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Impact of integrated nutrient management on growth yield and quality of Indian mustard (*Brassica juncea* L.)

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Abstract
A field experiment was conducted during the Rabi season of 2024–25 at the Research Farm, Department of Agronomy, United University, Prayagraj. The trial was laid out in a Randomized Block Design with eight treatments: T_1 (Control), T_2 (100% RDF), T_3 (75% RDF + 2.5 t/ha VC), T_4 (75% RDF + 5 t/ha FYM), T_5 (100% RDF + 25 kg/ha S), T6 (50% RDF + 25 kg/ha S), T_7 (75% RDF + 25 kg/ha S), and T_8 (100% RDF + 2.5 t/ha VC + 5 t/ha FYM + 25 kg/ha S). Growth attributes showed that T_8 consistently produced the tallest plants (173.51 cm), maximum dry matter accumulation (26.64 g at 120 DAS), highest LAI (11.62), superior NAR (0.891 g m^{-2} day^{-1}), and number of branches (19.67). The control consistently remained the least effective across all parameters. Overall, the study established that integration of 100% RDF with vermicompost, FYM, and sulphur (T_8) is the most effective nutrient management strategy, ensuring improved growth, yield, quality, nutrient uptake, and profitability of Indian mustard under the agro-climatic conditions of Prayagraj.

Keywords: Indian mustard, mustard, NAR, CGR

Introduction
Among oilseeds, mustard (rai) holds special importance. It accounts for nearly 70% of the rapeseed–mustard area, making India the world's leading producer with 27.5% of the global area and 20% of global output (Vanukuri & Pandey, 2022) [15]. Yet, the country's average yield (~900 kg/ha) lags behind the global average of 1408 kg/ha (Patel, 2024) [12]. Rajasthan, Punjab, Haryana, Uttar Pradesh, Madhya Pradesh, Gujarat, and West Bengal are the major producing states. Mustard contributes about 25% of India's total oilseed production, with 6.86 million hectares under cultivation, producing 9.12 million tonnes at an average yield of 1331 kg/ha. Rajasthan alone produces nearly half of this output. Mustard seeds contain 36–48% oil, widely used in cooking, food preservation, and also in industries for soap, lubrication, and biofuel. The residual oil cake serves as cattle feed and fertilizer, while mustard greens are consumed as vegetables, adding nutritional value.

Botanically, mustard (*Brassica juncea* L.) belongs to the family Brassicaceae, is an annual, self-pollinated amphidiploid species with 2n = 4x = 36 chromosomes (Nagaharu, 1935) [9]. Rich in bioactive compounds such as glucosinolates, flavonoids, carotenoids, ascorbic acid, and minerals (Kim *et al.*, 2007) [5], mustard is valued for both its culinary and medicinal applications. Traditionally, its leaves and oils have been used as stimulants, diuretics, and expectorants. Fermented mustard products also exhibit potential health benefits (Lee *et al.*, 2010) [7]. The crop has been cultivated across Eurasia for centuries, thriving in subtropical and temperate regions, with its primary origin traced to Central Asia, particularly northwestern and eastern India, and extending into China, Myanmar, Iran, and the Near East (Miceli *et al.*, 2014) [8].

As of 2022–23, mustard occupied about 7.14 million hectares in India, producing 10.95 million tonnes of seeds (DES, 2023) [2]. Rajasthan was the leading state in both acreage and output, followed by Haryana and Madhya Pradesh. In Uttar Pradesh alone, mustard covered 1.16 lakh hectares, yielding 2.73 million tonnes with an average productivity of 1607.85 kg/ha. Mustard cultivars vary in flavour and pungency, largely influenced by seed type, processing techniques, and additives. The leaves are particularly rich in chlorophyll, β-carotene, ascorbic acid, potassium, and calcium. The seeds are also nutrient-dense, containing proteins, carbohydrates, fats, dietary fibre, and vitamins (especially C and K), along with essential minerals such as calcium, iron, zinc, selenium, copper, manganese, and magnesium, as well as electrolytes like sodium and potassium (Campbell *et al.*, 2012; Jaiswal *et al.*, 2012) [1, 3].

