**Response of Mustard (*Brassica juncea L.*) to Nitrogen and Sulphur Fertilization Under Semi-Arid Conditions**

**Abstract**

A field experiment was conducted during the *rabi* 2023-24 at the Agronomy Research Farm, Nirwan University, Jaipur, Rajasthan, to evaluate the effect of nitrogen and sulphur levels on mustard growth, yield, and economic profitability. The study utilized a randomized complete block design (RCBD) with a factorial arrangement, comprising four nitrogen and three sulphur levels, replicated three times. The soil was sandy loam, alkaline (pH 8.4), low in nitrogen and sulphur, and medium in phosphorus and potassium. Results indicated that increasing nitrogen and sulphur levels significantly enhanced plant height and dry matter accumulation at all growth stages. The highest values were recorded at N150 and S40, reflecting improved nutrient assimilation, photosynthetic efficiency, and metabolic activity. Similarly, yield attributes, including siliquae plant-1, seeds siliqua-1, and test weight, improved with higher nitrogen and sulphur application, leading to increased seed and stover yield. The harvest index remained statistically non-significant, indicating a stable biomass partitioning pattern. Economic analysis revealed that N150 and S40 treatments resulted in the highest gross and net returns, with the best benefit-cost (B:C) ratio, demonstrating their superior economic efficiency. The current study highlights the importance of balanced nitrogen and sulphur fertilization in maximizing mustard productivity and profitability.

**Introduction**

Mustard (*Brassica juncea L.*) is one of the most important oilseeds crops globally, widely cultivated for its high oil content and nutritional value. It plays a crucial role in edible oil production, livestock feed, and industrial applications, particularly in South Asia, Canada, and parts of Europe. In India, among the seven edible oilseeds cultivated, rapeseed mustard (*Brassica* spp.) accounts for 28.6% of the total oilseed production. Mustard cultivation is particularly noteworthy in the states of Rajasthan, Gujarat, Madhya Pradesh, Uttarakhand, Uttar Pradesh, Bihar, West Bengal, and Assam. The cultivation area for mustard in India spans approximately 8.06 million hectares, yielding a production of 11.75 million tonnes with a productivity of 1458 Kg ha-1, (MoA & FW, 2023). Rajasthan leads in both cultivation area and production, while Gujarat boasts the highest productivity. Rajasthan, for instance, cultivates mustard on 3.37 million hectares, producing 5.48 million tonnes with a productivity of 1627 Kg ha-1 (MoA & FW, 2023). Indian mustard gives edible oil which is used as cooking medium in north India” (Prajapati et al., 2024). The increasing global demand for vegetable oils has highlighted the need for improved mustard productivity, which heavily depends on effective nutrient management.

Fertilizers have emerged as pivotal contributors to the enhancement of oilseed production. Mustard seeds typically contain oil content ranging from 37% to 39% (Bhowmik *et al.,* 2014; Sharma *et al.*, 2024), and achieving higher yields and improving nutrient utilization efficiency hinges on well-balanced fertilization practices. Notably, in our nation, oilseed crops are primarily cultivated under rainfed conditions, often in less fertile marginal lands with limited input availability. Therefore, optimizing fertilizer application becomes crucial in maximizing productivity and ensuring sustainable agricultural practices in such environments (Sharma *et al*., 2024; Meghwal *et al.,* 2025). Among essential nutrients, nitrogen and sulphur play a pivotal role in determining mustard growth, biomass accumulation, and overall yield. However, imbalanced fertilization often limits crop performance, making it essential to understand their combined impact on mustard production (Rana *et al*., 2025).

