Effect of Zinc and Sulphur on Growth, Yield attributes and yield of Indian Mustard [*Brassica juncea* (L).Czern and Coss]

Abstract

Field experiments were conducted to study the effect Zinc and Sulphur on growth parameters, yield components and yield of Mustard during *rabi* season of 2021-22 at students instructional farm, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur. The experiment consist of 14 treatments combinations in factorial randomized block design with three replications consisted of 7 fertility levels (including sulphur and zinc) and two variatal factors (i.e. Rohini & Maya). Mustard varietiesRohini & Maya were grown with the recommended agronomic practices. On the basis of results emanated from investigation it can be concluded that among the growth parameters maximum plant height at harvest is 160.6 cm and 161.2 cm, maximum number of primary branches is 8.5 and 8.3 and secondary branches is 14.4 and 14.8 during both the years of experimentation are associated with the treatment T_{14}[Var. Maya with Sulphur @900 ppm]. Similarly, among the yield components and productivity parameters maximum number of siliquae per plant, number of seedsiliqua^{-1}, 1000 test wt. (gm), grain yield (q ha^{-1}), stover yield (q ha^{-1})was also found in the treatment T_{14} [Var. Maya with Sulphur @900 ppm] followed by treatment T_{11} [Var. Maya with $ZnSo_4$ @1500] and treatment T_7 [Var. Rohini with Sulphur@1500].

Key Words: Mustard, Zinc, Sulphur and Yield.

Introduction

Oilseed crops are the second most significant factor affecting the agricultural economy, only after cereals. Oilseed self-sufficiency achieved during the "Yellow Revolution" in the early 1990s could only lasted for a little time. India is currently one of the biggest importers of vegetable oils while producing the fifth-largest amount of oilseed crops worldwide. Vegetable oil utilisation has increased significantly in recent years for both industrial and consumable purposes. Due to a severe supply-demand imbalance for edible oils, 60 % of the nation's needs were met by massive imports in 2016–17 (14.01 million tonnes at a cost of Rs. 73,048 crore). **(NFSM, 2018)**

Although domestic oilseed production of the nine annual crops performed admirably (Compound Annual Growth Rate of 3.89 %), it was unable to keep up with the 6 % growth in per capita demand because of increased per capita consumption of oil (18 kg per year), which was fuelled by population growth and rising per capita income. Soybean, groundnut, rapeseed-mustard, sesame, sunflower, castor, safflower, linseed, and Nigeria are some of the

UNDER PEER REVIEW

most cultivated oil seed crops worldwide. The average contribution of the nine oilseed crops grown in India to total oilseed output is dominated by the soybean (38 %), followed by rapeseed-mustard (27 %), and groundnut (27%). Similar to how soybeans make up the largest average percentage of the total oilseed area, it is followed by rapeseed-mustard (24 %) and groundnut (20 %). On average, the proportion of all Kharif oilseed crops to total production is roughly 67 % and the remaining 33 % is of Rabi/Summer oil seed crops.

India's population is constantly growing by 2025, and 2030, it is predicted to reach 1.42 and 1.48 billion. Similar to this, the level of living is rising, leading to increase per capita use of edible oil. Between 2011 and 2030, the demand for edible oil would increase by 3.54 % year. Accordingly, it is predicted that from its current level of 16.38 kg per year, the per capita consumption of edible oil would increase to 23.1 kg per year per person by the year 2030. Therefore, 34.10 mt of edible oil, or roughly mt of oilseeds, would be needed to achieve self-sufficiency in edible oil **(DRMR, 2011)**.

During the 2018–19 growing season, the estimated global rapeseed-mustard area, production, and yield were 36.59 million hectares (mha), 72.37 million tonnes (mt), and 1980 kg ha^{-1}, respectively. In terms of overall area and production worldwide, India accounts for 19.8 % and 9.8 %, respectively (USDA). The productivity has improved significantly over the past eight years, going from 1840 kg ha^{-1} in 2010-11 to 1980 kg ha^{-1} in 2018–19, and the production has gone up as well, going from 61.64 mt in 2010-11 to 72.42 mt in 2018-19. In India, rapeseed-mustard crops are cultivated in a variety of agroclimatic conditions, including irrigated/rainfed, timely/late sown, saline soils, and mixed cropping. These conditions range from north-eastern/north-western hills to down south. Around 75-80 % of the 6.23 million acres of these crops were planted with Indian mustard during the 2018-19 growing season **(DRMR, Bharatpur)**.

