



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(6): 786-790
Received: 27-03-2026
Accepted: 29-04-2026

Priyanka Yadav
Master Scholar, Agronomy, School of
Agricultural Sciences, Jaipur National
University, Jaipur, Rajasthan, India

Ajeet Singh
Assistant Professor, Agronomy, School
of Agricultural Sciences, Jaipur
National University, Jaipur, Rajasthan,
India

YA Tamboli
Assistant Professor, Agronomy, School
of Agricultural Sciences, Jaipur
National University, Jaipur, Rajasthan,
India

Vivekanand Sharma
Assistant Professor, Entomology, School
of Agricultural Sciences, Jaipur
National University, Jaipur, Rajasthan,
India

GR Chaudhary
Professor, Agronomy, School of
Agricultural Sciences, Jaipur National
University, Jaipur, Rajasthan, India

RK Bansal
Director & Professor, Plant Pathology,
School of Agricultural Sciences, Jaipur
National University, Jaipur-302017,
Rajasthan, India

Md Imraj Zaman
Assistant Professor, Plant Pathology,
School of Agricultural Sciences, Jaipur
National University, Jaipur, Rajasthan,
India

Corresponding Author:

Ajeet Singh
Assistant Professor, Agronomy, School
of Agricultural Sciences, Jaipur
National University, Jaipur, Rajasthan,
India

Effect nitrogen, sulphur and biofertilizers on growth and yield of Indian mustard [*Brassica juncea* (L.) Czern & Coss]

**Priyanka Yadav, Ajeet Singh, YA Tamboli, Vivekanand Sharma, GR
Chaudhary, RK Bansal and Md Imraj Zaman**

DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i6j.5788>

Abstract

A field experiment entitled “Effect of Nitrogen, Sulphur and Biofertilizers on Growth, Yield and Quality of Indian Mustard [*Brassica Juncea* (L.) Czern & Coss]” was carried out during *rabi* 2025-26 at the Agricultural Research Farm, School of Agricultural Sciences, Jaipur national University, Jaipur, Rajasthan. The results indicated that the higher growth parameters viz., plant height (cm), number of primary and secondary branches plant⁻¹, dry matter accumulation (DMA) and crop growth rate (CGR) recorded significantly with the application of 90 kg N ha⁻¹ and it was at par with the application of 60 kg N ha⁻¹. However, in response of sulphur levels the results indicated that the higher growth parameters viz., plant height (cm), number of primary and secondary branches plant⁻¹, DMA and CGR were recorded with the application of 50 kg S ha⁻¹ and it was at par with the application of 40 kg S ha⁻¹. Moreover, in response of biofertilizers inoculation the results indicated that the higher growth parameters viz., plant height (cm), number of primary and secondary branches plant⁻¹, DMA and CGR were recorded with seed inoculated by *Azotobacter*.

Furthermore, an examination of data indicated that the interaction effect of nitrogen and sulphur levels significantly observed. Results indicated that the application of 90 kg N ha⁻¹ + 50 kg S ha⁻¹ gave maximum plant height at harvest (182.07 cm), dry matter accumulation at harvest (46.73 g plant⁻¹) and it was statistically at par with the application of 60 kg N ha⁻¹ + 40 kg S ha⁻¹.

Keywords: indian mustard, nitrogen, sulphur, azotobacter, azospirillum, growth

1. Introduction

Indian mustard [*Brassica juncea* (L.) Czern. & Coss.] is one of the most important oilseed crops cultivated in India and ranks next to soybean and groundnut in terms of economic significance. India is among the leading producers of rapeseed-mustard in the world, second only to China. According to the Directorate of Economics and Statistics (DES, 2024) ^[10], rapeseed-mustard contributes about 8.32 million tonnes to the country's total oilseed production of 31.31 million tonnes. Out of the total edible oil production of approximately 7.36 million tonnes, rapeseed-mustard accounts for nearly 2.58 million tonnes. Mustard oil cake, a valuable by-product, contains about 5.10% nitrogen, 1.80% phosphorus and 1.20% potassium, along with nearly 40% protein. However, the presence of glucosinolates restricts its wider utilization as feed (Bhinda *et al.*, 2025) ^[4].

