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Effect of nitrogen and sulphur on the performance of the Indian mustard (*Brassica juncea* L.)

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Abstract
An experiment was carried out in an agriculture research farm at The Maharishi University of Information Technology in Lucknow, Uttar Pradesh in 20242025 called Rabi-season. A Factorial Randomized with three replications was used in the study, 20 treatments were grown. The most significant independent variable was nitrogen basing it on five levels of application (0, 40, 60, 80, 100 kg N/ha) whereas the second variable was at four levels of sulphur (0, 30, 35, and 40 kg S/ha). When used at doses of 40 to 100 kg N/ha, higher nitrogen levels were positively correlated with plant height, branching per plant, leaf area index, and total dry-matter production-trends that could not be sustained in most of the yield components by the data. With 100 kg N/ha, the maximum number of plant height, branching per plant, dry-matter production, leaf area index and all yield parameters (grain, stover and total biological yield) were attained. On the other hand, complementarily, 40 kg S/ha yielded the best values of all indicators associated with growth as well as yield parameters.
Economic analysis (gross income, net income and benefitcost ratios) indicated that the combination of 100 kg N/ha and 40 kg S/ha gave rise to the highest returns. These results reveal the interactive relationship between nitrogen and sulphur that influence the characters of crops and yield of crops in a three-replicate experiment carried out in the Uttar Pradesh, India.

Keywords: Indian mustard, *Brassica juncea*, nitrogen, sulphur, nutrient management

Introduction
In winter-sown oilseed crops, Indian mustard (*Brassica juncea* L.) constitutes the greatest source of production during the rabi season in India and is amongst the most influential globally. Being the greatest in size and the third producing country in mustard on the global scene, after China and Canada, India contributes about a quarter of the world production in a mustard and is therefore considered among the major producers of mustard. The combination of rapeseed and mustard encompasses a constituent that has been ranked third on the list of significant global oil seeds with soybean (Glycine max) and palm (*Elaies guineensis*) as the first and second oilseeds respectively. Among seven edible seed producing oils of India, rapeseed and mustard (Brassica spp.) is the source of 28.6% of total oilseeds produced in the country.
The seeds are rich nutritionally with a maximum percentage of 38 erucic acid, 5-13 percent of linoleic acid and 27 percent of oleic acid found in the seeds. The current per capita supply of mustard oil is 19 g per capita per day on average, which is close to 57% of the 33 g per capita per day that medical authorities recommend (Bhowmik *et al.*, 2014) [1]. The use of the fertilizers has been a major contributor to recent growth in oilseed.
Nitrogen is a critical growing and development nutrient of plant growth. It is necessary to the operations of metabolism, the transformation of energy, and to the formation of proteins and nucleic materials, chlorophyll, and protoplasm. A sufficient amount of nitrogen will facilitate the generation of chlorophyll, which increases photosynthetic capacity, dry matter accumulations, and total biomass production (Singh and Kumar 2014) [7].

Sulphur in Increased Yield of Mustard
Sulphur influences tremendously the yield and quality of Indian mustard. Sulphur in combination with other proper amounts of nutrients has been found to enhance soil

characteristics and increase the amount of nutrients (Verma et. al., 2018) [10]. It plays a further role in the biosynthesis of proteins and it is essential to numerous enzyme reactions in every living cell. Sulphur is the key building block in growth and regulation of metabolism as part of amino acids methionine, cysteine, and cystine. The difference in supply of sulphur has found experimental support indicating that it has profound effect on the production of seed and stover of mustard (Sharma *et al*. 2007) [9]. Lack of sulphur or of any of the essential sulphur-bearing amino acids may initiate rather severe disorders of human nutrition and lack of sulphur is wide-spread in the country.

Materials and Methods

It was a study conducted during the Rabi season of 2024-2025 in'the farm of Maharishi University of Information Technology (Lucknow, Uttar Pradesh). In which the field soil was silt-loam, with a pH value of 8.0, total organic carbon of 0.70%, total N, P, and K 270.0 kg ha-, 27.47 kg ha-1, 262.50 kg ha-1 respectively. Nitrogen (N) which was applied at 0,40 60,80 and 100 kg ha-1 3 and sulphur (S) at 0, 30 35 40 kg ha-1 3 were the two most critical factors of treatment.