With 9.34 mt of production, 6.23 m ha of area, and an average productivity of 1499 kg ha^{-1}, India came in third place overall for rapeseed and mustard production and area **(Directorate of Economics and Statistics, 2020-21 (DAC&FW))**. In terms of area and production, Rajasthan ranks top with 2.37 million hectares and 4.08 million tonnes, respectively, followed by Uttar Pradesh with about 0.75 million hectares and 1.12 million tonnes. The maximum acreage, production, and productivity in UP are found in the Mathura district, with respective values of 0.053 mha, 0.077 mt, and 1453 kg ha^{-1}. **(DAC&FW, 2020-21) (Directorate of Economics and Statistics)**.

UNDER PEER REVIEW

The plant species *Brassica juncea,* also referred to as Indian mustard or brown mustard, is a member of the *Brassicaceae* family. It is a significant crop that is widely grown around the world for its seeds, leaves, and oil. Annual plants like *Brassica juncea* often reach heights of 1 to 2 metres (3 to 6 feet). It features upright stems with large, lobbed leaves with green to purplish undertones. India and Bangladesh are the two countries in South Asia where Brassica juncea is indigenous. Other places with favourable weather conditions, including as portions of Africa, Europe, North America, and Australia, are also where it is grown **(Rai *et al.*, 2022).**

Rapeseed-mustard oil is regarded as a crucial component of the Indian diet and is used to make soap, flavour curries, cook vegetables, add flavour to hair oils, and preserve pickles. According to **Panday *et al.* (2013),** mustard seed typically contains 33-39 % oil, 17–25 % proteins, 8-10 % fibres, and 10-12 % extractable compounds. The most common uses for green stem, leaves, and cake are as manure and animal feed. Young plant leaves are consumed as green vegetables because they provide enough sulphur and minerals for a vegetarian diet. Mustard oil is used in the tanning industry to soften leather**(Singh *et al.*, 2015).**

The soils in Uttar Pradesh have been found to be deficient in micronutrients. The advent of high yielding crop varieties and intensive cropping systems has made the problem worse. Micronutrient deficits are predicted to worsen as nutrient demands for higher yields rise and plant needs for main nutrients are only partially satisfied. Farmers, extension agents, and researchers have all noted nutritional deficiencies in the soil of Uttar Pradesh. Poor vegetative development, flower and fruit drop, a low harvest index, and low seed production are all associated with a lack of the aforementioned micronutrients. The most important nutrients for the growth and development of oil seeds are sulphur and zinc**(Shukla *et al.*, 2018).**

It is widely known how certain micronutrients affect plant metabolism. Zn plays a role in the production of auxins and indole-3-acetic acid as a micronutrient. It activates a number of enzymes that are involved in plant metabolism. Additionally, it has been linked to photosynthesis, active salt absorption, hormone metabolism, cellular differentiation and development, fat metabolism, and phosphorus and nitrogen metabolism. Additionally, it aids in photosynthesis and increases the winter hardiness of crops. The growth and yield of mustard are influenced by major macronutrients like nitrogen, phosphorus, and potassium as well as minor micronutrients like zinc and manganese.

After nitrogen, phosphorus, and potassium, sulphur is regarded as the fourth most crucial necessary ingredient for plant growth. Numerous physiological processes involving

UNDER PEER REVIEW

sulphur include the creation of cysteine, methionine, chlorophyll, and oil in oil seed crops. Additionally, it is in charge of the synthesis of several vitamins (B, Biotin, and Thiamine), the metabolism of proteins and carbohydrates, and the oil creation of flavouring substances in crucifers. Since cysteine and methionine are two sulphur amino acids, plants naturally contain both nitrogen and sulphur. Methionine is a necessary amino acid and a donor of methyl (CH_3) in numerous transmethylation reactions that are important for metabolism. Methionine is a precursor of glucosinolates in mustard. Therefore, sulphur is needed for formation as well as for the synthesis of proteins and sulpholipids, which explains why Brassica crops have a considerably greater sulphur demand. Because its sulfhydryl (mercaptan) group (-SH) acts as the active core of all the enzyme fractions of the synthesise complex, it is also necessary for soil synthesis. Sulphur helps legumes nodulation by fixing nitrogen from the atmosphere. It is crucial for the synthesis of chlorophyll. In the chain of fatty acids, it functions as a biological agent **(Patil, 2011)**.

