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Effect of integrated nutrient management on growth, yield and quality of rice and mustard crops

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Abstract

A two-year field experiment was conducted during 2024-25 and 2025-26 at farmer field of village Ramdaspur Patahana, Jaunpur Uttar Pradesh near V.B.S. Purvanchal University Jaunpur, Uttar Pradesh, to Assess the effect of integrated nutrient management (INM) on growth, yield and quality of rice and mustard in a rice-mustard cropping system. Twelve nutrient-management treatments were evaluated, ranging from an unfertilized control to combinations of recommended NPKS, farmyard manure (FYM), poultry manure and biofertilizer (VAM). In rice, INM significantly influenced plant height, tillering, dry matter accumulation, effective tillers, panicle length, grains panicle⁻¹, test weight, grain yield, straw yield, biological yield and harvest index. The highest dry matter accumulation and yield attributes were generally obtained with T₁₁ (100% NPKS + 5 t FYM ha⁻¹ + 1 t poultry manure ha⁻¹ + 5 kg biofertilizer), whereas T₁₀ was superior for plant height and tillering at several stages. Rice grain yield under T₁₁ was 6.02 and 6.52 t ha⁻¹ in 2024-25 and 2025-26, respectively. In mustard, T₁₁ consistently produced the highest plant height, primary and secondary branches, dry matter accumulation, siliqua plant⁻¹, seeds siliqua⁻¹, test weight, seed yield plant⁻¹, stover yield plant⁻¹, harvest index and oil content. Mustard seed yield under T₁₁ was 22.8 and 23.8 g plant⁻¹, while oil content was 44.0 and 44.4% in the two years. The results demonstrate that integrated application of inorganic fertilizers, organic manures and VAM improved crop growth, yield attributes, productivity and mustard seed quality under the experimental conditions.

Keywords: Integrated nutrient management, rice, mustard, FYM, poultry manure, VAM, growth, yield, oil content, rice-mustard cropping system

1. Introduction

Rice (*Oryza sativa* L.) and mustard (*Brassica juncea* L.) constitute an important cereal-oilseed sequence in eastern Uttar Pradesh. Sustaining productivity of this system requires balanced nutrient supply and maintenance of soil fertility. Continuous dependence on chemical fertilizers alone may not adequately maintain soil productivity, whereas exclusive dependence on organic sources may not provide nutrients in sufficient quantities at the required time.

Integrated nutrient management combines inorganic fertilizers with organic manures and biological inputs. Such integration can provide nutrients in readily available as well as gradually mineralizable forms and may improve nutrient-use efficiency, soil biological activity, root development and crop productivity.

The present experiment evaluated twelve nutrient-management combinations involving recommended NPKS, FYM, poultry manure and biofertilizer (VAM) in rice and mustard during 2024-25 and 2025-26. The study particularly examined growth, yield attributes, yield and quality responses of both crops.

The objective was to determine the effect of integrated nutrient management on growth, yield attributes, productivity and quality of transplanted rice and mustard under a rice-mustard cropping system.

2. Materials and Methods

2.1 Experimental site and experimental design

A field experiment was conducted at farmer field of village Ramdaspur Patahana, Jaunpur Uttar Pradesh near V.B.S. Purvanchal University Jaunpur, Uttar Pradesh, during the agricultural years 2024-25 and 2025-26 to evaluate the effect of integrated nutrient management on growth, yield

and quality of rice and mustard under a rice-mustard cropping system. The experiment comprised twelve nutrient-management treatments (T₀-T₁₁), involving different combinations of recommended NPKS, farmyard manure (FYM), poultry manure and biofertilizer (VAM). The treatments were evaluated in a Randomized Block Design (RBD) with three replications. The

same treatment structure was maintained for comparison of crop performance across the two experimental years. Growth and yield observations were recorded at specified crop growth stages and at harvest following the procedures adopted in the original experimental study.

Treatment	Nutrient-management treatment
T ₀	Control (no fertilizer)
T ₁	100% NPKS (Recommended Dose of Fertilizer)
T ₂	50% NPKS (RDF) + 10 t FYM ha ⁻¹
T ₃	100% NPKS + 5 t FYM ha ⁻¹
T ₄	50% NPKS + 2.5 t poultry manure ha ⁻¹
T ₅	100% NPKS + 1 t poultry manure ha ⁻¹
T ₆	50% NPKS + 10 t FYM ha ⁻¹ + 10 kg biofertilizer (VAM)
T ₇	100% NPKS + 5 t FYM ha ⁻¹ + 5 kg biofertilizer (VAM)
T ₈	50% NPKS + 2.5 t poultry manure ha ⁻¹ + 10 kg biofertilizer (VAM)
T ₉	100% NPKS + 1 t poultry manure ha ⁻¹ + 5 kg biofertilizer (VAM)
T ₁₀	50% NPKS + 10 t FYM ha ⁻¹ + 2.5 t poultry manure ha ⁻¹ + 10 kg biofertilizer (VAM)
T ₁₁	100% NPKS + 5 t FYM ha ⁻¹ + 1 t poultry manure ha ⁻¹ + 5 kg biofertilizer (VAM)

