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Effect of nitrogen and sulphur levels on growth attributes and yield of mustard (*Brassica juncea* L.) grown in vertisol

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Abstract
A field experiment in factorial randomized block design (FRBD) with 3 replication and 9 treatment combinations was conducted at the AICRP of Mustard, College of Agriculture, Nagpur (Maharashtra) during the Rabi season of 2023-24 at research farm. The treatments included three levels of nitrogen (50, 65, and 80 kg N ha^{-1}) and three levels of sulphur (15, 30, and 45 kg S ha^{-1}). The results showed that, different nitrogen and sulphur levels had substantial effects on growth parameters such as plant height at 50% flowering stage (cm), number of siliqua $plant^{-1}$, weight of siliqua $plant^{-1}$, number of days taken for 50% flowering, 1000 seed weight (g), Yield of seed, straw yield, biological yield and harvesting index. However, the highest seed production (1225.11 kg ha^{-1}) was achieved with the application of 80 kg N ha^{-1}, which was significantly superior to lower levels 50 kg N ha^{-1} and which is at par with 65 kg N ha^{-1}. In comparison to sulphur levels, sulphur level 45 kg ha^{-1} produced the highest number of siliqua $plant^{-1}$, weight of siliqua $plant^{-1}$, 1000 grain weight (g) and maximum grain output (1201.56 kg ha^{-1}) were recorded.

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

Introduction
Mustard (*Brassica juncea*) commonly called as ‘Sarson' or 'Rai’ is an important edible rabi oilseed crop of India, ideally grown on 6.86 million ha area, Mustard has become an integral part of cropping system and being raised after rice, maize, pearl millet, urad bean, groundnut, and sunflower in various states. It contains about 37 to 49 percent oil in the seed low cost of production and high yield of potentials, hold promise for its large scale cultivation in the country.

Among oilseeds, mustard occupies a prestigious position and ranks second after soybean in area and production, contributing 18 per cent of total oilseed production. India has attained a record food grain production of 305.44 million tonnes during 2020-21. The total oilseeds production is expected to be 36.57 million tonnes during 2020-21. The rapeseed-mustard acreage increased from 6.12 m ha (2018-19) to 6.86 m ha (2019-20). However, production got slightly decreased from 9.26 mt (2018-19) to 9.12 mt (2019-20). The important mustard growing countries of the world are India, China, Canada, France, Poland and Pakistan. Canada being the 1st in terms of production followed by China and India. 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. Major states in India producing mustard are Rajasthan, Punjab, Haryana, Uttar Pradesh, Madhya Pradesh, West Bengal and Gujarat. 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. Area under mustard cultivation in Maharashtra was 11800 hectares with production of 3900 tonnes seed with an average productivity of 330 kg ha^{-1} (Anonymous, 2021) [1, 2] As much as 90 percent of total edible oil produced in our country comes from two oilseed crops namely mustard and groundnut. Fertilizers have played a significant influence in improving oilseed crop production. 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. 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 is the fourth main plant nutrient for all oilseed crops due to its importance in growth, development, and oil production. It is essential for the plants physiological and metabolic activities and also, Sulphur is important source for activation of enzymes, formation of chlorophyll, glucosinolate content in mustard, additionally it is also play role in increasing yield parameters of mustard and remarkable effect on oil content, fatty acid and glucosinolate in mustard (Ray *et al.* 2015) [15].

