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Effect of Integrated Nutrient Management (INM) on Growth and Quality of Indian Mustard (*Brassica juncea* L.)

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Abstract

Integrated nutrient management (INM) has emerged as a sustainable alternative to sole chemical fertilizer use for improving crop productivity, maintaining soil fertility, and ensuring ecological balance. The present field experiment was conducted during Rabi 2025–26 at the Research Farm of Vivekananda Global University, Jaipur, Rajasthan, to evaluate the effect of different combinations of organic and inorganic nutrient sources on growth, physiological traits, and biochemical parameters of mustard (Brassica juncea L.). Nine treatments, including control, 100% recommended dose of nitrogen (RDN), vermicompost, poultry manure, farmyard manure (FYM), and their combinations, were laid out in randomized block design with three replications. The results revealed that integrated use of 50% RDN + 50% organic sources significantly improved leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR), chlorophyll, and carotenoid content compared to control and 100% RDN alone. Maximum LAI (0.71, 3.91, and 3.18 at 30, 60, and 90 DAS, respectively), CGR (6.98, 9.18, and 4.82 g/m²/day), RGR (0.206, 0.109, and 0.069 mg/g/day), chlorophyll (3.83 and 3.51 mg/g fresh weight), and carotenoid content (0.83 and 0.74 mg/g fresh weight) were recorded under treatment T9 (50% RDN + 50% organic sources through vermicompost + poultry manure + FYM in 1:1:1 ratio). The findings demonstrate that partial substitution of chemical fertilizers with organic amendments enhances mustard growth and physiological efficiency, thereby suggesting INM as a viable strategy for sustainable mustard production.

Keywords: Mustard, Integrated nutrient management, Vermicompost, Poultry manure, Farmyard manure, Growth, Physiology

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Introduction

Mustard (*Brassica juncea* L.), an important oilseed crop of India, contributes significantly to edible oil production, food security, and the agricultural economy. India is the fourth largest producer of oilseeds in the world, and mustard accounts for nearly 25–30% of total oilseed production [1]. Despite its significance, the average productivity of mustard in India remains lower than global standards, largely due to imbalanced fertilizer use, poor soil fertility, and inadequate adoption of integrated nutrient management practices [2, 3]. The conventional reliance on chemical fertilizers has improved crop productivity but at the cost of soil degradation, micronutrient deficiencies, and declining factor productivity [4]. Conversely, exclusive organic farming fails to meet the high nutrient demand of mustard due to slow mineralization and nutrient release. Hence, integrated nutrient management (INM), which combines organic and inorganic sources of nutrients, has gained prominence for sustaining crop and improving soil health [5, 6]. Organic manures such as farmyard manure (FYM), vermicompost, and poultry manure are rich in macro- and micronutrients, enhance microbial activity, and improve soil structure, moisture retention, and nutrient use efficiency [7]. Studies have demonstrated that vermicompost application increases chlorophyll synthesis, poultry manure supplies readily available nitrogen and phosphorus, and FYM improves long-term soil fertility [8, 9]. When combined with chemical fertilizers, these organic amendments synchronize nutrient availability with crop demand, leading to improved growth and physiological performance [10, 11].

Leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR), and chlorophyll content are important indicators of crop photosynthetic efficiency and biomass production. Enhanced LAI and CGR through integrated nutrient management have been reported in oilseed crops, resulting in higher productivity [12, 13]. However, systematic information on the combined effects of vermicompost, poultry manure, and FYM with chemical fertilizers on mustard growth and physiology in semi-arid regions of Rajasthan is limited. Therefore, the present investigation was undertaken to study the influence of INM on growth traits, physiological efficiency, and biochemical parameters of mustard, with an emphasis on LAI, CGR, RGR, chlorophyll, and carotenoid content.