Sulphur is an essential secondary plant nutrient and fourth most importantnutrient in crop production to increase quality and productivity of mustard next to N, P and K. It is an essential constituent of S-containing amino acids and helps in synthesis of cystine (27% S), cysteine (26% S) and methionine (21% S), as about 90% of sulphur is present in these amino acids **(Havlin *et al*., 2013).** Sulphur is an essential component in the formation of chlorophyll, a constituent of vitamins biotine and thiamine (B_1) and iron sulphur proteins called ferredoxins. It also plays a role in activation of various vitamins and enzymes, sulphydryl (SH) linkages, synthesis of oil and protein **(Rathore *et al*., 2015).** It is also a component of glucosinolate and glycosidase enzyme, which are the source of aroma and pungency in mustard oil. Compared to other crops mustard is more responsive to sulphur. Therefore, adequate sulphur availability is very crucial for its productivity. Studies have confirmed that sulphur fertilizer increases the growth, yield and quality of Indian mustard **(Singh *et al*., 2015; Piri *et al*., 2011).** Application of sulphur has a significant effect on oil, fatty acids and glucosinate content in mustard seeds **(Falk *et al*., 2007).** Sulphur application also has marked effect on soil properties and is used as soil amendment to improve the availability of other nutrients in soil.

Experimental Site

The experiment was conducted during *rabi*season of 2021-22 and 2022-23 at student's Instructional farm, C.S.A. University of Agriculture and Technology, Kanpur Nagar (U.P.). The field was well leveled and irrigated by tube well. The farm is situated at main campus of

UNDER PEER REVIEW

the university, in the west northern part of Kanpur city under sub-tropical zone in v[th] agroclimatic zone (central plain zone).

EdaphicCondition

The soil was moist, well drained with uniform plane topography. The soil of the experimental field was alluvial in origin, sandy loam in texture and slightly alkaline in reaction having pH 7.97 and 7.92 (1:2.5 soil: water suspension method given by **Jackson, 1973**), electrical conductivity 0.36 and 0.35 dSm^{-1}(1:2.5 soil: water suspension method given by **Jackson, 1973**), Organic carbon percentage in soil is 0.35 and 0.35 per cent (Walkley and Black's rapid titration method given by **Walkley and Black, 1934**), with available nitrogen 197.25 and 198.42 kg ha^{-1}(Alkaline permanganate method given by **Subbiah and Asija, 1956**), available phosphorus as sodium bicarbonate-extractable P was 12.14 and 12.21 kg ha^{-1}(Olsen's calorimetrically method**, Olsen *et al.*, 1954**) available potassium was 265.15 and 266.68 kg ha^{-1} (Flame photometer method given by **Hanwey and Heidel, 1952**)

Detail of treatments and design

The 14 treatments combination of nutrient management practices having three each Zinc levels (500, 1000 and 1500 ppm) and Sulphurlevels (300, 600, 900ppm) along with two mustard varieties Rohini & Maya. Experiment was laid out in Factorial Randomized Block Design with three replications.

Table -1: detail of the treatment combinations:

S. No.	**Treatment Details**	**Symbol**
1.	Rohini + Control	V_1T_0
2.	Rohini + ZnSO4@ 500 ppm	V_1T_1
3.	Rohini + ZnSO4@ 1000 ppm	V_1T_2
4.	Rohini + ZnSO4@ 1500 ppm	V_1T_3
5.	Rohini + Sulphur@ 300 ppm	V_1T_4
6.	Rohini + Sulphur@ 600 ppm	V_1T_5
7.	Rohini + Sulphur@ 900 ppm	V_1T_6
8.	Maya + Control	V_2T_0
9.	Maya + ZnSO4@ 500 ppm	V_2T_1
10.	Maya + ZnSO4@ 1000 ppm	V_2T_2
11.	Maya + ZnSO4@ 1500 ppm	V_2T_3
12.	Maya + Sulphur@ 300 ppm	V_2T_4
13.	Maya + Sulphur@ 600 ppm	V_2T_5
14.	Maya + Sulphur@ 900 ppm	V_2T_6

Crop Husbandry

UNDER PEER REVIEW

A pre-sowing irrigation (Paleva) was done in the experimental field with an object to get optimum moisture conditions for attaining good germination. At proper tilth, one ploughing with tractor drawn mould bold plough was done followed by two ploughings by cultivator. Nitrogen @ 120 kg ha^{-1}, Phosphorous @ 60 kg $ha^{-1}$and potash @ 40 kg ha^{-1} applied uniformly through urea DAP and murate of potash respectively.Zinc and Sulphur were sprayed before flowering as per treatment. The sowing of mustard crop was done using a seed rate of 5 kg ha^{-1}withspacing45×15 cm spacing and 3-4 cm depth.

