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Effect of nitrogen and sulphur levels on growth yield and quality of Indian mustard (*Brassica juncea* L.)

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Abstract
A field experiment in Factorial randomized block design (FRBD) with replication and 10 treatment combinations was conducted at the Crop Research Centre-II, ITM University, Gwalior (Madhya Pradesh) during the *Rabi* season of 2022-23 at the polyhouse research farm. The treatments included three levels of nitrogen (30, 60, and 90 kg N ha-^{1}) and three levels of sulfur (12, 15, and 18 kg S ha-^{1}) with one absolute control. The results showed that different nitrogen and sulfur levels had substantial effects on growth parameters such as plant population (m^2), plant height (cm), number of primary and secondary branches plant-^{1}, leaf area index (LAI), and dry matter accumulation (g). and Increased nitrogen levels increased yield qualities such as Siliqua plant-^{1}, Siliqua plant length (cm), seeds Siliqua-^{1},1000 seed weight (g), quality such as oil content, and oil yield was highest at 90 kg N ha-^{1}. However, the highest grain production (1882 kg ha-^{1}) was achieved with the application of 90 kg N ha-^{1}, which was Significantly superior to lower levels (0 and 30 kg N ha-^{1}) of nitrogen, with the exception of 60 kg N ha-^{1}. In comparison to other Sulphur levels, Sulphur level 18 kg ha-^{1} produced the most plants (m^2), the tallest plants possible, the most primary and secondary branches per plant, the highest leaf area index, and the dry matter accumulation (g). The number of Siliqua plants, seeds, and Siliqua length (cm), 1000 grain weight (g), and maximum grain output (1817 kg ha-^{1}) were also recorded.

Keywords: Nitrogen, sulphur, Indian mustard, growth and yield attributes

Introduction
Indian mustard (*Brassica juncea* L.), a member of the Cruciferae family, is the most important winter rabi oilseed crop. India is one of the world's largest mustard-growing countries, ranking first in area and third in production behind China and Canada. Rapeseed and mustard are the world's third most significant oilseed crops, after soybean (*Glycine max* L.) and Rapeseed and mustard account for 28.6% of total oil seed crop production in India Mustard is a major rabi crop in Rajasthan, Gujarat, Madhya Pradesh, Uttarakhand, Uttar Pradesh, Bihar, West Bengal, and Assam. Mustard is produced on an estimated 35.95 million hectares worldwide, with production and productivity of 71.49 million tonnes and 1990 kg ha-^{1}, respectively. In India, mustard is grown on an area of around 6.85 million hectares, with production and productivity of 9.12 million tonnes and 1331 Kg ha-^{1}, respectively. Rajasthan is the most productive state in India, with an area of 3.08 million hectares and a yield of 4.20 million tonnes. Productivity is 1336 kg ha-^{1}. Mustard is planted on 0.75 million hectares in Uttar Pradesh, with a total production of 0.95 million tonnes and productivity of 1260 kg ha-^{1} (DRMR 2019-20). In India, mustard is produced in an area of around 8.1 million hectares, with production and productivity of 11.7 million tonnes 1458 Kg ha-^{1}, respectively. Fertilizers have played a significant influence in improving oil seed production. The oil content of mustard seeds ranges from 37-39% (Bhowmik *et al*., 2014) [3], and balanced fertilization is the key to enhancing production and increasing nutrient usage efficiency. Nitrogen (N) is required for rapid development, high output, and quality in mustard. Nitrogen is crucial in the formation of plant proteins and chlorophyll and is required in the greatest quantity when compared to other macronutrients. Plants with low N levels exhibit pale green to yellow leaves and are generally spindly. Yellowing of older leaves is another sign that mustard is lacking in nitrogen. Nitrogen is transported in the plant from older to younger leaves, therefore deficient symptoms develop first on older leaves. When a crop lacks N, the canopy is likely to be thin and open, and the blooming phase is shortened, resulting in a reduced pod set and poorer yield. Sulphur, as it is appropriately named, is the fourth main secondary plant nutrient for all key crops due to its importance in growth, development, and production. It is essential to the plant's physiological and metabolic processes.