Nitrogen is a primary macronutrient required for mustard growth, influencing various physiological and biochemical processes such as chlorophyll synthesis, protein formation, and enzyme activation (Anjum *et al.,* 2012). It directly affects plant height, dry matter accumulation, and reproductive development by enhancing flower formation, pod development, and seed filling. Adequate nitrogen application improves siliquae per plant, seeds per siliqua, and test weight, ultimately boosting seed yield and stover production. However, excessive nitrogen can lead to luxuriant vegetative growth at the expense of reproductive structures, while insufficient nitrogen results in stunted growth and poor seed development. Moreover, nitrogen-use efficiency is often limited by leaching and volatilization, necessitating optimized fertilization strategies for sustainable crop production. Sulphur, though required in smaller quantities than nitrogen, is equally vital for mustard growth and oil synthesis. It plays a critical role in nitrogen metabolism, enzyme activation, and the formation of sulphur-containing amino acids such as cysteine and methionine. Sulphur is particularly important in oilseed crops, as it enhances oil content and seed quality while improving stress tolerance (Dawar *et al*., 2023; Saharan *et al*., 2024). Deficiency of sulphur leads to chlorosis, reduced biomass accumulation, poor siliqua formation, and lower seed weight. Mustard has a higher sulphur requirement compared to cereals due to its rich glucosinolate content, which contributes to plant defense mechanisms and overall productivity. The interaction between nitrogen and sulphur is highly synergistic, as sulphur enhances nitrogen metabolism, while nitrogen availability facilitates sulphur uptake. An imbalance between these nutrients can reduce crop efficiency, leading to lower yields and inferior seed quality (Wang *et al*., 2015).

Both nitrogen and sulphur significantly influence mustard yield attributes, including siliquae per plant, seeds per siliqua, and test weight. Higher nitrogen levels promote flower retention and seed setting, while sulphur ensures proper seed filling and oil biosynthesis (Zenda *et al*., 2021). These nutrients also affect overall seed and stover yield by enhancing dry matter accumulation and improving nutrient partitioning within the plant. However, while nitrogen and sulphur improve total biomass production, their effect on the harvest index remains variable, depending on environmental factors and crop management practices. Achieving an optimal balance between nitrogen and sulphur is therefore critical for maximizing mustard productivity while maintaining soil health and sustainability.

Despite the known benefits of nitrogen and sulphur fertilization, challenges such as declining soil fertility, inefficient nutrient uptake, and environmental concerns necessitate further research. Precision nutrient management, integrated fertilization approaches, and the development of sulphur-responsive mustard varieties can help enhance productivity while minimizing nutrient losses. Additionally, understanding the interaction of nitrogen and sulphur with other micronutrients can provide deeper insights into nutrient-use efficiency. Given the increasing demand for high-yielding oilseed crops, this study aims to evaluate the effect of nitrogen and sulphur levels on mustard growth, yield attributes, and productivity. The findings will contribute to developing improved fertilization strategies that ensure optimal yield and sustainable crop production.

**Material & Methods**

The field experiment was conducted during the *rabi* season of 2023-24 at the Agronomy Research Farm, School of Agricultural Sciences, Nirwan University, Jaipur, Rajasthan situated at 26o86’N latitude and 76o11’E longitude falling under Zone IIIa agro-climatic zone of Rajasthan. The experiment comprised of two factors *viz.,* levels of nitrogen and sulphur, and was carried out using randomized complete block design with factorial arrangement. The first factor comprised of four levels of nitrogen whereas the second factor comprised of three levels of sulphur which were replicated thrice (Table 1). The soil of the experimental field was sandy loam in texture and alkaline in reaction (pH 8.4). The soil was deficient in available sulphur (8.1 mg ha-1), low in available nitrogen (128.6 kg ha-1), medium in available phosphorus (20.1 kg ha-1) and available potassium (280.6 kg ha-1). The mustard variety DRMRIJ-31 (Giriraj) was used with seed rate of 4 kg ha-1. The row to row spacing of 45 cm and plant to plant spacing of 15 cm was maintained. The data obtained was subjected to F-test followed by least significant difference post-hoc test as prescribed by Gomez and Gomez (1984).

