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# Synergistic effects of nitrogen and sulphur on the agronomic performance and quality characteristics of Indian mustard (*Brassica juncea* L.)

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**Abstract**
This study investigates the synergistic effects of nitrogen (N) and sulfur (S) levels on the agronomic performance and quality characteristics of Indian mustard (*Brassica juncea* L.), using data from a two-year trial (2022-23 and 2023-24) at A.N.D.U.A.T. Kumarganj, Ayodhya. A 4 × 4 factorial design was employed, with four levels of nitrogen (0, 40, 80, 120 kg ha$^{-1}$) and four levels of sulfur (0, 15, 30, 45 kg ha$^{-1}$). The results revealed significant improvements in growth parameters, seed yield, and straw yield when the highest levels of nitrogen and sulfur (120 kg ha$^{-1}$ N and 45 kg ha$^{-1}$ S) were applied, with maximum seed yield and straw yield reaching 23.26 kg ha$^{-1}$ and 79.68 kg ha$^{-1}$, respectively. Additionally, quality traits such as oil content (41.20%) and iodine value showed positive enhancement. Yield components, including the number of siliqua per plant, siliqua length, and seeds per siliqua, were also highest under this treatment. These findings highlight the importance of optimizing nitrogen and sulfur inputs to enhance both the yield and quality of Indian mustard, providing valuable insights for sustainable agricultural practices in mustard cultivation across diverse agro-climatic conditions.

**Keywords:** Sulfur, nitrogen interaction, nutrient management, mustard quality characteristics, fertilization, agronomy, *Brassica juncea*

## Introduction
Indian mustard (*Brassica juncea* L.) is a crucial oilseed crop in many parts of the world, particularly in India, where it plays a significant role in both agriculture and the economy. The crop is primarily cultivated for its oil-rich seeds, which provide a valuable source of edible oil, as well as for their high nutritional value, including protein and fiber. Mustard species, including Brassica, are known for their resilience across diverse agro-climatic conditions, making them an essential part of farming systems in both temperate and tropical regions (Yadav *et al.*, 2019) [5]. The yield and quality of Indian mustard are influenced by various factors, with soil nutrients being among the most important. Nitrogen (N) and sulfur (S) are two key macronutrients that significantly impact plant growth, development, and seed quality. Nitrogen is the primary nutrient influencing plant growth, affecting photosynthesis, protein synthesis, and overall biomass production. Sulfur, in turn, plays a critical role in the synthesis of amino acids, proteins, and enzymes, which are essential for plant metabolism and oil production (Singh *et al.*, 2017) [4]. While the individual effects of N and S have been widely studied, recent research emphasizes the synergistic benefits of combining these nutrients to enhance crop productivity, quality, and stress tolerance (Ali *et al.*, 2021) [1]. Optimizing nitrogen and sulfur applications is essential for improving mustard yield and oil content. Adequate nitrogen enhances photosynthetic efficiency and biomass accumulation, while sulfur improves seed quality by increasing oil content and altering fatty acid composition (Mishra *et al.*, 2018) [3]. However, determining the optimal ratio of N and S application is still a topic of ongoing research, as excessive or insufficient application of these nutrients can negatively affect both yield and quality (Dhillon *et al.*, 2020) [2].

Given these complexities, understanding the interaction between nitrogen and sulfur is crucial for developing sustainable fertilization strategies that maximize both mustard production and oil quality under varying environmental conditions. The present study aims to explore the combined effects of different nitrogen and sulfur levels on the growth, yield, and quality traits of Indian mustard, based on two years of data from the research farm at A.N.D.U.A.T. Kumarganj, Ayodhya. This research seeks to offer valuable insights into optimal nutrient management practices that can improve the agronomic performance and oil quality of Indian mustard.