Among the mustard-growing states of India, Rajasthan occupies the leading position, contributing nearly 46% of the national production. During 2024-25, the state produced about 4.20 million tonnes of mustard, followed by Haryana and Madhya Pradesh. Besides these states, mustard is also cultivated in Uttar Pradesh, Gujarat and several non-traditional regions such as Karnataka, Tamil Nadu and Andhra Pradesh. The crop is grown under both irrigated and rainfed ecosystems, with a larger share under irrigation. Because mustard responds favourably to nutrient application, irrigated cultivation generally results in higher productivity and profitability (DES, 2024) ^[10].

In recent decades, continuous cultivation of high-yielding varieties and intensive cropping systems have led to depletion of essential plant nutrients from agricultural soils. The increasing pressure on limited land resources to meet the food and oil requirements of a growing population has further aggravated nutrient deficiencies.

Consequently, mustard is often cultivated under suboptimal nutrient conditions, which adversely affects its growth, development and productivity (Chandel *et al.*, 2025) [5]. Rising fertilizer costs, gradual reduction in fertilizer subsidies and concerns regarding environmental pollution caused by excessive fertilizer use have highlighted the need for balanced nutrient management. An integrated nutrient management approach involving chemical fertilizers, organic manures and biofertilizers offers a sustainable solution for maintaining soil fertility while improving crop productivity and environmental quality.

Nitrogen is one of the most essential nutrients required for plant growth and development. It plays a key role in metabolic activities, energy transfer, synthesis of proteins, nucleic acids, chlorophyll and protoplasm. Adequate nitrogen supply promotes chlorophyll formation, enhances photosynthetic efficiency and increases dry matter accumulation, ultimately resulting in higher biomass production and yield (Sahu *et al.*, 2025) [35]. Sulphur is another important nutrient for Indian mustard because of its direct involvement in protein synthesis and oil formation. It contributes to the production of sulphur-containing amino acids, vitamins and enzymes and is necessary for chlorophyll development and several metabolic processes. Sulphur also improves nutrient availability and soil health when supplied in appropriate quantities. Since oilseed crops have a comparatively higher sulphur requirement, its deficiency can significantly reduce seed yield and oil content. Approximately 41% of Indian soils are reported to be deficient in sulphur. Deficiency symptoms usually appear first on young leaves as pale green or yellow coloration. Adequate sulphur nutrition is therefore indispensable for realizing the yield and quality potential of mustard, particularly in sulphur-deficient soils (Singh and Singh, 2018) [39].

Biofertilizers have emerged as an important component of sustainable agriculture. These preparations contain beneficial microorganisms that colonize the rhizosphere or plant tissues and enhance plant growth through various mechanisms. They improve nutrient availability by fixing atmospheric nitrogen, solubilizing phosphorus, oxidizing sulphur and producing plant growth-promoting substances (Verma *et al.*, 2019) [51]. Among the beneficial microorganisms, *Azotobacter* is a free-living aerobic nitrogen-fixing bacterium that contributes significantly to crop growth and productivity. It synthesizes growth-promoting substances such as auxins, cytokinins and gibberellins and helps plants tolerate various biotic and abiotic stresses (Bhattacharjee and Dey, 2014) [3]. Similarly, *Azospirillum* has gained considerable importance in mustard cultivation due to its ability to associate with plant roots and improve nitrogen availability. It stimulates root growth, enhances nutrient uptake and increases chlorophyll content, leading to better plant vigor and productivity. Moreover, *Azospirillum* produces phytohormones such as indole acetic acid, gibberellins and cytokinins, which positively influence plant growth and development (Kumar *et al.*, 2018) [21]. Seed inoculation with *Azospirillum* has been reported to improve germination, growth parameters, yield attributes and oil content in mustard. Its integrated use with inorganic fertilizers can reduce nitrogen fertilizer requirements while improving soil biological activity and long-term soil fertility (Dubey *et al.*, 2021) [11].

Considering the importance of nitrogen, sulphur and biofertilizers in enhancing crop growth, nutrient use efficiency, yield and quality of Indian mustard, their optimum management is essential for achieving sustainable productivity. Therefore, the present field experiment was undertaken to evaluate the effect of different nitrogen levels, sulphur levels and biofertilizer inoculation on the growth, yield and quality of Indian mustard.