Deficiencies of key nutrients, particularly micronutrients such as sulphur, pose a significant limitation to mustard production, often resulting in weak plant growth, poor seed set, and reduced oil content. Sulphur is indispensable for enzyme activation, protein synthesis, and growth regulation, making its adequate supply critical for achieving optimum yields. However, the exclusive reliance on chemical fertilizers in Indian agriculture has accelerated sulphur depletion and contributed to the deterioration of soil structure. In this context, vermicompost, a biologically active organic amendment, offers a sustainable means of improving soil fertility by stimulating microbial activity, enhancing moisture retention, and increasing the availability of nutrients, including sulphur and other micronutrients. The integration of sulphur fertilization with vermicompost application may provide a synergistic effect, simultaneously improving crop productivity and restoring soil health. Such a strategy ensures balanced nutrient supply, reduces dependence on synthetic inputs, and promotes sustainable production practices. Given mustard's importance as a major oilseed crop with high nutritional and economic significance, it becomes essential to evaluate the combined impact of varying sulphur doses and vermicompost application. Identifying the most effective nutrient combinations will not only enhance mustard yield but also safeguard soil fertility, thereby contributing to eco-friendly agriculture and long-term food security.

Materials and Methods

The present investigation was carried out at the Research Farm of Department of Agronomy, Faculty of Agriculture and Allied Sciences, United University, Prayagraj, Uttar Pradesh, during the *Rabi* seasons of 2024-25. United University, situated at Rawatpur, Jhalwar in Prayagraj, holds a strategically significant location with seamless connectivity to the city and nearby regions, thereby ensuring convenient accessibility for academic and research activities. Prayagraj is situated within the Central Plain sub-zone of Agro-climatic Zone V of Uttar Pradesh, as classified by the Department of Land Development and Water Resources, Government of Uttar Pradesh. The experimental field is geographically positioned between 20°33' to 21°50' N latitude and 73°27" to 73°56" E longitude. The area experiences a tropical climate, characterized by scorching summers, moderately cold winters, and a humid, warm monsoon season. The region receives substantial rainfall, primarily from June to September, with the majority of precipitation occurring during the southwest monsoon, particularly in July and August. The treatments consisted of T_1 (Control); T_2 (100% RDF); T_3 (75% RDF + @ 2.5 t/ha VC); T_4 (75% RDF + @ 5 t/ha FYM); T_5 (100% RDF + 25 Kg/ha S); T_6 (50% RDF + 25 Kg/ha S); T_7 (75% RDF + 25 Kg/ha S) and T_8 (100% RDF + VC 2.5 t/ha + 5 t/ha FYM + 25 kg/ha S). Five randomly selected plants were measured for height from the ground to the top of the plant at maturity. Plant height was measured from the ground level to the tip of the shoot at 30, 60, and 90 days after sowing (DAS) using a 100 cm meter scale. Five plants were randomly selected from each plot, and the mean value of each replication was recorded and subjected to statistical analysis. Dry matter accumulation was assessed at 30, 60, and 90 DAS. At each stage, five plants were randomly sampled from the net plot area, thoroughly washed, and separated into roots, stems, leaves, and reproductive parts wherever applicable. The samples were sun-dried for 2–3 days, followed by oven-drying at 65 ± 2 °C until a constant weight was achieved. The dry weight of each plant part was recorded, summed to obtain total dry matter per plant, and expressed as grams per plant. These values were subsequently converted to kilograms per hectare for analysis. From the samples collected for dry matter estimation, leaves of five plants were observed at 30, 60, and 90 DAS, and leaf area was measured with the help of a leaf area meter (LA-3100). After recording the leaf area, these leaves were again mixed with the respective samples of dry matter estimation. The leaf area for each sample so recorded was averaged to obtain the leaf area per plant. Land area per plant was then used to compute LAI:

$$\text{LAI} = \frac{Leaf\ area\ (cm\ sq)}{Land\ area\ (cm)}$$

The mean crop growth rate (CGR) was defined as the increase in dry weight of plant material per unit area per unit time. Observation was recorded for 30-60 DAS, 60-90 DAS and 90-120 DAS. It was calculated according to the method from periodic dry matter recorded at different stages using the formula:

$$\text{CGR (gm}^{-2}\text{ day}^{-1}) = \frac{W2-W1}{t2-t1} \text{ X } \frac{1}{A}$$

Relative growth rate (RGR) is the rate of increase in dry matter per unit of existing dry matter per unit time. Observation was recorded for 30-60 DAS, 60-90 DAS and 90-120 DAS. It was estimated according to formula:

$$\text{RGR (g/g day}^{-1}) = \frac{Log\ 10\ (W2-W1)}{t2-t1}$$

The statistical analysis was conducted using Fisher and Yates (1967).