Sulphur insufficiency, on the other hand, is one of the most serious nutritional deficits in plants, affecting more than 70 countries worldwide, including India. Sulphur, like seed protein, amino acids, enzymes, chlorophyll, and glucosinolate, is needed in plants for increasing oil synthesis. Sulphur is especially important in rapeseed and mustard, where it influences production, oil quality and quantity, and resistance. Rapeseed and mustard have the highest Sulphur requirements of any field crop. Sulphur enhanced mustard production by 12 to 48% under irrigated settings and 17 to 124% under rainfed conditions, according to various research. However, the availability of Sulphur to the plant for uptake is decreasing day by day. According to India's new Oilseed Mission 19, the average production of rapeseed and mustard is only 1145 kg/ha, which needs to be increased to 2562 kg/ha by the end of 2030 in order to achieve self-sufficiency in edible oil.

Materials and Methods

During the Rabi season of 2022-2023, a field experiment was conducted near the polyhouse research farm, Crop Research Centre-II, School of Agriculture ITM University, Gwalior. Madhya Pradesh is a state in India. The research site is in the subtropics, at a height of 196 meters above sea level, with coordinates of 26o 21' N latitude and 78o 17' E longitude, representing the Indo-Gangetic plains region. The summers and winters in Gwalior are both extremely hot. A semiarid, subtropical climate characterizes Gwalior, with chilly temperatures ranging from mild to bitterly bitter in the winter, hot, dry days and desiccating hot winds in the summer, and warm, humid conditions during the monsoon season. With uneven changes in its distribution, the yearly rainfall runs from 600 to 700 mm. The southwest monsoon contributes between 80 and 90% of the region's total rainfall between July and September, and the region's typical climate ranges from a maximum temperature of 48 °C in the summer with hot, desiccating winds to a minimum temperature of 0 °C lower in the winter with frost. In order to conduct a chemical study of the soil in the experiment area prior to planning the layout, 5 samples were randomly selected from the soil profile between 0 and 15 cm deep. The soil type at the experimental location was sandy loam, with accessible soil nutrients (N, P, and K) total of 178.03, 24.45, and 382.15 kg/ha, as well as soil organic carbon at 0.41% and a soil PH of 7.4 at the time. The experiment was set up using a Factorial Randomized Block Design, with 10 treatments combination that included one absolute control and various nitrogen levels of 30, 60, and 90 kg N/ha and 12 to 18 kg/ha of Sulphur. in the experimental plots and also complete RDF of P and K with three replications with a gross plot size of 15.75 m2 (5m × 3.15m) having the total number of plots 30, the details of the treatments are as T1: absolute control, T2: 30 kg/ha Nitrogen + 12 kg/ha Sulphur, T3: 30 kg/ha Nitrogen + 15 kg/ha Sulphur, T4: 30 kg/ha Nitrogen + 18 kg/ha Sulphur, T5: 60 kg/ha Nitrogen + 12 kg/ha Sulphur, T6: 60 kg/ha Nitrogen + 15 kg/ha Sulphur, T7: 60 kg/ha Nitrogen + 18 kg/ha Sulphur, T8: 90 kg/ha Nitrogen + 12 kg/ha Sulphur, T9: 90 kg/ha Nitrogen + 15 kg/ha Sulphur, T10: 90 kg/ha Nitrogen + 18 kg/ha Sulphur. and 90:60:40 kg/ha NPK fertilizer, which is the recommended dosage. At random times during the experimentation's growth and yield, as well as at intervals of 30, 60, and 90 DAS, and at the harvest stage for each treatment, parameters were measured and recorded.