**Results & Discussion**

1. **Plant height**

The results indicate that increasing nitrogen and sulphur levels significantly enhanced mustard plant height at all growth stages (Table 2). The highest plant height was recorded in the N150 (196.03 cm) and S40 (183.01 cm) treatments at maturity, while the lowest was observed in the N0 (133.34 cm) and S0 (156.32 cm) treatments. At 30 DAS, plant height ranged from 29.50 cm (N0) to 38.17 cm (N150) and 31.44 cm (S0) to 37.26 cm (S40). This trend continued at 60 DAS (100.46 cm in N0 vs. 127.18 cm in N150 and 105.18 cm in S0 vs. 124.65 cm in S40) and at 90 DAS (129.62 cm in N0 vs. 186.65 cm in N150 and 148.99 cm in S0 vs. 177.01 cm in S40). Nitrogen is a key macronutrient required for plant growth, primarily influencing vegetative development, leaf expansion, and photosynthetic efficiency (Khare *et al*., 2025). The increase in plant height with higher nitrogen levels can be attributed to its role in protein synthesis, enzymatic activity, and chlorophyll production, which enhances metabolic processes and promotes elongation of internodes (Karthika *et al*., 2020). Similarly, sulphur plays a vital role in crop growth by contributing to amino acid and enzyme synthesis, improving chlorophyll formation, and facilitating nitrogen metabolism (Zenda *et al*., 2021). The significant increase in plant height under higher sulphur levels (S40) suggests that sulphur supplementation optimizes nutrient uptake and physiological activities, thereby enhancing plant vigor.

1. **Dry matter accumulation**

The results show that increasing nitrogen and sulphur levels significantly enhanced dry matter accumulation in mustard at all growth stages, highlighting their crucial role in plant growth and biomass production (Table 3). The highest dry matter accumulation was recorded in the N150 (51.86 g plant⁻¹) and S40 (52.92 g plant⁻¹) treatments at harvest, while the lowest was observed in N0 (36.87 g plant⁻¹) and S0 (39.22 g plant⁻¹). At 30 DAS, dry matter accumulation ranged from 1.52 g (N0) to 1.96 g (N150) and 1.61 g (S0) to 1.92 g (S40), indicating early-stage biomass enhancement with nitrogen and sulphur application. At 60 DAS, plants treated with N150 (24.51 g) accumulated significantly more dry matter than those in N0 (17.78 g), while sulphur supplementation also showed a substantial effect (24.54 g in S40 vs. 18.55 g in S0). This trend continued at 90 DAS, where dry matter accumulation peaked in N150 (45.01 g) and S40 (45.62 g), compared to the lowest values in N0 (31.76 g) and S0 (33.78 g). At harvest, the superior dry matter production in N150 and S40 treatments underscores the importance of optimal nitrogen and sulphur nutrition in achieving maximum biomass accumulation. The progressive increase in dry matter with higher nitrogen levels suggests improved nitrogen assimilation and partitioning of assimilates into structural and storage components, leading to higher biomass production (Bhattacharya, 2022). These finding are same with previous studies that reported increased vegetative growth and yield components in mustard with higher nitrogen levels, as it enhances metabolic efficiency and carbohydrate translocation (Mandal & Sinha, 2004).

Similarly, sulphur plays a vital role in biomass accumulation by facilitating nitrogen metabolism, protein synthesis, and enzymatic activation (Shah *et al*., 2022). The significant improvement in dry matter accumulation under S40 treatment suggests that sulphur application enhances nitrogen use efficiency, leading to better vegetative growth and biomass partitioning (Shah *et al*., 2022). Sulphur is a key component of essential amino acids such as cysteine and methionine, which are crucial for protein formation and overall plant metabolism (Narayan *et al.*, 2023).

1. **Yield attributes**

The data reveal a significant improvement in key yield attributes of mustard—siliquae plant-1, seeds siliqua-1, and test weight—with increasing nitrogen and sulphur application. The highest values for these parameters were recorded at the N150 and S40 levels, highlighting their essential role in enhancing mustard productivity (Table 4).