2. Materials and Methods

The field experiment was carried out at the Agronomy Research Farm, School of Agricultural Sciences, Jaipur National University, Jaipur, Rajasthan during kharif season of 2025. The experimental site is situated in semi-arid eastern plains of Rajasthan and lies between 26 °92' North latitude, 75 °78' East longitude and at an altitude of 430 meters from the mean sea level. The soil of the experimental field was sandy in texture and slightly alkaline in reaction with PH 7.58, organic carbon (OC) (0.43%), available nutrient (nitrogen 217.30 kg ha⁻¹; phosphorus 20.28 kg ha⁻¹ and potassium 219.20 kg ha⁻¹). The experiment was laid out in factorial randomized block design with three replications. The field trial consisted four nitrogen levels viz., (i) control, (ii) 30 kg N ha⁻¹, (iii) 60 kg N ha⁻¹ and (iv) 90 kg N ha⁻¹; three sulphur levels viz., (i) control, (ii) 40 kg S ha⁻¹ and (iii) 50 kg S ha⁻¹ and three biofertilizers inoculation (i) control, (ii) *Azotobacter* and (iii) *Azospirillum*. The Indian Mustard variety 'Radhika (DRMR 2017-15)' was sown @ 5 kg seed ha⁻¹ with spacing of 30 cm x 10 cm. The two irrigations are applied. All agricultural practices were kept uniform in all the plots.

3. Results and Discussion

3.1 Growth Parameters

3.1.1 Effect of nitrogen levels

Result indicated that the highest growth parameters viz. plant height (cm), DMA (g/plant) at 60, 80, 100 DAS, at harvest, Number of primary and secondary branches plant⁻¹ at 80, 100 DAS and at harvest and crop growth rate at 40-60 DAS, 60-80 DAS, 80-100 DAS and 100 DAS-at harvest of the Indian mustard were recorded with the application of 90 kg N ha⁻¹ and it was at par with the application of 60 kg N ha⁻¹ (Table 1). These findings align with observations of Hera *et al.* (2017) and Meena *et al.* (2019) [15, 27], who attributed increased plant height under adequate nitrogen supply to enhanced cell elongation, accelerated meristematic activity, and greater internode elongation driven by improved photosynthetic efficiency. Increased availability of nitrogen promotes biosynthesis of indole acetic acid (IAA), a phytohormone directly responsible for cell elongation, which explains the progressive height response to nitrogen increments. Nitrogen's role in chlorophyll synthesis ensures a greater photosynthetically active leaf area, which in turn channels more assimilates towards branch development. The positive response of DMA to nitrogen was attributed to enhanced leaf area development, improved canopy architecture, and greater sink activity. These results are in conformity with those reported by Patel and Jadav (2018) and Sharma *et al.* (2020) [33, 36] in Brassica juncea, who observed that nitrogen-driven improvements in photosynthetic capacity directly translated into higher dry matter production.

3.2 Effect of sulphur levels

The sulphur levels significantly enhanced the growth parameters of Indian mustard. The highest growth parameters viz. plant height (cm), DMA (g plant⁻¹) at 60, 80, 100 DAS, at harvest, Number of primary and secondary branches plant⁻¹ at 80, 100 DAS and at harvest and crop growth rate at 40-60 DAS, 60-80 DAS, 80-100 DAS and 100 DAS-at harvest of the Indian mustard were recorded with the application of 50 kg S ha⁻¹ and it was at par with the application of 40 kg S ha⁻¹ (Table 1). Sulphur-induced enhancement in chlorophyll content and photosynthetic rate facilitates more efficient carbon assimilation, thereby supporting greater vegetative growth. Sulphur-mediated improvement in branching to enhanced auxin metabolism and stimulated lateral bud development. These findings are in agreement with Tripathi

and Singh (2018), Yadav and Kumar (2019), Meena *et al.* (2019) and Mishra *et al.* (2020) [49, 54, 27, 31].