Methods and Materials

During the rabi season of 2023-2024, experiment was conducted at research farm of AICRP of Mustard, College of Agriculture, Nagpur (Maharashtra). The research site has sub-tropical climate with dry conditions prevailing for most of the year. An average annual rainfall of 1064.1 mm. The mean annual temperature of the region is 25.9ºC. The average maximum temperature is 33.70ºC in *Kharif* (June-Sept), 27.50 °C in *Rabi* (Oct-Jan) and 38.80ºC in *summer* (Feb-May). May is generally hottest month with maximum temperature reaching above 45 °C for a short period of 5 to 10 days. Whereas minimum temperature varies between 8ºC to 30.80ºC and humidity ranges from 26.4 to 94.1 percent. 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 clayey, with accessible soil nutrients (N, P, K and S) total of 253.28, 18.42 and 344.00 kg ha^{-1}, 9.51 mg kg^{-1}, as well as soil organic carbon 5.21 g kg^{-1} and pH of soil 7.93 at the time. The experiment was set up using a factorial randomized block design (FRBD), with 9 treatments combination with 3 nitrogen levels of 50, 65 and 80 kg N ha^{-1} and 3 sulphur levels of 15, 30 and 45 kg ha^{-1} with three replications having gross plot size of 18 m^2 (4.5 x 4.0 m) and total 27 plots. The results obtained was statistically analysed as per methods suggested by Gomez and Gomez (1984) [6].

Results and Discussion

Effects of Nitrogen and sulphur application on ancillary data of mustard

An examination of data in Table 1. on plant height at 50% flowering stage, number of days for 50% flowering, weight of siliqua $plant^{-1}$ and number of siliqua $plant^{-1}$ of mustard.

Plant height at 50% flowering stage

Result revealed that, the plant height at 50% flowering stage of mustard increased significantly with the applications of 80 kg nitrogen ha^{-1} as compared to other treatments. Similarly, plant height at 50% flowering stage increased significantly with successive increase in the levels of sulphur. Increase in plant height at 50% flowering stage obtained by applications of (133.73 cm) 80 kg nitrogen ha^{-1} as compared to other treatments (127.40 cm) 65 kg nitrogen ha^{-1} and (123.67 cm) 50 kg nitrogen ha^{-1}.Similar result were found by Pagaria *et al.* (2019) [12] done a field demonstration and revealed maximum mean plant height of mustard (115.3 cm) on application of bentonite Sulphur than control (101.4 cm), Jat *et al.* (2012) [7], Mohiuddin *et al.* (2011) [10]. Increase in plant height at 50% flowering stage obtained by applications of (130.20 cm) 45 kg sulphur ha^{-1} as compared to other treatments (125.93 cm) 15 kg sulphur ha^{-1} and (128.67 cm) 30 kg sulphur ha^{-1}. Interaction effect of nitrogen and sulphur found statistically non- significant. The maximum values were obtained with the combined application of 80 kg nitrogen $ha^{-1}$and 45 kg sulphur ha^{-1}.

Weight of siliqua $plant^{-1}$ (gm)

Increase in weight of siliqua $plant^{-1}$ obtained by application of (14.18) 80 kg nitrogen ha^{-1} as compared to other treatments (13.67) 65 kg nitrogen ha^{-1} and (13.01) 50 kg nitrogen ha^{-1}. Similarly, highest weight of siliqua $plant^{-1}$ was obtained (13.86) by application of 45 kg sulphur ha^{-1} as compared to other treatments (13.26) 15 kg sulphur ha^{-1} and (13.75) 30 kg sulphur ha^{-1}. Data pertaining the interaction effect of nitrogen and sulphur levels on weight of siliqua $plant^{-1}$ presented in Table 1. It is evident from the table that, effects of both nitrogen and sulphur were found statistically significant.

Number of days for 50% flowering

Number of days for 50% flowering were taken by the mustard through the application of (41.36 days) 80 kg nitrogen ha^{-1} lesser than other treatments (42.09 days) 65 kg nitrogen ha^{-1} and (45.13 days) 50 kg nitrogen ha^{-1}. Similarly, increases in application of sulphur required less number of days for 50% flowering, while number of days for 50% flowering were taken by the mustard through the treatment (42.38) 45 kg sulphur ha^{-1} lesser than other treatments (43.33) 15 kg sulphur ha^{-1} and (42.87) 30 kg sulphur ha^{-1} and the combine effect of nitrogen and sulphur was found statistically non- significant. Similar, results were revealed by Alam *et al.* (2014) [4], Kumar *et al.* (2018) [8].

