EFFECT OFNITROGENANDSULPHURLEVELSONGROWTHATTRIBUTESANDYIELD OF INDIAN MUSTARD [*Brassica juncea*(L.) Czern&Coss] IN VINDHYA PLATEAUREGIONOFMADHYAPRADESH

Abstract

In the Rabi season of 2022, a field experiment was conducted in the Vindhya plateau region of Madhya Pradesh at the agricultural field of SAGE University Bhopal. The objective was to investigate the impact of nitrogen and sulfur nutrition on the growth and yield of Indian mustard (Brassica juncea L.). The experimental soil, characterized as sandy loam with a slightly alkaline pH, exhibited good drainage. Despite having a moderate amount of available phosphorus and potassium, the soil had low levels of organic carbon and nitrogen, with a low electrical conductivity of 1.65 dS/m (1:2, soil: water).

The experiment comprised 27 nitrogen and sulfur treatment combinations in a split-plot design with three replications. The treatments included three nitrogen levels (100, 120, and 140 kg ha-1) and three sulfur levels (20, 40, and 60 kg ha-1). The mustard variety Giriraj was cultivated, and the study focused on evaluating the effects of these treatments on growth, yield, and nutrient uptake.

Results indicated that various mustard crop attributes, such as plant height, number of green leaves-1, branches plant-1, siliqua plant-1, seeds siliqua-1, and 1000 seed weight, as well as yields (biological, seed, and oil yield), exhibited significant increases with rising nitrogen levels from 100 kg N ha-1 to 140 kg N ha-1. Similarly, applying 60 kg S ha-1 resulted in maximum plant height, number of green leaves, dry matter production, oil yield, and the highest net returns among sulfur levels.

The combination of 140 kg N ha-1 and 60 kg S ha-1 proved to be cost-effective, leading to increased yields, net returns, and a higher B:C ratio compared to other nitrogen and sulfur levels. Therefore, this study recommends the application of 60 kg S ha-1 and 140 kg N ha-1 for enhancing mustard crop yields, net returns, and the benefit-cost ratio.

Keyword- Mustard crop nutrition study, Nitrogen and sulfur effects on Indian mustard, Field experiment in Madhya Pradesh Rabi season, Crop growth and yield attributes, Optimal nitrogen and sulfur levels for mustard, Cost-effective mustard crop management, Net returns and B:C ratio in mustard cultivation, Sustainable nutrient application for increased yields.

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Introduction

Indian mustard (Brassica juncea L.), a member of the Cruciferae family, holds significant importance as one of the foremost oilseed crops. Currently securing the third position globally in both production and cultivated area, it stands as the second most crucial edible oilseed crop in India, contributing to nearly 30% of the country's total oilseed production. In terms of rapeseed mustard cultivation, India leads globally in area and holds the second position in production, following China, solidifying its position as one of the largest producers worldwide.

Rapeseed and mustard exhibit an oil content ranging from 33% to 46%, with average oil recovery falling between 32% and 38%. This places them among the high-yielding oilseed crops. The extraction of oil from these seeds yields rapeseed/mustard meal, a vital component in the production of feed for both cattle and poultry. With its substantial production and versatile applications, Indian mustard plays a pivotal role in the agricultural landscape and the overall oilseed industry in India.

Projected for 2023, the demand for mustard oilseeds is expected to reach 11.5 million metric tons (Mt). Rapeseed, mustard, groundnut, linseed, castor, safflower, and Niger collectively occupy 13% of the annual cropped area, as per the Ministry of Agriculture and Farmers'

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Welfare. Notably, India has witnessed a substantial increase in rapeseed and mustard production over the past eight years, surging from 61.64 million tons in 2010-11 to 72.42 million tons in 2018-19. Productivity has seen a rise from 1840 kg ha-1 in 2010-11 to 1980 kg ha-1 in 2018-19. In the fiscal year 2019-20, India recorded an average yield of 1.4 tons per hectare (Kalia et al., 2021). Projections for the year 2022-2023 indicate an estimated average productivity of 1203 kg/ha, resulting in a total mustard production of 115.25 lakh tons.