2.2 Observations and laboratory analysis

In rice, observations on plant height, tillers hill⁻¹, dry matter accumulation, effective tillers hill⁻¹, panicle length, grains panicle⁻¹, test weight, grain yield, straw yield, biological yield and harvest index were recorded. In mustard, observations included plant height, primary and secondary branches plant⁻¹, dry matter accumulation, siliquae plant⁻¹, seeds siliqua⁻¹, test weight, seed yield plant⁻¹, stover yield plant⁻¹, harvest index, oil content and nutrient content. Plant samples were collected at harvest for estimation of nutrient concentration, while mustard seed quality was assessed through oil content. Nutrient uptake was calculated from nutrient concentration and corresponding dry matter/yield values wherever applicable. The analytical procedures and units of measurement followed those adopted in the thesis and the experimental laboratory protocol.

2.3 Statistical analysis

The experimental data obtained from both years were subjected to analysis of variance (ANOVA) appropriate for a Randomized Block Design to determine the significance of treatment effects. The treatment means were compared using the critical difference (CD) at the 5% level of probability, wherever the F-test indicated significant differences. The standard error of mean (SEm±) was calculated to indicate the precision of treatment means. Statistical significance was interpreted at P = 0.05. For each parameter, the treatment mean, SEm± and CD (5%) were presented as reported in the original thesis tables. The statistical analysis was performed separately for the respective experimental years, and treatment differences were interpreted on the basis of the significance levels obtained from the analysis of variance.

3. Results and Discussion

3.1 Growth performance of rice

3.1.1 Plant height

Plant height of rice increased progressively with advancement of crop growth from 30 days after transplanting (DAT) to harvest in both experimental years. The increase in plant height under all nutrient-management treatments reflected continued vegetative growth, while the magnitude of response varied considerably among treatments. The integrated nutrient-management treatments generally produced taller plants than the control, indicating a favourable response of rice to combined application of inorganic fertilizers, organic manures and biofertilizer.

At 30 DAT, plant height during 2024-25 ranged from 33.5 cm in T₀ to 41.9 cm in T₁₁, while during 2025-26 it ranged from 33.2 to 42.15 cm, respectively. At 60 DAT, the corresponding range was 58.2-77.2 cm in 2024-25 and 58.5-77.6 cm in 2025-26. At 90 DAT, plant height varied from 78.4 to 106.6 cm and 78.0 to 107.0 cm, respectively. At harvest, the maximum value recorded was 123.8 cm in 2024-25 and 124.0 cm in 2025-26 under T₁₀, whereas T₀ recorded only 92.1 and 92.4 cm, respectively. The thesis data therefore show that T₁₀ was the most effective treatment for plant height, although T₁₁ was statistically and numerically close at most stages.

The superiority of T₁₀ may be attributed to the complementary contribution of 50% NPKS + FYM + poultry manure + VAM. The organic materials supplied nutrients through mineralization and may have improved soil aggregation, moisture retention and microbial activity. VAM colonization can further enhance root exploration and nutrient acquisition, particularly phosphorus, thereby supporting shoot growth. The greater availability of nitrogen under integrated management also promotes cell division, cell elongation and chlorophyll formation, ultimately increasing plant height.

The present finding agrees with Apon *et al.* (2018), who reported improved growth and yield of rice under integrated nutrient management. Similarly, Kharlukhi *et al.* (2024) reported positive effects of INM on paddy growth and yield. More recently, an INM study on rice reported that combinations of recommended fertilizer, FYM and biofertilizers improved yield-contributing characters compared with the control.

3.1.2 Tillers hill⁻¹

The number of tillers hill⁻¹ increased markedly from 30 to 90 DAT under all treatments and declined slightly by harvest, which may be associated with the death of non-effective tillers during crop maturation. Nutrient management significantly affected tillering at the reported stages.

At 30 DAT, the number of tillers ranged from 3.8 to 6.4 during 2024-25 and from 3.6 to 6.9 hill⁻¹ during 2025-26. At 60 DAT, T₁₀ recorded 19.0 and 19.3 tillers hill⁻¹, while T₀ recorded only 8.5 and 8.4 tillers hill⁻¹. At 90 DAT, the highest values were 20.1 and 20.4 tillers hill⁻¹ under T₁₀, compared with 10.2 and 10.0 tillers hill⁻¹ under T₀. At harvest, T₁₀ maintained the highest number at 18.7 and 19.0 tillers hill⁻¹.

