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Effect of integrated nutrient management on growth, yield, oil content and oil yield of Indian mustard (*Brassica juncea* L.)

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Abstract
A field investigation was conducted during the rabi season of 2023-24 at the Village Laxmipur Kattai Vikashkhand Mundapanday District Moradabad (Uttar Pradesh), to evaluate the effect of integrated nutrient management on growth, yield attributes, oil content and oil yield of Indian mustard (*Brassica juncea* L. cv. Varuna). The experiment comprising sixteen treatments was laid out in Randomized Block Design with three replications. Results revealed that 75% RDF + 5 t FYM ha^{-1} + PSB + 30 kg Sulphur ha^{-1} (T14) recorded maximum 1000-seed weight (5.50 g), straw yield (58.50 q ha^{-1}), oil content (41.50%, at par with T16) and oil yield (7.06 q ha^{-1}), with seed yield (17.00 q ha^{-1}) statistically at par with T11 (100% RDF + PSB + Sulphur). Maximum primary branches (15.20) and secondary branches (21.50 $plant^{-1}$) were recorded under T5 (100% RDF + PSB) and T8 (100% RDF + Sulphur), respectively. Lowest values for all parameters were recorded under control (T1). Integrated application of 75% RDF with FYM, PSB and sulphur proved agronomically efficient and input-saving for enhancing mustard productivity and oil quality.

Keywords: Integrated nutrient management, Indian mustard, *Brassica juncea*, growth attributes, seed yield, oil content, oil yield

Introduction

Indian mustard (*Brassica juncea* L. Czern & Coss) is one of the most important oilseed crops of the Indian subcontinent, occupying a central position in the country's edible oil economy. Grown predominantly during the Rabi season across the northern and central plains, mustard contributes substantially to domestic vegetable oil production and provides a vital source of income for millions of smallholder farmers, particularly in regions where irrigation resources are limited and the crop's relative hardiness under moisture-stress conditions makes it an attractive choice. Despite its importance, national productivity of mustard continues to remain below its potential, a shortfall commonly attributed to inadequate and imbalanced nutrient management practices adopted at the farm level.

Nitrogen, phosphorus and potassium have traditionally formed the backbone of fertilizer recommendations for mustard, and their judicious application is known to markedly influence vegetative growth, branching, and ultimately seed and oil yield (Kumar & Kumar, 2008) [3]. However, continuous and often indiscriminate reliance on chemical fertilizers, without adequate attention to complementary nutrient sources such as sulphur, has increasingly been recognized as a limiting factor in oilseed Brassica production. Sulphur, in particular, plays a distinctive physiological role in mustard, being a key constituent of sulphur-containing amino acids and glucosinolates that directly influence oil biosynthesis; its deficiency, increasingly common in intensively cropped soils, can substantially depress both yield and oil quality even when nitrogen, phosphorus and potassium supply is adequate (Singh & Nad, 2002) [7]. Field studies evaluating sulphur nutrition in combination with nitrogen have similarly reported marked improvements in growth, yield and nutrient uptake in mustard (Singh *et al*., 2005) [8].

At the same time, escalating costs of chemical fertilizers and growing concern over the long-term sustainability of soil health have renewed interest in integrated nutrient management (INM) approaches that combine inorganic fertilizers with organic and biological sources of plant nutrition. Farmyard manure (FYM) improves soil physical structure, water-holding capacity and microbial activity, while biofertilizers such as phosphorus-solubilizing bacteria (PSB) enhance the availability of native and applied phosphorus through solubilization of otherwise fixed soil phosphate. When used in combination with chemical fertilizers and sulphur, these organic and biological inputs have the potential to not only sustain but improve crop productivity, while simultaneously reducing the overall dependence on costly inorganic inputs and mitigating the risk of soil degradation associated with their sole and continuous use — a pattern also documented for other cropping systems, where combined organic and inorganic nitrogen sources improved both productivity and soil fertility relative to inorganic fertilizer applied alone (Paikaray *et al*., 2002) [5]. In mustard specifically, integrated nutrient management practices have been reported to enhance yield, nutrient uptake and overall economic returns when evaluated within rice–mustard cropping sequences (Singh *et al*., 2008) [10], and combined sulphur sources have