**Siliquae Plant-1**

The number of siliquae per plant increased progressively with higher nitrogen and sulphur levels, indicating improved reproductive efficiency. Among nitrogen treatments, N150 recorded the highest siliquae plant-1 (192.33), significantly outperforming the control N0 (137.11 siliquae plant-1). Similarly, sulphur application led to a substantial increase in siliquae formation, with S40 (189.03 siliquae plant-1) producing the highest value, compared to S0 (149.60 siliquae plant-1). This increase can be attributed to the enhanced availability of nitrogen, which promotes photosynthetic activity, cell division, and assimilate translocation, leading to better flower retention and pod formation (Khare *et al*., 2025). Sulphur further supports this process by improving enzyme activation, chlorophyll synthesis, and nutrient uptake, ensuring optimal reproductive development (Zenda *et al*., 2021). The findings align with earlier research suggesting that nitrogen and sulphur deficiencies result in poor flower retention, lower pod set, and reduced yield potential in mustard (Shah *et al*., 2022).

**Seeds Siliqua-1**

A significant increase in the number of seeds per siliqua was observed with higher nitrogen and sulphur levels. Among nitrogen treatments, N150 produced the highest number of seeds siliqua-1 (10.56), while N0 recorded the lowest (8.74 seeds siliqua-1). A similar trend was observed with sulphur application, where S40 (10.54 seeds siliqua-1) outperformed S0 (9.02 seeds siliqua-1). The increased seed count under higher nitrogen levels can be attributed to enhanced protein synthesis, carbohydrate accumulation, and hormonal regulation, leading to better pollen viability, fertilization success, and seed set (Zhang *et al*., 2017; Sharma *et al*., 2023). Sulphur further enhances seed development by facilitating nitrogen metabolism, improving oil and protein synthesis, and strengthening seed formation processes (Shah *et al*., 2022). The significant improvement in seeds per siliqua under S40 treatment confirms that adequate sulphur availability enhances reproductive efficiency by supporting nutrient assimilation and reducing seed abortion (Pareek, 2021).

**Test Weight (g)**

Seed weight is a critical determinant of yield quality, and both nitrogen and sulphur application significantly influenced this parameter. The highest test weight was recorded in N150 (4.64 g), whereas N0 showed the lowest (3.47 g). Similarly, sulphur application significantly improved test weight, with S40 (4.26 g) producing the heaviest seeds compared to S0 (4.01 g). The increase in seed weight with nitrogen application is attributed to better nitrogen assimilation, which promotes enhanced seed filling, starch accumulation, and metabolic activity, leading to increased seed size and weight. Sulphur further enhances test weight by stimulating seed protein synthesis, improving lipid metabolism, and supporting enzymatic functions necessary for seed development (Bhandari et al., 2021). The findings align with earlier research indicating that a deficiency of nitrogen and sulphur limits seed growth, resulting in smaller and lighter seeds due to restricted nutrient translocation and inefficient metabolic processes (Zenda *et al*., 2021).

1. **Yield**

The results indicate that nitrogen and sulphur application significantly influenced seed yield and stover yield, while the harvest index (HI) exhibited a slight increase but remained statistically non-significant (Table 5).

**Seed Yield (kg ha⁻¹)**

Seed yield exhibited a significant increase with higher nitrogen and sulphur levels, with N150 (1742 kg ha⁻¹) and S40 (1810 kg ha⁻¹) recording the highest values, while the lowest yields were observed in N0 (1249 kg ha⁻¹) and S0 (1306 kg ha⁻¹). The substantial increase in seed yield with nitrogen application is attributed to its role in enhancing vegetative growth, photosynthetic efficiency, and reproductive development, leading to greater siliqua formation, higher seed set, and improved seed weight (Zenda e*t al.*, 2021). Similarly, sulphur supplementation significantly enhanced seed yield by facilitating nitrogen metabolism, optimizing enzyme activity, and improving oil and protein synthesis, all of which are critical for seed development and grain filling (Singh *et al*., 2013).

**Stover Yield (kg ha⁻¹)**

Stover yield followed a similar trend as seed yield, increasing with nitrogen and sulphur application. The highest stover yield was observed in N150 (5881 kg ha⁻¹) and S40 (6202 kg ha⁻¹), while the lowest values were recorded in N0 (4856 kg ha⁻¹) and S0 (4748 kg ha⁻¹). The increase in stover yield with nitrogen application is associated with enhanced vegetative biomass production, increased leaf area, and improved structural development, which collectively contribute to greater stover accumulation (Singh *et al*., 2013). Sulphur application further promoted biomass production by enhancing chlorophyll synthesis, nitrogen use efficiency, and root development, leading to a greater accumulation of dry matter (Zenda *et al*., 2021). These findings are in agreement with previous studies demonstrating that adequate nitrogen and sulphur availability leads to robust plant growth, resulting in higher biomass and stover yield (Shah *et al*., 2022).