Table 1: Effect of nitrogen, sulphur and biofertilizers on growth parameters of Indian mustard at successive stage

Treatment	Plant height (cm)					No. of primary branches plant ⁻¹			No. of secondary branches plant ⁻¹			Dry matter accumulation (g plant ⁻¹)				
	40 DAS	60 DAS	80 DAS	100 DAS	At harvest	80 DAS	100 DAS	At harvest	80 DAS	100 DAS	At harvest	40 DAS	60 DAS	80 DAS	100 DAS	At harvest
Nitrogen levels																
Control	54.34	58.69	100.63	134.51	136.54	4.23	5.68	6.04	8.55	11.60	11.92	7.55	14.30	30.42	33.17	35.05
30 kg N ha ⁻¹	54.76	66.33	112.06	149.78	152.04	4.71	6.32	6.72	9.52	12.92	13.27	7.60	15.93	33.88	36.93	39.03
60 kg N ha ⁻¹	55.13	75.68	126.04	168.47	171.02	5.30	7.11	7.56	10.70	14.53	14.93	7.65	17.92	38.10	41.54	43.90
90 kg N ha ⁻¹	56.32	77.22	128.35	171.56	174.15	5.40	7.25	7.70	10.90	14.80	15.20	7.80	18.25	38.80	42.30	44.70
SEm±	1.42	0.59	0.88	1.18	1.20	0.04	0.05	0.05	0.07	0.10	0.10	0.18	0.13	0.27	0.29	0.31
CD (p=0.05)	3.99	1.66	2.49	3.32	3.37	0.10	0.14	0.15	0.21	0.29	0.27	NS	0.35	0.75	0.82	0.87
Sulphur levels																
Control	52.79	62.92	106.95	142.96	145.12	4.50	6.04	6.42	9.08	12.33	12.67	7.35	15.20	32.33	35.25	37.25
40 kg S ha ⁻¹	55.89	72.15	120.76	161.42	163.86	5.08	6.82	7.25	10.26	13.93	14.30	7.75	17.17	36.51	39.80	42.06
50 kg S ha ⁻¹	56.74	73.37	122.59	163.86	166.34	5.16	6.92	7.35	10.41	14.14	14.52	7.86	17.43	37.06	40.40	42.70
SEm±	1.23	0.51	0.76	1.02	1.04	0.03	0.04	0.05	0.06	0.09	0.08	0.16	0.11	0.23	0.25	0.27
CD (p=0.05)	3.46	1.44	2.15	2.88	2.92	0.09	0.12	0.13	0.18	0.25	0.23	NS	0.31	0.65	0.71	0.75
Biofertilizers inoculation																
Control	54.53	65.41	110.68	147.94	150.17	4.66	6.25	6.64	9.40	12.76	13.11	7.57	15.73	33.46	36.48	38.55
<i>Azotobacter</i>	56.69	73.31	122.50	163.74	166.21	5.15	6.91	7.35	10.40	14.13	14.51	7.85	17.41	37.03	40.37	42.66
<i>Azospirillum</i>	54.18	69.72	117.13	156.57	158.93	4.93	6.61	7.03	9.95	13.51	13.87	7.53	16.65	35.41	38.60	40.80
SEm±	1.23	0.51	0.76	1.02	1.04	0.03	0.04	0.05	0.06	0.09	0.08	0.16	0.11	0.23	0.25	0.27
CD (p=0.05)	3.46	1.44	2.15	2.88	2.92	0.09	0.12	0.13	0.18	0.25	0.23	NS	0.31	0.65	0.71	0.75

Table 2: Effect of nitrogen, sulphur and biofertilizers on yield attributes and yield of Indian mustard

Treatment	Yield attributes				Yield (kg ha ⁻¹)			Harvest index
	Number of silique plant ⁻¹	Length of silique (cm)	Number of seeds siliqua ⁻¹	Test weight (g)	Seed yield	Stover yield	Biological yield	
Nitrogen levels								
Control	231.28	3.37	8.94	3.27	1050	2478	3528	26.62
30 kg N ha ⁻¹	257.55	3.75	9.95	3.64	1701	3954	5655	28.06
60 kg N ha ⁻¹	289.69	4.22	11.20	4.09	1970	4063	6033	30.71
90 kg N ha ⁻¹	295.00	4.30	11.40	4.16	2014	4164	6178	30.54
SEm±	2.03	0.03	0.08	0.03	16	35	51	1.30
CD (p=0.05)	5.71	0.08	0.22	0.08	44	99	143	NS
Sulphur levels								
Control	245.82	3.58	9.50	3.47	1495	3237	4732	28.69
40 kg S ha ⁻¹	277.57	4.05	10.73	3.92	1761	3839	5599	29.13
50 kg S ha ⁻¹	281.77	4.11	10.89	3.98	1796	3918	5714	29.13
SEm±	1.75	0.03	0.07	0.02	13	31	44	0.95
CD (p=0.05)	4.95	0.07	0.19	0.07	38	86	124	NS
Biofertilizers inoculation								
Control	254.38	3.71	9.83	3.59	1567	3399	4966	28.86
<i>Azotobacter</i>	281.55	4.10	10.88	3.97	1794	3914	5708	29.10
<i>Azospirillum</i>	269.22	3.92	10.40	3.80	1691	3681	5371	28.99
SEm±	1.75	0.03	0.07	0.02	13	31	44	0.95
CD (p=0.05)	4.95	0.07	0.19	0.07	38	86	124	NS