Number of siliqua $plant^{-1}$

Increase in number of siliqua $plant^{-1}$ were obtained by application of (257.76) 80 kg nitrogen ha^{-1} highest as compared to other treatments (241.67) 65 kg nitrogen ha^{-1} and (221.38) 50 kg nitrogen ha^{-1}. Similarly, number siliqua $plant^{-1}$ obtained by application of (245.40) 45 kg sulphur ha^{-1} higher as compared to other treatments (234.87) 15 kg sulphur ha^{-1} and (240.53) 30 kg sulphur ha^{-1} and the interaction effect of nitrogen and sulphur levels on the number of siliqua $plant^{-1}$ found statistically significant. Similar result was found by Jat *et al.* (2023) [3].

Effect of nitrogen and sulphur on yield of mustard

An examination of data in Table 2. on test weight, seed yield, stover yield, biological yield and harvest index of mustard.

Test weight (1000 seed weight)

In the case of 1000 seed weight, significant variation observed among all treatment, the highest test weight was obtained with application of (4.15 gm) 80 kg nitrogen ha^{-1} which was found to be at par with application of (3.92 gm) 65 kg nitrogen ha^{-1}. The significant increase in test weight of mustard was recorded with the increase supply of nitrogen. The highest test weight of mustard (3.97 gm) was recorded with the application of 45 kg S ha^{-1} over (3.58 gm) 15 kg S ha^{-1} which was found to be at par with the application of 30 kg sulphur ha^{-1} (3.70 gm) and the interaction effect of nitrogen and sulphur was found statistically significant. Similar result obtained by Yadav *et al.* (2014) [20], Kumar *et al.* (2016) [9].

Table 1: Effects of nitrogen and sulphur levels on growth parameters of mustard.

Treatment	Plant height at 50% flowering	Number of days for 50% flowering	Number of siliquae	Weight of siliqua plant^{-1}
Levels of nitrogen				
N1 (50 kg Nitrogen ha^{-1})	123.67	45.13	221.38	13.01
N2 (65 kg Nitrogen ha^{-1})	127.40	42.09	241.67	13.67
N3 (80 kg Nitrogen ha^{-1})	133.73	41.36	257.76	14.18
SE	1.58	1.4	2.49	0.14
CD at 5%	4.75	NS	7.46	0.43
Levels of Sulphur				
S1 (15 kg Sulphur ha^{-1})	125.93	43.33	234.87	13.26
S2 (30 kg Sulphur ha^{-1})	128.67	42.87	240.53	13.75
S3 (45 kg Sulphur ha^{-1})	130.20	42.38	245.40	13.86
SE	1.58	1.4	2.49	0.14
CD at 5%	NS	NS	7.46	0.43
Interaction (Nitrogen X Sulphur)				
SE	2.74	2.43	4.31	0.25
CD at 5%	NS	NS	12.93	0.74

Seed yield (kg ha^{-1})

The highest seed yield of mustard (1225.11 kg ha^{-1}) was obtained with application of 80 kg nitrogen ha^{-1}, (1184.33 kg ha^{-1}) and which was found to be at par with application of 65 kg nitrogen ha^{-1}. The significant increase in seed yield of mustard was recorded with the increase supply of nitrogen. Similar results were reported by Neha *et al.* (2012) [11]. The results revealed that, maximum seed and stover yield, yield attributes and growth characters of mustard. Response of sulphur to seed yield of mustard was significant with increasing levels of sulphur. The highest seed yield of mustard (1201.56 kg ha^{-1}) was recorded with the application of 45 kg S ha^{-1} over 15 kg S ha^{-1} (1106.11 kg ha^{-1}) and which was found to be at par with the application of 30 kg sulphur ha^{-1} (1166.67 kg ha^{-1}). Interaction between the nitrogen and sulphur found statistically significant and the maximum seed yield was obtained with the combined application of nitrogen and sulphur at the rate of 80 kg N ha^{-1} and 45 kg S ha^{-1}. Similar results were reported by Tetarwal *et. al* (2013) [18] seed and stover yield increased significantly up to 30 kg S ha^{-1}. Also, Solanki *et al.* (2015) [17].

