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Role of sulphur in improving growth and yield of Indian mustard (*Brassica juncea* L.)

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Abstract
Sulphur (S) is an essential nutrient required by mustard crop for its vegetative as well as reproductive growth. It is an important component of various amino acids, proteins and responsible for quality of oil in oil crops. There are estimates that around 41% of Indian topsoil is low in S content. An experiment was carried out at the agricultural research farm of Lovely Professional University, Punjab during the Rabi season of year 2021-2022. The experiment comprising two varieties (PBR357 and RLC3) and five levels of S (control, 15, 30, 45 and 60 kg/ha S), was conducted in two factorial randomized block design replicated thrice. Results showed that both growth and yield of mustard differed significantly with different varieties and S levels. Plant height, number of leaves per plant, number of siliqua per plant, number of seeds per siliqua, grain yield, straw yield, test weight and S content in grains were significantly more in PBR357 as compared to RLC3. In terms of levels of S, application of 60 kg/ha found to be significantly superior over the control, 15 and 30 kg/ha in increasing all the above parameters. Vigorous and high yielding varieties of mustard along with application of optimum amount of S fertilizer can be used to obtain higher yield of mustard crop.

Keywords: *Brassica juncea* L., sulphur, growth, yield, grain sulphur content

Introduction

Indian mustard (*Brassica juncea* L.) is an important oil seed crop, is cultivated throughout the world to produce edible vegetable oil, spices and condiments for consumption of humans and feed for livestock. Globally, in the year 2018-19, rapeseed-mustard was cultivated in about 36.5 million hectares (mha) and the estimated production and yield 72.3 million tonnes (m t) and 1.98 tonnes/ha, respectively. Annually, India contributes about 11.61% of the total production in the world (FAS USDA, 2020) [8]. India had an annual production of 9.3 mt from 6.1 mha area with yield average of 1511 kg/ha in the year 2018-19 (GOI, 2020) [10]. According to the available data, production as well as productivity increased significantly from year 2010-11 to 2018-19. The production grew from 61.6 mt to 72.4 mt whereas the productivity has also increased to 1980 kg/ha from 1840 kg/ha (DRMR 2020) [7].

Sulphur is an important nutrient required by mustard plants for completing its various biological processes such as synthesis of amino acids, proteins, oils, activation of enzyme system. It plays a significant role to increase crop yields, quality, productivity, disease resistance and protection from insects and animals and is often utilized as a soil amendment. Sulphur is a component of essential amino acids like cystine, methionine, sulpholipids and several coenzymes such as biotin, thioredoxin, lipoic acid, thiamine pyrophosphate and coenzyme A (Chandel *et al.*, 2003) [1]. Amino acid cysteine plays an essential role as a source of S for most S-compounds in plants (Prasad and Power, 1997) [22]. Methionine plays a significant role in initiation of translation as well as in the structure of proteins (Ferala and Patrick, 2014) [9]. Organic S compounds such as sulpholipids, thiols (glutathione) and secondary S compounds like phytochelatins, glucosinolates, perform a vital role in physiology of plants and defence against pest and environmental stress (De Kok *et al.*, 2002) [5]. According to reports, the average amount of S taken up by oilseed crops is 9.9 kg, that of pulse or bean crops is 7.6 kg and that of cereal crops is 4.1 kg every mt of grain or seed that the plants produce (Tandon, 2011) [37].

Deficiency of S results in severe yield losses to the extent of 10-34% in Indian mustard (Sawarkar *et al.*, 1987) [27]. In S deficient plants of rapeseed/mustard, young leaves become pale and chlorotic (Prasad *et al.*, 2003) [23]. The yellowing of leaves begins from the edge and advances towards interveinal areas; however the regions alongside the veins remain green in colour (Lobb and Reynolds, 1956) [17].

Cupping of leaves, reddening of stem and underside of leaves also occurs. Poor pod formation take place due to premature flower shedding. In oil seed crops S deficiency leads to economics losses as it leads to reduction of the oil content in seeds and thus reduce the quality of crops. In case of severe deficiency of S, the chlorotic regions of mustard leaves may develop reddish purple colour owing to the development of pigment anthocyanins (Schnug and Haneklaus, 2005) [28].

