



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(9): 27-31
Received: 17-06-2026
Accepted: 20-07-2026

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Effect of integrated nutrient management on growth and development of Indian mustard (*Brassica juncea* L.) under irrigated condition

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DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i9a.6461>

Abstract

A field experiment was conducted for two consecutive *Rabi* seasons (2023-24 and 2024-25) at the Agricultural Research Farm, Department of Agronomy, R.B.S. College, Bichpuri, Agra (U.P.), to study the effect of integrated nutrient management (INM) on growth and development of Indian mustard (*Brassica juncea* L.) cv. Giriraj (DRMRIJ-31) under irrigated condition. Thirteen treatments, viz., T₁: 100% RDF (N:120, P:60, K:60, S:40 kg ha⁻¹); T₂: 75% RDF; T₃: 75% RDF + FYM @ 5 t ha⁻¹; T₄: 75% RDF + vermicompost @ 1.0 t ha⁻¹; T₅: 75% RDF + NPK consortia @ 200 ml per 10 kg seed; T₆: 75% RDF + FYM @ 5 t ha⁻¹ + NPK consortia @ 200 ml per 10 kg seed; T₇: 75% RDF + vermicompost @ 1.0 t ha⁻¹ + NPK consortia @ 200 ml per 10 kg seed; T₈: 50% RDF; T₉: 50% RDF + FYM @ 7.5 t ha⁻¹; T₁₀: 50% RDF + vermicompost @ 2.0 t ha⁻¹; T₁₁: 50% RDF + NPK consortia @ 200 ml per 10 kg seed; T₁₂: 50% RDF+FYM @ 7.5 t ha⁻¹ + NPK consortia @ 200 ml per 10 kg seed; and T₁₃: 50% RDF + vermicompost @ 2.0 t ha⁻¹ + NPK consortia @ 200 ml per 10 kg seed, were evaluated in a Randomized Block Design with three replications. Results revealed that application of 75% RDF + vermicompost @ 1.0 t ha⁻¹ + NPK consortia @ 200 ml per 10 kg seed (T₇) recorded significantly higher plant height, number of primary and secondary branches plant⁻¹, leaf area index and dry matter accumulation at all the stages of crop growth during both the years, and remained statistically at par with 75% RDF + FYM @ 5 t ha⁻¹ + NPK consortia (T₆), 100% RDF (T₁) and 75% RDF + vermicompost (T₄). Treatment 75% RDF + vermicompost @ 1.0 t ha⁻¹ + NPK consortia @ 200 ml per 10 kg seed also recorded the maximum days to 75% flowering and days to maturity, indicating a prolonged vegetative phase associated with better nutrient availability.

Keywords: Indian mustard, integrated nutrient management, growth, FYM, vermicompost, NPK consortia, dry matter accumulation

Introduction

Indian mustard (*Brassica juncea* L.), a major *Rabi* oilseed crop of the country, occupies a pivotal position among edible-oilseed crops of India and contributes nearly a quarter of the total oilseed production. Indian mustard is the third most important oil seed crops after groundnut and soyabean in India occupying 9.21 M ha acreage, 11.51 MT production and 1447 kg ha⁻¹ productivity in 2024-25 (Sharma *et al.*, 2026) ^[23]. It is grown extensively in Rajasthan, Uttar Pradesh, Madhya Pradesh, Haryana and West Bengal and continues to remain a source of quality cooking oil and cake meant for livestock feed. The contribution of Indian mustard to the total oilseed production in India is around 26 percentage. Domestic production of edible oils meets only 50 percent of the total requirements, while rest is imported. Sharma *et al.*, 2026) ^[23]. Notwithstanding its acreage and production, national productivity of mustard continues to lag behind its potential, largely on account of an imbalanced and injudicious use of fertilizers, low organic matter status of soils and inadequate microbial activity in the rhizosphere.

Growth and development of a crop, reflected through plant stand, plant height, branching pattern, leaf area index and dry matter accumulation, form the physiological foundation on which yield is subsequently built. A judicious and balanced supply of nutrients through combined use of inorganic fertilizer, organic manures (FYM, vermicompost) and liquid bio-inoculants (NPK

consortia) not only improves nutrient-use efficiency but also enhances soil physical, chemical and biological health, thereby permitting a rational reduction in the recommended dose of costly chemical fertilizers without compromising crop performance (Nadeem *et al.*, 2018) [16]. Integrated nutrient management (INM) is, therefore, being widely advocated as a sustainable strategy for boosting the growth attributes and, in turn, the productivity of Indian mustard (Meena *et al.*, 2020; Kumar *et al.*, 2019) [10, 14]. Keeping this in view, the present investigation was undertaken to study, in isolation, the effect of different combinations of inorganic fertilizer, organic manures and NPK consortia on the growth and developmental attributes of Indian mustard under irrigated condition of the semi-arid agro-climate of Agra region.