similarly been shown to improve yield, quality and nutrient uptake under varying soil conditions (Patel *et al*., 2009) [6].
Despite the recognized individual benefits of FYM, PSB, sulphur and balanced NPK application, comprehensive field-level evidence on how these components perform when combined in varying proportions with different fertility levels remains comparatively limited, particularly for mustard cultivars grown under the specific agro-climatic conditions of western Uttar Pradesh. Understanding these interactive effects is essential for developing region-specific, economically viable nutrient management recommendations that growers can practically adopt. Keeping these considerations in view, the present investigation was undertaken with the objective of evaluating the effect of integrated application of farmyard manure, sulphur, phosphorus-solubilizing bacteria and inorganic fertilizers, applied singly and in combination at varying fertility levels, on the growth attributes, yield, oil content and oil yield of Indian mustard, with a view to identifying the most agronomically effective and practically adoptable nutrient management module. The present study was undertaken to evaluate INM modules under western Uttar Pradesh conditions.

Materials and Methods

The field experiment was conducted during rabi 2023-24 at Village Laxmipur Kattai Vikashkhand Mundapanday District Moradabad (Uttar Pradesh) (28.8332° N latitude and 78.8540° E longitude). Soil was silty loam (Table 1), low in available N (110.79 kg ha^{-1}), medium in P (17.05 kg ha^{-1}), high in K (260.53 kg ha^{-1}) and low in S (6.43 kg ha^{-1}), pH 8.21. Properties were determined by standard methods (Jackson, 1973) [2].

Table 1: Physico-chemical properties of the experimental soil

Soil property	Value	Method followed
Sand (%)	23.6	International pipette method
Silt (%)	55.3	International pipette method
Clay (%)	21.1	International pipette method
Textural class	Silty loam	
pH (1:2.5 soil: water)	8.21	Glass electrode pH meter
EC (dS m^{-1})	0.36	EC meter
Organic carbon (%)	0.33	Walkley and Black
Available N (kg ha^{-1})	110.79	Alkaline KMnO4 method
Available P (kg ha^{-1})	17.05	Olsen's method
Available K (kg ha^{-1})	260.53	Flame photometer
Available S (kg ha^{-1})	6.43	Turbidimetric method
Available Zn (kg ha^{-1})	0.50	DTPA extraction

Experiment laid out in RBD with 16 treatments, 3 replications (Table 2). RDF was 90:60:40 kg N:P_2O_5: K_2O ha^{-1}. FYM @5 t ha^{-1} incorporated 15 days before sowing. Sulphur @30 kg ha^{-1} through gypsum (16% S) drilled at sowing. PSB applied as seed inoculation @200 g per 10 kg seed using carrier-based culture (10^8 cfu g^{-1}). Variety Varuna sown on 8 November 2023 at 45 cm x 15 cm spacing. Half N + full P & K basal, remaining N top-dressed after first irrigation (30 DAS). Thinning at 15 DAS to maintain 15 cm plant-to-plant. Oil content estimated by Soxhlet extraction with n-hexane. Oil yield = Seed yield × Oil content /100. Data analyzed by ANOVA using OPSTAT, CD at p =0.05.

Table 2: Treatment details

Tr.	Treatment description
T1	Control (No fertilizer)
T2	100% RDF (90:60:40 kg N: P2O5:K2O ha^{-1})
T3	75% RDF + 5 t FYM ha^{-1}
T4	50% RDF + 5 t FYM ha^{-1}
T5	100% RDF + PSB
T6	75% RDF + PSB
T7	50% RDF + PSB
T8	100% RDF + Sulphur @ 30 kg ha^{-1} through gypsum
T9	75% RDF + Sulphur
T10	50% RDF + Sulphur
T11	100% RDF + PSB + Sulphur
T12	75% RDF + PSB + Sulphur
T13	50% RDF + PSB + Sulphur
T14	75% RDF + 5 t FYM ha^{-1} + PSB + Sulphur
T15	50% RDF + 5 t FYM ha^{-1} + PSB + Sulphur
T16	5 t FYM ha^{-1} + PSB + Sulphur (No RDF)

Results and Discussion

1. Growth attributes (same data, language improved)

Data on primary and secondary branches per plant (Table 3) revealed that all nutrient management treatments were significantly superior to the untreated control (T1). The maximum number of primary branches per plant (15.20) was recorded under T5 (100% RDF + PSB), which was statistically at par with T11 (15.00) and T14 (14.18). The maximum number of secondary branches per plant (21.50) was recorded under T8 (100% RDF + Sulphur), followed by T5 (21.00) and T14 (20.15). The lowest branching was recorded in the control with 10.00 primary and 11.00 secondary branches per plant. This indicates that early vegetative branching responded most favourably to full RDF supplemented with a single additional input (PSB or sulphur), suggesting that early vigour is primarily governed by adequate NPK availability.