The increased tillering under T₁₀ indicates that integrated nutrient supply promoted vegetative growth and the formation of

productive tillers. Nitrogen is particularly important for tiller initiation and leaf-area development, while phosphorus enhances root development and early crop establishment. Potassium contributes to water regulation, enzyme activity and assimilate translocation. The organic manures probably supplied nutrients progressively and improved nutrient-retention capacity of the soil, while VAM may have enhanced nutrient uptake.

The result is consistent with the findings of Kumar *et al.* (2012), who reported improved yield attributes and nutrient uptake of rice with combined organic and inorganic nutrient sources. Similar enhancement of effective tillers and other yield attributes under INM has also been reported in recent rice studies.

3.2 Dry matter accumulation of rice

Dry matter accumulation increased continuously with crop age, irrespective of treatment, because of progressive production of leaves, stems and reproductive structures. However, substantial differences were observed among nutrient-management treatments.

At harvest, the lowest dry matter accumulation was recorded under the control, 841.88 and 841.96 g m⁻² in 2024-25 and 2025-26, respectively. In contrast, T₁₁ recorded the maximum values of 1592.28 and 1592.26 g m⁻², representing almost 1.9 times the dry matter production of the control. At 90 DAT, T₁₁ accumulated 1085.76 and 1085.50 g m⁻², compared with 511.59 and 511.99 g m⁻² under T₀.

The marked increase in biomass under T₁₁ can be explained by the combined availability of nutrients from NPKS, FYM and poultry manure and improved nutrient acquisition through VAM. Adequate nitrogen enhances leaf expansion and chlorophyll formation, thereby increasing photosynthetic capacity. Phosphorus supports energy transfer and root development, while potassium improves photosynthate translocation and physiological efficiency. Organic manures may additionally improve soil physical properties and microbial activity, creating a favourable rhizosphere for crop growth.

The results are in agreement with studies showing that INM improves biomass production through sustained nutrient availability. Kharlukhi reported improvement in growth and yield of paddy under integrated nutrient management, while Apon also observed improved rice growth under integrated nutrient application.

3.3 Yield attributes of rice

3.3.1 Effective tillers hill⁻¹

Effective tillers are one of the most important determinants of rice grain yield because only productive tillers contribute directly to panicle number and grain production. The integrated nutrient treatments substantially increased effective tiller production compared with the control.

T₁₁ produced the highest effective tiller number, recording 15.8 and 16.0 effective tillers hill⁻¹ during 2024-25 and 2025-26, respectively. The control produced only 8.1 and 7.3 effective tillers hill⁻¹. Thus, T₁₁ nearly doubled productive tillering compared with the control.

The improvement may be attributed to better nitrogen availability during the active tillering phase together with improved root growth and nutrient acquisition resulting from phosphorus, potassium, sulphur and VAM. FYM and poultry manure also provide a slow-release source of nutrients and improve the soil environment.

Comparable findings have been reported by studies in which integrated application of fertilizer, FYM and biofertilizers

increased effective tillers and other rice yield components. A recent rice study also found that INM significantly improved effective tillers, panicle length, grains panicle⁻¹ and test weight compared with the control.

3.3.2 Panicle length

Panicle length is an important yield attribute because longer panicles generally provide greater space for spikelet development. In the present study, panicle length increased with improvement in nutrient supply.

The maximum panicle length was recorded under T₁₁, with 28.6 cm in 2024-25 and 28.86 cm in 2025-26, whereas the control recorded only 20.2 and 20.16 cm, respectively.

The improvement in panicle length under T₁₁ may be related to better crop nutrition during panicle initiation and reproductive development. Adequate nitrogen and phosphorus support panicle differentiation, while potassium and sulphur contribute to assimilate production and translocation towards reproductive organs.

The result agrees with recent research showing that integrated application of inorganic fertilizers with FYM and biofertilizers enhances panicle length and other yield-contributing characteristics of rice.

3.3.3 Grains panicle⁻¹

The number of grains panicle⁻¹ showed a clear response to nutrient management. T₁₁ recorded the highest number, 162.0 grains panicle⁻¹ in 2024-25 and 162.2 grains panicle⁻¹ in 2025-26, compared with only 92.0 and 91.2 grains panicle⁻¹ under the control.

The greater number of grains panicle⁻¹ under T₁₁ may be due to improved nutrient availability during panicle initiation and flowering. Balanced NPKS nutrition supports spikelet formation, while organic amendments may improve nutrient availability throughout the crop season. VAM may further improve phosphorus acquisition and root functioning.

The present result is supported by earlier work showing that integrated nutrient management improves grains panicle⁻¹ and overall rice productivity. Kumar *et al.* (2012) also reported positive effects of combined organic and inorganic nutrient sources on rice yield attributes.

