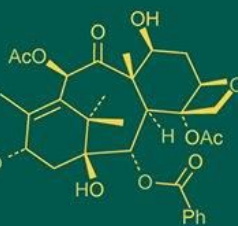
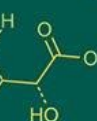
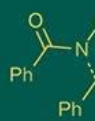


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Optimizing fertility levels for enhancing yield and nutrient uptake of Indian mustard (*Brassica juncea* L.) in Dehradun region of Uttarakhand

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Abstract

A field experiment was conducted during the Rabi season of 2022 at Shri Guru Ram Rai University's Agricultural Research Farm, Dehradun, to assess the impact of NPK and sulfur on the yield, nutrient uptake, and quality of Indian mustard (*Brassica juncea* L.). NPK and sulfur, applied at 25-100% in a Randomized Block Design, significantly enhanced productivity. The combination of 100% NPK and 100% sulfur yielded the highest test weight (4.35 g), seed yield (19.35 q/ha), and nutrient uptake (N: 87.24 kg/ha, P: 25.47 kg/ha, K: 111.73 kg/ha, S: 38.15 kg/ha). This synergy improved soil fertility and promoted sustainable mustard cultivation in Uttarakhand.

Keywords: NPK, sulfur, mustard yield, nutrient uptake, productivity

1. Introduction

Indian mustard (*Brassica juncea* L.) is an important oilseed crop grown widely across India, playing a pivotal role in ensuring food security, supporting rural livelihoods, and contributing to the national economy. It accounts for a significant share of India's edible oil production, with its seeds containing up to 40% oil and 25% protein (Kumar *et al.*, 2020) ^[2]. However, mustard productivity in India, including the Dehradun region of Uttarakhand, remains below its genetic potential, primarily due to suboptimal soil fertility, poor nutrient management, and a lack of region-specific agronomic practices (Sharma *et al.*, 2021) ^[10]. The productivity and quality of Indian mustard are heavily dependent on proper nutrient management. Among the primary macronutrients, nitrogen (N) is essential for vegetative growth and chlorophyll formation, phosphorus (P) is crucial for energy transfer and root development, and potassium (K) enhances disease resistance and stress tolerance. Sulfur (S), although a secondary nutrient, is critical for oilseed crops as it enhances oil content, improves seed protein, and aids in enzyme activity (Patra *et al.*, 2019) ^[6]. Imbalanced or insufficient application of these nutrients often results in poor crop growth, reduced yield, and depleted soil health, particularly in regions like Dehradun, where soil fertility varies significantly due to diverse topography and climatic conditions. Research indicates that the combined application of NPK and sulfur in optimal quantities can significantly enhance mustard productivity and nutrient uptake. Studies by Meena *et al.* (2017) ^[4] and Yadav *et al.* (2020) ^[12] have shown that balanced fertilization not only improves seed yield but also enhances the quality parameters such as oil content and nutrient use efficiency. Furthermore, the synergistic interaction between sulfur and nitrogen plays a critical role in increasing protein and glucosinolate synthesis in mustard, which directly influences crop quality (Kumar *et al.*, 2021) ^[3].

In the Dehradun region, characterized by moderate to low soil fertility and a growing demand for sustainable farming practices, optimizing fertility levels is essential to achieve higher productivity while maintaining soil health. This research aims to evaluate the effects of different levels of NPK in combination with sulfur on the yield, nutrient uptake, and soil fertility status of Indian mustard. By developing region-specific recommendations for nutrient management, the study seeks to provide a sustainable strategy for enhancing mustard productivity in Uttarakhand and similar agro-ecological zones.

2. Material and Methods

A field experiment was conducted during 2022 at Agriculture research farm of School of Modern Agriculture, DBS Global University, Dehradun, Uttarakhand (30.377522° N, 77.863423° E longitude and an altitude of 435 m above mean sea level). The soil was sandy loam with a pH of 6.5, organic carbon content of 0.4%, available nitrogen of 3.52%, available phosphorus of 7.1%, and available potassium of 18.1%. The net plot size was 2 x 3 meter square and 40cm row spacing and 15cm plant to plant spacing. The experiment was laid out in Randomized Block Design with eight treatment and three replications to evaluate the effects of different levels of macronutrients (NPK) and sulfur on Indian mustard. T₁: control, T₂: 100% of the recommended dose of NPK was applied. T₃: 75% of the recommended nitrogen and phosphorus (NP) + 25% potassium (K), T₄: 50% NPK +75% sulfur (S), T₅: 25% NPK + 75% sulfur, T₆: 100% NPK +100% sulfur, T₇: 100% NPK + 50% sulfur, T₈: 50% NPK +100% sulfur. The experimental data obtained from various observations on growth, yield and quality were analysed using standard procedure for randomised block design and treatment comparisons were made at 5 percent level of significance.