Results and Discussions

Nitrogen application

According to the findings, nitrogen levels affect plant development characteristics such as plant population (m^2), plant height (cm), the number of primary and secondary branches per plant, dry matter accumulation (g), leaf area index (LAI), and plant population (m^2) The highest recorded plant counts at planting and harvest, respectively, were 28.14 and 26.40. The populations of plants do not differ significantly. and Maximum plant height (147.01 cm) was recorded at harvest, along with a higher number of primary and secondary branches (8.79 and 13.09, respectively), maximum leaf area (4.14 cm^2), and the maximum dry matter accumulation (g), which was produced at harvest with 90 kg of nitrogen per hectare but it was at par with to 60 g N/ha, at 126.89 g. with respect to 0 and 30 kg N/ha. With increasing nitrogen levels up to 90 kg N ha^{-1}, these growth characteristics were significantly enhanced. and 90 kg N/ha consistently displayed at parity with 60 kg N/ha. The availability of additional nutrients and a good environment for the mustard plant's growth were probably ensured by 90 kg N ha^{-1}. Increases in plant height, leaf area index, and the number of branches per plant are all morphological expressions of nitrogen-induced cell size growth. As a result of improved chlorophyll synthesis, which expands the region where photosynthesis can occur and produces more dry matter, nitrogen gives leaves their deep green colour. These findings agree with Singh and Kumar *et al.* (2014) [2] The application of 90 kg ha^{-1} produced the highest levels of the yield characteristics, including siliqua $plant^{-1}$, siliqua plant length (cm), siliqua seeds $siliquae^{-1}$, 1000 seed weight (g), and quality parameters, including oil content (%) and oil yield (kg/ha) (Table 1, 2). Maximum number of siliquae (276.91) and longer length of siliqua (4.75 cm), number of seeds $siliqua^{-1}$ (11.02), 1000 seed weight (4.97g), and quality parameters such as maximum oil content (41.08%), oil yield (810.98 kg/ha) were significantly superior to 30 kg N ha^{-1} and control, which was found to be comparable to 60 kg N ha^{-1}.

The maximum grain yield (1882 kg ha^{-1}), stover yield (5226 kg ha^{-1}), and biological yield (7108 kg/ha) significantly at 90 kg N ha^{-1}, and the maximum harvest index (25.72%) was recorded. It is generally understood that nitrogen, as a part of amino acids, proteins, chlorophyll, and protoplast, has a direct influence on growth and yield contributing properties through greater utilization of photosynthates. The application of nitrogen increased the rapeseed-mustard plant's growth and yield characteristics, according to Singh and Kumar *et al.* (2014) [2] report. Acetyl-carrying proteins are employed to synthesize fatty acids from acetyl Co-A when there is insufficient nitrogen available. Because of Co-A, seeds have more oil. Nevertheless, the amount of oil in seeds was decreased as a result of nitrogen treatment. The findings of Singh and Meena *et al.* (2004) [15] are supported by these data.

Sulphur application

Sulphur has been shown to have a considerable impact on mustard plant growth, yield, and quality indices. Sulphur fertilization at an application rate of 18 kg ha^{-1} resulted in considerably greater plant height (cm), leaf area index (LAI), and branches/plant. Sulphur application improved the nutritional environment for plant growth at the active vegetative stage as a result of improvements in root growth, cell multiplication, elongation, and cell expansion in the plant body, which ultimately increased plant height, leaf area index, and branches/plant. Katiyar *et al.*, (2014) [2] found a similar finding. Growth parameters such as (m^2) plant population There is no significant difference between plants when the maximum number of plants (28.11) and (25.93) were recorded initially and during harvest. At harvest, the maximum plant height (147.06 cm) was recorded, as well as the maximum number of primary and secondary branches (8.65 and 13.01, respectively), at 90 DAS, and the maximum leaf area index (4.14), at 90 DAS, and the maximum dry matter accumulation (121.83g) at harvest, as a result of Sulphur application of 18 kg ha^{-1}. It was at par with 15 kg S ha^{-1}. Non-significant growth indices significantly with increasing levels of Sulphur up to 18 kg S ha^{-1} as compared to 12 kg S ha^{-1}, control, 18 and 15 kg S ha^{-1}. The results were always at par with 15 kg S/ha.