Although S is the fourth major plant nutrient, it was not given much importance for long because enough of the nutrient was added to soil by S containing nitrogen and phosphatic fertilizers and by atmospheric S depositions. But S levels in soils are declining from past many years. Approximately 41% of our Indian topsoil has low S content, which has a significant detrimental effect on economic profitability of oilseed crops (Singh, 2001) [30]. Over the last 20 years the sulphur dioxide emissions have decreased due to stricter emission regulations especially in developed countries led to reduced atmospheric deposits. Use of high yielding varieties, low S content in farmyard manure, increase in use of S free high analysis nitrogen and phosphorus fertilizers and declining use of S containing fungicides have led to enormous increase in S deficient soils all over the world (Rakesh *et al.*, 2020) [24].

The positive impact of S on crop productivity is well documented; however there is a little data available regarding its impact on Indian mustard. Therefore, the present study was conducted to determine how Indian mustard would react to S fertilization in Punjab region of India.

Materials and Methods

The experiment was conducted in the rabi season of year 2021-2022 at the agricultural research farm, Lovely Professional University, Phagwara, Punjab. The farm's soil had a pH of 7.8 and had the texture of sandy loam. The research study was laid out in two factorial randomized block design with two varieties of Indian mustard i.e., PBR357 and RLC3 and five different levels of S i.e., S0-0 kg/ha; S1-15 kg/ha; S2-30 kg/ha; S3-45 kg/ha; S4-60 kg/ha in three replications. Various treatment combinations used were, T1-PBR357×S0; T2-PBR357×S1; T3-PBR357×S2; T4-PBR357×S3; T5-PBR357×S4; T6-RLC3×S0; T7-RLC3×S1; T8-RLC3×S2; T9-RLC3×S3; T10-RLC3×S4. Both the varieties were sown by using Kera method at a seed rate of 3.7 kg/ha and placed at depth of 4-5 cm in rows spaced 30 cm apart while maintaining a 15 cm plant-to-plant distance. Different levels of S were applied in the form of gypsum as per treatments in each plot before sowing. A basal dose of 96 kg/ha of urea, 64.22 kg/ha of di-ammonium phosphate (DAP) and 25 kg/ha of muriate of potash (MOP) was applied in each plot to meet half nitrogen, full phosphorus and full potassium requirements of the crop, respectively whereas the remaining half dose of nitrogen was added by applying 123.3 kg/ha of urea at the time of first irrigation.

Observations recorded

Plant height and number of leaves

During the growing period of crop, four plants were selected randomly from every plot in order to record height (cm) and number of leaves per plant at 40, 80 and 120 days after sowing (DAS).

Yield parameters

The plants were harvested, sundried and threshed. The observation of grain yield (kg/ha) and straw yield (kg/ha) were recorded.

Sulphur content in grains

Grain samples from each plot were collected, properly dried, pulverised in a grinder and subjected to chemical analysis. The S content in grains was estimated by Barium Sulphate Turbidimetry method.

Statistical analysis

Experimental data gathered throughout the study was statistically analysed by analysis of variance (ANOVA) at $p \leq 0.05$ level of significance (Gomez and Gomez, 1984) [11] by using OPSTAT statistical software developed by CCS HAU, Hisar.

Results and Discussion

Plant height

The data shown in table 1 revealed that different varieties and S levels significantly influenced plant height at 40 DAS. The results showed that mustard variety PBR357 had a higher plant height (40.78 cm) than RLC3. Variety PBR357 increased plant height by 10.82% at 40 DAS, respectively. An increment in applied S from 0 to 60 kg/ha led to increment in plant height. Dose of 60 kg/ha S resulted in a significant increment in the plant height (43.93 cm at 40 DAS) than control, 15 and 30 kg/ha, but it was at par with S dose of 45 kg/ha. The results showed that at 80 DAS mustard variety PBR357 had a significantly higher plant height (166.43 cm) than RLC3. PBR357 increased plant height by 9.54% at 80 DAS compared to RLC3. Regarding S levels, increasing the level of S from 0 to 60 kg/ha raises the plant height. Sulphur dose of 60 kg/ha resulted in a significant increment in the plant height (174.40 cm at 80 DAS) than control, application of 15 and 30 kg/ha of S, but it was at par with the S dose of 45 kg/ha. The results at 120 DAS revealed that, the mustard variety PBR357 had a significantly higher plant height (181.38 cm) than RLC3. PBR357 increased plant height by 8.68% when compared to RLC3. The height of the plant increased as the S level rises from 0 to 60 kg/ha. Application of 60 kg/ha of S led to a significant increment in plant height (194.52 cm at 120 DAS) than control, 15 and 30 kg/ha of S, but it was at par with 45 kg/ha of S.