3. Results and Discussion

3.1 Yield parameters

The test weight of mustard seeds showed significant variation across treatments, with T₆ (NPK-100% + S-100%) achieving the highest value (4.35 g) which was at par with treatment seven (NPK-100% + S-50%). Statistical analysis confirmed the significance of differences, with a standard error of the mean (SEm) of 0.19 and a coefficient of variation (C.V.) of 6.47%, indicating reliable data and low experimental error (Table 1). These results align with prior research highlighting the synergistic effect of NPK and sulfur in improving seed weight and overall crop performance (Sharma *et al.*, 2020) ^[8,9].

The analysis revealed that the highest seed yield (19.30 q/ha) was achieved with the treatment T₆ (NPK-100% + S-

100%), followed closely by T₇ (NPK-100% + S-50%) at 18.00 q/ha, demonstrating the synergistic effect of sulfur with NPK (Table 1). Control (T₁) yielded the lowest (8.50 q/ha), highlighting the critical role of nutrient application in mustard cultivation. Treatments with partial NPK or sulfur (e.g., T₃ and T₄) showed moderate yields. Statistical significance was confirmed with a SEM of 0.25 and a low C.V. of 2.92%, emphasizing the reliability of the results. Thus, balanced NPK and sulfur application significantly enhances mustard productivity.

The analysis of the harvest index (HI) revealed that the treatment T₆ (NPK-100% + S-100%) recorded the highest value of 27.73%, followed closely by T₇ (NPK-100% + S-50%) with 27.62%, indicating the positive role of balanced NPK and sulfur in improving biomass partitioning towards economic yield. Statistical validation with a standard error of the mean (SEm) of 0.87 and a coefficient of variation (CV) of 5.66% indicates the reliability of these results (Table 1). These findings suggest that integrating sulfur with recommended NPK rates enhances both physiological efficiency and yield outcomes in mustard cultivation, aligning with previous research that highlights the importance of sulfur in oilseed crops for optimal productivity. Sharma, N. *et al.* (2020) ^[7] and Meena, R.S., *et al.* (2018) ^[5]

The analysis of stover yield showed that T₆ (NPK-100% + S-100%) achieved the highest value of 50.40 q/ha, followed by T₇ (NPK-100% + S-50%) with 47.20 q/ha. These results emphasize the benefits of balanced NPK combined with sulfur for maximizing biomass production. The lowest stover yield (25.25 q/ha) was recorded in the control treatment (T₁), indicating insufficient nutrient supply (Table 1). Statistical analysis showed a low standard error of the mean (SEm) of 1.54 and a coefficient of variation (CV) of 6.63%, confirming the reliability of the data. These findings align with previous studies highlighting the synergistic effects of sulfur and NPK on improving stover yield and overall productivity in mustard cultivation. Singh, M., *et al.* (2019) ^[11] and Gupta, R., *et al.* (2020) ^[1].

Table 1. Yield parameters of Indian mustard

Treatments	Test weight (g)	Seed yield (q/ha)	Harvest Index (%)	Stover yield (q/ha)
T ₁	3.96	8.5	25.16	25.25
T ₂	4.23	17.5	27.25	46.4
T ₃	4.16	15	26.8	42.9
T ₄	4.05	13.7	26.19	38.6
T ₅	4.1	10.9	26.82	31.35
T ₆	4.35	19.3	27.73	50.4
T ₇	4.11	14.2	26.57	39.4
T ₈	4.11	12	26.57	31.35
SE (m)	0.19	0.25	0.87	1.54
SE (d)	0.27	0.35	1.23	2.18
C.V.	6.47	2.92	5.66	6.63

3.2 Nutrient content parameters

The analysis of nitrogen, phosphorus, potassium, and sulfur content in mustard grain revealed significant variation across treatments, indicating the critical role of balanced fertilization in nutrient uptake and assimilation. Among the treatments, T₆ (NPK-100% + S-100%) showed the highest values for nitrogen (3.25%), phosphorus (0.69%), potassium (27.73%), and sulfur (50.40%), highlighting the importance of a complete nutrient package for maximizing nutrient uptake. This treatment's performance underscores the synergistic effect of sulfur with NPK in enhancing nutrient

concentration in grain. T₇ (NPK-100% + S-50%) also performed well, showing slightly lower nutrient values but maintaining higher sulfur content (47.20%). Control (T₁) recorded the lowest values for nitrogen (3.02%), phosphorus (0.57%), potassium (25.16%), and sulfur (25.25%), demonstrating the inadequacy of nutrient uptake under unfertilized conditions. Treatments with reduced NPK or sulfur (e.g., T₄ and T₅) exhibited intermediate nutrient values, further affirming the importance of balanced nutrient management. Statistical analysis confirmed the significance of differences among treatments. The standard error of the

mean (SEm) ranged from 0.21% for nitrogen to 1.54% for sulfur, indicating precise measurements. The coefficient of variation (C.V.) was 11.67% for nitrogen, 13.63% for phosphorus, 5.66% for potassium, and 6.63% for sulfur, reflecting moderate experimental variability (Table 2). These low CV values suggest reliable data with minimal experimental error. The results align with previous studies demonstrating the role of sulfur in enhancing nitrogen metabolism and protein synthesis in oilseed crops (Sharma *et al.*, 2020) [8, 9]. Phosphorus and potassium contribute to energy transfer and osmotic regulation, crucial for seed formation and quality. The findings indicate that integrating 100% NPK with sulfur not only improves nutrient content but also supports sustainable mustard production in nutrient-depleted soils.