Comment [PS3]: Give recent data

Contrary to the Ministry of Agriculture's estimate of 98.02 hectares, the anticipated rapeseed and mustard acreage for 2022-2023 in India is 95.77 lakh hectares, according to the Solvent Extractor Association (SEA). This reveals a notable difference in the estimated acreage, emphasizing the importance of accurate agricultural assessments for planning and resource allocation.

Sulphur (S) is a vital element for the synthesis of proteins, enzymes, vitamins, and chlorophyll in plants. Its significance extends to legume nodule formation and effective nitrogen fixation. Sulphur is an integral component of various amino acids and vitamins present in both plants and animals. Notably, protein synthesis, particularly the formation of oils within seeds, is contingent upon an ample supply of sulphur. Consequently, the sulphur content in food plays a crucial role in determining its nutritional value. In India, 41% of the soil is deficient in sulphur.

Plants deprived of sulphur exhibit distinctive signs, such as pale green leaves, initially noticeable in younger leaves and progressing to the entire plant taking on a light yellow-green appearance. The application of sulphur significantly influences the yield characteristics, overall yield, and oil content of oilseeds to realize their potential. For rapeseed mustard, a sufficient supply of sulphur facilitates the synthesis of essential amino acids, proteins, and oils. In soils lacking sulphur, even with additional nutrients or improved crop management practices, the full yield potential of mustard cannot be achieved, as emphasized by Singh and Singh in 2018. This underscores the critical role sulphur plays in maximizing crop productivity and nutritional value.

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Methodology

During the Rabi season in 2022, the field experiment was carried out at the agricultural field of SAGEuniversity Bhopal (M.P). The experiment was conducted using a three-replication Split plot design(SPD). There were three nitrogen concentrations— 100,120 and 140kg ha^{-1}—and three sulphurconcentrations— 20,40 and 60 kg ha^{-1} in the treatment. The experimental field soil was sandy loam intexture, slightly alkaline, and well-drained. It had a low electrical conductivity (1:2, soil: water) at adS/mof1.65andamediumlevelofavailablephosphorusandpotassium.Growth,yield,andeconomics as influencedbyvarious treatments wereevaluated.Themustardvarietywas Giriraj.

Results and Discussion

Nitrogenapplication

The application of nitrogen fertilizer significantly influences the growth and yield characteristics of plants across various stages of crop development, notably impacting mustard seed yield. Elevating nitrogen fertilization rates has a pronounced effect on multiple growth parameters, including plant height, the number of green leaves-1, branches plant-1, siliqua plant-1, seeds siliqua-1, and 1000 seed weight. Marked increases in dry matter per plant were observed with higher doses of nitrogen application, leading to a substantial enhancement in yields, encompassing biological, seed, and oil yield. The positive impact of nitrogen levels was evident in the progressive rise of these growth parameters up to 140 kg N ha-1.

Comment [PS5]: Add plant

The application of 140 kg N ha-1 likely ensured the availability of additional nutrients and favorable conditions for robust mustard plant growth. Nitrogen played a pivotal role in enlarging cell size, as evidenced by the heightened plant height, number of leaves/plants, and branches/plant. The incorporation of nitrogen resulted in a darker green tone in leaves, attributed to improved chlorophyll amalgamation, thereby expanding the effective area of photosynthesis and consequently increasing dry matter. These findings align with the observations of Singh and Kumar (2014), reinforcing the substantial impact of nitrogen fertilization on mustard crop growth and yield.

The application of 140 kg ha-1 demonstrated the most pronounced impact on the number of siliqua plant-1, siliqua length, and seeds per siliqua in Indian mustard. The rationale behind the expectation of improvements in growth and yield characteristics with nitrogen application lies in its role as a constituent of proteins, amino acids, chlorophyll, and protoplasts. It is well-established that an increased utilization of photosynthates, facilitated by nitrogen, directly influences the growth and yield attributes of Indian mustard.