3.3 Effect of biofertilizers inoculation

The biofertilizers inoculation significantly enhanced the growth parameters of Indian mustard. the maximum growth parameters viz. plant height (cm), DMA (g/plant) at 60, 80, 100 DAS, at harvest, Number of primary and secondary branches plant⁻¹ at 80, 100 DAS and at harvest and crop growth rate at 40-60 DAS, 60-80 DAS, 80-100 DAS and 100 DAS-at harvest of the Indian mustard were recorded with seed inoculated by *azotobacter* (Table 1). *Azotobacter* contributes significantly to nitrogen availability in the rhizosphere, thereby supporting enhanced vegetative growth. *Azospirillum*, as an associative nitrogen-fixer, similarly benefits plant growth through root morphology improvement and hormone production, though generally to a lesser extent than *Azotobacter* (Vessey, 2003) [53]. Biofertilizer-induced improvement in DMA and CGR is linked to enhanced availability of mineral nutrients, improved water-use efficiency, and augmented photosynthetic capacity, as elaborated by Tilak *et al.* (2005) and Goswami *et al.* (2016) [45, 13].

3.4 Yield attributes and yield

3.4.1 Effect of nitrogen levels

The highest Yield attributes and yield viz., length of silique, number of silique plant⁻¹, number of seeds silique⁻¹, test weight

and yield viz., seed yield, stover yield, biological yield and harvest index recorded with the application of 90 kg N ha⁻¹ and it was significantly at par with 60 kg N ha⁻¹ (Table 2). These improvements are attributed to the role of nitrogen in promoting greater photosynthetic activity, extended leaf area duration, and enhanced partitioning of assimilates to reproductive structures. These findings are consistent with those of Jat *et al.* (2019) and Choudhary *et al.* (2021) [17, 6], who reported that adequate nitrogen supply during reproductive growth significantly enhanced silique number and seed filling efficiency in mustard. These results are in close conformity with similar findings reported by Verma *et al.* (2018) [52].

3.4.2 Effect of sulphur levels

The highest yield attributes and yield viz., length of silique, number of silique plant⁻¹, number of seeds silique⁻¹, test weight and yield viz., seed yield, stover yield, biological yield and harvest index recorded with the application of 50 kg S ha⁻¹ and it was significantly at par with 40 kg S ha⁻¹ (Table 2). These improvements are attributed to sulphur critical role in the synthesis of glucosinolates and sulphur-containing amino acids

which are involved in pollen viability and fertilization efficiency, ultimately contributing to better seed set and seed filling (Ganeshamurthy *et al.*, 2021) ^[12]. The findings conform with results reported by Kumar and Sharma *et al.* (2020), Jat *et al.* (2020) and Verma and Choudhary (2021) in *Brassica juncea* ^[54, 36, 17, 50].

3.4.3 Effect of biofertilizers Inoculation

The maximum yield attributes and yield viz., length of silique, number of silique plant⁻¹, number of seeds silique⁻¹, test weight and yield viz., seed yield, stover yield, biological yield and harvest index recorded with seed inoculated by *Azotobacter* (Table 2). This improvement is attributed to better nutrient acquisition, improved soil structure through exopolysaccharide production, and enhanced symbiotic associations that collectively support better plant establishment and productivity and the superior performance of *Azotobacter* over *Azospirillum* in improving yield attributes may be attributed to its additional mechanisms of phosphate solubilization and production of growth-promoting metabolites that enhance reproductive efficiency. These results are in close conformity with similar findings reported by Yadav *et al.*, (2022) ^[56].