## Materials and Methods

The experiment was carried out over two consecutive years (2023-2024) at the research farm of A.N.D.U.A.T. Kumarganj, Ayodhya. The soil at the site was clay loam with a pH of 8.20. A factorial design was used, with four levels of nitrogen (0, 40, 80, and 120 kg ha$^{-1}$) and four levels of sulfur (0, 15, 30, and 45 kg ha$^{-1}$), each with three replications. The mustard variety "Varuna" was sown at a rate of 5 kg/ha, with a planting depth of 3-4 cm and a row spacing of 25 cm. Nitrogen was applied in two equal splits (50% at sowing and 50% at the first irrigation), while sulfur was applied as gypsum at sowing. Growth parameters, such as plant height, number of green leaves, number of branches, and fresh and dry weights, were recorded at 30, 45, and 60 days after sowing (DAS), as well as at harvest. At harvest, yield components, including siliqua per plant, siliqua length, number of seeds per siliqua, and test weight, were measured. Seed yield, straw yield, and harvest index were also calculated. The oil content and iodine value of the seeds were determined following standard laboratory procedures. The data were analyzed using analysis of variance (ANOVA) with R software, and treatment effects were considered significant at $p \leq 0.05$. The least significant difference (LSD) was used to compare means among treatments.

## Results and Discussion

Synergistic Effects of Nitrogen and Sulphur on the Agronomic Performance and Quality Characteristics of Indian Mustard (*Brassica juncea* L.) at A.N.D.U.A.T. Kumarganj, Ayodhya, over two consecutive years (2023-2024). The results demonstrated significant impacts of both N and S, on plant growth, yield parameters, and oil quality, highlighting that their combined application enhances mustard productivity.

Plant height, number of green leaves, and number of branches showed significant increases with higher levels of nitrogen and sulfur (Table 1 and Fig 1). A similar positive trend was observed for both fresh and dry weights, with the highest values recorded under the combination of 120 kg N ha$^{-1}$ and 45 kg S ha$^{-1}$. These improvements in growth parameters under higher nutrient levels underscore the critical roles of N and S in promoting physiological processes such as photosynthesis, protein synthesis, and biomass production. These findings align with previous studies indicating that nitrogen promotes vegetative growth and biomass accumulation in mustard (Ali *et al.*, 2021; Mishra *et al.*, 2018) [1, 3], while sulfur boosts photosynthetic efficiency and contributes to protein and oil biosynthesis (Dhillon *et al.*, 2020) [2].

The number of siliqua per plant, siliqua length, and seeds per siliqua were significantly higher with the combined application of 120 kg N ha$^{-1}$ and 45 kg S ha$^{-1}$ (Table 2 and Fig 3). This led to substantial increases in both seed yield (23.26 kg) and straw yield (79.68 kg), compared to the lower nutrient treatments. The synergistic effect of N and S in enhancing yield components is likely due to improved nutrient availability, which supports better plant growth and higher reproductive success (Yadav *et al.*, 2019) [5]. Similar positive effects of N and S on seed yield and yield components in mustard were reported by Singh *et al.* (2017) [4] and Ali *et al.* (2021) [1].

Oil content reached a maximum of 41.20% under the optimal treatment (120 kg N ha$^{-1}$ and 45 kg S ha$^{-1}$), while the iodine value also increased, indicating enhanced oil quality. The improvement in oil content under these nutrient levels is likely attributed to the increased synthesis of oils and fatty acids, as sulfur is crucial in the biosynthesis of proteins and oils (Mishra *et al.*, 2018) [3]. Likewise, nitrogen contributes to overall metabolic processes that promote higher oil accumulation in seeds (Singh *et al.*, 2017) [4]. These results are consistent with the findings of Dhillon et al. (2020) [2], who reported significant improvements in oil yield and iodine value with optimal N and S fertilization.

## Statistical Analysis

The analysis of variance (ANOVA) revealed that both nitrogen and sulfur levels significantly affected the growth, yield, and quality parameters. The combined application of 120 kg N ha$^{-1}$ and 45 kg S ha$^{-1}$ consistently produced the highest values for all measured traits, confirming the synergistic effect of these nutrients. The least significant difference (LSD) test at $p \leq 0.05$ further validated the significance of the treatments in improving mustard performance.