Materials and Methods

A field experiment was conducted during two consecutive *Rabi* seasons of 2023-24 and 2024-25 at the Agricultural Research Farm of the Department of Agronomy, R.B.S. College, Bichpuri, Agra, situated at 27°02' N latitude, 77°09' E longitude and an altitude of 168.0 m above mean sea level, falling under agro-climatic sub-region 4.1 of western Uttar Pradesh. The soil of the experimental field was sandy loam in texture, weakly alkaline in reaction (pH 8.10-8.15), low in available nitrogen (166.45-168.82 kg ha⁻¹), medium in available phosphorus (30.0-30.5 kg P₂O₅ ha⁻¹) and rich in available potassium (297.0-302.2 kg K₂O ha⁻¹), with organic carbon content of 0.35-0.36%. The experiment comprised thirteen treatments, viz., T₁: 100% RDF (N120P60K60S40 kg ha⁻¹); T₂: 75% RDF; T₃: 75% RDF + FYM @ 5 t ha⁻¹; T₄: 75% RDF + vermicompost @ 1.0 t ha⁻¹; T₅: 75% RDF + NPK consortia @ 200 ml per 10 kg seed; T₆: 75% RDF + FYM @ 5 t ha⁻¹ + NPK consortia; T₇: 75% RDF + vermicompost @ 1.0 t ha⁻¹ + NPK consortia; T₈: 50% RDF; T₉: 50% RDF + FYM @ 7.5 t ha⁻¹; T₁₀: 50% RDF + vermicompost @ 2.0 t ha⁻¹; T₁₁: 50% RDF + NPK consortia; T₁₂: 50% RDF + FYM + NPK consortia; and T₁₃: 50% RDF + vermicompost + NPK consortia, laid out in a Randomized Block Design with three replications. Indian mustard cv. Giriraj (DRMRIJ-31) was sown at a spacing of 45 cm × 10 cm using a seed rate of 5 kg ha⁻¹. Growth and developmental observations, viz., germination count and crop stand, plant height (cm), number of primary and secondary branches plant⁻¹, leaf area index (LAI) and dry matter accumulation (g plant⁻¹) were recorded at 30, 60 and 90 days after sowing (DAS) and at harvest, from five randomly tagged plants in the net plot. Days taken to 75 per cent flowering and days to physiological maturity were also recorded treatment-wise. Leaf area index was computed as the ratio of leaf area per plant to the ground area occupied per plant. The data recorded for each character were subjected to analysis of variance appropriate for a

Randomized Block Design (Gomez and Gomez, 1984) [7] and treatment means were compared at 5% level of significance.

Results and Discussion

Crop stand

Germination count recorded at 10 DAS did not differ significantly among the INM treatments during either year, indicating that seed emergence in mustard is governed mainly by seed viability and genetic make-up of the cultivar rather than by post-sowing nutrient management (Das *et al.*, 2024) [5]. Crop stand at 30 DAS and at harvest, however, was significantly influenced by the treatments; T₇ (75% RDF + vermicompost + NPK consortia) maintained the maximum plant stand at harvest (27.33 and 27.80 plants, respectively, during 2023-24 and 2024-25), while the minimum stand was recorded under treatment T₈ (50% RDF). The favourable rhizosphere created by vermicompost, together with improved nutrient solubilization through the microbial consortia, appears to have promoted better root proliferation and seedling survival, corroborating the findings of Kumar *et al.* (2019) [10] in Indian mustard. Genotype-driven differences in early vigour and establishment, superimposed on nutrient management, have also been highlighted by Sharma *et al.* (2025) [22], who reported cultivar PM-28 to be more responsive to improved nutrition than PM-29 and PDZ-31.

Plant height

Plant height increased progressively from 30 DAS to harvest under all the treatments and was significantly influenced by INM practices at every growth stage during both years of experimentation (Table 1). Treatment T₇ recorded the tallest plants at harvest (209.00 and 211.42 cm during 2023-24 and 2024-25, respectively), remaining statistically at par with treatment T₆ (75% RDF + FYM + NPK consortia), but significantly superior to the rest of the treatments, showing an increase of 5.91 to 17.20 per cent over the significantly inferior treatments. The shortest plants were recorded under treatment T₈ (50% RDF; 178.33 and 180.83 cm), followed by treatment T₁₁ (50% RDF + NPK consortia). The taller plants under integrated treatments may be ascribed to a steady and synchronized nutrient release from combined organic-inorganic-biological sources, promoting sustained cell elongation and internodal growth, a trend also reported by Kumar and Meena (2020) [12, 14] and Singh (2024) in Indian mustard. A balanced and adequate nutrient supply enhancing plant height of mustard cultivars has similarly been documented by Sharma *et al.* (2026) [23], who recorded significantly taller plants (up to 200 cm) under a combined foliar nutrition schedule as against a lower nutrient level.