3.3.4 Test weight

Test weight increased progressively with improved nutrient management. T₁₁ recorded the maximum test weight of 27.2 and 27.4 g during 2024-25 and 2025-26, respectively, while T₀ recorded only 21.6 and 20.8 g.

Higher test weight under T₁₁ indicates better grain filling. Adequate potassium is particularly important for translocation of photosynthates from source tissues to developing grains. Balanced nitrogen and phosphorus nutrition also supports reproductive development and grain filling.

Similar improvement in test weight through integrated nutrient management has been reported in rice where FYM and biofertilizers were combined with mineral fertilizers.

3.4 Rice grain yield, straw yield, biological yield and harvest index

Rice grain yield represents the cumulative response of the crop to vegetative growth and yield components. The present experiment showed a pronounced effect of nutrient management on grain yield.

The highest grain yield was obtained under T₁₁, recording 6.02 t ha⁻¹ in 2024-25 and 6.52 t ha⁻¹ in 2025-26, whereas the control

produced only 2.38 and 2.32 t ha⁻¹, respectively. Thus, T₁₁ increased grain yield by approximately 153% in the first year and 181% in the second year compared with the control.

The superiority of T₁₁ was accompanied by higher effective tillers, longer panicles, more grains panicle⁻¹ and greater test weight. This demonstrates that the higher grain yield was not the result of a single yield component but of cumulative improvement in several components.

Straw yield under T₁₁ was 7.04 and 7.30 t ha⁻¹, compared with 3.92 and 3.91 t ha⁻¹ under T₀. Biological yield under T₁₁ was 13.06 and 12.92 t ha⁻¹, while harvest index reached 46.1 and 46.3%, respectively.

The improved productivity under integrated management can be attributed to synchronized nutrient supply from mineral fertilizers and organic sources. FYM and poultry manure may have improved nutrient availability and soil structure, whereas VAM enhanced the effective root-soil interface. This combination probably improved nutrient-use efficiency and photosynthate production.

These findings are strongly supported by Sharma *et al.*, who reported that partial substitution of mineral NPK with FYM combined with biofertilizers increased rice grain yield and nutrient uptake over 100% NPK alone. Similarly, a rice-mustard cropping-system study reported that integrated application of NPK, FYM and biofertilizers increased rice and mustard yields compared with farmer practice.

3.5 Growth performance of mustard

3.5.1 Plant height

Mustard plant height increased progressively from 30 DAS to harvest in all treatments. The magnitude of increase was considerably greater under integrated nutrient management.

T₁₁ produced the maximum plant height at harvest, 189.8 cm in 2024-25 and 190.06 cm in 2025-26, compared with 120.4 and 120.6 cm under the control.

The increase in plant height under T₁₁ may be associated with the continuous availability of nitrogen and other essential nutrients. Nitrogen promotes cell division and elongation, while phosphorus supports root development and energy metabolism. Potassium contributes to water regulation and photosynthetic efficiency. FYM and poultry manure provide nutrients gradually and may improve soil microbial activity and nutrient availability.

The present findings agree closely with Mandal and Sinha, who reported that integrated nutrient management improved plant height and other growth parameters of Indian mustard. Kumawat *et al.* (2014)^[1] likewise reported significant improvement in plant height and dry matter accumulation with increasing nutrient and FYM supply.

3.6 Branching in mustard

3.6.1 Primary branches plant⁻¹

Primary branches increased progressively with crop age. At harvest, T₁₁ produced the highest number of primary branches, 9.5 and 9.9 plant⁻¹ during 2024-25 and 2025-26, respectively, whereas T₀ recorded 4.8 and 5.0 plant⁻¹.

The greater number of branches under T₁₁ increased the potential sites for flowering and siliqua formation. Nitrogen promotes vegetative growth and branch development, while balanced phosphorus and potassium nutrition supports reproductive growth.

Similar findings were reported by Singh and Singh, who observed significant increases in branches and siliquae plant⁻¹ with integrated application of FYM, inorganic nutrients and

biofertilizers.

3.6.2 Secondary branches plant⁻¹

Secondary branches appeared later than primary branches, and the thesis records zero values at the early stages. At harvest, secondary branching increased markedly under INM. T₁₁ recorded 19.7 and 20.5 secondary branches plant⁻¹ in 2024-25 and 2025-26, respectively, compared with 8.4 and 8.7 under T₀.

The greater secondary branching under T₁₁ provided a larger reproductive framework for siliqua formation. The response may be attributed to sustained nitrogen availability and improved nutrient uptake due to the combined application of FYM, poultry manure and VAM.

The findings are consistent with Mandal and Sinha, who reported improvement in branches plant⁻¹ of mustard through integrated nutrient management.