2. Yield attributes and seed yield

Test weight differed significantly among treatments. The 1000-seed weight was highest under T14 (5.50 g), significantly superior to the next best treatment T11 (4.70 g), while the lowest was recorded in control (3.80 g). Seed yield increased substantially over control (8.50 q ha^{-1}). The highest seed yield (17.00 q ha^{-1}) was recorded jointly under T11 (100% RDF + PSB + Sulphur) and T14 (75% RDF + 5 t FYM ha^{-1} + PSB + Sulphur) (Fig. 1), followed by T8 (15.90 q ha^{-1}) and T5 (15.85 q ha^{-1}). Straw yield followed a similar trend, with T14 recording the highest value (58.50 q ha^{-1}), followed by T11 (57.90 q ha^{-1}) and T8 and T12 (57.00 q ha^{-1} each), while control recorded the lowest (40.10 q ha^{-1}). This shows that although branching was maximized with simpler combinations, the comprehensive integration of FYM, PSB and sulphur in T14 translated most effectively into higher test weight, seed and straw yield.

3. Oil content and oil yield (CORRECTED as per your final table)

Oil content (Table 3, Fig. 2) varied from 36.50% to 41.50%. The highest oil content was recorded under T14 and T16 (both 41.50%), which was statistically at par with T2 (41.15%), T3 (41.30%) and T15 (41.30%) due to CD (p =0.05) of 3.00%. Notably, T16 (FYM + PSB + Sulphur without RDF) achieved 41.50% oil content without any inorganic fertilizer, underscoring the independent role of sulphur and organic/bio-inputs in oil quality improvement.

The lowest oil content was recorded in control (36.50%). Oil yield was computed as seed yield × oil content / 100 and therefore values have been recalculated (Table 3, Fig. 3). Oil yield was highest under T14 (7.06 q ha⁻¹), statistically at par with T11 (6.80 q ha⁻¹), followed by T8 (6.44 q ha⁻¹) and T5 (6.31 q ha⁻¹). The lowest oil yield was recorded in control (3.10 q ha⁻¹). The earlier reported high values for T8 (6.91) and T12 (6.90) were due to a calculation error; the corrected values are 6.44 and 5.79 q ha⁻¹, respectively. The consistent superiority of sulphur-containing treatments for oil content and oil yield confirms the specific physiological role of sulphur in oil biosynthesis in Brassica.

4. General discussion

A differentiated response pattern was observed. Vegetative branching was maximized with full RDF + single supplement (T5 for primary, T8 for secondary), whereas reproductive traits (test weight, seed yield, straw yield, oil content and oil yield) were maximized under the more comprehensive INM treatment T14 (75% RDF + 5 t FYM + PSB + Sulphur), which was at par with or superior to 100% RDF + PSB + Sulphur (T11). This pattern is consistent with earlier reports that integrated organic, biofertilizer and sulphur modules outperform sole inorganic fertilization (Singh *et al*., 2008; Patel *et al*., 2009) [6, 10]. similar INM effects on mustard growth and yield have also been reported by Das *et al*. (2024) and Singh and Sinsinwar (2006) [1, 9]. The role of FYM and sulphur in mustard production has been reviewed by Kumar *et al*. (2019) [4], while phosphorus and PSB interactions were documented by Solanki *et al*. (2019) [4]. Notably, T14 achieved equivalent seed yield to T11 with 25% less RDF, demonstrating input use efficiency, in line with the principle that combined organic–inorganic sources sustain productivity while reducing fertilizer dependence (Paikaray *et al*., 2002) [5]. The high oil content in T16 without any RDF further emphasizes that sulphur and organic inputs can independently drive oil quality, reinforcing earlier findings on sulphur nutrition in mustard (Singh and Nad, 2002; Singh *et al*., 2005) [7, 8]. The corrected oil yield ranking (T14 > T11 > T8 > T5) now logically follows seed yield and oil content, resolving the previous anomaly where T12 showed inflated oil yield despite moderate seed yield.