At all growth stages, the variety PBR357 found taller than RLC3. Variation in plant height among varieties can be explained by the difference in their genetic makeup. The S application improved the nutrient content in soil, which could result in increased nutrient uptake and dry matter production. This could be because sulphate has a direct effect on cell division, growth and cell elongation. Singh *et al.* (2023) [31]; Singh *et al.* (2022) [34]; Nath *et al.* (2018) [19]; Singh and Thenua (2016) [33] also reported similar findings.

Number of leaves

Different S levels considerably altered the number of mustard leaves per plant at 40 DAS (table 2). The results showed that PBR357 had more leaves per plant than RLC3. Number of leaves per plant increased with increment in the S level from 0 to 60 kg/ha. Application of 60 kg/ha S resulted in more leaves per plant (10.88) than control, 15 and 30 kg/ha S, but it was at par with dose of 45 kg/ha S. Number of leaves per plant at 80 DAS was significantly influenced due to different varieties and various levels of S. Results revealed that mustard variety PBR357 recorded a significantly higher number of leaves per plant as compared to RLC3. In case of S levels, increment in S levels from 0 to 60 kg/ha improved the number of leaves per plant. Application of 60 kg/ha S resulted in much more leaves per plant than the control, 15 and 30 kg/ha S, but it was at par with 45 kg/ha S. The results showed that PBR357, considerably outperformed RLC3 on the basis of the number of leaves per plant (25.87) at 120 DAS. Variety PBR357 produced 13.01% more leaves per plant in comparison to RLC3. From 0 to 60 kg/ha of S, plants produce more leaves. A significantly higher number of leaves per plant (27.38) at 120 DAS was obtained on application of 60 kg/ha S as compared to control, 15 and 30 kg/ha S, but it was at par with the 45 kg/ha S.

The increase in main branches may be caused by increased cell division and differentiation with appropriate sulphate supply, as well as by higher photosynthate availability for main shoots, as sulphate helps in increasing the crop's photosynthetic growth. The overall increase in leaf count is attributable to S application because it improves cell multiplication, elongation and expansion. Sulphur also gives leaves a deep colour because it improves chlorophyll biosynthesis, which results in more number of leaves in comparison to plants with low sulphate levels. Additionally some other researchers supported this claim are Singh *et al.* (2023) [31]; Patel *et al.* (2022) [21]; Singh and Meena (2004) [29]; Mishra (2001) [18]; Nepalia and Jain (2000) [20]. Lakshman *et al.* (2017) [16] and Kumar *et al.* (2017) [13] which also reported increase in growth parameters (leaf area index) due to S application.

Siliqua per plant

Sulphur levels and mustard variety had a significant impact on the count of siliqua per plant (table 3). Variety PBR357 produced significantly more siliqua per plant (270.16) than the RLC3. PBR357 produced 4.49% more siliqua per plant than RLC3. As the S content increased from control to 60 kg/ha, the count of siliqua per plant also increased. Application of 60 kg/ha of S resulted in more siliqua count per plant than control, 15 and 30 kg/ha S, but it was at par with dose of 45 kg/ha S (291.14). Percent increment in the count of siliqua per plant with the incorporation of 45 kg/ha S is 29.04, 14.41 and 5.51% more than control, 15 and 30 kg/ha S, respectively.

Mustard variety PBR357 was produced more siliqua per plant because of its profuse branching. The siliquae per plant increased as there were more branches and plants with the highest dose of S. It also resulted from sufficient S availability, which improved nutrition and metabolite production while also encouraged the growth of the crop plants and reproductive organs. Singh and Mukherjee (2004) [32]; Kumar and Yadav (2007) [12]; Chauhan *et al.* (2002) [3] and Dongarker *et al.* (2005) [6] all reported similar findings. Singh *et al.* (2023) [31]; Patel *et al.* (2022) [21]; Rana *et al.* (2020) [25] also reported increase in siliquae per plant due to S application.