Results and Discussion

Plant population

The uniformity in plant population across treatments, despite numerical differences, can be attributed to the fact that seed germination and early seedling establishment in mustard are primarily governed by seed quality, soil moisture availability, and sowing technique rather than post-sowing nutrient application. Since identical seed lots, sowing methods, and seed rates were used across all treatments, variations due to nutrient management were minimal. Moreover, the favourable field conditions ensured satisfactory emergence and survival of seedlings in all plots. The slight numerical advantage observed in treatments receiving integrated application of RDF along with vermicompost, FYM, and sulphur (T_8) may be linked to improved soil physical conditions and microbial activity that aided early establishment, but the differences were too small to be statistically significant. These findings are consistent with earlier reports where nutrient management influenced crop vigour and yield attributes but had limited impact on initial plant population, which generally remains unaffected once uniform sowing and favourable germination conditions are ensured. Findings were in accordance with works of Saini *et al.* (2024) [13] and Nandhini *et al.* (2024) [10].

Crop growth parameters

The consistent superiority of treatment T_8 (100% RDF + VC 2.5 t/ha + FYM 5 t/ha + S 25 kg/ha) across growth parameters such as plant height (173.51 cm at 90 DAS), dry matter accumulation (26.64 g at 120 DAS), leaf area index (11.62 at 90–120 DAS), and crop growth rate (1.183×10^{-3} g m^{-2} day^{-1} at 30–60 DAS) can be attributed to the synergistic effects of integrated nutrient management. The combination of inorganic fertilizers (RDF) with organics (vermicompost and FYM) ensured both immediate and sustained nutrient supply. While the RDF provided readily available nutrients essential for rapid vegetative growth, the gradual mineralization of organics released nutrients steadily over time, reducing losses and maintaining crop vigour throughout the season. Organic amendments further improved soil physical properties, such as aeration, porosity, and water-holding capacity, which enhanced root proliferation and nutrient absorption. Vermicompost also enriched the soil microbial population, stimulating enzymatic activities and accelerating nutrient transformation processes, thereby increasing nutrient-use efficiency. The inclusion of sulphur played a vital role in chlorophyll synthesis, amino acid formation, and oil biosynthesis in mustard, which not only enhanced photosynthetic activity but also supported higher assimilate production and partitioning. Together, these effects led to taller plants, greater leaf expansion, higher biomass accumulation, and improved canopy structure. Kumar *et al.* (2024) [6] reported similar trends in plant height, crop growth rate and dry matter accumulation in mustard when applied with NPK and S doses. Verma *et al.* (2023) [16] also reported similar trends on using integrated nutrient management in mustard.

In contrast, the poor performance of the control (T_1) and sub-optimal nutrient combinations (T_2, T_3, T_5, and T_6) was due to inadequate nutrient supply, which restricted cell division and elongation, reduced photosynthetic efficiency, and ultimately lowered biomass accumulation. Although treatments such as T_7 (75% RDF + VC + S) also performed well and remained statistically comparable to T_8 in some growth traits, the absence of FYM or reduced RDF levels limited their capacity to sustain growth at later stages. The decline in Relative Growth Rate (RGR) with crop age, despite higher dry matter accumulation in nutrient-rich treatments, can be explained by the dilution effect, where the relative increase in biomass becomes smaller as plants mature. This trend is well-documented in mustard and similar crops. Overall, the results clearly establish that integrated application of inorganic fertilizers with vermicompost, FYM, and sulphur is superior to either source alone, as it enhances both soil fertility and physiological efficiency, resulting in improved growth dynamics of mustard. These findings are in close agreement with earlier studies reporting that integrated nutrient management improves crop vigour, leaf area expansion, and biomass production by ensuring a balanced and sustained nutrient environment.