The study revealed significant variation in nutrient content (NPK and sulfur) in mustard straw across treatments, emphasizing the critical role of balanced fertilization in enhancing nutrient recovery. Treatment T₆ (NPK-100% + S-100%) achieved the highest nitrogen (0.49%), phosphorus (0.24%), potassium (1.79%), and sulfur (0.44%) levels, demonstrating the effectiveness of full NPK and sulfur application in improving nutrient uptake and assimilation. Similarly, T₇ (NPK-100% + S-50%) recorded notable nutrient content, with values of 0.48%, 0.23%, 1.76%, and 0.43% for nitrogen, phosphorus, potassium, and sulfur, respectively (Table 2). These findings highlight the

synergistic effect of sulfur and NPK on nutrient dynamics in straw. The control (T₁) exhibited the lowest nutrient content, with nitrogen (0.45%), phosphorus (0.20%), potassium (1.55%), and sulfur (0.37%), underscoring the importance of fertilization in nutrient-deficient soils. Treatments with partial NPK or sulfur, such as T₄ (NPK-50% + S-75%) and T₈ (NPK-50% + S-100%), showed intermediate nutrient content, reaffirming the role of balanced fertilization in enhancing nutrient uptake. Statistical analysis validated these findings, with the standard error of the mean (SEm) ranging from 0.05% for nitrogen and phosphorus to 0.09% for potassium (Table 2). The coefficient of variation (C.V.) values for nitrogen (19.12%), phosphorus (43.10%), potassium (9.29%), and sulfur (14.26%) indicated varying degrees of experimental variability, with phosphorus showing the highest variability. These results suggest a need for precise phosphorus management to ensure consistent nutrient uptake.

Previous studies have shown the importance of sulfur in protein synthesis, enzymatic activity, and nitrogen assimilation, which directly enhance nutrient recovery in oilseed crops such as mustard (Sharma *et al.*, 2020) [8, 9]. Potassium regulates osmotic balance and enzyme activation, while phosphorus facilitates energy transfer processes crucial for plant growth. The synergistic effect of sulfur with NPK supports improved nutrient assimilation in mustard straw and grain yield.

Table 2: Performance of NPK and Sulphur in grain and straw of Indian Mustard

Treatments	Nitrogen (Grain)	Phosphorous (Grain)	Potassium (Grain)	Sulphur (Grain)	Nitrogen (Straw)	Phosphorous (Straw)	Potassium (Straw)	Sulphur (Straw)
T ₁	3.02	0.57	25.16	25.25	0.45	0.2	1.55	0.37
T ₂	3.2	0.65	27.25	46.4	0.48	0.23	1.76	0.4
T ₃	3.15	0.61	26.8	42.9	0.47	0.21	1.72	0.38
T ₄	3.07	0.59	26.19	38.6	0.46	0.21	1.64	0.38
T ₅	3.05	0.58	26.82	31.35	0.46	0.2	1.64	0.36
T ₆	3.25	0.69	27.73	50.4	0.48	0.23	1.85	0.43
T ₇	3.2	0.61	26.57	39.4	0.46	0.21	1.72	0.4
T ₈	3.11	0.6	26.57	31.35	0.45	0.2	1.64	0.36
SE (m)	0.1	0.03	0.87	1.54	0.01	0.01	0.04	0.02
SE (d)	0.31	0.08	1.24	2.18	0.03	0.03	0.09	0.04
C.V.	11.67	13.63	5.66	6.53	19.12	43.1	9.29	14.26

4. Conclusion

The study highlights the significant role of balanced NPK and sulfur fertilization in enhancing mustard crop performance, both in terms of yield and nutrient content. The highest seed yield, stover yield, and harvest index were achieved with treatment T₆ (NPK-100% + S-100%), showcasing the synergistic effect of sulfur and full NPK application on crop productivity. Similarly, the highest nutrient content in both grain and straw was observed in T₆, with superior nitrogen, phosphorus, potassium, and sulfur concentrations, emphasizing the importance of complete fertilization for maximizing nutrient uptake and assimilation. Statistical analysis further validated these findings, with low standard errors and coefficients of variation confirming the reliability of the results. In comparison, the control treatment (T₁) showed the lowest values for all yield and nutrient parameters, underlining the critical role of fertilization in nutrient-deficient soils. The study aligns with previous research by Sharma *et al.* (2020) [8, 9], which also emphasized the synergistic benefits of sulfur and NPK in enhancing mustard productivity. These findings suggest that integrating 100% NPK with sulfur is crucial for

optimizing yield, improving nutrient content, and supporting sustainable mustard production, particularly in soils with nutrient deficiencies. Thus, this study contributes to better nutrient management practices for mustard cultivation.

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