**Table 1:** Effect of different levels of nitrogen and sulphur on different growth parameters of Indian mustard

| | | Plant height | | | | Number of green leaves plant$^{-1}$ | | | Number of branch plant$^{-1}$ | | | Fresh weight (g) | | | Dry weight (g) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 30 DAS | 45 DAS | 60 DAS | At Harvest | 30 DAS | 45 DAS | 60 DAS | 30 DAS | 45 DAS | 60 DAS | 30 DAS | 45 DAS | 60 DAS | 30 DAS | 45 DAS | 60 DAS |
| Nitrogen levels (kg ha$^{-1}$) | 0 | 21.84 | 41.31 | 59.03 | 138.2 | 5.54 | 14.92 | 18.64 | 1.67 | 8.45 | 15.35 | 5.54 | 14.92 | 18.64 | 1.53 | 16.05 | 21.03 |
| | 40 | 22.24 | 44.55 | 63.65 | 147.6 | 5.64 | 18.36 | 22.96 | 1.70 | 9.50 | 17.22 | 5.64 | 18.36 | 22.96 | 1.56 | 18.05 | 23.67 |
| | 80 | 22.95 | 46.90 | 67.02 | 154.6 | 5.85 | 21.80 | 27.27 | 1.72 | 9.70 | 17.64 | 5.85 | 21.80 | 27.28 | 1.58 | 20.70 | 27.27 |
| | 120 | 23.45 | 48.84 | 69.78 | 160.93 | 5.96 | 23.30 | 29.14 | 1.77 | 9.93 | 18.03 | 5.96 | 23.30 | 29.14 | 1.61 | 22.48 | 29.67 |
| | SE(m)± | 0.45 | 0.82 | 1.14 | 2.5 | 0.10 | 0.34 | 0.46 | 0.03 | 0.15 | 0.21 | 0.10 | 0.34 | 0.46 | 0.03 | 0.37 | 0.56 |
| | CD (p=0.05) | NS | 2.37 | 3.29 | 7.21 | NS | 0.97 | 1.32 | NS | 0.42 | 0.60 | NS | 0.97 | 1.32 | NS | 1.08 | 1.64 |
| Sulphur levels (kg ha$^{-1}$) | 0 | 21.89 | 41.96 | 59.95 | 141.4 | 5.54 | 15.90 | 19.90 | 1.67 | 8.70 | 15.77 | 5.54 | 15.90 | 19.90 | 1.54 | 17.40 | 22.83 |
| | 15 | 22.18 | 45.55 | 65.08 | 146.1 | 5.76 | 18.53 | 23.17 | 1.70 | 9.41 | 17.13 | 5.74 | 18.53 | 23.17 | 1.57 | 18.80 | 24.68 |
| | 30 | 22.86 | 46.50 | 66.41 | 154.1 | 5.86 | 21.55 | 26.94 | 1.75 | 9.66 | 17.52 | 5.84 | 21.55 | 26.94 | 1.58 | 19.98 | 26.30 |
| | 45 | 23.57 | 47.61 | 68.03 | 159.8 | 5.86 | 22.38 | 27.98 | 1.75 | 9.81 | 17.84 | 5.84 | 22.38 | 27.98 | 1.61 | 21.10 | 27.84 |
| | SE(m)± | 0.45 | 1.06 | 1.47 | 3.2 | 0.13 | 0.43 | 0.59 | 0.04 | 0.19 | 0.27 | 0.13 | 0.43 | 0.59 | 0.03 | 0.37 | 0.56 |
| | CD (p=0.05) | NS | 3.06 | 4.24 | 9.3 | NS | 1.25 | 1.71 | NS | 0.55 | 0.77 | NS | 1.25 | 1.71 | NS | 1.08 | 1.64 |

**Table 2:** Effect of different levels of nitrogen and sulphur on different Yield and Quality parameters of Indian mustard.