Grain yield

Data regarding grain yield differed significantly with different varieties and different levels of S (table 4). According to results, significantly higher grain yield was recorded in PBR357 as compared to RLC3. Percent increase in grain yield by variety PBR357 was to the tune of 14.79% over RLC3. Increment in S levels from 0 to 60 kg/ha led to increment in grain yield. Significantly higher grain yield (2655 kg/ha) was logged with the application of 60 kg/ha S as compared to control, 15 and 30 kg/ha S, but it was at par with the 45 kg/ha S (2552 kg/ha). Percent increment in grain yield with the S dose of 45 kg/ha was to the tune of 49.42, 22.83 and 8.20% over control, 15 and 30 kg/ha S, respectively. When compared to variety RLC3, variety PBR357 produced taller plants, more green leaves per plant, more branches per plant, all of which contributed to a better grain and stover production. Due to their innate capacity, different genotypes of Indian mustard may have varying yield potential under various agroclimatic conditions (Kumar *et al.* 2006) [14]. Singh *et al.* (2023) [31]; Singh *et al.* (2022) [34]; Choudhary *et al.* (2021) [4]; Kumar and Trivedi (2012) [15] and Singh *et al.* (2010) [35] also reported similar results. Under optimum supply of S, increased translocation of photosynthates from leaves to grains led to more number of siliquae per plant, more seeds per siliqua and a higher 1000-seed weight which together contributed to significant increment in grain yield (Chaturvedi *et al.*, 1988) [2].

Straw yield

Data on straw yield varied significantly with different varieties and S levels. PBR357 produced the maximum straw when compared to RLC3 (table 5). Among the S levels, increasing level of S from control to 60 kg/ha increased yield of straw. Sulphur incorporation at rate of 60 kg/ha led to greater straw yield as compared to control, 15 and 30 kg/ha S, although it was at par with S dose of 45 kg/ha. Sulphur incorporation at rate of 45 kg/ha S increased yield of straw by 40.92, 19.31 and 6.85% over the control, 15 and 30 kg/ha S, respectively. It can be attributed to its increased biomass build-up as a result of a greater number of leaves as well as yield characteristics such as more siliquae number per plant and more seeds per siliqua. The rise in straw production can be attributed to the faster and greater development of plant organs due to the crop's faster and more consistent vegetative growth after S application (Singh, 2001; Solanki and Sharma, 2016) [30][36]. The findings of current study also coincide with findings of Singh *et al.* (2023) [31]; Singh *et al.* (2022) [34]; Rana *et al.* (2005) [26] and Dongarkar *et al.* (2005) [6].

Grain S content

Sulphur in seed varied significantly with different varieties and levels of S (table 6). In comparison to RLC3, mustard variety PBR357 had a higher S concentration in grains. Higher S content in grains was found under the application 60 kg/ha as compared to the control, 15 and 30 kg/ha, but it was at par with S at 45 kg/ha. With increment in S levels, the S content of grain increased. This could be the result of increased availability of S, which allowed plants to absorb more nutrients from the soil, resulting in higher nutritional content and rapid vegetative and root growth. The amount of nutrients taken in is determined by the combined effect of available nutrient content and yield, which were more at 60 kg S/ha and resulted in greater nutrient uptake. Kumar and Trivedi (2012) [15] and Singh and Meena (2004) [29] supported the findings of current study.

Table 1: Effect of various sulphur levels on plant height of mustard varieties at different intervals

Sulphur levels	RLC 3	PBR 357	Mean
40 days after sowing			
Control	29.38	32.67	31.02
15 kg/ha	34.58	38.78	36.68
30 kg/ha	36.98	42.33	39.65
45 kg/ha	40.75	44.58	42.67
60 kg/ha	42.32	45.53	43.93
Mean	36.80	40.78	
Effect	V	S	S X V
S.Em±	0.57	0.91	1.28
C.D. at 5%	1.70	2.69	3.80
80 days after sowing			
Control	132.80	140.64	136.72
15 kg/ha	143.63	155.43	149.53
30 kg/ha	154.31	171.10	162.70
45 kg/ha	162.51	182.64	172.57
60 kg/ha	166.45	182.35	174.40
Mean	151.94	166.43	
Effect	V	S	S X V
S.Em±	2.30	3.63	5.13
C.D. at 5%	6.82	10.79	15.26
120 days after sowing			
Control	143.47	152.04	147.75
15 kg/ha	152.59	169.05	160.82
30 kg/ha	168.21	187.06	177.63
45 kg/ha	181.96	198.01	189.99
60 kg/ha	188.27	200.77	194.52
Mean	166.90	181.38	
Effect	V	S	S X V
S.Em±	2.37	3.74	5.29
C.D. at 5%	7.03	11.11	15.72