The results indicated that nutrient management treatments significantly influenced the net assimilation rate of mustard. During the early vegetative stage (30–60 DAS), the maximum NAR was recorded in T_8 (2.880 g m^{-2} day^{-1}), followed by T_7 (2.496 g m^{-2} day^{-1}), whereas the minimum occurred in the control T_1 (0.113 g m^{-2} day^{-1}). At 60–90 DAS, the highest NAR was observed in T_7 (1.082 g m^{-2} day^{-1}), followed closely by T_8 (1.036 g m^{-2} day^{-1}), while the lowest was in T_5 (0.092 g m^{-2} day^{-1}). During the later stage (90–120 DAS), the maximum NAR was again noted in T_8 (0.891 g m^{-2} day^{-1}), followed by T_7 (0.682 g m^{-2} day^{-1}), while the lowest was in T_6 (0.047 g m^{-2} day^{-1}). Overall, NAR peaked at 30–60 DAS and then declined with crop maturity, a trend commonly associated with increasing leaf senescence and declining photosynthetic efficiency. The superiority of T_8 and T_7 can be attributed to better nutrient availability, which enhanced chlorophyll content, photosynthetic rate, and assimilation efficiency per unit leaf area. The contribution of vermicompost and FYM in improving soil aeration, microbial activity, and nutrient mineralization likely supported sustained assimilation, while sulphur enhanced enzymatic activity and protein synthesis, further improving NAR. In contrast, the control (T_1) and sulphur-alone treatments (T_5 and T_6) recorded the lowest values, owing to nutrient deficiencies that restricted carbon assimilation and reduced efficiency of the photosynthetic apparatus. Tripathi *et al.* (2025) [14] and Jat *et al.* (2023) [4] studied the effect of different types of vermicompost, combined with graded levels of recommended fertilizer dose (RDF), on yield and yield-attributing traits of Indian mustard and concluded similar trends with relative crop growth rate, net assimilation rate.

Branch production in mustard showed significant improvement under integrated nutrient management. At 30 DAS, the highest number of branches was recorded in T_8 (7.70), followed by T_7 (7.27), while the control (T_1) registered the minimum (4.27). At 60 DAS, branch number remained highest in T_8 (11.90), followed by T_7 (11.47) and T_6 (10.87), while the minimum was in T_1 (7.60). By 90 DAS, T_8 attained the maximum (19.67), followed by T_7 (18.57) and T_6 (17.10), while the lowest was in the control (13.50). Overall, T_8 consistently maintained the highest branching across all growth stages, registering nearly 45.77% more branches at 90 DAS over the control. The higher branch production in T_8 can be explained by its balanced and continuous nutrient supply, which promoted vigorous vegetative growth and supported apical dominance release, thereby facilitating lateral shoot development. The combined role of organics and sulphur enhanced root activity, nutrient uptake, and hormonal balance (particularly cytokinins), which are crucial for axillary bud initiation and branching. Conversely, limited nutrient availability under control and sulphur-alone treatments restricted vegetative vigour and reduced branching. Similar findings were also concluded by Pandey *et al.* (2020) [11] in mustard.

Table 1: Effect of different level of NPK, S and organics on plant population and plant height of mustard

Treatment Details		Plant population (000' plants/ha)		Plant height (cm)		
		15 DAS	Harvest	30 DAS	60 DAS	90 DAS
T_1	Control	222.07	220.75	42.00	73.63	111.79
T_2	100% RDF	232.62	231.30	45.62	118.26	143.63
T_3	75% RDF + @ 2.5 t/ha VC	226.95	225.63	46.39	119.53	144.90
T_4	75% RDF + @ 5 t/ha FYM	223.91	222.59	53.82	132.53	157.90
T_5	100% RDF + 25 Kg/ha S	226.99	225.67	54.96	134.58	159.95
T_6	50% RDF + 25 Kg/ha S	227.80	226.48	57.42	138.95	166.63
T_7	75% RDF + 25 Kg/ha S	230.95	229.63	60.50	144.41	172.08
T_8	100% RDF + VC 2.5 t/ha + 5 t/ha FYM + 25 kg/ha S	234.42	233.10	60.63	144.59	173.51

'F' test	**NS**	**NS**	**S**	**S**	**S**
SE. d (±)	-	-	0.94	1.70	1.56
CV. (%)	-	-	6.08	8.34	5.76
$CD_{0.05}$	-	-	2.85	5.16	4.75

Table 2: Effect of different level of NPK, S and organics on dry matter accumulation of mustard

Treatment Details		Dry matter accumulation (g)			
		30 DAS	**60 DAS**	**90 DAS**	**120 DAS**
T_1	Control	4.45	15.70	19.34	21.98
T_2	100% RDF	7.26	16.96	20.65	24.50
T_3	75% RDF + @ 2.5 t/ha VC	6.20	14.61	18.18	21.07
T_4	75% RDF + @ 5 t/ha FYM	7.26	16.04	19.69	22.87
T_5	100% RDF + 25 Kg/ha S	6.28	14.66	17.77	21.14
T_6	50% RDF + 25 Kg/ha S	6.41	14.09	17.89	19.80
T_7	75% RDF + 25 Kg/ha S	7.79	18.97	22.81	24.29
T_8	100% RDF + VC 2.5 t/ha + 5 t/ha FYM + 25 kg/ha S	8.86	21.08	23.57	26.64
'F' test		**S**	**S**	**S**	**S**
SE. d (±)		0.27	0.69	0.75	1.15
CV. (%)		6.80	7.25	6.46	8.72
$CD_{0.05}$		0.81	2.10	2.26	3.48