| | | No of siliqua plant$^{-1}$ | Lenth of siliqua | No of seeds siliqua$^{-1}$ | Test weight (g) | Seed yield (kg) | Straw yield (kg) | Harvest Index % | Oil % | Iodine value |
|---|---|---|---|---|---|---|---|---|---|---|
| Nitrogen levels (kg ha$^{-1}$) | 0 | 215.26 | 6.03 | 11.50 | 4.88 | 16.30 | 57.55 | 22.06 | 40.05 | 103.91 |
| | 40 | 281.87 | 7.18 | 13.62 | 5.01 | 18.37 | 64.30 | 22.21 | 40.45 | 104.96 |
| | 80 | 315.70 | 7.48 | 14.20 | 5.03 | 21.33 | 73.45 | 22.48 | 40.80 | 106.28 |
| | 120 | 338.23 | 7.69 | 14.61 | 5.14 | 23.26 | 79.68 | 22.56 | 41.20 | 107.25 |
| | SE(m)± | 5.83 | 0.12 | 0.26 | 0.10 | 0.42 | 1.32 | 0.46 | 0.58 | 1.45 |
| | CD (p=0.05) | 16.85 | 0.37 | 0.76 | NS | 1.22 | 3.81 | NS | NS | NS |
| Sulphur levels (kg ha$^{-1}$) | 0 | 240.87 | 6.46 | 12.26 | 4.94 | 17.73 | 62.28 | 22.13 | 40.36 | 104.70 |
| | 15 | 278.80 | 6.97 | 13.25 | 4.98 | 19.18 | 66.92 | 22.23 | 40.50 | 105.48 |
| | 30 | 307.50 | 7.37 | 14.01 | 5.02 | 20.51 | 71.03 | 22.38 | 40.80 | 106.11 |
| | 45 | 323.90 | 7.58 | 14.41 | 5.12 | 21.84 | 74.80 | 22.56 | 40.86 | 106.12 |
| | SE(m)± | 5.83 | 0.12 | 0.26 | 0.10 | 0.42 | 1.32 | 0.46 | 0.58 | 1.45 |
| | CD (p=0.05) | 16.85 | 0.37 | 0.76 | NS | 1.22 | 3.81 | NS | NS | NS |