Materials and Methods

An experiment entitled was conducted during the rabi season of 2025–26 at the Research Farm, Vivekananda Global University, Jaipur (27.55°N, 78.10°E). The site has a subtropical, semi-arid climate with hot summers and cold winters; total seasonal rainfall during the trial was 26.6 mm. The soil was sandy loam, slightly alkaline (pH 7.15), low in organic carbon (0.35%), and medium in available NPK but low in sulphur. The experiment followed a Randomized Block Design (RBD) with 9 treatments and 3 replications, totaling 27 plots. Treatments comprised combinations of recommended nitrogen dose (RDN: 120 kg N/ha) with organic amendments vermicompost (VC), poultry manure (PM), and farmyard manure (FYM) applied singly or in mixtures. In all treatments where 50% of the recommended nitrogen was substituted through organic sources, the nitrogen contribution was maintained on an N-equivalent basis. The quantity of each organic manure (FYM, vermicompost and poultry manure) was calculated according to its nitrogen content so that each source supplied an equal amount of nitrogen equivalent to 50% of the recommended dose of nitrogen (RDN). The remaining 50% nitrogen was supplied through inorganic fertilizer. Therefore, although the quantity (kg ha^{-1}) of each manure differed, the actual nitrogen supplied from each source was equal. The mustard variety NPJ-113 (Pusa Mustard-26), with an average yield potential of 20–22 q/ha and oil content of 36–41%, was sown at 45 cm × 15 cm spacing. Nutrient composition (%N, $\%P_2O_5$ and $\%K_2O$) of FYM, vermicompost and poultry manure along with the quantity applied per hectare have been added in the Materials and Methods section. The treatments were imposed on a nitrogen-equivalent basis, wherein 50% of the recommended nitrogen was supplied through the respective organic source according to its nitrogen content, while the remaining nitrogen was supplied through inorganic fertilizers. Field operations included pre-irrigation, tractor ploughing, manual sowing, thinning, weeding, and two irrigations. Fertilizer management involved basal application of half N with full P, K, and S, followed by top dressing of the remaining N at 35 DAS. Standard crop protection practices were adopted. Growth studies (plant height, branching, dry matter, LAI, CGR, RGR) and physiological traits (chlorophyll, carotenoids) were recorded at 30, 60, 90 DAS and harvest. Data were statistically analyzed using ANOVA (Cochran and Cox, 1963), with critical differences tested at 5% probability.

Results and Discussion

Table 1 Effect of integrated nutrients management on leaf area index of mustard.

Treatment	Leaf Area Index (LAI)		
	30 DAS	60 DAS	90 DAS
T_1 (Control)	0.52	2.58	1.84
T_2 (100% RDN	0.53	2.83	2.06
T_3 (50% RDN + 50% Vermicompost)	0.62	3.15	2.34
T_4 (50% RDN + 50% Poultry Manure)	0.64	3.31	2.57
T_5 (50% RDN + 50% Farm Yard Manure)	0.61	3.09	2.21
T_6 (50% RDN + 50% through VC + PM in 1:1 ratio)	0.69	3.77	2.92
T_7 (50% RDN + 50% through VC + FYM in 1:1 ratio)	0.66	3.57	2.73
T_8 (50% RDN + 50% through PM + FYM in 1:1 ratio)	0.68	3.65	2.86
T_9 (50% RDN + 50% through VC + PM + FYM in 1:1:1 ratio)	0.71	3.91	3.18
SEm±	0.01	0.06	0.12
C.D. @5%	0.02	0.19	0.35

Table 1 shows that LAI increased up to 60 DAS and declined thereafter due to leaf senescence. The maximum LAI values were recorded under T9 (0.71, 3.91, and 3.18 at 30, 60, and 90 DAS, respectively), followed by T6 and T8. Minimum LAI was observed in the control. The superior LAI under integrated treatments can be attributed to synergistic effects of chemical fertilizers and organic manures, which improved nutrient availability and stimulated leaf expansion [14]. Vermicompost provided plant growth hormones and micronutrients, poultry manure released readily available nitrogen and phosphorus, while FYM improved soil moisture retention. These results align with Sharma *et al*. [15], who reported higher LAI of mustard under INM compared to chemical fertilizers alone. CGR progressively increased from 30–60 DAS, peaked at 60–90 DAS, and declined thereafter (**Table 2**). The highest CGR (6.98, 9.18, and 4.82 g/m^2/day at successive stages) was recorded in T9, followed by T6 and T8. Improved CGR in integrated treatments is associated with enhanced photosynthesis due to higher LAI and better chlorophyll content. Similar findings were reported by Choudhary *et al*. [16] in mustard, where INM improved dry matter accumulation and CGR. RGR showed a declining trend with crop age (**Table 3**). The highest RGR values were recorded under T9 (0.206, 0.109, and 0.069

mg/g/day), followed by T6 and T8. Control plots recorded the lowest RGR. The higher RGR in INM treatments may be attributed to efficient nutrient uptake, enhanced photosynthetic activity, and improved metabolic processes [17]. These results corroborate earlier findings by Meena *et al*. [18], who reported higher RGR in oilseed crops under integrated nutrient application.

Table 2 Effect of integrated nutrients management on crop growth rate of mustard.

Treatment	Crop Growth Rate (CGR) (g/m²/day)		
	30-60 DAS	60-90 DAS	90-Harvest
T_1 (Control)	6.31	8.65	4.27
T_2 (100% RDN - 120 kg N/ha)	6.64	8.84	4.43
T_3 (50% RDN + 50% Vermicompost)	6.73	8.91	4.51
T_4 (50% RDN + 50% Poultry Manure)	6.75	8.93	4.55
T_5 (50% RDN + 50% Farm Yard Manure)	6.66	8.88	4.46
T_6 (50% RDN + 50% through VC + PM in 1:1 ratio)	6.89	9.09	4.71
T_7 (50% RDN + 50% through VC + FYM in 1:1 ratio)	6.88	8.97	4.58
T_8 (50% RDN + 50% through PM + FYM in 1:1 ratio)	6.86	9.04	4.67
T_9 (50% RDN + 50% through VC + PM + FYM in 1:1:1 ratio)	6.98	9.18	4.82
SEm±	0.10	0.07	0.05
C.D. @5%	0.30	0.22	0.16