Several growth parameters including germination percentage, height, root length, accumulation of dry matter, number of grains in siliques, average weight of 1000 grains and harvest index among others and yield observation including yield of grains and yield of straw were calculated during the experimental period. There was also an evaluation of nutrient uptake of the crop. Statistical determinations were done on all parameters. On each of the attributes, the SEM and CD calculated at the 5% level of confidence on treatment means.

Results and Discussion

Growth attributes of plants

Nitrogen treatment also played the major role in the height of seedlings of all the stages of development. The highest observed (166.75 cm) was when the dosage of 100 kg N/ha was applied implying that the application of this essential macronutrient facilitates the occurrence of essential biomolecules that are required during cell division and that of cell elongation and hence increases height. Since the plant height was recorded as higher at earlier stages of growth, this indicates that the availability of nitrogen all the time does not only result in production of more leaves, but also promote photosynthetic rate.

Similarly, in the same line of argument, the use of nitrogen had a great impact on the number of branches per plant, the leaf area index (LAI) and dry matter build-up at each stage of the growth period. The fertilisation in 100 kg N/ha reported the largest number of branches per plant, the LAI and the length of accumulation of dry matter (25.34 g) as reported by Zimik (2010) [11]. The necessity of nitrogen is attested by such findings since its ability to increase the speed of growth does not just promote the growth of the shoot but also permits the formation of a dense canopy.

The Sulphur drastically increased the height of plants during growth period as compared to that of the control. The highest plant height (160. 35 cm) was observed with 40 kg S/ha at all the stages of development. It can be contributed in part to the height increase given better nutritional conditions which were imposed by the use of the S, allowing increases in the acquisition of nutrients, growth of dry material and, as a result, extending the stems. Jhosi *et al*., (1991) and Singh (1975)

There was a maximum of (13.73) live branches at 40 kg S/ha at all stages. Likewise, maximum of dry-matter accumulation (21.79 g/m2) was measured under the same S rate. Singh *et al*., (2002) [8].

Total leaf area index also showed remarkable increment with augmenting S levels at all crop growth phases. The highest LAI (1.64, 4.24, and 3.71) was also recorded at 40 kg S/ha in accordance with the perception that the application of S provokes growth of roots, cell proliferation, elongation, and expansion thus increasing leaf area expansion.

Development studies

Table 5 displays the data concerning the number of days of 50% flowering and maturity. Days to 50% flowering and maturity had a lot of interaction with the rates of application of Nitrogen and Sulphur.

The conversion of days to 50 fascinating flowering was so enormous due to the increment of Nitrogen supply to 100 kg ha-1 although, the highest was recorded on addition of 100 kg N ha-1. On the contrary, in the control treatment, the minimum was observed (55.83 days). The same finding has been seen with maturity which was well marked with treatment of 100 kg N ha-1 taking the longest duration (117.75 days) and under control the least duration (117.75 days). The long reproductive time at high N supply can be attributed to larger increase in vegetative growth resulting in the maturity and flowering delay compared to the treatment without N application.

Flowering and maturity frequencies of up to 50% per day or 50% also had a large linear reduction with the increase of Sulphur dressing of 0 to 40 kg S ha-1 and maximum was achieved when Sulphur was dressed with 60 kg S ha-1. Under the control, the least flowering was (44.93 days) and maturity was (106.13 days). The longer the phases, the greater the Sulphur addition, and this was explained by the higher absorption of Sulphur and other nutrients that ensured healthier vegetative growth which, in its turn, slowed down flowering and maturity in comparison to the situation when Sulphur was not added.

Yield attributes

Experimental results proved that the placement of nitrogen caused a great elevation on all the yield-related parameters. The maximum mean siliquae per plant (247.16), siliquae length (5.23 cm) and seeds per siliquae (12.91) and test weight (5.31g) were reflected at the highest rate of 100 kg N/ha. Enhanced nitrogen addition triggered several biomolecular activities in the division of cells and elongation of cells which subsequently increased the photosynthate and translocation of the produced into the reproductive organs producing high-quality grains.