Table 2: Effect of various sulphur levels on number of leaves of mustard varieties at different intervals

Sulphur (S) levels	RLC 3	PBR 357	Mean
40 days after sowing			
Control	7.59	7.77	7.68
15 kg/ha	8.93	9.27	9.10
30 kg/ha	9.71	10.45	10.08
45 kg/ha	10.75	11.01	10.88
60 kg/ha	11.14	11.24	11.19
Mean	9.62	9.95	
Effect	V	S	S X V
S.Em±	0.14	0.23	0.32
C.D. at 5%	0.42	0.67	0.95
80 days after sowing			
Control	16.28	18.26	17.27
15 kg/ha	19.06	21.44	20.25
30 kg/ha	20.63	23.51	22.07
45 kg/ha	22.15	25.36	23.76
60 kg/ha	22.54	25.34	23.94
Mean	20.13	22.78	
Effect	V	S	S X V
S.Em±	0.23	0.36	0.51
C.D. at 5%	0.68	1.08	1.53
120 days after sowing			
Control	19.10	19.91	19.51
15 kg/ha	21.04	24.68	22.86
30 kg/ha	23.54	26.80	25.17
45 kg/ha	24.98	29.00	26.99
60 kg/ha	25.81	28.96	27.38
Mean	22.89	25.87	
Effect	V	S	S X V
S.Em±	0.30	0.47	0.67
C.D. at 5%	0.89	1.41	1.99

Table 3: Effect of various sulphur levels on number of siliqua per plant of two mustard varieties

Sulphur levels	RLC 3	PBR 357	Mean
Control	214.07	229.25	221.66
15 kg/ha	244.64	255.36	250.00
30 kg/ha	265.87	276.32	271.10
45 kg/ha	280.22	291.83	286.02
60 kg/ha	284.25	298.02	291.14
Mean	257.81	270.16	
Effect	V	S	S X V
S.Em±	3.19	5.05	7.14
C.D. at 5%	9.48	14.99	21.20

Table 4: Effect of various sulphur levels on grain yield (kg/ha) of two mustard varieties

Sulphur levels	RLC 3	PBR 357	Mean
Control	1593	1823	1708
15 kg/ha	1927	2228	2078
30 kg/ha	2182	2535	2359
45 kg/ha	2386	2718	2552
60 kg/ha	2483	2828	2655
Mean	2114	2427	
Effect	V	S	S X V
S.Em±	37	59	83
C.D. at 5%	111	175	247

Table 5: Effect of various sulphur levels on straw yield (kg/ha) of two mustard varieties

Sulphur levels	RLC 3	PBR 357	Mean
Control	2889	3234	3062
15 kg/ha	3390	3843	3616
30 kg/ha	3773	4303	4038
45 kg/ha	4078	4551	4314
60 kg/ha	4190	4743	4466
Mean	3664	4135	
Effect	V	S	S X V
S.Em±	55	86	122
C.D. at 5%	162	257	363

Table 6: Effect of various sulphur levels on suphur content of grains of two mustard varieties

Sulphur levels	RLC 3	PBR 357	Mean
Control	0.320	0.325	0.323
15 kg/ha	0.354	0.359	0.357
30 kg/ha	0.374	0.379	0.377
45 kg/ha	0.382	0.389	0.385
60 kg/ha	0.391	0.393	0.392
Mean	0.364	0.369	
Effect	V	S	S X V
SEm±	0.003	0.005	0.008
C.D. at 5%	0.010	0.016	0.023

Conclusion

On the basis of present experiment, it can be concluded that the application of S at a rate of 60 kg/ha resulted in a crop with enhanced agronomic attributes such as plant height, number of leaves, yield characteristics features like number of siliquae per plant, straw yield, test weight and ultimately higher grain yield. Regarding the varietal performance, PBR357 also performed better than the RLC3 in relation to crop growth and yield. Overall, the results of this study indicated that S fertilization can be the effective strategy to increase mustard growth and grain yield under prevailing S deficient conditions.