Stover Yield (kg ha^{-1})

The stover yield of mustard was significantly increased with increase in nitrogen levels. The highest stover yield (2971.35 kg ha^{-1}) was obtained with the application of nitrogen 80 kg ha^{-1} which was significantly superior over 50 kg ha^{-1} (2588.79 kg ha^{-1}) and which was found to be at par with 65 kg ha^{-1} (2874.42 kg ha^{-1}) of nitrogen application. i.e. significantly increased the straw yield over lower level of nitrogen. Similar finding were also reported by Verma *et al.* (2018) [19], Rajput *et al.* (2018) [13].

Application of sulphur significantly influenced the stover yield of mustard. The highest stover yield (2915.78 kg ha^{-1}) was recorded with 45 kg sulphur ha^{-1} which was significantly superior over 15 kg ha^{-1} (2687.74 kg ha^{-1}) and found to be at par with 30 kg sulphur ha^{-1} (2831.44 kg ha^{-1}). Interaction between the nitrogen and sulphur found statistically significant.

Similar results were also recorded by Raman and Trivedi (2012) [14] revealed that, the seed and straw yield of mustard increased significantly with each successive increase in the levels of applied Sulphur, the application of 20, 40 and 60 kg ha^{-1} increase seed yield over the control by 13.9, 28.1 and 28.6% respectively on an average of 2 years. Also, Singh and Singh (2022) [16].

Biological yield

In the case of biological yield and the combine effect of nitrogen and sulphur was found significant. Therefore, the highest yield was obtained (4196.46 kg ha^{-1}) with 80 kg Nitrogen ha^{-1} and (4117.34 kg ha^{-1}) 45 kg sulphur kg^{-1} which is at par with (4059.15 kg ha^{-1}) 65 kg Nitrogen ha^{-1} and (3998.11 kg ha^{-1}) 30 kg sulphur kg^{-1}

Harvest index

Harvest index increases with increase in the application nitrogen and sulphur upto 80 kg nitrogen ha^{-1} and 45 kg sulphur ha^{-1} therefore, the highest value was obtained (29.20%) with application of 80 kg Nitrogen ha^{-1} and (29.18%) 45 kg sulphur kg^{-1} followed by (29.18%) 65 kg Nitrogen ha^{-1} and (29.18%) 30 kg sulphur kg^{-1} and the interaction effect of nitrogen and sulphur was found statistically non-significant. These results are in conformity with the findings of Gill *et al*. (2021) [5].

Table 2: Effects of nitrogen and sulphur levels on yield attributes of mustard.

Treatments	Test weight	Seed yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest Index%
Treatment					
Levels of nitrogen					
N1 (50 kg Nitrogen ha^{-1})	3.18	1064.89	2588.79	3653.68	29.15
N2 (65 kg Nitrogen ha^{-1})	3.92	1184.33	2874.42	4059.15	29.18
N3 (80 kg Nitrogen ha^{-1})	4.15	1225.11	2971.35	4196.46	29.20
SE	0.05	16.0	39.2	55.12	0.03
CD at 5%	0.15	48.0	117.4	165.24	NS
Levels of Sulphur					
S1 (15 kg Sulphur ha^{-1})	3.58	1106.11	2687.74	3793.85	29.15
S2 (30 kg Sulphur ha^{-1})	3.70	1166.67	2831.44	3998.11	29.18
S3 (45 kg Sulphur ha^{-1})	3.97	1201.56	2915.78	4117.34	29.18
SE	0.05	16.00	39.2	55.12	0.03
CD at 5%	0.15	48.00	117.4	165.24	NS
Interaction (Nitrogen X Sulphur)					
SE	0.09	27.8	67.8	95.46	0.05
CD at 5%	0.26	83.2	203.4	286.20	NS

Conclusion

The application of nitrogen up to 80 kg ha^{-1} and sulphur up to 45 kg ha^{-1} significantly increased the grain and stover yield of mustard and variation in growth attributes was recorded which is at par with 65 kg N and 30 kg S kg ha^{-1}.

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