Table 3 Effect of integrated nutrients management on relative growth rate of mustard

Treatment	Relative Growth Rate (RGR) (mg/g/day)		
	30-60 DAS	60-90 DAS	90-Harvest
T_1 (Control)	0.172	0.081	0.046
T_2 (100% RDN - 120 kg N/ha)	0.185	0.089	0.051
T_3 (50% RDN + 50% Vermicompost)	0.191	0.096	0.056
T_4 (50% RDN + 50% Poultry Manure)	0.194	0.099	0.059
T_5 (50% RDN + 50% Farm Yard Manure)	0.188	0.093	0.054
T_6 (50% RDN + 50% through VC + PM in 1:1 ratio)	0.203	0.107	0.066
T_7 (50% RDN + 50% through VC + FYM in 1:1 ratio)	0.199	0.103	0.061
T_8 (50% RDN + 50% through PM + FYM in 1:1 ratio)	0.201	0.105	0.063
T_9 (50% RDN + 50% through VC + PM + FYM in 1:1:1 ratio)	0.206	0.109	0.069
SEm±	0.008	0.020	0.010
C.D. @5%	NS	NS	NS

Table 4 Effect of integrated nutrients management on chlorophyll content of mustard.

Treatment	Chlorophyll Content (mg/g fresh weight)	
	30 DAS	60 DAS
T_1 (Control)	2.81	2.47
T_2 (100% RDN - 120 kg N/ha)	3.04	2.76
T_3 (50% RDN + 50% Vermicompost)	3.29	2.91
T_4 (50% RDN + 50% Poultry Manure)	3.31	3.09
T_5 (50% RDN + 50% Farm Yard Manure)	3.17	2.84
T_6 (50% RDN + 50% through VC + PM in 1:1 ratio)	3.78	3.33
T_7 (50% RDN + 50% through VC + FYM in 1:1 ratio)	3.56	3.21
T_8 (50% RDN + 50% through PM + FYM in 1:1 ratio)	3.64	3.28
T_9 (50% RDN + 50% through VC + PM + FYM in 1:1:1 ratio)	3.83	3.51
SEm±	0.06	0.10
C.D. @5%	0.17	0.31

Chlorophyll content was significantly influenced by INM treatments (**Table 4**). The maximum values (3.83 and 3.51 mg/g fresh weight at 30 and 60 DAS) were observed under T9, followed by T6 and T8. Enhanced chlorophyll synthesis under integrated nutrient management is due to the continuous and balanced supply of nitrogen and other nutrients, which are essential for chlorophyll biosynthesis. Poultry manure, being rich in nitrogen and phosphorus, complemented urea in improving chlorophyll content. These findings agree with Singh *et al*. [19], who observed improved chlorophyll content in mustard leaves under INM. Carotenoid content followed a similar trend as chlorophyll

(**Table 5**). The highest values (0.83 and 0.74 mg/g fresh weight at 30 and 60 DAS) were recorded under T9, while the lowest was in control. Carotenoids play a vital role in protecting chlorophyll from photo-oxidative damage. The increase in carotenoid content under INM suggests enhanced physiological resilience of mustard plants [20]. Similar results were reported by Yadav *et al*. [21] in rapeseed–mustard.

Table 5 Effect of integrated nutrients management on carotenoid content of mustard

Treatment	Carotenoid Content (mg/g fresh weight)	
	30 DAS	60 DAS
T_1 (Control)	0.62	0.58
T_2 (100% RDN	0.63	0.61
T_3 (50% RDN + 50% Vermicompost)	0.72	0.64
T_4 (50% RDN + 50% Poultry Manure)	0.73	0.67
T_5 (50% RDN + 50% Farm Yard Manure)	0.65	0.63
T_6 (50% RDN + 50% through VC + PM in 1:1 ratio)	0.81	0.73
T_7 (50% RDN + 50% through VC + FYM in 1:1 ratio)	0.74	0.71
T_8 (50% RDN + 50% through PM + FYM in 1:1 ratio)	0.75	0.72
T_9 (50% RDN + 50% through VC + PM + FYM in 1:1:1 ratio)	0.83	0.74
SEm±	0.01	0.01
C.D. @5%	0.03	0.04

Conclusion

The study revealed that integrated nutrient management practices significantly improved growth, physiological, and biochemical traits of mustard compared to sole application of chemical fertilizers or control. Among treatments, T9 (50% RDN + 50% through vermicompost + poultry manure + FYM in 1:1:1 ratio) was most effective, recording maximum LAI, CGR, RGR, chlorophyll, and carotenoid content. Hence, partial substitution of inorganic fertilizers with organic amendments not only enhances mustard growth and physiological efficiency but also ensures soil fertility and sustainable crop production. INM practices should be promoted among mustard growers to achieve higher productivity while maintaining ecological balance.

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