3.7 Dry matter accumulation of mustard

Dry matter accumulation increased steadily with crop age. The lowest biomass production was recorded under T₀, whereas T₁₁ consistently produced the maximum dry matter.

At harvest, T₁₁ recorded 1389.6 g m⁻² in 2024-25 and 1389.8 g m⁻² in 2025-26, compared with 582.4 and 581.6 g m⁻² under the control. T₁₀ and T₉ were the next best treatments.

The higher biomass accumulation under T₁₁ reflects enhanced vegetative growth and photosynthetic activity resulting from balanced nutrient supply. FYM and poultry manure may have improved soil moisture retention and nutrient mineralization, while VAM could have promoted root development and nutrient absorption. Kumawat *et al.* (2014)^[1] reported significant increases in dry matter accumulation of mustard with FYM and increasing nutrient levels, supporting the present findings.

3.8 Yield attributes of mustard

3.8.1 Siliquae plant⁻¹

Siliquae plant⁻¹ is a major determinant of mustard seed yield. The number of siliquae increased markedly with improvement in nutrient supply.

T₁₁ recorded 442 and 456 siliquae plant⁻¹ during 2024-25 and 2025-26, respectively, compared with 172 and 178 siliquae plant⁻¹ under T₀. The superiority of T₁₁ was associated with greater plant height, primary and secondary branching and biomass accumulation.

The improved siliqua formation may be attributed to adequate nutrient availability during flowering and pod development. Sulphur is particularly important in mustard because of its role in protein and oil metabolism, while nitrogen supports reproductive growth.

The present result agrees with Mandal and Sinha, who reported improved siliquae plant⁻¹ under integrated nutrient management. Similar findings were also reported by Kumawat *et al.* (2014)^[1], who found that FYM and nutrient application increased siliquae plant⁻¹.

3.8.2 Seeds siliqua⁻¹

T₁₁ produced 19.6 and 20.3 seeds siliqua⁻¹ in the two years, whereas the control recorded only 11.4 and 11.8 seeds siliqua⁻¹. The increase in seeds siliqua⁻¹ indicates improved reproductive efficiency under balanced nutrition.

Adequate phosphorus and sulphur during flowering and seed formation may have supported better fertilization and seed development. The organic nutrient sources likely provided a sustained nutrient supply during the reproductive period. The result is comparable with the findings of Mandal and Sinha and

Kumawat *et al.*, who observed increases in seeds silique⁻¹ under integrated nutrient management.

3.8.3 Test weight

Test weight was also improved by integrated nutrient management. T₁₁ recorded 5.80 and 5.88 g in 2024-25 and 2025-26, respectively, compared with 4.32 and 4.38 g under T₀.

Higher test weight indicates better seed filling and accumulation of assimilates during seed development. Balanced nitrogen, phosphorus, potassium and sulphur nutrition probably improved photosynthetic activity and translocation of assimilates to developing seeds.

The present findings are consistent with previous mustard research showing that INM improves 1,000-seed weight and seed yield. Mandal and Sinha and Singh and Singh reported similar responses to integrated nutrient application.

3.9 Mustard seed yield, stover yield and harvest index

The combined effect of improved growth and yield attributes was reflected in seed yield.

T₁₁ recorded the maximum seed yield of 22.8 g plant⁻¹ in 2024-25 and 23.8 g plant⁻¹ in 2025-26, compared with 7.2 and 7.5 g plant⁻¹ under the control. Thus, T₁₁ produced approximately three times the seed yield of the control.

Stover yield was also highest under T₁₁, with 22.8 and 23.7 g plant⁻¹, while harvest index reached 50.0 and 50.2%, respectively.

The higher seed yield was the cumulative result of improved plant height, branching, dry matter accumulation, siliques plant⁻¹, seeds silique⁻¹ and test weight. Integrated nutrient management therefore enhanced both source development and sink formation.

The findings agree with Mandal and Sinha, who found that 100% recommended NPK combined with FYM improved seed and oil yield compared with NPK alone. Tripathi *et al.* also reported significant yield enhancement through combinations of FYM and sulphur with mineral fertilizer.

Similarly, a rice-mustard system study found that integration of mineral fertilizer, FYM and biofertilizers increased both rice and mustard yields over conventional/farmer practice.

3.10 Oil content of mustard

Oil content is a major quality parameter determining the economic value of mustard seed. A clear treatment effect was observed in the present investigation.

The control recorded 36.4 and 36.7% oil in 2024-25 and 2025-26, respectively, whereas T₁₁ recorded the maximum oil content of 44.0 and 44.4%.

The improvement in oil content under T₁₁ may be associated particularly with balanced sulphur nutrition. Sulphur is essential for sulphur-containing amino acids and enzymes involved in oilseed metabolism and is closely associated with quality and oil formation in Brassica crops. Adequate nitrogen and phosphorus additionally support seed development and assimilate production.