**Harvest Index (%)**

The harvest index (HI), which represents the efficiency of assimilate partitioning into economic yield (seed yield relative to total biomass), showed a slight but statistically non-significant increase with nitrogen and sulphur application. The highest HI was recorded in N150 (29.85%) and S40 (29.13%), while the lowest was observed in N0 (25.73%) and S0 (27.72%). The increase in HI with nitrogen and sulphur supplementation suggests improved reproductive efficiency, where a greater proportion of biomass is allocated to seed production rather than vegetative growth (Mahto *et al*., 2024). However, the lack of statistical significance indicates that while nitrogen and sulphur enhance overall yield, their effect on biomass partitioning remains relatively stable. This is consistent with earlier research indicating that while nitrogen and sulphur significantly increase both seed and stover yield, their influence on HI is often minor unless there are severe nutrient deficiencies (Bhandari *et al*., 2021).

1. **Economics**

The economic analysis of mustard cultivation under varying nitrogen and sulphur levels reveals a significant impact on cost of cultivation, gross returns, net returns, and benefit-cost (B:C) ratio. Both nitrogen and sulphur applications enhanced economic profitability, with higher levels resulting in greater returns.

**Cost of Cultivation**

The cost of cultivation increased progressively with higher nitrogen and sulphur levels due to increased input costs. Among nitrogen treatments, N150 recorded the highest cost of cultivation (₹36,043 ha-1), while N0 had the lowest (₹34,087 ha-1). Similarly, sulphur application also increased production costs, with S40 incurring the highest cost (₹36,131 ha-1**),** compared to S0 (₹33,998 ha-1). The higher costs are associated with increased fertilizer application, labor, and management practices.

**Gross and Net Returns**

Gross returns improved significantly with increasing nitrogen and sulphur levels, reflecting enhanced yield and productivity. The highest gross returns were recorded in N150 (₹1,12,582 ha-1) and S40 (₹1,17,243 ha-1), while the lowest were observed in N0 (₹82,639 ha-1) and S0 (₹85,417 ha-1). Consequently, net returns followed the same trend, with N150 (₹76,539 ha-1) and S40 (₹81,112 ha-1) achieving the highest profitability. The substantial increase in returns indicates the positive effect of nitrogen and sulphur on mustard yield, leading to greater market value and economic gains.

**Benefit-Cost (B:C) Ratio**

The B:C ratio, which measures profitability per unit investment, improved with higher nitrogen and sulphur levels. The highest B:C ratio was recorded in N150 (2.11) and S40 (2.24), highlighting the superior economic efficiency of these treatments. In comparison, N0 (1.42) and S0 (1.51) had the lowest ratios, indicating reduced profitability under low nutrient application.

**Conclusion**

The study highlights the crucial role of nitrogen and sulphur in enhancing mustard growth, biomass accumulation, yield attributes, and overall productivity and profitability. Increasing nitrogen and sulphur levels significantly improved plant height, demonstrating their importance in promoting vegetative growth. Similarly, dry matter accumulation increased with higher nitrogen and sulphur application, reflecting better nutrient assimilation and biomass production. Yield attributes such as siliquae per plant, seeds per siliqua, and test weight showed notable improvements with adequate nitrogen and sulphur supply, emphasizing their role in reproductive development and seed formation. Higher nutrient availability enhanced seed yield and stover yield, confirming that nitrogen and sulphur fertilization is essential for maximizing mustard productivity. Although the harvest index showed a slight increase, it remained statistically non-significant, indicating a stable partitioning of biomass between vegetative and reproductive components. To further enhance mustard productivity, future research should focus on optimizing nitrogen and sulphur use efficiency through precision fertilization strategies and integrated nutrient management. Exploring synergistic effects with micronutrients and adopting site-specific nutrient recommendations can help achieve higher yields while maintaining soil health and sustainability. Additionally, breeding mustard varieties with improved sulphur responsiveness could further enhance yield potential and nutrient utilization efficiency.