Singh and Kumar (2014) [10] previously noted that nitrogen application enhances the growth and yield characteristics of rapeseed mustard. In the current study, the application of nitrogen resulted in a significant increase in both biological yield and yields of seeds and stover. Notably, the optimum yield, encompassing biological, seed, and Stover yield, was achieved with the application of 140 kg N ha-1. This heightened yield may be attributed to nitrogen's substantial role in chlorophyll and amino acid synthesis, fundamental components of proteins.

Through a source-sink relationship, nitrogen not only influenced seed yield by increasing photosynthetic production but also enhanced translocation to reproductive parts. Recognized as one of the essential nutrients for plant growth and development, nitrogen has been reported to boost the yield of Brassica species, as indicated by Singh et al. (2002) [7]. Furthermore, the oil yield of mustard demonstrated a significant increase with the elevation of nitrogen levels from 100 to 140 kg N ha-1, aligning with similar findings reported by Singh et al. (1992).

Sulphurapplication

Reports indicate that the application of sulphur fertilizer significantly influences various parameters related to the growth, yield, and quality of mustard plants. Employing a sulphur treatment at a rate of 60 kg ha-1 resulted in notably greater plant height, number of leaves/plant, and branches/plant compared to lower sulphur application dosages. The application of sulphur created a more favorable nutritional environment for plant growth during the active vegetative stage, enhancing root growth, cell multiplication, elongation, and cell expansion in the plant body. Consequently, there was a substantial increase in plant height, number of leaves/plants, and branches/plant, with the improvement in these growth parameters likely attributable to the enhanced nutritional conditions facilitated by sulphur.

This observed impact on plant growth aligns with similar findings reported by Katiyar et al. (2014) [3]. The reported outcomes emphasize the crucial role of sulphur fertilization in promoting the overall growth and development of mustard plants, particularly during the active vegetative stage.

The peak accumulation of dry matter was achieved with the application of 60 kg S ha-1, indicating an increase in sulphur application. This could be attributed to the enhanced growth characteristics of mustard facilitated by sulphur, resulting in leaves exhibiting a rich green color due to improved chlorophyll synthesis. The deep green hue contributed to an expanded effective area for photosynthesis, ultimately leading to a higher accumulation of dry matter. These findings align with the observations of Singh et al. (2002) [7], reinforcing the positive impact of sulphur application on mustard plant growth and chlorophyll synthesis.With the incremental application of sulphur up to 60 kg S ha-1, there was a notable increase in yield-attributing characteristics such as the number of siliqua, siliqua length, seeds per siliqua, and 1000 seed weight. Sulphur played a key role in enhancing both primary and secondary branches, which bear siliqua-carrying organs, particularly in the terminal flowers. Consequently, the number of siliqua plants increased, correlating with the number of branches. Mustard plants well-supplied with sulphur exhibited a moderately larger photosynthesizing region, leading to the accumulation of higher amounts of photosynthates. These were then transported to sink sites, such as siliqua and seeds, resulting in an increase in siliqua size, number of seeds per siliqua, and seed weight. This observation aligns with findings reported by Rao et al. (2013) [4].

The seed yield demonstrated a steady increase from 20 to 60 kg S ha-1, reaching its maximum at the latter rate of sulphur application. This increase in seed yield can be attributed to the overall positive impact on yield and enhanced plant growth due to sulphur application. The recorded increase in yield attributes, including siliqua per plant, seeds per siliqua, 1000 seed weight, and siliqua seed length, significantly contributed to the seed yield with sulphur fertilization.

Higher values for stover, biological yield, and harvest index were also noted at 60 kg S ha-1, possibly indicating an increased sulphur supply and improved photosynthetic movement to seeds, thereby enhancing the harvest index. These findings are consistent with the results reported by Rao et al. (2013) [4].