The result is in agreement with Mandal and Sinha, who reported improvement in oil content and oil yield of Indian mustard through integrated nutrient management. Singh and Singh also reported increased oil content and oil yield with integrated application of FYM, nitrogen and biofertilizers.

Further, Katiyar *et al.* reported a positive response of mustard yield and oil content to sulphur fertilization, supporting the importance of balanced sulphur nutrition in mustard.

3.11 Nutrient content and nutrient uptake

The nutrient-content data in your thesis indicate that integrated nutrient management improved the concentration of major nutrients in mustard seed. The highest values were generally associated with T₁₁, reflecting improved nutrient availability and acquisition under combined mineral, organic and biological nutrient sources.

The integrated treatment provides nutrients through different release pathways. Mineral fertilizer supplies readily available nutrients, whereas FYM and poultry manure undergo decomposition and mineralization, providing a more sustained nutrient supply. VAM may enhance the effective absorbing area of roots and improve particularly phosphorus acquisition. Consequently, better plant nutrition can result in greater nutrient concentration as well as greater nutrient uptake because of increased biomass and seed production.

This interpretation is supported by Sharma *et al.*, who reported significantly greater N, P, K, S and Zn uptake by rice under integrated application of fertilizer, FYM and biofertilizers. In mustard, Singh and Singh reported improved nutrient uptake under integrated nutrient management, while Rajesh Kumar Singh and Amitesh Kumar Singh found that organic-source combinations with FYM and microbial inoculants improved yield attributes, yield and nutrient uptake of mustard.

3.12 Comparative response of rice and mustard to INM

The two-year results demonstrate that the response of rice and mustard to nutrient management was consistently positive, although the optimum treatment differed slightly among individual growth parameters.

In rice, T₁₀ was particularly effective for plant height and tillering, whereas T₁₁ produced the maximum dry matter accumulation and major yield attributes. This distinction is important and should be retained in the final manuscript rather than describing T₁₁ as the best treatment for every rice parameter. The original thesis data clearly show T₁₀ values of 41.0-41.03 cm at 30 DAT, 77.2-77.6 cm at 60 DAT and 20.1-20.4 tillers hill⁻¹ at 90 DAT, while T₁₁ was highest for rice dry matter accumulation.

In contrast, T₁₁ consistently ranked first for mustard growth, yield attributes, seed yield and oil content. This suggests that the full NPKS dose combined with FYM, poultry manure and VAM provided an especially favourable nutrient environment for mustard.

The overall trend agrees with published evidence that integrated use of mineral fertilizers, organic manures and microbial inoculants can improve nutrient availability, crop growth, yield formation and nutrient uptake compared with either inadequate fertilization or fertilizer-only approaches. Studies in rice-mustard systems have specifically demonstrated benefits from combining inorganic fertilizers with FYM and biofertilizers.

3.13 Overall discussion

The overall superiority of integrated nutrient management can be explained by nutrient complementarity and synchronization. Chemical fertilizers provide immediately available nutrients, while FYM and poultry manure supply nutrients progressively through decomposition and mineralization. Organic amendments also contribute to improved soil structure, water-holding capacity, microbial activity and nutrient buffering. VAM provides an additional biological mechanism for nutrient acquisition by increasing the effective root-soil interface.

The stronger response under T₁₁, particularly for yield and quality, indicates that the combination of 100% NPKS + 5 t

FYM ha⁻¹ + 1 t poultry manure ha⁻¹ + 5 kg VAM ha⁻¹ provided a favourable balance between readily available and slowly released nutrients. The higher rice grain yield and mustard seed yield under this treatment were supported by improvements in the individual yield components.

Importantly, the results are consistent with previous studies conducted under different agro-ecological conditions. Research on rice-mustard systems has shown that combining mineral fertilizers with FYM and biofertilizers improves crop yield and nutrient uptake. In mustard, studies by Mandal and Sinha, Singh

and Singh, and Kumawat *et al.* have independently demonstrated improvements in growth, yield attributes, seed yield, oil content and nutrient uptake through integrated nutrient management.

Thus, the present two-year investigation provides evidence that INM is not merely a means of increasing crop yield but also a strategy for improving crop growth, yield components, nutrient utilization and produce quality in the rice-mustard cropping system.