With the sulphur treated, similar trend could be observed. Application of 40 kg S/ha represented the optimum values on the number of siliquae per plant (211.83), siliquae length (5.04 cm), and seeds per siliquae (11.40) and it gave the optimum test weight (4.92 g). This was in regard to the good availability of sulphur, absorption and subsequent enhancement of plant growth and development.

The grain yield measurements, straw yield measurements, and biological yield measurements and harvest index were obtained during the harvest and analysed statistically as illustrated in Table 4.

Empirical results indicate that use of 100 kg N ha 1 provided the highest grain (25.80 q ha 1), straw (53.32 q ha 1), biological yield (79.12 q ha 1) at the end of the harvest compared to 80 kg N ha 1 (grain, 24.80 q ha 1; straw, 51.14 q ha 1; biological yield, 76.04 q ha 1), 60 kg N ha 1 (grain, 2 It is a compound outcome giving rise to plant growth and their attributes; the enhancement in the attributes so observed as the amount of nitrogen application increased is what leads to the subsequent increment in enhanced yield. The HI was maximum at 30 days after sowing (DAS) at 80 kg N ha1(HI = 32.56 percent) and 60 kg N ha1(HI = 30.24 percent) whereas the least HI value was recorded in the no-nitrogen treatment (HI = 27.19 percent).

On sulphur, the highest grain, straw and organic yield was recorded at the highest rate of sulphur fertiliser: 40 kg S ha 1gave a yield of 21. 10 q ha 1 (grain), 48.80 q ha 1 (straw), and 69.91 q ha 1 (biological) compared to 38.88 q ha 1 (grain), 43.90 q ha 1 (straw), and 82.78 q ha 1 (biological

Among the sulphur-treated plots, the treatment of 40 kg S ha 1 ranked first as the resulting HI was 29.90 at 30 DAS, which is higher than 28.34 of 40 and 18.80 of 10 kg S ha 1. Application of 40 kg S ha 1 also produced more panicles that were much longer and bulky as compared to those volumes that were recipients to lower rates of sulphur.

Oil Content (%)

Variations in oil proportion (%), under the impact of increasing doses of Nitrogen, showed an ascending curve: the largest result (40.60%) was found in the control, whereas 60 kg N/ha, 90 kg N/ha, and 100 kg N/ha delivered the outcomes of 39.09%, 37.15 (%), and 38.12% respectively. These trends are congruent with theoretical prediction that an increase in vegetative growth causes dilution of leaf lipids resulting in a reduction in the proportion of oil. It is especially worth noting that the maximum rate of N application resulted in the lowest oil yield. This means that the most profitable per unit of oil product per area was the treatment of 60 kg N/ha.

As regards sulphur, a higher application level was related to an increased oil content (%) after hydrolysis; that of 41.03 at 40 kg S/ha, 40.15 at 35 kg S/ha, 39.47 at 30 kg S/ha versus 37.68 at 0 kg S/ha. Such findings are not surprising and digress with the logical chemometric and biochemical outcomes of high accessible morphid sulphur into both output and quality variables. With this, 40 kg S/ha was the most effective treatment that produced oil yield of 865.73 kg/ha.

Table 1: Plant growth as affected by the levels of nitrogen and Sulphur.

Treatments	At harvest stage			
	Plant height (cm)	Number of branches/plants	Dry matter accumulation (g plant)	Leaf Area Index
Levels of Nitrogen (Kg ha-1)				
0	142.71	8.33	17.55	3.26
40	151.57	10.50	19.20	3.50
60	155.75	12.00	21.17	3.60
80	159.73	13.66	22.91	3.70
100	166.75	16.25	25.34	3.70
SEM±	0.191	0.151	0.202	0.007
C.D. (P = 0.05)	0.548	0.434	0.581	0.020
Levels of Sulphur (Kg ha-1)				
0	150.84	10.66	20.52	3.26
30	153.68	11.53	21.04	3.47
35	156.36	12.66	21.58	3.61
40	160.35	13.73	21.79	3.71
SEM±	0.171	0.135	0.181	0.007
C.D. (P = 0.05)	0.49	0.388	0.520	0.020

Table 2: Development studies as affected by the levels of nitrogen and Sulphur.

