1995). Response of Gobi Sarson (*Brassica napus* L.) to nitrogen and sulphur. *Journal of the Indian Society of Soil Science*, **43**(2): 220–223.

Blackshaw, R. E., Brandt, R. N., Janzen, H. H., & Entz, T. (2004). *Weed species response to phosphorus fertilization*. *Weed Science*, **52**(3), 406–412. https://doi.org/10.1614/WS-03-122R.

Chahar, K., Swaroop, N., Thomas, T., Kumar, H., Poonia, R., & Yadav, S. L. (2024). Effect of different levels of NPK, vermicompost and sulphur on growth, yield and economics attributes of mustard (*Brassica juncea* L.) var. Giriraj. *International Journal of Plant & Soil Science*, **36**(8), 106–112. https://doi.org/10.9734/IJPSS/2024/v36i84839

Chauhan, Z. Y., Patel, D. K., & Patel, C. K. (2021). Effect of nitrogen, phosphorus and sulphur on growth, yield and quality of Indian mustard (*Brassica juncea* L.). *Journal of Oilseeds Research*, **38**(2). https://doi.org/10.56739/jor.v38i2.137105

Gangwal, T. V., Patel, M. V. and Jadhav, N. J. (2011). Effect of phosphorus, sulphur and phosphate solubilizing bacteria on yield, nutrient uptake and soil fertility after harvest of mustard (*Brassica juncea* L.). *Indian Journal of Fertilisers*, **7**(8): 32–40

Gangwal, T. V., Patel, M. V., & Jadhav, N. J. (2011). Effect of phosphorus, sulphur and phosphate solubilizing bacteria on yield, nutrient uptake and soil fertility after harvest of mustard (*Brassica juncea* L.). *Indian Journal of Fertilizer*, **7**, 32–40.

Kumar, R., Singh, V., Meena, B. S., & Kumar, A. (2021). Effect of phosphorus, sulphur and biofertilizers on productivity, nutrient uptake and economics of Indian mustard (*Brassica juncea* L.). *International Journal of Chemical Studies*, **9**(1), 1943–1947.

Meena, D. S., Tetarwal, J. P., Ram, B., & Meena, R. H. (2018). Effect of phosphorus, sulphur and biofertilizers on yield, quality and economics of Indian mustard (*Brassica juncea* L.). *Journal of Pharmacognosy and Phytochemistry*, **7**(6), 1500–1504.

Mohapatra, A., Behura, A. K., Jena, J., Behera, S. D., & Behera, B. (2024). Productivity and profitability of mustard (*Brassica juncea* L.) under varying levels of sulphur and boron application methods. *Journal of Applied and Natural Science*, **16**(3). https://doi.org/10.31018/jans.v16i3.5527

Naik, B. R. S. S., Kumar, S., & Dokala, M. (2024). Effect of various sources and doses of sulphur on yield and economics of Indian mustard (*Brassica juncea* L.). *International Journal of Research in Agronomy*, **7**(Special Issue 8), 169–171. https://doi.org/10.33545/2618060X.2024.v7.i8Sc.1248

Rathore, S. S., Shekhawat, K., Kandpal, B. K., Premi, O. P., Singh, S. P., Singh, G. C., & Singh, D. (2015). Sulphur management for increased productivity of Indian mustard: A review. *Annals of Plant and Soil Research*, **17**(1), 1–12.

Sharma, A., Singh, R., & Yadav, L. R. (2020). Integrated nutrient management in Indian mustard: Effect on productivity, nutrient uptake and economics. *International Journal of Current Microbiology and Applied Sciences*, **9**(8), 2858–2865.

Singh, P., Tiwari, D., & Singh, G. (2020). Yields, yield gaps and economic efficiency of mustard cultivation in south-western and central Punjab, India. *Journal of Community Mobilization and Sustainable Development*, **15**(2), 441–447.

Solanki, R. L., Sharma, M., & Indoria, D. (2020). Effect of phosphorus, sulphur and PSB on yield of Indian mustard (*Brassica juncea* L.) and available macronutrients in soil. *Journal of the Indian Society of Soil Science*, **68**(3), 291–296.

Solanki, R.L. and Sharma, M. (2016). Effect of phosphorus, sulphur and PSB on growth and yield of mustard in Southern Rajasthan. *Annals of Plant and Soil Research*, **18**(1): 66–69.