Table R1: Effect of Integrated Nutrient Management on plant height at different growth stages of transplanted rice

Treatment	30 DAT		60 DAT		90 DAT		At Harvest	
	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26
T ₀ Control (no fertilizer)	33.5	33.2	58.2	58.5	78.4	78.0	92.1	92.4
T ₁ 100% NPKS (Recommended Dose of Fertilizer)	38.4	38.5	72.6	73.0	98.3	98.9	115.4	115.9
T ₂ 50% NPKS (RDF) + 10 t FYM ha ⁻¹	36.8	36.5	70.1	70.7	95.7	96.0	112.3	112.0
T ₃ 100% NPKS + 5 t FYM ha ⁻¹	40.2	40.23	75.4	75.8	102.1	102.3	119.2	119.23
T ₄ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹	37.5	38.2	71.8	72.4	96.9	97.6	114.0	114.7
T ₅ 100% NPKS + 1 t Poultry Manure ha ⁻¹	39.6	39.8	74.2	74.5	100.5	100.7	117.6	117.8
T ₆ 50% NPKS + 10 t FYM ha ⁻¹ + 10 kg Biofertilizer (VAM)	38.9	39.3	73.5	73.7	99.4	99.8	116.5	116.9
T ₇ 100% NPKS + 5 t FYM ha ⁻¹ + 5 kg Biofertilizer (VAM)	41.3	41.6	76.8	77.1	104.2	104.5	121.4	121.7
T ₈ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	39.8	40.3	74.9	75.3	101.3	101.7	118.7	119.1
T ₉ 100% NPKS + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	40.7	41.3	75.9	76.5	103.0	103.6	120.1	120.7
T ₁₀ 50% NPKS + 10 t FYM ha ⁻¹ + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	41.0	41.03	77.2	77.6	106.6	107.0	123.8	124.0
T ₁₁ 100% NPKS + 5 t FYM ha ⁻¹ + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	41.9	42.15	76.9	77.1	106.3	106.5	122.0	122.3
S.E.m ±	0.82	0.91	1.15	1.18	1.30	1.42	1.68	2.21
CD (P=0.05)	2.41	2.71	3.38	3.46	3.90	4.27	4.94	6.60

Table R2: Effect of Integrated Nutrient Management on tillers hill⁻¹

Treatment	30 DAT		60 DAT		90 DAT		At Harvest	
	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26
T ₀ Control (no fertilizer)	3.8	3.6	8.5	8.4	10.2	10.0	10.4	10.6
T ₁ 100% NPKS (Recommended Dose of Fertilizer)	5.6	6.0	14.8	15.4	17.3	17.8	16.1	16.6
T ₂ 50% NPKS (RDF) + 10 t FYM ha ⁻¹	5.2	5.0	13.9	13.7	16.0	15.9	15.3	15.0
T ₃ 100% NPKS + 5 t FYM ha ⁻¹	6.1	6.13	16.2	16.4	18.9	19.3	17.6	17.63
T ₄ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹	5.4	6.1	14.4	15.1	16.9	17.5	15.8	16.5
T ₅ 100% NPKS + 1 t Poultry Manure ha ⁻¹	5.9	6.1	15.7	15.9	18.2	18.5	17.0	17.2
T ₆ 50% NPKS + 10 t FYM ha ⁻¹ + 10 kg Biofertilizer (VAM)	5.7	6.1	15.3	15.7	17.8	18	16.6	17
T ₇ 100% NPKS + 5 t FYM ha ⁻¹ + 5 kg Biofertilizer (VAM)	6.4	6.7	17.0	17.3	19.8	20.1	18.4	18.7
T ₈ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	6.0	6.4	16.0	16.4	18.5	18.9	17.3	17.8
T ₉ 100% NPKS + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	6.2	6.8	16.5	17.1	19.2	19.8	17.9	18.5
T ₁₀ 50% NPKS + 10 t FYM ha ⁻¹ + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	6.3	6.9	19.0	19.3	20.1	20.4	18.7	19.0
T ₁₁ 100% NPKS + 5 t FYM ha ⁻¹ + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	6.1	6.6	18.1	18.3	20.0	20.1	18.5	18.8
S.E.m ±	0.18	0.25	0.32	0.38	0.41	0.49	0.54	0.67
CD (P=0.05)	0.53	0.74	0.94	1.12	1.20	1.47	1.61	2.00

Table R3: Effect of Integrated nutrient management on Dry matter accumulation (gm⁻²) at different growth stages of transplanted rice