The application of sulphur had a substantial impact on increasing both the oil content and oil yield of mustard seeds, with the maximum effect observed at 60 kg S ha-1. Sulphur plays a crucial role in activating enzymes and promoting the production of glycosides and glucosinolates, contributing to heightened oil production during hydrolysis and biochemical reactions within the plant. Additionally, sulphur influences the generation of alkyl isothiocyanate, responsible for the pungency of mustard. The observed increase in oil content and yield can be attributed to these biochemical processes.

Oil yield, being the combined outcome of seed yield and oil content, reached its peak at the application rate of 60 kg S ha-1. This suggests that the optimal sulphur supply had a synergistic effect on both seed yield and oil content, leading to the highest oil yield. These results closely align with the findings reported by Sah et al. (2013) [6], reinforcing the significant impact of sulphur application on mustard seed oil content and oil yield.

Table-

1Growthattributesofmustard

Nitrogenlevelskg/ha

Treatments (kg/ha)	Plant height (cm)	No. of Green leavesplant^{-1}	No.ofPrimarybranchesplant^{-1}	No. of Secondarybranchesplant^{-1}	Dry matteraccumulationplant^{-1}(g/plant)
100	186.71	29.36	7.53	10.14	55.21
120	189.09	32.62	8.32	10.61	59.25
140	193.74	35.63	8.97	11.49	72.31
SE m±	0.65	0.28	0.10	0.06	0.05
CD at5%	2.56	1.13	0.39	0.23	0.19

Sulphurlevelskg/ha

Comment [PS6]: Get in one line

Comment [PS7]: Put all in one table

Treatments (kg/ha)	Plant height(cm)	No.ofGreenleavesplant^{-1}	No. of Primarybranchesplant^{-1}	No. of Secondarybranchesplant^{-1}	Dry matteraccumulationplant^{-1}(g/plant)
20	188.1	31.63	7.92	10.41	62.34
40	189.72	32.65	8.31	10.67	62.77
60	191.62	33.53	8.64	11.03	63.3
SE m±	0.40	0.25	0.06	0.11	0.07
CD at5%	1.24	0.79	0.21	0.35	0.21

Table-

2YieldattributesandyieldNitrogenl

evelskg/ha

Treatments(kg/ha)	Numberofsiliqua/plants	Siliqua length (cm)	Number ofseeds/siliqua	1000 seedweight(g)	Seedyield(q ha $^{-1}$)	Stovery ield (qha^{-1})	Biological yield(qha^{-1})	Harvest index(%)
100	229.21	5.06	11.16	5.07	15.43	54.51	69.96	22.05
120	258.54	5.52	11.87	5.47	17.03	58.03	75.07	22.68
140	267.54	5.82	12.35	5.78	19.61	62.06	81.66	23.97
SE m±	0.94	0.0 5	0.06	0.0 4	0.20	0.26	0.39	0.20
CD at5%	3.70	0.21	0.21	0.17	0.80	1.02	1.55	0.81

Sulphurlevels(kg/ha)

Treatments (kg/ha)	Numberofsiliqua/plants	Siliqua length (cm)	Numberofseeds/siliqua	1000 seedweight(g)	Seed yield (qha^{-1})	Stover yield(qha^{-1})	Biological yield(qha^{-1})	Harvest index(%)
20	249.32	5.25	11.51	5.25	16.42	57.05	73.51	22.27
40	252.15	5.48	11.86	5.44	17.24	58.10	75.37	22.83
60	254.54	5.83	12.04	5.63	18.10	59.16	77.31	23.38
SE m±	0.66	0.11	0.05	0.04	0.17	0.23	0.36	0.16
CD at5%	2.03	0.34	0.15	0.14	0.52	0.72	1.11	0.49

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Table-

3LaboratorystudiesNitroge

nlevelskg/ha

Comment [PS9]: Put in tabular form

Treatments(kg/ha)	Oilcontentinseed(%)	Oilyield(kgha^{-1})
100	36.37	530.11
120	37.26	620.22
140	38.46	721.75
SE m±	0.007	7.61
CD at5%	0.03	29.89