Table 1: Plant height (cm) of Indian mustard at different stages of crop growth as influenced by integrated nutrient management (mean of 2023-24 and 2024-25)

Treatments	Plant height (cm)							
	30 DAS		60 DAS		90 DAS		At harvest	
	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25
T ₁	24.14	26.33	67.67	69.83	129.83	132	197.33	201.5
T ₂	23.25	25.42	64.92	67	125.58	127.75	193.33	195.17
T ₃	23.67	25.92	66.42	68.75	125.83	128.42	193.33	196.17
T ₄	24	26	67	69	127	129.25	198.33	200.58
T ₅	21.83	24.42	61.08	63.67	115.67	117.25	185.67	188.42
T ₆	25.58	27.5	71.25	73.67	134	136	203	204.08
T ₇	25.92	28	73.25	74.83	139.58	142	209	211.42
T ₈	21.17	23.83	59.25	62.08	108	110.5	178.33	180.83
T ₉	21.83	24.42	61.08	63.67	117.58	120.17	186.33	188.92
T ₁₀	22.58	24.58	63	65.83	120.83	123.17	187.67	189.25
T ₁₁	21.33	24	59.75	62.25	113.33	114.92	180	182.58
T ₁₂	23	24.83	64.5	66.08	121.17	123.67	192.67	194.58
T ₁₃	23	25.25	64.5	66.25	121.33	123.75	193	194.58
SEm±	0.55	0.62	1.68	1.70	1.89	1.88	2.50	3.05
CD (P=0.05)	1.32	1.51	4.06	4.11	4.57	4.56	6.04	7.38

Number of primary and secondary branches plant⁻¹

The number of primary and secondary branches plant⁻¹ increased steadily with the advancement of crop growth stage and was significantly affected by the INM treatments (Table 2). Treatment T₇ recorded the maximum primary branches (9.25 and 11.75 at 60 DAS) and secondary branches (18.50 and 20.92 at 90 DAS) during 2023-24 and 2024-25, respectively, and was statistically comparable with treatment T₆ and, at certain stages, with treatment T₁. The lowest branching was recorded under treatment T₈, followed by treatments T₁₁ and T₅. Superior branching under the integrated treatments is attributable to enhanced availability of nitrogen and micronutrients from the biofertilizer consortia, which favours auxiliary bud initiation and cell division, in agreement with the observations of Yadav *et al.* (2018) and Jadhav and Chavan (2024)^[9] in mustard. Sharma *et al.* (2026)^[23] also recorded a marked increase in the number of primary and secondary branches plant⁻¹ of mustard cultivars under an integrated/combined nutrient schedule as compared with a single-nutrient or lower-level application, supporting the present findings.

Leaf area index (LAI)

Leaf area index increased from 30 to 60 DAS and thereafter declined at 90 DAS under all treatments, reflecting rapid canopy build-up during vegetative growth followed by senescence of lower leaves at later stages. LAI did not differ significantly among treatments at 30 DAS, but at 60 and 90 DAS the differences were significant (Table 2), with treatment T₇ recording the highest LAI (3.13 and 3.84 at 60 DAS during 2023-24 and 2024-25), remaining at par with treatments T₆, T₁ and T₄, and significantly superior to treatment T₈, which recorded the lowest LAI throughout the growth period. Improved leaf expansion under the integrated nutrient sources may be linked to greater nitrogen availability promoting chlorophyll synthesis and leaf-area development, similar to the findings of Kumar and Meena (2020)^[10] and Patel *et al.* (2024)^[18]. Better canopy development and vegetative vigour of mustard under enriched nutrient regimes have also been reported by Sharma *et al.* (2025 and 2026)^[22, 23], who attributed the improvement to the synergistic role of balanced nutrition in enhancing photosynthetic surface area.

Table 2: Number of primary and secondary branches plant⁻¹ and leaf area index of Indian mustard as influenced by integrated nutrient management (2023-24 and 2024-25)

Treatments	Primary branches plant ⁻¹ (60 DAS)		Secondary branches plant ⁻¹ (90 DAS)		Leaf area index (60 DAS)	
	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25
T1	7.58	10.08	17.5	19.75	2.63	2.73
T2	6.83	9.25	16.75	19.17	2.26	2.36
T3	7.42	9.67	17.01	19.67	2.4	2.55
T4	7.58	9.75	17.5	19.75	2.61	2.71
T5	6.42	8.42	16.08	18.08	1.80	1.97
T6	8	10.42	17.67	19.75	2.85	2.95
T7	9.25	11.75	18.5	20.92	3.13	3.84
T8	5.92	8.08	15.33	17.92	1.70	1.92
T9	6.58	8.5	16.42	18.08	1.87	2.02
T10	6.58	8.92	16.42	18.33	1.96	2.07
T11	6.42	8.17	15.58	17.92	1.72	1.93
T12	6.58	8.92	16.5	18.67	1.97	2.08
T13	6.67	9	16.5	18.67	2.15	2.33
SEm±	0.29	0.42	0.40	0.53	0.223	0.405
CD (P=0.05)	0.70	1.00	0.97	1.29	0.540	0.980