4. Conclusion

Based on a one-year field study on cluster bean, it may be concluded that: The application of 90 kg N ha⁻¹ + 50 kg S ha⁻¹ + *azotobacter* was suitable to attain the higher growth parameters, yield attributes and yield of Indian mustard and it was followed by 60 kg N ha⁻¹ + 40 kg S ha⁻¹ + *azotobacter*.

5. Acknowledgement

The authors express their gratitude to the School of Agricultural Sciences, Jaipur National University, Jaipur, and the Rajasthan Agricultural Research Institute, Durgapura, Jaipur, for their support in conducting the field experiments and for providing meteorological data.

Reference

- Adesemoye AO, Kloepper JW. Plant-microbes interactions in enhanced fertilizer-use efficiency. *Applied Microbiology and Biotechnology*. 2009;85(1):1-12.
- Bhardwaj D, Ansari MW, Sahoo RK, Tuteja N. Biofertilizers function as key player in sustainable agriculture by improving soil fertility, plant tolerance and crop productivity. *Microbial Cell Factories*. 2014;13:66.
- Bhattacharjee R, Dey U. Biofertilizer, a way towards organic agriculture: A review. *African Journal of Microbiology Research*. 2014;8(24):2332-2343.
- Bhinda B, Tamboli YA, Singh A, Chaudhary GR, Bansal RK, Sastry EVD, *et al.* Impact of irrigation levels and bio-regulators on physiological and yield traits of Indian mustard (*Brassica juncea* L.). *International Journal of Research in Agronomy*. 2025;8(10):680-685.
- Chandel A, Singh A, Tamboli YA, Chaudhary GR, Singh AK, Sastry EVD, *et al.* Response of weed management practices on growth and yield of Indian mustard [*Brassica juncea* (L.) Czern & Coss]. *International Journal of Research in Agronomy*. 2025;8(10):1112-1115.
- Choudhary R, Jat BL, Sharma OP, Meena SL. Response of nitrogen levels and biofertilizers on yield attributes and yield of Indian mustard in semi-arid conditions. *Journal of Pharmacognosy and Phytochemistry*. 2021;10(1):1435-1439.
- Choudhary SK, Yadav MR, Singh RK. Interaction effect of sulphur and nitrogen levels on growth and yield of Indian mustard (*Brassica juncea* L.). *Annals of Agri-Bio Research*. 2013;18(2):205-208.
- Choudhury BU, Khanif YM. Effect of biofertilizers and nitrogen management on soil microbial activity, nutrient uptake and crop yield. *Communications in Soil Science and Plant Analysis*. 2020;51(12):1572-1589.
- Das AC, Bhattacharya D, Lahiri S. Influence of biofertilizers on nutrient uptake and yield of Indian mustard. *Journal of Crop and Weed*. 2013;9(1):126-129.
- DES. Directorate of Economics and Statistics, Ministry of Agriculture. 2024. www.agri.com.
- Dubey SK, Tripathi SK, Singh B. Effect of integrated nutrient management on growth and yield of Indian mustard (*Brassica juncea* L.). *The Pharma Innovation Journal*. 2021;10(1):156-160.
- Ganeshamurthy AN, Satisha GC, Patil P. Sulphur nutrition in Indian oilseed crops: Critical limits, responses and management. *Indian Journal of Agronomy*. 2021;66(3):421-430.
- Goswami D, Thakker JN, Dhandhukia PC. Portraying mechanics of plant growth promoting rhizobacteria (PGPR): A review. *Cogent Food and Agriculture*. 2016;2(1):1127500.
- Hawkesford MJ. Plant responses to sulphur deficiency and the genetic manipulation of sulphate transporters to improve S-utilization efficiency. *Journal of Experimental Botany*. 2000;51(342):131-138.
- Hera L, Rahman MM, Islam MR. Effect of nitrogen fertilizer on growth and yield of mustard. *Bangladesh Agronomy Journal*. 2017;20(2):71-76.
- Jat BL, Meena RS. Economics of nitrogen application and biofertilizers on Indian mustard under rainfed conditions. *Economic Affairs*. 2018;63(3):745-751.
- Jat R, Choudhary S, Sharma R. Yield attributes and yield of Indian mustard as influenced by nitrogen fertilization and biofertilizers. *Progressive Agriculture*. 2019;19(2):178-182.
- Jat SL, Lal AA, Patel MK. Influence of sulphur levels and methods of application on growth, yield and quality of Indian mustard. *Journal of Oilseed Brassica*. 2020;11(1):47-52.
- Kopriva S, Calderwood A, Weckopp SC, Koprivova A. Plant sulphur and Big Data. *Plant Science*. 2012;241:1-10.
- Kumar A, Singh RK. Influence of nitrogen levels and biofertilizers on productivity and profitability of Indian mustard in alluvial soils. *Journal of Plant Nutrition*. 2020;43(11):1680-1694.
- Kumar A, Meena RN, Yadav L. Effect of organic management practices on growth and yield of mustard. *International Journal of Current Microbiology and Applied Sciences*. 2018;7(9):1234-1240.
- Kumar D, Yadav RK. Effect of sulphur and micronutrient on productivity and quality of Indian mustard (*Brassica juncea* L.). *Journal of Pharmacognosy and Phytochemistry*. 2019;8(3):2453-2457.
- Kumar N, Meena RK, Sharma A. Effect of nitrogen and sulphur nutrition on yield and quality of mustard. *Indian Journal of Agronomy*. 2016;61(4):477-481.
- Kumar V, Yadav BD, Gupta OP. Nutrient management for maximizing productivity and quality in Indian mustard. *Annals of Plant and Soil Research*. 2021;23(1):1-8.
- Mahajan G, Sardana V, Sarlach RS. Sulphur fertilization and seed quality of Indian mustard. *Journal of Oilseed Brassica*. 2019;10(2):91-95.
- Mahanty T, Bhattacharjee S, Goswami M, Bhattacharyya P, Das B, Ghosh A, *et al.* Biofertilizers: A potential approach for sustainable agriculture development. *Environmental*