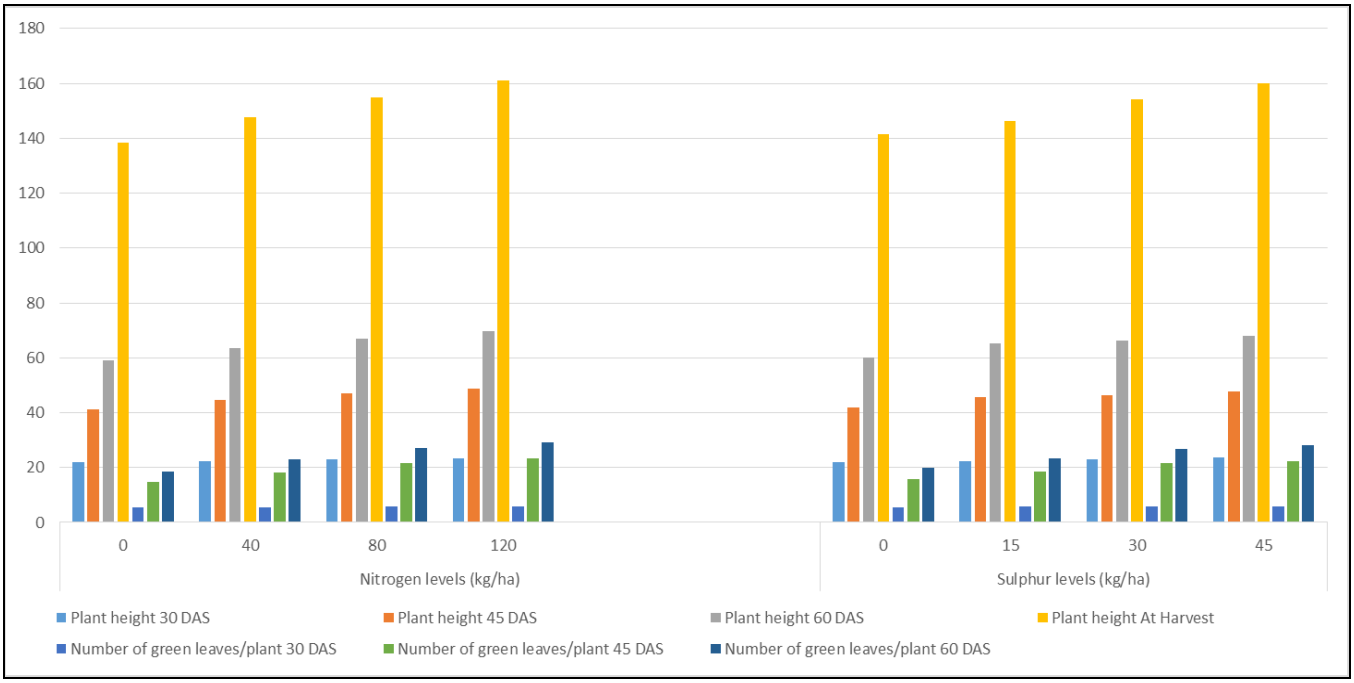


**Fig 1:** Effect of different levels of nitrogen and sulphur on different growth parameters of Indian mustard

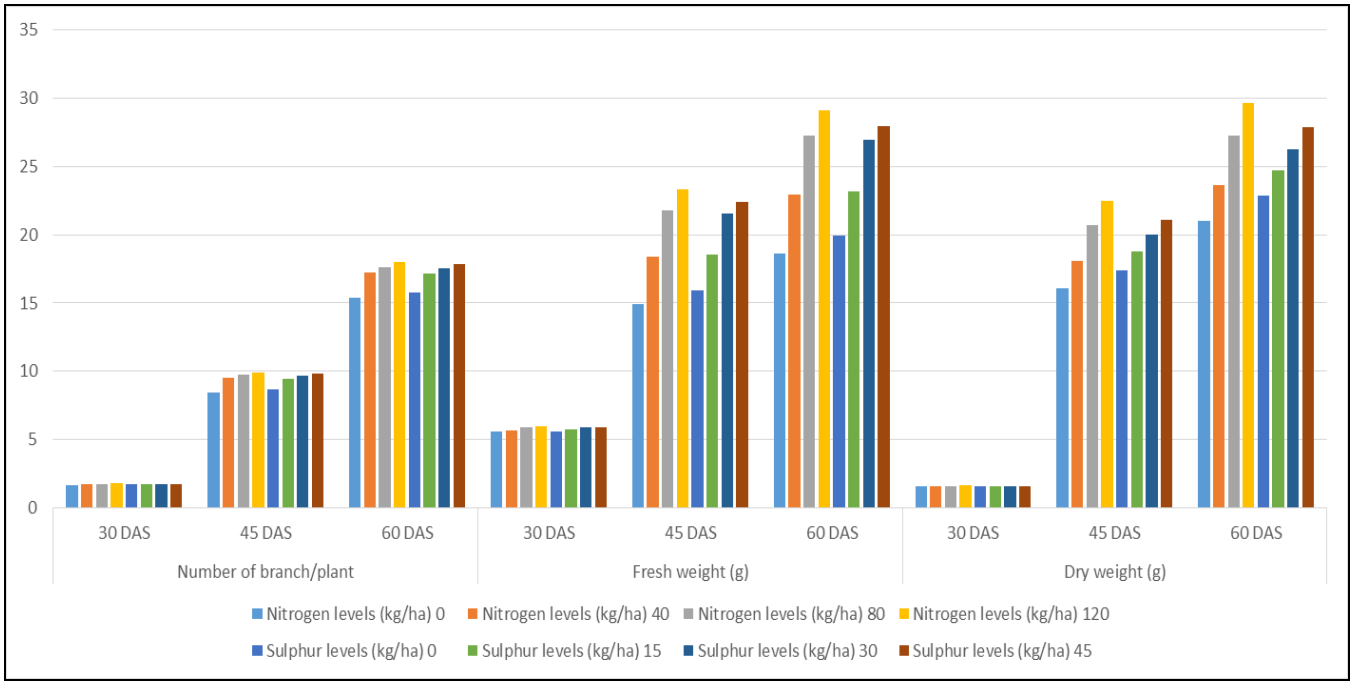


**Fig 2:** Effect of different levels of nitrogen and sulphur on different growth parameters of Indian mustard.

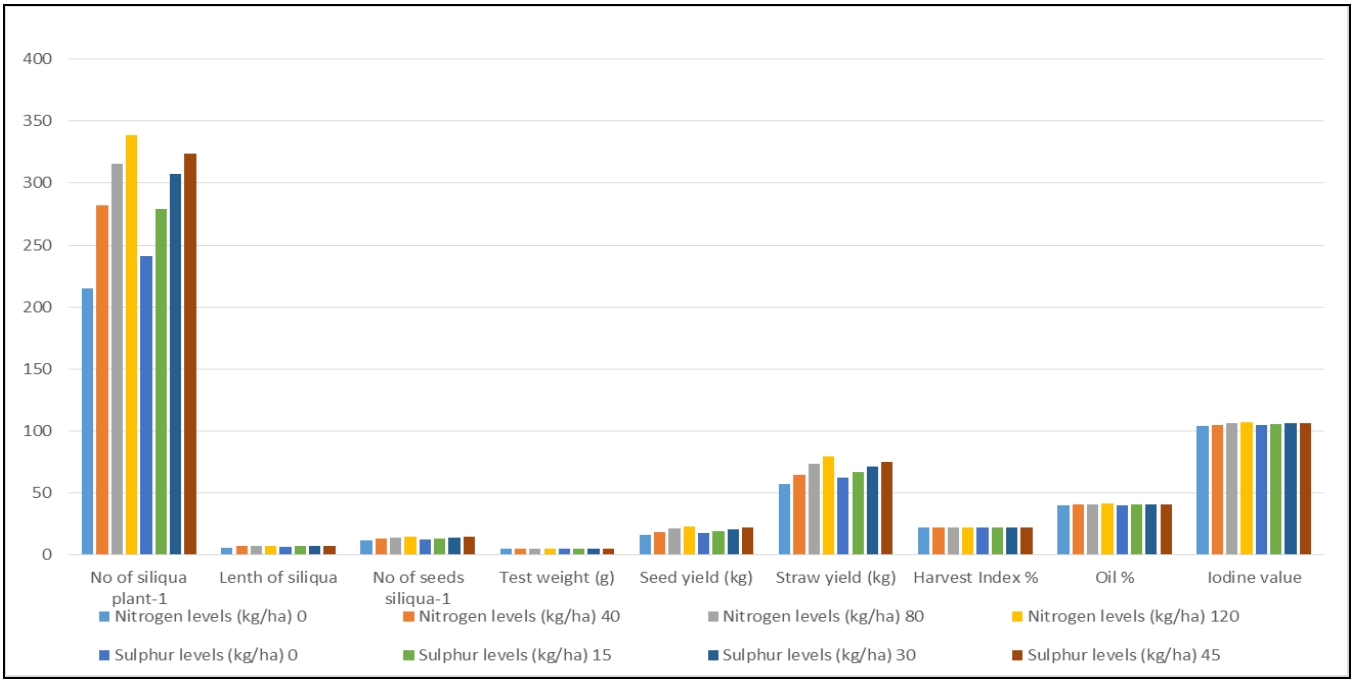


**Fig 3:** Effect of different levels of nitrogen and sulphur on different Yield and Quality parameters of Indian mustard.

## Conclusion

The findings of this study indicate that the combined application of 120 kg N $ha^{-1}$ and 45 kg S $ha^{-1}$ has a synergistic effect on the growth, yield, and quality of Indian mustard. The observed increases in plant height, biomass accumulation, seed yield, and oil content at these nutrient levels emphasize the essential roles of nitrogen and sulfur in optimizing both agronomic performance and quality traits in mustard. This research highlights the importance of integrated nutrient management strategies that incorporate both nitrogen and sulfur to improve mustard productivity and oil quality across various agro-climatic conditions. Future research should focus on assessing the long-term effects of these nutrient combinations on soil health and sustainability in mustard cultivation, contributing to the development of more sustainable agricultural practices for mustard production.

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