**References**

Anjum, N. A., Gill, S. S., Umar, S., Ahmad, I., Duarte, A. C., & Pereira, E. (2012). Improving growth and productivity of oleiferous Brassicas under changing environment: significance of nitrogen and sulphur nutrition, and underlying mechanisms. *The Scientific World Journal*, *2012*(1), 657808.

Bhandari, D., Singh, A., & Ghosh, S. (2021). Nutraceutical profile for genetic diversity assessment in leafy mustard (*Brassica juncea* var. rugosa) genotypes.

Bhattacharya, A. (2022). Effect of low temperature on dry matter, partitioning, and seed yield: A review. *Physiological processes in plants under low temperature stress*, 629-734.

Dawar, R., Karan, S., Bhardwaj, S., Meena, D. K., Padhan, S. R., Reddy, K. S., & Bana, R. S. (2023). Role of sulphur fertilization in legume crops: A comprehensive review. *Int. J. Plant Sci*, *35*, 718-727.

Gomez K.A. and Gomez A.A. (1984). Statistical procedures for agricultural research. 2nd (eds.). New York, Wiley

Karthika, K. S., Philip, P. S., & Neenu, S. (2020). *Brassicaceae* plants response and tolerance to nutrient deficiencies. *The Plant Family Brassicaceae: Biology and Physiological Responses to Environmental Stresses*, 337-362.

Khare, N., Khare, P., & Singh, S. (2025). Molecular and Physiological Concepts: Macronutrients in Crop Plant Growth and Development. In *Agricultural Crop Improvement* (pp. 148-164). CRC Press.

Mahto, R., Singh, R. K., Singh, J. P., Tiwari, R. K., Vishwakarma, D. K., Obaidullah, A. J., ... & Yadav, A. K. (2024). Evaluation of *Brassica* species for growth, yield and heat use efficiency under nitrogen nutrition and iron sulphide nanoparticles application. *Scientia Horticulturae*, *333*, 113278.

Mandal, K. G., & Sinha, A. C. (2004). Nutrient management effects on light interception, photosynthesis, growth, dry‐matter production and yield of Indian mustard (*Brassica juncea*). *Journal of Agronomy and Crop Science*, *190*(2), 119-129.

Meghwal, D. R., Singh, A., Bhinda, N. K., Choudhary, V., & Kumar, R. (2025). Effect of weed management practices on productivity and profitability of Indian mustard (*Brassica juncea* L.). *International Journal of Research in Agronomy, 8*(1): 277-81.

MoA & FW.  2023.  Agricultural statistics at a glance 2022. Ministry of Agriculture & Farmers Welfare, Government of India, New Delhi.

Narayan, O. P., Kumar, P., Yadav, B., Dua, M., & Johri, A. K. (2023). Sulphur nutrition and its role in plant growth and development. *Plant Signaling & Behavior*, *18*(1), 2030082.

Pareek, K. T., & Po, K. (2021). *Effect of sulphur and boron on growth and yield of mustard (Brassica juncea* L*.)* (Doctoral dissertation, College of Agriculture Nagpur, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola).

Prajapati, V., Mankotia, B.S., Rana, B.B., Sharma, A., Dogra, P., Sharma, S., Verma, A., Sharma, J. & Meena, D. (2024). Effect of biofertilizers at different fertility levels on nutrient content and uptake by Gobhi Sarson (*Brassica napus* L.) under Himalayan Region. *Journal of Experimental Agriculture International*, *46*(12), 214-221.