Treatments	Days of 50% flowering	Days taken at Maturity
Levels of Nitrogen (Kg ha-1)		
0	39.75	102.83
40	39.41	104.83
60	46.33	107.00
80	51.83	110.00
100	55.83	117.75
SEM±	0.244	0.146
C.D. (P = 0.05)	0.702	0.419
Levels of Sulphur (Kg ha-1)		
0	44.93	106.13
30	46.00	107.33
35	47.46	109.66
40	48.13	110.80
SEM±	0.218	0.130
C.D. (P = 0.05)	0.628	0.375

Table 3: Yield attributes as affected by the levels of nitrogen and Sulphur.

Treatments	Number of siliquae per plant	Length of siliquae (cm)	Number of seeds per siliquae	Test weight (g)
Levels of Nitrogen (Kg ha-1)				
0	183.17	4.26	8.63	4.20
40	188.07	4.91	9.63	4.38
60	197.83	5.04	10.71	4.51
80	203.62	5.10	11.15	5.16
100	247.16	5.23	12.91	5.31
SEM±	1.304	0.034	0.089	0.027
C.D. (P = 0.05)	3.748	0.102	0.255	0.077

Levels of Sulphur (Kg ha-1)				
0	196.90	4.84	9.91	4.49
30	201.62	4.94	10.32	4.67
35	205.54	4.80	10.80	4.77
40	211.83	5.04	11.40	4.92
SEM±	1.167	0.030	0.079	0.024
C.D. (P = 0.05)	3.353	0.091	0.228	0.069

Table 4: Yield characters as affected by different levels of Nitrogen and levels of Sulphur.

Treatments	Seed yield (q/ha)	Stover yield (q/ha)	Biological yield (q/ha)	Harvest index (%)
Levels of Nitrogen (Kg ha-1)				
0	14.64	39.21	53.86	27.19
40	18.03	45.49	64.52	27.93
60	19.85	49.25	69.10	28.72
80	22.85	51.04	73.17	30.24
100	25.80	53.32	79.12	32.56
SEM±	0.084	0.131	0.152	0.097
C.D. (P = 0.05)	0.242	0.377	0.436	0.279
Levels of Sulphur (Kg ha-1)				
0	19.25	47.04	66.30	28.87
30	19.70	47.54	67.25	29.09
35	20.31	48.05	68.37	29.46
40	21.10	48.80	69.91	29.90
SEM±	0.075	0.337	0.136	0.087
C.D. (P = 0.05)	0.217	0.117	0.436	0.250

Table 5: Oil content (%) and Oil yield (kg/ha) as affected by different levels of Nitrogen and levels of Sulphur.

Treatments	Oil content (%)	Oil yield (kg/ha)
Levels of Nitrogen (Kg ha-1)		
0	40.60	594.38
40	39.28	708.21
60	38.81	770.37
80	38.29	874.92
100	38.12	983.49
SEM±	0.016	2.947
C.D. (P = 0.05)	0.046	8.553
Levels of Sulphur (Kg ha-1)		
0	37.68	725.34
30	38.51	758.64
35	39.76	807.52
40	41.03	865.733
SEM±	0.012	2.566
C.D. (P = 0.05)	0.036	6.533

Conclusion

In the conclusion drawn below, the findings discussed in the above chapter are synthesized.

- Significantly, the use of nitrogen rate of 100 kg/ha generated the highest grain and stalk yield and generated the highest net income plus the benefit: cost ratio.
- Crops applied 40 kg S/ha had highly superior grain weight, stalk weight, net income and benefit: cost ratio.

Recommendation

Critical review of past results is explicit in the finding that under the Central Plain Zone in the state of Uttar Pradesh, 100 kg N/ha + 40 kg S/ha is the ideal use that can be used to achieve the maximum production, net income and economic efficiency (benefit: cost) of mustard oil seed.

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