- Science and Pollution Research. 2017;24(4):3315-3335.
27. Meena RS, Bohra JS, Singh SP, Meena NK. Effect of nitrogen levels on growth and yield of Indian mustard under varied crop establishment. *Bangladesh Journal of Botany*. 2019;48(4):1097-1103.
 28. Meena RS, Patel D, De N, Singh A, Gurjar DS, Kumar S, *et al*. Response of polymers and nutrient management on growth, yield and quality of Indian mustard [*Brassica juncea* (L.) Czernj and Cosson]. *Indian Journal of Agricultural Sciences*. 2020;90(11):2237-2240.
 29. Meena RS, Yadav RS, Reager ML. Yield and quality of mustard (*Brassica juncea*) as influenced by *Azotobacter* and *Azospirillum* inoculation. *Current Agriculture Research Journal*. 2018;6(3):231-236.
 30. Meena S, Kumar A, Singh DK, Bohra JS. Nitrogen use efficiency and nutrient uptake as influenced by nitrogen levels in Indian mustard. *Journal of the Indian Society of Soil Science*. 2020;68(3):356-362.
 31. Mishra RK, Singh AK, Patel VB. Effect of sulphur levels on growth, branching pattern and yield of mustard. *International Journal of Agriculture, Environment and Biotechnology*. 2020;13(3):421-426.
 32. Nandini S, Meena RL, Yadav GL. Effect of sulphur application on oil quality parameters in mustard (*Brassica juncea* L.). *Journal of Oilseed Brassica*. 2018;9(2):82-87.
 33. Patel MM, Jadav KT. Influence of nitrogen levels on dry matter accumulation and growth analysis of Indian mustard under semi-arid conditions. *Current Journal of Applied Science and Technology*. 2018;26(3):1-8.
 34. Patel S, Thakur A, Chand R. Nutrient uptake and soil available nutrient status as influenced by nitrogen and sulphur fertilization in mustard. *Journal of Pharmacognosy and Phytochemistry*. 2019;8(6):1523-1527.
 35. Sahu G, Nath A, Mishra BK. Effect of nitrogen and sulphur on the performance of the Indian mustard (*Brassica juncea* L.). *International Journal of Research in Agronomy*. 2025;8(8):552-556.
 36. Sharma KC, Jain NK, Dashora SL, Jain R. Productivity and profitability of Indian mustard as influenced by nitrogen levels and biofertilizers under arid conditions. *Journal of Oilseed Brassica*. 2020;11(1):34-39.
 37. Sharma M, Kumar R, Verma AK. Effect of nitrogen and sulphur fertilization on seed quality traits of Indian mustard. *Research in Environment and Life Sciences*. 2021;14(2):78-84.
 38. Singh A, Meena RS. Response of bioregulators and irrigation on plant height of Indian mustard (*Brassica juncea* L.). *Journal of Oilseed Brassica*. 2020;11(1):9-14.
 39. Singh DK, Singh A, Bohra JS. Phytohormone changes and growth response of Indian mustard to varying nitrogen doses. *Journal of Plant Growth Regulation*. 2018;37(2):631-641.
 40. Singh J, Yadav RS, Kumar M. Influence of biofertilizers and nitrogen levels on growth and yield of mustard. *International Journal of Current Microbiology and Applied Sciences*. 2019;8(5):1632-1640.