Rana, B. B., Sharma, V., Manuja, S., Sharma, S. K., Singh1&3, A., Sharma, R., & Chauhan, G. (2025). Evaluation of herbicide efficacy on growth indices of maize cultivated under conservation agriculture system. *Plant Archives*, *25*(1), 2808-2817. [10.51470/PLANTARCHIVES.2025.v25.supplement-1.388](http://dx.doi.org/10.51470/PLANTARCHIVES.2025.v25.supplement-1.388)

Saharan, S., Singh, J., Sharma, R., Singh, A., Narwal, K., Rana, B. B., ... & Prashar, D. Revitalizing Rainfed Agriculture: The Transformative Potential of Watershed Development. DOI: [10.9734/ijpss/2024/v36i74809](http://dx.doi.org/10.9734/ijpss/2024/v36i74809)

Shah, S. H., Islam, S., & Mohammad, F. (2022). Sulphur as a dynamic mineral element for plants: a review. *Journal of Soil Science and Plant Nutrition*, *22*(2), 2118-2143.

Shah, S. H., Parrey, Z. A., Islam, S., Tyagi, A., Ahmad, A., & Mohammad, F. (2022). Exogenously Applied Sulphur Improves Growth, Photosynthetic Efficiency, Enzymatic Activities, Mineral Nutrient Contents, Yield and Quality of Brassica juncea L. *Sustainability*, *14*(21), 14441.

Sharma, R., Manuja, S., Kumar, N., Sharma, R. P., Saharan, S., Sharma, T., & Rana, B. B. (2023). Effect of foliar spray of nano nitrogen and nano zinc on growth, development, yield and economics of rice (*Oryza sativa* L.). *The Pharma Innovation*, *12*(11), 2016-2020.

Sharma, S., Singh, A., Yadav, B., Choudhary, V., & Rana, B. B. (2024). Influence of Different Levels of Sulphur and Phosphorus on Growth and Productivity of Mustard (*Brassica juncea* L.). *International Journal of Plant & Soil Science*, *36*(12), 623-629.

Sharma, T., Singh, J., Madaik, S., Kumar, P., Singh, A., Rana, B. B., & Chauhan, G. (2024). Organic input incorporation for enhancing sustainability and economic viability of cowpea in North-Western Himalayan region. *Frontiers in Agronomy*, *6*, 1458603.

Singh, R. K., Singh, R. P., & Singh, M. K. (2013). Weed management in rapeseed-mustard-A review. *Agricultural Reviews*, *34*(1), 36-49.

Wang, T., Wang, L. X., Wu, D. L., Xia, W., & Jia, D. Z. (2015). Interaction between nitrogen and sulfur in co-doped graphene and synergetic effect in supercapacitor. *Scientific reports*, *5*(1), 9591.

Zenda, T., Liu, S., Dong, A., & Duan, H. (2021). Revisiting sulphur—The once neglected nutrient: It’s roles in plant growth, metabolism, stress tolerance and crop production. *Agriculture*, *11*(7), 626.

**Table 1. Details of the treatment**

|  |  |
| --- | --- |
| 1. **Nitrogen levels (kg ha-1)**
 | **Notation** |
| 0 | N0 |
| 50 | N50 |
| 100 | N100 |
| 150 | N150 |
| 1. **Sulphur levels (kg ha-1)**
 |  |
| 0 | S0 |
| 20 | S20 |
| 40 | S40 |

**Table 2. Effect of nitrogen and sulphur levels on plant height (cm) of mustard at successive growth stages.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatment** | **30 DAS** | **60 DAS** | **90 DAS** | **Maturity** |
| **Nitrogen levels** |  |  |  |  |
| N0 | 29.50 | 100.46 | 129.62 | 133.34 |
| N50 | 33.83 | 109.31 | 157.81 | 164.54 |
| N100 | 36.29 | 124.02 | 178.40 | 184.86 |
| N150 | 38.17 | 127.18 | 186.65 | 196.03 |
| SEm± | 0.86 | 2.91 | 4.40 | 4.19 |
| CD(P=0.05) | 2.51 | 8.52 | 12.91 | 12.30 |
| **Sulphur levels** |  |  |  |  |
| S0 | 31.44 | 105.18 | 148.99 | 156.32 |
| S20 | 34.64 | 115.89 | 163.36 | 169.74 |
| S40 | 37.26 | 124.65 | 177.01 | 183.01 |
| SEm± | 0.74 | 2.52 | 3.81 | 3.63 |
| CD (P=0.05) | 2.18 | 7.382 | 11.18 | 10.65 |