The application of Sulphur 18 kg ha^{-1} resulted in the highest yield attributes such as Siliqua $plant^{-1}$, length of siliqua (cm), seeds $siliquae^{-1}$, and 1000 seed weight (g), as well as quality parameters such as oil content (%) and oil yield (kg/ha). The maximum number of siliquae (271.0) and larger siliqua length (4.59 cm), number of seeds $siliqua^{-1}$ (10.51), and 1000 seed weight (4.88g) were considerably higher than 12 kg S ha^{-1}. and control, found to be at par with 15 kg S ha^{-1}, and quality parameters such as maximum oil content (40.89), oil yield (778.18 kg/ha), maximum grain yield (1817 kg ha^{-1}), maximum stover yield (5219 kg ha^{-1}), and biological yield (7103 kg ha^{-1}), increased significantly at 18 kg S ha^{-1}. Harvest index was also recorded (25.59%) at 18 kg S ha^{-1}, which may be due to an increased supply of Sulphur and better translocation of photosynthates, increasing Keivarad and Zandi *et al.* (2012) [6] found a related finding as well.

Table 1: Effect of Nitrogen and Sulphur Levels on growth parameters of Indian Mustard

Treatment	Plant population (m^2)		Plant height at harvest	No of primary and secondary branches $plant^{-1}$		Leaf area index at 90 DAS	Dry matter accumulation (g) at harvest
	Initial	Harvest		at harvest	at harvest		
Nitrogen (kg/ha)							
control	23.96	22.76	117.14	5.07	9.35	3.09	82.04
N_1 -30	24.97	23.29	129.92	6.28	10.71	3.57	101.29
N_2 -60	26.34	25.04	142.84	7.71	12.39	4.12	123.01
N_3- 90	28.14	26.40	147.01	7.82	12.95	4.14	126.89
S.Em±	0.69	0.65	3.67	0.21	0.38	0.12	3.79
CD at 5%	NS	NS	10.91	0.63	1.13	0.37	11.25
Sulphur (kg/ha)							
S_1 -12	24.91	23.78	129.04	6.74	10.99	3.67	108.86
S_2 -15	26.43	25.03	143.68	7.38	11.13	4.05	120.51
S_3-18	28.11	25.93	147.06	7.68	12.93	4.11	121.83
S.Em±	0.69	0.65	3.67	0.21	0.38	0.12	3.79
CD at5%	NS	NS	10.91	0.63	1.13	0.37	11.25
Interaction							
S.Em±	2.06	3.34	6.36	0.37	0.66	0.21	6.56
C.D at 5%	NS	NS	NS	NS	NS	NS	NS

Table 2: Effect of nitrogen and sulphur levels on yield attributes of Indian mustard

Treatment	Siliqua $plant^{-1}$	Siliqua length(cm)	Seed $Siliqua^{-1}$	1000 seed weight(g)	Oil content (%)	Oil yield (kg/ha)	Grain yield (kg/ha)	Biological yield (kg/ha)	Stover yield(kg/ha)	HI (%)
Nitrogen (kg/ha)										
Control	181.94	2.87	6.90	3.64	32.33	395.76	1233	5486	4252	19.82
N_1 -30	217.22	3.50	7.90	4.18	35.77	566.99	1477	6197	4720	22.26
N_2 -60	270.86	4.41	10.97	4.63	40.70	748.44	1751	6944	5156	24.66
N_3 - 90	276.91	4.75	11.02	4.97	41.18	810.98	1882	7108	5226	25.72
S.Em±	8.55	0.13	0.32	0.12	1.27	27.10	47	204	191	0.80
CD at 5%	25.39	0.37	0.95	0.36	3.77	80.52	140	605	566	2.37
Sulphur (kg/ha)										
S_1 -12	230.80	3.81	8.93	4.23	36.00	597.05	1576	6317	4751	22.12
S_2 -15	263.19	4.26	10.45	4.66	40.75	751.18	1717	6829	5112	24.93
S_3-18	271.00	4.59	10.51	4.88	40.89	778.18	1817	7103	5219	2.59
S.Em±	8.55	0.13	0.32	0.12	1.27	27.10	47	204	191	0.80
CD at5%	23.39	0.37	0.95	0.36	3.77	80.52	140	605	566	2.37
Interaction										
S.Em±	14.80	0.22	0.56	0.21	2.20	46.94	81	353	330	1.38
C.D at 5%	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

Conclusion

Based on a one-year field experiment, it was determined that the application of 90 kg N ha^{-1} and 18 kg S ha^{-1} was significant on the growth and yield parameters of Indian mustard, with the absolute control producing the lowest yield.

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