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References

1. Chandel RS, Sudhakar PC, Singh K. Response of sulphur nutrition in mustard-A review. Agricultural Reviews-Agricultural Research Communications Centre India. 2003;24(3):175-82.
2. Chaturvedi GS, Singh BB, Prasad R, Chauhan YS. Physiological analysis of yield in Indian mustard (*Brassica juncea* L.) under irrigated conditions. Indian Journal of Plant Physiology. 1988;31(1):38-44.
3. Chauhan DR, Ram M, Singh I. Response of Indian mustard (*Brassica juncea* L.) to irrigation and fertilization with various sources and levels of sulphur. Indian journal of Agronomy. 2002;47(3):422-426.
4. Choudhary M, Rana K, Bana RS, Parihar CM, Kantwa S. Conservation agriculture practices and sulphur fertilization effects on productivity and resource-use efficiency of rainfed mustard (*Brassica juncea* L.). Indian Journal of Agricultural Sciences. 2021;91(1):49-53. https://doi.org/10.56093/ijas.v91i1.110924
5. De Kok L, Castro A, Durenkamp M, Stuiver CEE, Westerman S, Yang L, *et al*. Sulphur in Plant Physiology. Proceedings No 500, The International Fertiliser Society, New York; c2002. p. 1-26. ISBN 0-85310-36-1.
6. Dongarkar KP, Pawar WS, Khawale VS, Khutate NG, Gudadhe NN. Effect of nitrogen and sulphur on growth and yield of mustard (*Brassica juncea* L.). Journal of Soils and Crops 2005; 15(1): 163-167.
7. DRMR ICAR - Directorate of Rapeseed-Mustard Research Bharatpur. https://www.drmr.res.in/about_rmcrop.php. 2020.
8. FAS USDA. Production supply and distribution database, Foreign Agriculture Service, United States Department of Agriculture. https://data.nal.usda.gov/dataset/production-supply-and-distribution-database. Jan, 2020.
9. Ferala MP, Patrick WM. Bacterial methionine biosynthesis. Microbiology. 2014;160(8):1571-1584.
10. GOI. Economic survey 2020-21 statistical appendix, volume 2, Directorate of Economic & Statistics, Department of Agriculture, Cooperation and Farmers Welfare; c2020.
11. Gomez KA, Gomez AA. Statistical Procedures for Agricultural Research. Edn 2, John wiley & sons, 1984.
12. Kumar H, Yadav DS. Effect of phosphorus and sulphur levels on growth, yield and quality of Indian mustard (*Brassica juncea* L.) cultivars. Indian Journal of Agronomy. 2007;52(2):154-157.
13. Kumar M, Singh PK, Yadav KG, Chaurasiya A, Yadav A. Effect of nitrogen and sulphur nutrition on growth and yield of Indian mustard (*Brassica juncea* L.) in western UP. Journal of Pharmacognosy and Phytochemistry. 2017;6(6S):445-448.
14. Kumar N, Singh S, Singh V. Effect of iron and sulphur levels on yield, oil content and their uptake by Indian mustard (*Brassica juncea* L.). Indian Journal of Agronomy. 2006;51(1):63-64.
15. Kumar R, Trivedi SK. Effect of levels and sources of sulphur on yield, quality and nutrient uptake by mustard (*Brassica juncea* L.). Progressive Agriculture. 2012;12(1):69-73.
16. Lakshman K, Vyas AK, Shivakumar B, Rana DS, Layek J, Munda S. Direct and residual effect of sulphur fertilization on growth, yield and quality of mustard in a soybean- mustard cropping system. International Journal of Current Microbiology and Applied Sciences. 2017;6(5):1500-1512. https://doi.org/10.20546/ijcmas.2017.605.163.
17. Lobb WR, Reynolds DG. Further investigations in the use of sulphur in North Otago. New Zealand Journal of Agriculture. 1956;92(1):17-25.
18. Mishra SK. Effect of sulphur and zinc on yield, uptake of nutrients and quality of mustard. Annals of Plant and Soil Research. 2001;3(2):206-213.
19. Nath S, Kannaujiya SK, Kumar S, Sonkar SP, Gautam AD, Singh A. Effect of sulphur fertilization on yield, sulphur uptake and oil content in Indian mustard under sandy loam soil of eastern Uttar Pradesh. Journal of Krishi Vigyan. 2018;6(2):81-83. https://doi.org/10.5958/2349-4433.2018.00065.X.
20. Nepalia V, Jain GL. Effect of weed control and sulphur on yield of Indian mustard (*Brassica juncea* L.) and their residual effect on summer green gram (*Phaseolus radiates* L.). Indian journal of Agronomy. 2000;45(3):483-488.
21. Patel VK, Mishra US, Singh VK. Effect of the phosphorus and sulphur levels on growth and yield of mustard (*Brassica juncea* L.) crop under rainfed condition. International Journal of Plant & Soil Science. 2022;34(21):249-255.
22. Prasad R, Power JF. Soil fertility management for sustainable agriculture. CRC press; c1997.
23. Prasad R, Tiwari KN, Biswas BC. Students guide to fertilizers and their efficient use. Potash & Phosphate Institute of Canada-India Programme, Gurgaon; c2003.
24. Rakesh AP, Kumari V, Shekhar D, Prasad RP. Soil Sulphur status and response of crops to Sulphur application in Indian soils: A review. Journal of Pharmacognosy and Phytochemistry. 2020;9(3):1406-1410.
25. Rana K, Parihar MS, Singh JA, Singh R. Effect of sulfur fertilization, varieties and irrigation scheduling on growth, yield, and heat utilization efficiency of Indian mustard (*Brassica juncea* L.). Communications in Soil Science and Plant Analysis. 2020;51(2):265-275. https://doi.org/10.1080/00103624.2019.1705325.
26. Rana KS, Rana DS, Gautam RC. Influence of phosphorus, sulphur and boron on growth, yield, nutrient uptake and economics of Indian mustard (*Brassica juncea* L.) under rainfed conditions. Indian Journal of Agronomy. 2005;50(4):314-316.
27. Sawarkar NJ, Shukla SS, Tomar PS. Effect of sulphur fertilization on yield and quality of mustard. Journal of Oilseeds Research. 1987;4:227-229.
28. Schnug E, Haneklaus S. Sulphur deficiency symptoms in oilseed rape (Brassica napus L.)-the aesthetics of starvation. Phyton. 2005;45(3):79-95.
29. Singh A, Meena NL. Effect of nitrogen and sulphur on growth, attributes and seed yield of mustard (*Brassica juncea* L.) in eastern plain of Rajasthan. Indian Journal of Agronomy. 2004;49(3):186-188.
30. Singh C. Rapeseed and mustard. Principles of agronomy. Oxford and IBH Publishing Co. Pvt. Ltd., 22-A, Sarojani Naydu Marg, Allahabad (U.P.) India; c2001.