**Table 3. Effect of nitrogen and sulphur levels on dry matter accumulation (g plant-1) of mustard at successive growth stages.**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatment** | **30 DAS** | **60 DAS** | **90 DAS** | **At harvest** |
| **Nitrogen levels** |  |  |  |  |
| N0 | 1.52 | 17.78 | 31.76 | 36.87 |
| N50 | 1.74 | 21.12 | 39.11 | 46.44 |
| N100 | 1.85 | 23.07 | 43.40 | 49.66 |
| N150 | 1.96 | 24.51 | 45.01 | 51.86 |
| SEm± | 0.05 | 0.65 | 0.93 | 1.08 |
| CD(P=0.05) | 0.14 | 1.90 | 2.72 | 3.16 |
| **Sulphur levels** |  |  |  |  |
| S0 | 1.61 | 18.55 | 33.78 | 39.22 |
| S20 | 1.77 | 21.77 | 40.06 | 46.48 |
| S40 | 1.92 | 24.54 | 45.62 | 52.92 |
| SEm± | 0.04 | 0.56 | 0.80 | 0.93 |
| CD (P=0.05) | 0.12 | 1.65 | 2.35 | 2.73 |

**Table 4. Effect of nitrogen and sulphur levels on primary and secondary branches of mustard**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments** | **Siliquae plant-1** | **Seed siliqua-1** | **Test weight (g)** |
| **Nitrogen levels** |  |  |  |
| N0 | 137.11 | 8.74 | 3.47 |
| N50 | 166.86 | 9.68 | 4.03 |
| N100 | 184.11 | 10.11 | 4.41 |
| N150 | 192.33 | 10.56 | 4.64 |
| SEm± | 4.69 | 0.19 | 0.05 |
| CD(P=0.05) | 13.74 | 0.55 | 0.14 |
| **Sulphur levels** |  |  |  |
| S0 | 149.60 | 9.02 | 4.01 |
| S20 | 171.68 | 9.75 | 4.14 |
| S40 | 189.03 | 10.54 | 4.26 |
| SEm± | 4.06 | 0.16 | 0.04 |
| CD (P=0.05) | 11.90 | 0.48 | 0.12 |

**Table 5. Effect of nitrogen and sulphur levels on yield and harvest index of mustard**

|  |  |  |  |
| --- | --- | --- | --- |
| **Treatments** | **Seed yield** | **Stover yield** | **Harvest index** |
| **(kg ha-1)** | **(kg ha-1)** | **(%)** |
| **Nitrogen levels** |  |  |  |
| N0 | 1249 | 4856 | 25.73 |
| N50 | 1565 | 5436 | 28.74 |
| N100 | 1682 | 5734 | 29.46 |
| N150 | 1742 | 5881 | 29.85 |
| SEm± | 40 | 145 | 1.19 |
| CD(P=0.05) | 116 | 425 | NS |
| **Sulphur levels** |  |  |  |
| S0 | 1306 | 4748 | 27.72 |
| S20 | 1563 | 5481 | 28.49 |
| S40 | 1810 | 6202 | 29.13 |
| SEm± | 34 | 125 | 1.03 |
| CD (P=0.05) | 101 | 368 | NS |

**Table 6. Effect of nitrogen and sulphur levels on economics of mustard crop**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Treatment** | **Cost of cultivation** | **Gross returns** | **Net returns** | **B:C ratio** |
| **(₹/ha)** | **(₹/ha)** | **(₹/ha)** |  |
| **Nitrogen levels** |  |  |  |  |
| N0 | 34087 | 82639 | 48552 | 1.42 |
| N50 | 34739 | 101601 | 66862 | 1.92 |
| N100 | 35391 | 108871 | 73480 | 2.07 |
| N150 | 36043 | 112582 | 76539 | 2.11 |
| **Sulphur levels** |  |  |  |  |
| S0 | 33998 | 85417 | 51419 | 1.51 |
| S20 | 35065 | 101608 | 66543 | 1.89 |
| S40 | 36131 | 117243 | 81112 | 2.24 |