Sulphurlevelskg/ha

Treatments(kg/ha)	Oilcontentinseed(%)	Oilyield(kgha^{-1})
20	37.36	615.82
40	37.67	651.62
60	37.95	689.21
SE m±	0.007	6.22
CD at5%	0.024	19.17

Table4:Economicsofmustardcropasinfluencedbyvariousnutrientmanagementtreatments.Nitrogen levels

Treatments(kg/ha)	Variable cost (Rsha-1)	Totalcostof cultivation (Rsha-1)	Gross return (Rsha-1)	Net return(Rs ha-1)	B:C
100	3996.03	69548.43	92349	22800.57	4.14
120	4256.43	69827.06	101760	31932.94	4.26
140	4516.83	70105.68	116784	46678.32	4.46
SEm±	-	-	1221	1221	0.018
CDAT5%	-	-	4794	4794	0.069
Interaction	NS	NS	NS	NS	NS

Sulphurlevels

Treatments(kg/ha)	Variable cost (Rsha-1)	Totalcostofc ultivation(R sha-1)	Gross return (Rsha-1)	Netreturn (Rsha-1)	B:C
20	2756.43	68222.06	98167	29944.94	4.31
40	4256.43	69827.06	103053	33225.94	4.28
60	5756.43	71432.06	108048	34615.94	4.25
SEm±	-	-	1232	1232	0.018
CDAT5%	-	-	3797	3797	0.055
Interaction	NS	NS	NS	NS	NS

Comment [PS10]: Put in one table

Conclusion

The application of nitrogen fertilizer has proven to be a crucial factor influencing the growth and yield characteristics of Indian mustard plants. Elevated nitrogen levels, particularly at 140 kg N ha-1, resulted in significant improvements in various parameters such as plant height, number of leaves and branches per plant, siliqua and seed production, as well as 1000 seed weight. The positive impact of nitrogen on dry matter accumulation and subsequent enhancement in biological, seed, and oil yield underscore its pivotal role in promoting robust mustard plant growth.

Furthermore, the source-sink relationship established by nitrogen was instrumental in increasing photosynthetic production, influencing seed yield, and enhancing translocation to reproductive parts. The substantial role of nitrogen in chlorophyll and amino acid synthesis, fundamental components of proteins, contributed to the observed heightened yields. These findings align with previous studies, emphasizing the significant influence of nitrogen fertilization on rapeseed mustard growth and yield.

Similarly, the application of sulphur fertilizer demonstrated a significant impact on various growth parameters, yield attributes, and quality characteristics of mustard plants. A sulphur treatment at 60 kg ha-1 emerged as the optimal dosage, leading to increased plant height, leaves and branches per plant, as well as enhanced root growth and cell multiplication during the active vegetative stage. This resulted in the accumulation of dry matter and a richer green color in leaves due to improved chlorophyll synthesis, ultimately expanding the effective area for photosynthesis.

Moreover, incremental sulphur application up to 60 kg S ha-1 positively influenced the number of siliqua, siliqua length, seeds per siliqua, and 1000 seed weight. Sulphur played a key role in enhancing both primary and secondary branches, leading to larger photosynthesizing regions and increased accumulation of photosynthates. This, in turn, contributed to improved yield attributes and seed yield. The application of sulphur at 60 kg ha-1 also substantially increased oil content and oil yield, highlighting its role in activating enzymes and promoting biochemical reactions within the plant.

Both nitrogen and sulphur application have demonstrated significant positive effects on the growth, yield, and quality of mustard plants. The findings underscore the importance of optimal nutrient management, particularly at 140 kg N ha-1 for nitrogen and 60 kg S ha-1 for sulphur, in maximizing the overall productivity and oil content of Indian mustard crops.

Comment [PS11]: As you have comup with higher doses of nitrogen and sulphur so mention the intial and final status of soil nutrients in material method and discussion respectively

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