Table 3: Effect of different level of NPK, S and organics on leaf area index of mustard

Treatment Details		Leaf area index				Crop growth rate (10^{-3} g m^{-2} day^{-1})		
		30 DAS	**60 DAS**	**90 DAS**	**120 DAS**	**30-60 DAS**	**60-90 DAS**	**90-120 DAS**
T_1	Control	1.27	2.91	8.91	8.91	1.089	0.352	0.255
T_2	100% RDF	1.53	3.33	10.20	10.20	0.939	0.357	0.373
T_3	75% RDF + @ 2.5 t/ha VC	1.72	3.38	9.75	9.75	0.814	0.346	0.280
T_4	75% RDF + @ 5 t/ha FYM	1.80	3.28	10.77	10.77	0.850	0.354	0.307
T_5	100% RDF + 25 Kg/ha S	1.57	3.91	10.62	10.62	0.811	0.301	0.327
T_6	50% RDF + 25 Kg/ha S	2.04	3.44	10.95	10.95	0.743	0.368	0.185
T_7	75% RDF + 25 Kg/ha S	2.16	3.70	11.12	11.12	1.082	0.371	0.143
T_8	100% RDF + VC 2.5 t/ha + 5 t/ha FYM + 25 kg/ha S	2.29	4.35	11.62	11.62	1.183	0.241	0.297
'F' test		**S**	**S**	**S**	**S**	**S**	**S**	**NS**
SE. d (±)		0.10	0.20	0.52	0.52	2.06	4.03	-
CV. (%)		9.86	9.92	8.56	8.56	10.48	13.31	-
$CD_{0.05}$		0.31	0.61	1.57	1.57	6.09	12.09	-

Table 4: Effect of different level of NPK, S and organics on relative growth rate, net assimilation rate and number of branches per plant of mustard

Treatment Details		Relative growth rate (10^{-3} g g^{-1} day^{-1})			Net assimilation rate (10^{-3} g m^{-2} day^{-1})			No of branches per plant		
		30-60 DAS	**60-90 DAS**	**90-120 DAS**	**30-60 DAS**	**60-90 DAS**	**90-120 DAS**	**30 DAS**	**60 DAS**	**90 DAS**
T_1	Control	0.035	0.019	0.012	0.113	0.123	0.253	4.27	7.60	13.50
T_2	100% RDF	0.033	0.019	0.013	1.756	0.153	0.167	5.13	8.47	15.37
T_3	75% RDF + @ 2.5 t/ha VC	0.031	0.018	0.012	1.490	0.141	0.135	5.78	9.11	15.68
T_4	75% RDF + @ 5 t/ha FYM	0.031	0.019	0.012	1.895	0.146	0.101	6.04	9.71	15.94
T_5	100% RDF + 25 Kg/ha S	0.031	0.016	0.010	1.003	0.092	0.412	5.29	7.96	14.86
T_6	50% RDF + 25 Kg/ha S	0.029	0.019	0.012	1.485	0.120	0.047	6.87	10.87	17.10
T_7	75% RDF + 25 Kg/ha S	0.035	0.019	0.012	2.496	1.082	0.682	7.27	11.47	18.57
T_8	100% RDF + VC 2.5 t/ha + 5 t/ha FYM + 25 kg/ha S	0.036	0.013	0.006	2.880	1.036	0.891	7.70	11.90	19.67
'F' test		**NS**	**NS**	**NS**	**S**	**S**	**S**	**S**	**S**	**S**
SE. d (±)		-	-	-	0.32	0.52	0.89	0.34	0.49	0.52
CV. (%)		-	-	-	8.34	7.51	6.61	9.86	8.88	5.56
$CD_{0.05}$		-	-	-	0.97	1.56	2.67	1.04	1.50	1.59