Dry matter accumulation

Dry matter accumulation increased progressively from 30 DAS to harvest under all treatments, with the maximum proportion (about 67-68%) accumulated between 90 DAS and harvest, coinciding with the reproductive phase. Treatment T₇ recorded the highest dry matter accumulation at harvest (161.67 and 174.08 g plant⁻¹ during 2023-24 and 2024-25), an increase of 12.80 to 91.33 per cent over the significantly inferior treatments, and remained statistically at par with treatments T₆, T₄ and T₁. The lowest dry

matter accumulation was recorded under treatment T₈ (84.50 and 96.00 g plant⁻¹). The higher biomass production under integrated treatments may be attributed to greater leaf area, improved photosynthetic efficiency and a sustained supply of nutrients throughout the crop cycle, corroborating the findings of Pal *et al.* (2022)^[17] and Dey *et al.* (2024) in mustard. Enhanced fresh and dry biomass accumulation of mustard under balanced/combined nutrient management, relative to an inadequate nutrient supply, has also been reported by Sharma *et al.* (2026)^[23].

Table 3: Dry matter accumulation at harvest and days to 75% flowering and maturity of Indian mustard as influenced by integrated nutrient management

Treatments	Dry matter accumulation at harvest (g plant ⁻¹)		Days to 75% flowering		Days to maturity	
	2023-24	2024-25	2023-24	2024-25	2023-24	2024-25
T ₁	149.33	161.50	56.67	59.00	142.00	145.67
T ₂	143.00	154.58	54.93	57.50	138.67	143.00
T ₃	143.33	155.17	55.17	57.67	140.00	143.00
T ₄	148.33	160.58	55.37	58.00	143.33	145.00
T ₅	130.00	142.58	53.83	56.83	134.00	138.33
T ₆	153.33	165.42	57.30	59.80	144.67	146.67
T ₇	161.67	174.08	58.00	60.75	145.67	148.33
T ₈	84.50	96.00	53.50	56.17	132.00	135.67
T ₉	135.67	148.42	54.08	56.92	135.67	140.33
T ₁₀	136.33	148.92	54.75	57.00	136.00	140.67
T ₁₁	125.00	137.50	53.67	56.33	133.00	137.67
T ₁₂	140.00	152.83	54.83	57.00	136.33	141.00
T ₁₃	142.67	154.58	54.92	57.43	137.00	142.00
SEm±	7.85	7.93	0.67	1.15	1.97	2.02
CD (P=0.05)	18.99	19.18	1.62	2.78	4.76	4.88

Days to 75% flowering and days to maturity

Days to 75% flowering and days to maturity were significantly influenced by the INM treatments during both years (Table 3). Treatment T₇ required the maximum number of days to attain 75% flowering (58.00 and 60.75 days) and maturity (145.67 and 148.33 days), and was statistically at par with treatments T₆, T₁ and T₄, indicating a prolonged vegetative phase and extended reproductive period under a steady nutrient supply. In contrast, treatment T₈ (50% RDF) attained flowering and maturity earliest, followed by treatments T₁₁ and T₅, reflecting hastened phenological development under nutrient-limited conditions. Similar delay in flowering and maturity under integrated and higher nutrient regimes has been reported by Choudhary *et al.* (2024)^[4] and Das *et al.* (2024)^[5] in Indian mustard. Sharma *et al.* (2026)^[23] also observed a slight but favourable delay in days to 75% flowering and pod formation of mustard under a combined nutrient schedule, attributing it to prolonged vegetative growth prior to the reproductive switch.

Conclusion

The result revealed that application of 75% RDF + vermicompost @ 1.0 t ha⁻¹ + NPK consortia @ 200 ml per 10 kg seed (T₇), being statistically at par with 75% RDF + FYM @ 5 t ha⁻¹ + NPK consortia (T₆), 100% RDF (T₁) and 75% RDF + vermicompost (T₄), consistently recorded superior growth and developmental attributes, viz., crop stand, plant height, primary and secondary branches, leaf area index and dry matter accumulation of Indian mustard over both years of study. The integration of organic manures and microbial (NPK) consortia with 75% RDF may, therefore, be recommended as an effective and sustainable nutrient management strategy that permits a 25 per cent reduction in the recommended dose of chemical fertilizer without compromising the growth performance of Indian mustard under irrigated conditions of the semi-arid agro-climate of western Uttar Pradesh.

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