 41. Singh RK, Yadav BL. Economic analysis of sulphur fertilization in Indian mustard under north-western arid conditions. *Economic Affairs*. 2020;65(3):411-417.
 42. Singh S, Singh M. Influence of nitrogen and sulphur application on growth, yield attributes, yield and quality of mustard (*Brassica juncea* L.) in Bundelkhand region. *International Journal of Fauna and Biological Studies*. 2018;5(2):83-85.
 43. Singh S, Rathore SS, Kumar D. Sulphur nutrition effects on chlorophyll biosynthesis and photosynthesis in Indian mustard. *Photosynthetica*. 2020;58(4):1012-1020.
 44. Singh V, Yadav AL, Sharma MK. Protein and oil quality improvement in mustard through balanced sulphur nutrition. *Journal of Oilseed Brassica*. 2021;12(1):18-24.
 45. Tilak KVBR, Ranganayaki N, Pal KK, De R, Saxena AK, Shekhar Nautiyal C, *et al*. Diversity of plant growth and soil health supporting bacteria. *Current Science*. 2005;89(1):136-150.
 46. Tiwari A, Dwivedi AK. Biofertilizer and nutrient management effects on soil health and mustard productivity. *Indian Journal of Agricultural Sciences*. 2020;90(8):1496-1501.
 47. Tiwari DD, Pandey AN, Katiyar NK. Sulphur level effects on morpho-physiological traits of Indian mustard. *International Journal of Pure and Applied Bioscience*. 2019;7(3):350-356.
 48. Tripathi MK, Tiwari S, Tripathi N. Nitrogen influence on fatty acid composition and oil biosynthesis in *Brassica* species. *Journal of Oilseed Brassica*. 2019;10(2):108-114.
 49. Tripathi R, Singh M. Dry matter accumulation, crop growth rate and yield of Indian mustard as affected by levels of sulphur. *Environment and Ecology*. 2018;36(2):500-505.
 50. Verma G, Choudhary RK. Effect of sulphur levels and time of application on yield and quality of mustard under semi-arid conditions. *International Journal of Chemical Studies*. 2021;9(4):3152-3156.
 51. Verma M, Mishra J, Arora NK. Plant growth-promoting rhizobacteria: Diversity and applications. In: *Environmental Biotechnology: For Sustainable Future*. Singapore: Springer; 2019. p. 129-173.
 52. Verma V, Singh A, Tiwari A. Optimization of nitrogen dose for Indian mustard under semi-arid Rajasthan conditions. *Journal of Pharmacognosy and Phytochemistry*. 2018;7(3):1683-1687.
 53. Vessey JK. Plant growth promoting rhizobacteria as biofertilizers. *Plant and Soil*. 2003;255(2):571-586.
 54. Yadav H, Kumar P. Sulphur-induced improvement in branching and canopy development of Indian mustard. *Journal of Applied and Natural Science*. 2019;11(1):261-265.
 55. Yadav H, Sharma K. Nitrogen-phosphorus-potassium uptake and their relationship with yield in Indian mustard under varying nitrogen applications. *Indian Journal of Agronomy*. 2021;66(2):184-189.
 56. Yadav T, Singh SP, Verma RK. *Azotobacter* and *Azospirillum* inoculation effects on productivity and economics of mustard: A meta-analytic review. *Journal of Soil Science and Plant Nutrition*. 2022;22(2):1876-1888.