Harvesting and threshing: the crop was harvested at maturity and was allowed to dry in sun. Separate bundles were made for each plot and weighted. The after drying harvest was threshed manually.

Grain yield

After threshing the grain yield from each plot was separately weighed and recorded after converting into quintals per hectare.

Stover yield

After subtracting the grain yield per plot from the total biological yield. After converting the yields into quintals per hectare, yields were recorded.

Statistical analysis: The growth parameters and yields were recorded and analyzed as per Gomez and Gomez (1984) the tested at 5% level of significance to interpret the significant differences.

Result and Discussion

Growth Parameters

A critical perusal of the data given in Table-2 and depicted in fig.-1 clearly shows that among the growth parameters of Mustard such as plant height (cm)at harvest, number of primary branches $plant^{-1}$ and number of secondary branches $plant^{-1}$significantly increase due to the application of Sulphur and Zinc. Growth parameters also increased with lapse of time. Plant height at harvest varied from 124.7-160.9 cm, number of primary branches $plant^{-1}$ varied from 5.4-8.4 and number of secondary branches $plant^{-1}$ varied from 11.1-14.6on pooled basis. Maximum plant height (161.2 cm) at harvest, number of primary branches $plant^{-1}$ (8.5), and number of secondary branches $plant^{-1}$ (14.8) was associated with the treatment T_{14} [Maya with Sulphur @900 ppm] followed by T_{11} [Var. Maya with $ZnSO_4$ @1500] and T_7 [Var. Rohini with Sulphur@1500] during the second year (2022-23) of experimentation. Minimum plant height (124.5 cm) at harvest, number of primary branches $plant^{-1}$ (5.3) and number of secondary $plant^{-1}$ (11.00) were associated with the treatment T_1 [Rohini + Control] during the

UNDER PEER REVIEW

first year (2021-22) of experimentation. The interaction between mustard varieties and fertilitylevels on growth attributes was not statistically significant. The growth parameters of mustard might be increased due to essentiality of sulphur and zinc for growth and developments. The consequences of the current investigation are additionally in concurrence with the investigation of**Indira *et al.* (2021)**, **Rahangdale (2022)**,**Bhalavi*et al.* (2023)**,**Mishra *et al.* (2023), Singh *et al.* (2023).**

Table-2: Effect of different treatment combination on growth parameters of Mustard

Treatments	Plant Height (cm) at harvest			Number of primary Branches Plant^{-1}			Number of secondary branches Plant^{-1}		
	2021-22	2022-23	Pooled	2020-21	2021-22	Pooled	2020-21	2021-22	Pooled
T_1	124.5	124.9	124.7	5.3	5.4	5.4	11	11.2	11.1
T_2	126.9	127.4	127.2	6	6.2	6.1	11.5	11.9	11.7
T_3	140.2	140.6	140.4	6.9	7.3	7.1	12.2	12.5	12.4
T_4	151.3	151.8	151.6	7.8	8.1	8.0	13.5	13.8	13.7
T_5	133.8	134.7	134.3	6.1	6.4	6.3	11.7	12.1	11.9
T_6	141.9	142.5	142.2	7.1	7.2	7.2	12.6	12.8	12.7
T_7	155.1	155.5	155.3	7.9	8	8.0	13.9	14.2	14.1
T_8	125.7	127.3	126.5	5.5	5.6	5.6	11.1	11.7	11.4
T_9	135.5	134.6	135.1	6.3	6.5	6.4	11.9	12.3	12.1
T_{10}	146.2	146.8	146.5	7.2	7.3	7.3	12.8	13.4	13.1
T_{11}	158.5	159	158.8	8.2	8.5	8.4	14.1	14.5	14.3
T_{12}	140.3	140.8	140.6	6.6	6.9	6.8	12.1	12.6	12.4
T_{13}	148.1	148.6	148.4	7.4	7.5	7.5	13.2	13.7	13.5
T_{14}	160.6	161.2	160.9	8.3	8.5	8.4	14.4	14.8	14.6
S.Ed±	2.415	3.080	2.452	0.163	0.149	0.147	0.347	0.281	0.310
C.D. at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS

Yield Components

At a glance over the data given in the Table-3clearly shows that among the yield attributing characters of mustard such as number of siliqua plant^{-1}, number of seed siliqua^{-1} and test weight (gm) increase due to the application of sulphur and zinc but the increase could not reach up to the level of significance.Thenumber of siliqua plant^{-1}, number of seed siliqua^{-1} and test weight (gm)increased to the magnitude of 226.0 to 316.9, 11.31 to 14.18 and 4.57 to 5.93 respectively, on pooled basis. Maximum number of siliqua plant^{-1} (317.5), number of seed siliqua^{-1} (14.26) and 1000 grain weight (6.02 g) was associated with the treatment T_{14} [Maya with Sulphur @900 ppm] during the second year (2022-23) of experimentation. Minimum number of siliqua plant^{-1} (222.4), number of seed siliqua^{-1} (11.23) and 1000 grain

UNDER PEER REVIEW

weight (4.50 g) was associated with the treatment T_1 [Rohini + Control] during the first year (2021-22) of experimentation. The results of the present investigation are also in agreement with the findings of**Kumar *et al.* (2022), Nandan and Bhatnagar(2022) and Pandey *et al.* (2023).**

Table-3: Effect of different treatment combinations on yield components of mustard

Treatments	Number of siliqua Plant^{-1}			Number of seed siliqua^{-1}			Test Weight (gm)		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
T_1	222.4	229.5	226.0	11.23	11.38	11.31	4.50	4.63	4.57
T_2	233.5	241.6	237.6	12.35	12.51	12.43	4.61	4.78	4.70
T_3	259.5	263.4	261.5	13.17	13.27	13.22	4.98	5.1	5.04
T_4	282.1	285.8	284.0	13.65	13.89	13.77	5.54	5.83	5.69
T_5	240.8	244.5	242.7	12.64	12.51	12.58	4.66	4.76	4.71
T_6	264	262.9	263.5	13.21	13.48	13.35	5.10	5.24	5.17
T_7	297.2	299.7	298.5	13.78	13.82	13.80	5.62	5.89	5.76
T_8	225.5	229.2	227.4	11.66	11.56	11.61	4.52	4.92	4.72
T_9	245.6	248.3	247.0	12.85	12.94	12.90	4.75	4.9	4.83
T_{10}	271.8	278.1	275.0	13.32	13.56	13.44	5.14	5.25	5.20
T_{11}	310.5	311.2	310.9	13.95	13.99	13.97	5.76	5.96	5.86
T_{12}	252.4	255.8	254.1	12.98	13.2	13.09	4.85	5.11	4.98
T_{13}	275.3	281.4	278.4	13.44	13.52	13.48	5.32	5.56	5.44
T_{14}	316.2	317.5	316.9	14.1	14.26	14.18	5.83	6.02	5.93
S.Ed±	6.185	5.693	7.389	0.283	0.319	0.289	0.118	0.083	0.095
C.D. at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS

Fig.-1: Effect of different treatment combinations on yield components of chickpea

Productivity Parameters

It is visualized from the data given in Table-4 clearly indicate that among the productivity parameters viz. grain yield (q ha^{-1}) and stover yield (q ha^{-1}) significantly increase due to the application of sulphur and zinc. Grain yield varied from 18.66 to 23.24 q ha^{-1} and stover yield varied from 41.56 to 53.95 q ha^{-1}on pooled basis. The maximum grain yield (23.48 q ha^{-1}), stover yield (54.1 q ha^{-1}), were associated with the treatment T_{14} [Maya with Sulphur @900 ppm] during the second year (2022-23) of experimentation. The minimum grain yield (18.59 q ha^{-1}) and stover yield (41.43 q ha^{-1}) during the first year (2020-21) of experimentation were associated with the treatment T_1 [Rohini + Control] during the second year (2021-22) of experimentation. The surge in seed and stover yields under adequate nutrients supply might be attributed to mainly to the collective effect of a greater number of plant^{-1}, number seed siliqua^{-1}and higher test weight, which was the result of improved translocation of