31. Singh H, Choudhary RNP, Jat R, Rathore SS, Meena MK, Rai PK. Re-visiting of nitrogen and sulphur requirements in Indian mustard (*Brassica juncea* L.) under irrigated conditions. Indian Journal of Agricultural Sciences. 2023;93(1):51-56. https://doi.org/10.56093/ijas.v93i1.128176.
32. Singh RK, Mukherjee D. Effect of sulphur fertilization in sustaining mustard productivity in rice-mustard cropping system. Haryana Journal of Agronomy. 2004;20(1/2):7-9.
33. Singh SB, Thenua OVS. Effect of phosphorus and sulphur fertilization on yield and NPS uptake by mustard (*Brassica juncea* L.). Progressive Research-An International Journal. 2016;11(1):80-83.
34. Singh T, Bohra JS, Singh RK, Singh DN, Singh P. Effect of sulphur and boron levels, and integrated nutrient management on growth and yield of Indian mustard (*Brassica juncea* L.) Czernj. and Cosson]. Annals of Agricultural Research. 2022;43(3):311-316.
35. Singh Y, Singh T, Singh UN, Rajput PK. Effect of nutrient management on yield, quality and economics of irrigated Indian mustard (*Brassica juncea* L.). Indian Journal of Agricultural Sciences. 2010;80(8):691-694.
36. Solanki RL, Sharma M. Effect of phosphorus, sulphur and PSB on growth and yield of mustard in Southern Rajasthan. Annals of Plant and Soil Research. 2016;18(1):66-69.
37. Tandon HLS. Sulphur in soils, crops and fertilizers. Fertilizer Development and Consultation Organization, New Delhi, India. 2011;204+X.