Conclusion

The present investigation clearly demonstrated that nutrient management practices exerted a significant influence on plant growth and physiological parameters. Among the treatments, T_8 (100% RDF + 2.5 t/ha vermicompost + 5 t/ha FYM + 25 kg/ha sulphur) consistently outperformed all others, recording the tallest plants, maximum dry matter accumulation, highest LAI, NAR, and number of branches per plant. T_7 also maintained superior growth performance, particularly in plant height, LAI, and NAR, thereby ranking next to T_8. In contrast, the control (T_1) and treatments T_2, T_3, and T_5 generally remained among the lower performers for most growth attributes. Physiological indices varied across treatments. T_2 excelled in CGR and RGR at later stages, indicating its effectiveness in sustaining growth rate, while T_8 and T_7 dominated during early stages, highlighting their vigour and superior resource utilization. Despite some variations, T_8 consistently registered higher percent gains over the control, reflecting the effectiveness of its nutrient regime. Overall, the results confirm that T_8 was the most efficient treatment in promoting plant height, biomass production, leaf area development, and branching capacity, thereby providing a distinct growth advantage over other treatments.

References

1. Campbell MK, Farrell SO, McDougal OM. Biochemistry. 7th ed. Brooks/Cole, Cengage Learning; 2012.
2. DES. Agricultural Statistics at a Glance 2023–oilseed area under production and yield. Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Government of India; 2023.
3. Jaiswal V, DerMarderosian A, Porter JR. Anthocyanins and polyphenol oxidase from *Brassica juncea* (Indian mustard) leaves. Food Chem. 2012;133(1):159-65.
4. Jat A, Pandey BK, Jat H. Growth and yield parameters of mustard (*Brassica juncea* L.) as affected by different sources of organic manures, fertilizer and micronutrients. Pharma Innov J. 2023;12(12):3598-602.
5. Kim SJ, Jin S, Ishii G. Isolation and structural elucidation of 6-methylsulfinylhexyl glucosinolate from daikon (*Raphanus sativus* L.) and its antioxidant activity. Biosci Biotechnol Biochem. 2007;71(2):312-21.
6. Kumar A, Suman B, Gurjar OP, Jakhar C, Yadav IR. Effect of sulphur and zinc on growth and yield of Indian mustard (*Brassica juncea*). Asian Res J Agric. 2024;17(4):908-13.
7. Lee JH, Choi SH, Park KY. Antioxidant and anticancer activity of fermented mustard leaf kimchi. J Med Plants Res. 2010;4(20):2078-84.
8. Miceli A, Moncada A, Vetrano F, D'Anna F. Mustard (*Brassica* spp.): A review on the agronomic practice and environmental aspects. Agron Res. 2014;12(1):141-50.
9. Nagaharu U. Genome analysis in *Brassica* with special reference to the experimental formation of *B. napus* and peculiar mode of fertilization. Jpn J Bot. 1935;7:389-452.
10. Nandhini G, Kumar RS, Gopal GV, Sampath O. Effect of sulphur and micronutrients (Zn and B) on growth, yield attributes and yield of transplanted mustard (*Brassica juncea* L.). Int J Res Agron. 2024;7(8):719-23.
11. Pandey BK, Pathak SO, Anshuman K, Singh AK. Effect of zinc and FYM on growth and yield of mustard (*Brassica juncea* L.). Int J Chem Stud. 2020;8(3):2323-5.
12. Patel KK, Priya Y, Tekam Y, Shah AK, Kumar K, Kumhare A, Dwarka. Effect of vermicompost on soil properties, plant growth and environmental sustainability: A review. Int J Plant Soil Sci. 2024;36(12):688-93.
13. Saini H, Debbarma V, Asha T, Singh U. Effect of sulphur, zinc and boron on growth and yield of mustard (*Brassica juncea* L.). Int J Res Agron. 2024;SP-7(5):271-6.
14. Tripathi KM, Kumar D, Panwar GS, Tiwari JK, Gupta AK, Shukla G, Pathak J. Effect of vermicompost on yield and yield attributing characteristic of Indian mustard (*Brassica juncea* L.). Int J Environ Clim Change. 2025;15(7):492-501.
15. Vanukuri AR, Pandey MK. Genetic variability and genetic diversity studies in Indian mustard (*Brassica juncea* L.). Int J Curr Microbiol Appl Sci. 2022;11(4):1966-74.
16. Verma S, Yadav DD, Yadav PK, Verma S, Rastogi M, Dheer V, Singh V. Vermicompost and fertility levels on growth, yield and profitability of Indian mustard (*Brassica juncea* (L.) Czern and Cosson). Environ Ecol. 2023;41(1A):313-20.