UNDER PEER REVIEW

photosynthates from source to sink ultimately yield is increased. The increase in grain yield under adequate nutrients supply mainly due to more yield attributes ultimately resulted more grain yield. Grain, stover and biological yield of chickpea significantly increased due to sulphur and zinc application over their controls. These results also confirms the findings of **Rai *et al.*, (2014)**, **Abhilish & Sirothia (2016) and Yanthan & Singh (2021)**

Table-4: Effect of different treatment combinations on productivity parameters of mustard

Treatments	Grain Yield (q ha^{-1})			Stover Yield (q ha^{-1})		
	2021-22	2022-23	Pooled	2021-22	2022-23	Pooled
T_1	18.59	18.72	18.66	41.43	41.69	41.56
T_2	19.64	19.68	19.66	42.11	42.4	42.26
T_3	20.33	21.12	20.73	46.21	46.89	46.55
T_4	21.97	22.31	22.14	50.34	51.12	50.73
T_5	19.65	19.98	19.82	43.21	43.59	43.40
T_6	20.64	21.15	20.90	47.31	47.56	47.44
T_7	22.15	22.56	22.36	50.65	51.19	50.92
T_8	18.75	18.93	18.84	41.69	42.14	41.92
T_9	19.88	20.41	20.15	44.61	44.89	44.75
T_{10}	21.00	21.56	21.28	48.56	48.75	48.66
T_{11}	22.58	22.93	22.76	52.38	52.67	52.53
T_{12}	20.01	21.06	20.54	45.32	45.83	45.58
T_{13}	21.59	21.82	21.71	49.62	49.98	49.80
T_{14}	23.00	23.48	23.24	53.8	54.1	53.95
S.Ed±	0.296	0.294	0.377	0.638	0.787	0.859
C.D. at 5 %	NS	NS	NS	NS	NS	NS

UNDER PEER REVIEW

Conclusion

The current study demonstrate the benefit of Zinc and Sulphur with recommended N, P and K for achieving higher growth parameters and productivity by mustard crop. Application of Zinc and Sulphur increased yield attributes and yield of mustard crop. Finally it can be concluded that the treatment T_{14} [Maya with Sulphur @900ppm] is a best option for improving productivity of mustard crop.

References

Abhilish, M. U., & Sirothia, P. (2016). Consequence of sulphur and boron on growth and yield of mustard under rainfed conditions. *International Journal of Research in Technology and Management*, *2*(8), 1-5.

Bhalavi, R., Singh, T., Tiwari, A. S., & Kumar, P. (2023). Effect of sulphur level and date of sowing on growth, yield and quality of linseed (*Linum usitatissimum* L).*The Pharma Innovation Journal*; 12(1): 2204-2210.

Chesnin, L., & Yien, C. H. (1951). Turbidimetric determination of available sulfates. *Soil Science Society of America Journal*, *15*(C), 149-151.

DRMR. (2011). VISION 2030. Directorate of Rapeseed-Mustard Research, Bharatpur-321303, Rajasthan, p. 30.

Falk, K.L., Tokuhisa, J.G. and Gershenzon, J. (2007). Effect of sulphur nutrition on plant glucosinolate content: physiology and molecular mechanisms. *PlantBiology,* **9**: 573–581.

Gomez, K. A., & Gomez, A. A. (1984). *Statistical procedures for agricultural research*. John wiley & sons.

Hanway, J.J; and Heidel, H. (1952). Soil analysis methods as used in Iowa State College, Soil Testing Laboratory. *Iowa Agriculture* **54**: 1-31.

Havlin, J.L., Tisdale, S.L., Nelson, W.L., & Beaton. J.D. (2013). Soil Fertility and Fertilizers: An Introduction to Nutrient Management (Eighth Edition). Pearson India Education Services Pvt. Ltd.

Indira, G., Yadav, R. B., Naresh, R. K., Chandra, M. S., Nath, A., & Pachauri, R. K. (2021). Effect of Different Nutrients and its Integration on Growth, Yield and Quality of Double Zero Indian Mustard (*Brassica juncea* L.). *International Journal of Plant & Soil Science*, *33*(22), 1-11.

Jackson, M.L. (1973). Soil chemical analysis. Prentice Hall of India Pvt. Ltd, New Delhi.

Kumar, P., Niwas, R., & Singh, S. (2022). Effect of different level of nitrogen and sulphur on growth and yield of Indian mustard (Brassica juncea L.) in central plain zone of UP.*The Pharma Innovation Journal*, 11(7): 2279-2282.