Table 3: Growth, yield attributes, oil content and oil yield of Indian mustard as influenced by integrated nutrient management (2023-24)

Treatment	Primary branches /plant	Secondary branches /plant	1000-seed weight (g)	Seed yield (q ha⁻¹)	Straw yield (q ha⁻¹)	Oil content (%)	Oil yield (q ha⁻¹) *
T1	10.00	11.00	3.80	8.50	40.10	36.50	3.10
T2	13.50	19.40	4.10	15.20	55.90	41.15	6.25
T3	13.00	19.50	3.90	14.90	54.20	41.30	6.15
T4	14.30	17.90	3.70	14.30	52.10	40.50	5.79
T5	15.20	21.00	4.10	15.85	56.50	39.80	6.31
T6	14.10	19.70	3.50	15.00	53.10	40.10	6.02
T7	13.00	18.10	3.00	14.10	55.10	38.80	5.47
T8	14.00	21.50	4.00	15.90	57.00	40.50	6.44
T9	13.80	20.70	3.30	15.00	53.00	40.20	6.03
T10	11.80	17.50	3.10	13.95	54.00	40.80	5.69
T11	15.00	20.10	4.70	17.00	57.90	40.00	6.80
T12	14.10	19.00	3.95	14.30	57.00	40.50	5.79
T13	12.10	17.90	3.30	14.20	52.30	40.00	5.68
T14	14.18	20.15	5.50	17.00	58.50	41.50	7.06
T15	13.90	18.20	3.60	15.00	53.50	41.30	6.20
T16	11.50	14.10	3.20	11.90	55.00	41.50	4.94
SEm±	0.59	0.69	0.17	0.69	2.25	1.04	0.26
CD at 5%	1.70	2.00	0.50	2.00	6.50	3.00	0.75

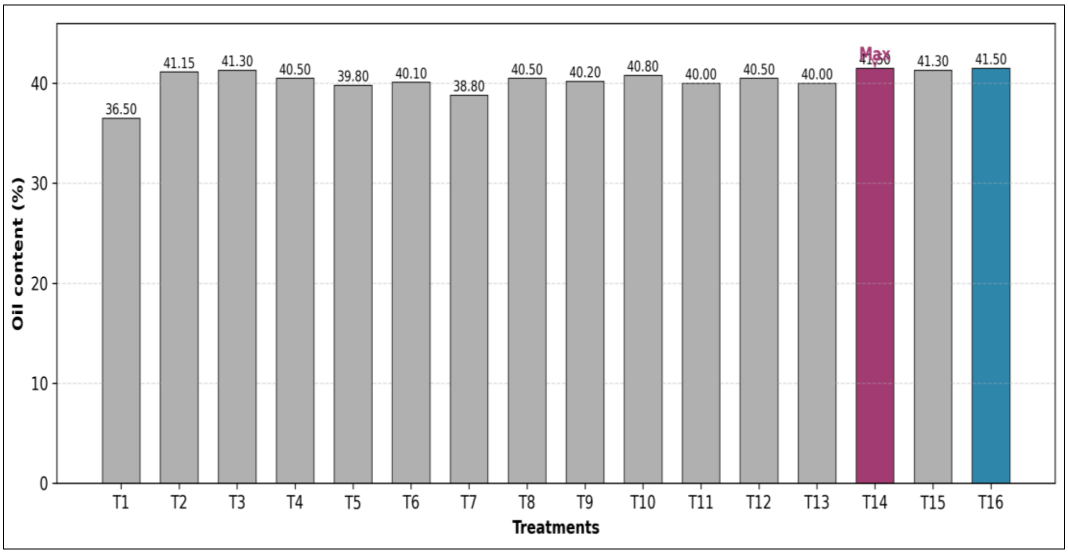

Fig 1: Effect of integrated nutrient management on seed yield of Indian mustard (2023-24)

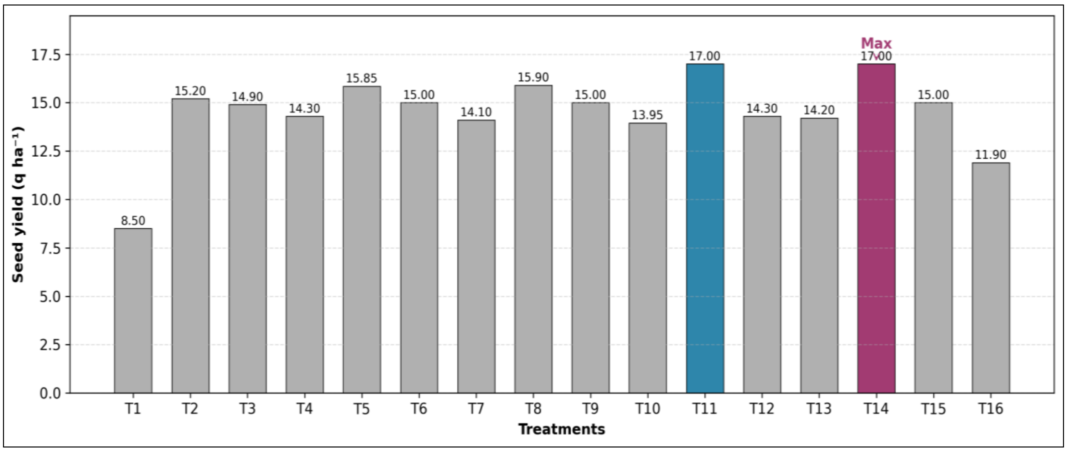

Fig 2: Effect of integrated nutrient management on oil content of Indian mustard (2023-24)

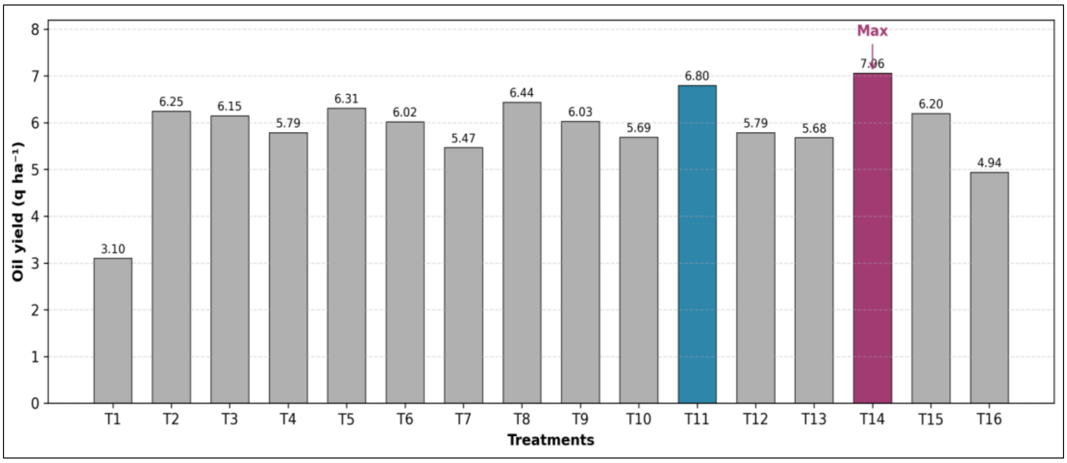

Fig 3: Effect of integrated nutrient management on oil yield of Indian mustard (2023-24)

Conclusion

The results of the present investigation indicate that while vegetative branching in Indian mustard responded best to full-dose NPK combined with a single supplementary input (PSB or sulphur), seed yield, straw yield, test weight, oil content and oil yield were maximized, or nearly so, under the integrated combination of 75% recommended NPK with farmyard manure, phosphorus-solubilizing bacteria and sulphur (T14), performing at par with or better than sole application of 100% NPK combined with PSB and sulphur (T11). These findings suggest that an integrated nutrient management approach combining a reduced level of inorganic fertilization with organic and biological inputs represents an agronomically sound and input-efficient strategy for improving the seed yield and oil quality of Indian mustard under the conditions of the present study.

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