UNDER PEER REVIEW

Lindsay, W. L., & Norvell, W. (1978). Development of a DTPA soil test for zinc, iron, manganese, and copper. *Soil science society of America journal*, *42*(3), 421-428.

Mishra, A., Gupta, H., Mishra, U. S., Sirothia, P., & Darwai, P. (2023). Interaction Effect of Sulphur and NPK on Growth Parameters and Yield of Mustard. *International Journal of Plant & Soil Science*, *35*(15), 138-144.

Nandan, D., & Bhatnagar, G. S. (2022). To study the effect of biofertilizers, phosphorus and sulphur on yield, yield attributes and economics of Indian mustard (*Brassica juncea* L.).*The Pharma Innovation Journal*; SP-11(7): 195-199.

Olsen, S.R, Cole, C.V., Watanable, F. S. and Dean, L. A. (1954). Estimation of available phosphorous in soil by extraction with sodium bicarbonate. *USDA, Cric*. **930**:19- 2

Pandey, S. B., Sachan, R., Patel, V., & Bhawan, R. (2022). Effect of Sulphur, Potassium and PSB on Growth Parameters, Root Architecture and Quality of Mustard (*Brassica juncea* L.). *International Journal of Plant & Soil Science*, *34*(24), 122-127.

Pandey, S., Kabdal, M., & Tripathi, M. K. (2013). Study of inheritance of erucic acid in Indian mustard (Brassica juncea L. Czern & Coss). *Octa Journal of Biosciences*, 1(1).

Patil, S. C., Jagtap, D. N. and Bhale, V. M. (2011). Effect of phosphorus and sulphur on growth and yield of moongbean. *Int. J. Agric. Sci*., 7(2): 348-351.

Piri, I., Nik, M.M., Tavassoli, A., Rastegaripour, F. and Babaeian, M. (2011). Effect of irrigation frequency and application levels of sulphur fertilizer on water use efficiency and yield of Indian mustard (*Brassica juncea*). *African Journal ofBiotechnology*, **10**(55): 11459-11467.

Rahangdale, V., Mishra, A., Mishra, U. S., Sirothia, P., & Singh, O. K. (2022). Effect of Sulphur and Boron on Growth Characterstics, Yield Components and Productivity Parameters of Mustard (*Brassica juncea* L.) under Rainfed Condition of Chitrakoot Region, Madhya Pradesh, India. *International Journal of Plant & Soil Science*, *34*(24), 225-232.

Rai, P. K., Yadav, P., Kumar, A., Sharma, A., Kumar, V., & Rai, P. (2022). Brassica juncea: A Crop for Food and Health. In *The Brassica juncea Genome* (pp. 1-13). Cham: Springer International Publishing.

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Rai, S., Maurya, K. K., Kushwaha, S., Mishra, P., Nath, T., & Singh, R.(2014). Response of Indian Mustard (*Brassica Juncea L.*) as influenced by different doses and sources of sulphur. *Plant Archives* Vol. 14 No. 2, 2014 pp. 855-858 ISSN 0972-5210.

Shukla, A. K., Behera, S. K., Pakhre, A., & Chaudhari, S. K. (2018). Micronutrients in soils, plants, animals and humans. *Indian Journal of Fertilisers*, *14*(3), 30-54.

Singh, H., Choudhary, R. L., Jat, R. S., Rathore, S. S., Meena, M. K., & Rai, P. K. (2023). Re-visiting of nitrogen and sulphur requirements in Indian mustard [*Brassica juncea*(L.)] under irrigated conditions.*Indian Journal of Agricultural Sciences* 93 (1): 51–56.

Singh, S. K., Pal, L., Singh, S. P., & Singh, B. R. (2015). Effect of Phosphorus, Sulphur and Zinc on Siliqua per plant, Test weight and Seed yield per plant of Mustard. *The Journal of Rural and Agricultural Research*, *15*(2), 71-73.

Subbiah, B.V. and Asija, C.L. (1956). A rapid procedure for the estimation of available N in Soil. *Curr. Sci.* **25**:259-260.

Walkley, A. and Black, C. S.A. (1934). Old piper, S.S. soil and plant analysis. Soil Sci. 37:29- 38.

Yanthan, M. R., & Singh, R. (2021). Effect and boron and zinc level on growth, yield and yield parameters of Mustard (*Brassica campestris* L.). *The Pharma Innovation Journal J*, *10*(11), 474-476.

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