Treatment	30 DAT		60 DAT		90 DAT		At Harvest	
	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26
T ₀ Control (no fertilizer)	82.19	81.99	247.12	247.2	511.59	511.99	841.88	841.96
T ₁ 100% NPKS (Recommended Dose of Fertilizer)	128.04	128.02	428.59	428.09	912.22	912.02	1385.52	1385.02
T ₂ 50% NPKS (RDF) + 10 t FYM ha ⁻¹	118.37	118.07	402.46	402.06	864.98	864.91	1324.47	1324.07
T ₃ 100% NPKS + 5 t FYM ha ⁻¹	137.86	137.95	469.2	468.3	982.04	982.09	1472.81	1471.91
T ₄ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹	122.4	122.2	415.19	415.1	892.26	892.06	1356.29	1356.2
T ₅ 100% NPKS + 1 t Poultry Manure ha ⁻¹	133.15	133.91	452.56	452.5	957.8	958.3	1437.3	1437.24
T ₆ 50% NPKS + 10 t FYM ha ⁻¹ + 10 kg Biofertilizer (VAM)	130.21	130.09	442.6	442.3	935.22	935.1	1412.42	1412.12
T ₇ 100% NPKS + 5 t FYM ha ⁻¹ + 5 kg Biofertilizer (VAM)	145.12	145.06	492.09	491.99	1028.56	1028.5	1526.16	1526.06
T ₈ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	136.6	136.3	465.52	465.02	978.4	978.1	1468.8	1468.3
T ₉ 100% NPKS + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	141.13	141.1	478.17	478.07	1005.53	1005.5	1498.13	1498.03
T ₁₀ 50% NPKS + 10 t FYM ha ⁻¹ + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	143	142.5	496.1	495.9	1042.6	1042.1	1548.7	1548.5
T ₁₁ 100% NPKS + 5 t FYM ha ⁻¹ + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	152.56	152.3	518.22	518.2	1085.76	1085.5	1592.28	1592.26
S.E.m ±	5.34	5.09	13.87	13.57	23.95	23.75	33.7	33.4
CD (P=0.05)	14.35	13.6	38.88	37.98	68.8	68.2	97.4	96.5

Table R4: Effect of Integrated Nutrient Management on effective tillers hill⁻¹, panicle length, grains panicle⁻¹ and test weight of transplanted rice

Treatments	Effective tillers hill ⁻¹		Panicle length (cm)		Grains panicle ⁻¹		Test weight (g)	
	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26
T ₀ Control (no fertilizer)	8.1	7.3	20.2	20.16	92	91.2	21.6	20.8
T ₁ 100% NPKS (Recommended Dose of Fertilizer)	11.4	11.49	23.6	23.62	118	118.09	23.8	23.89
T ₂ 50% NPKS (RDF) + 10 t FYM ha ⁻¹	12.2	12.26	24.4	24.47	125	125.06	24.4	24.46
T ₃ 100% NPKS + 5 t FYM ha ⁻¹	13.5	13.8	26.1	26.01	138	138.3	25.5	25.8
T ₄ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹	12.7	12.8	25.0	25.2	130	130.1	24.9	25
T ₅ 100% NPKS + 1 t Poultry Manure ha ⁻¹	13.9	14.4	26.8	26.04	142	142.5	26.0	26.5
T ₆ 50% NPKS + 10 t FYM ha ⁻¹ + 10 kg Biofertilizer (VAM)	13.2	13.5	26.0	26.12	136	136.3	25.2	25.5
T ₇ 100% NPKS + 5 t FYM ha ⁻¹ + 5 kg Biofertilizer (VAM)	15.1	14.98	28.0	28.06	155	154.88	26.8	26.68
T ₈ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	13.8	13.82	26.5	26.8	140	140.02	25.7	25.72
T ₉ 100% NPKS + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	14.6	14.67	27.4	27.43	148	148.07	26.4	26.47
T ₁₀ 50% NPKS + 10 t FYM ha ⁻¹ + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	14.9	15.8	27.8	28.3	150	150.9	26.6	27.5
T ₁₁ 100% NPKS + 5 t FYM ha ⁻¹ + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	15.8	16	28.6	28.86	162	162.2	27.2	27.4
SEm ±	0.42	1.32	0.48	1.43	4.6	5.49	0.35	1.3
CD (P=0.05)	1.23	2.23	1.40	2.6	13.5	14.8	1.02	2.22

Table R5: Effect of Integrated Nutrient Management on grain yield, straw yield, biological yield and harvest index of transplanted rice

Treatments	Grain yield (t ha ⁻¹)		Straw yield (t ha ⁻¹)		Biological yield (t ha ⁻¹)		Harvest index (%)	
	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26
T ₀ Control (no fertilizer)	2.38	2.32	3.92	3.91	6.30	6.7	37.8	37
T ₁ 100% NPKS (Recommended Dose of Fertilizer)	4.26	4.28	5.74	5.76	10.00	6.26	42.6	42.69
T ₂ 50% NPKS (RDF) + 10 t FYM ha ⁻¹	4.58	4.51	5.96	6.03	10.54	10.02	43.5	43.56
T ₃ 100% NPKS + 5 t FYM ha ⁻¹	5.12	5.21	6.32	6.27	11.44	10.61	44.8	45.1
T ₄ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹	4.86	4.92	6.18	6.38	11.04	11.35	44.0	44.1
T ₅ 100% NPKS + 1 t Poultry Manure ha ⁻¹	5.28	5.58	6.54	6.45	11.82	11.24	44.7	45.2
T ₆ 50% NPKS + 10 t FYM ha ⁻¹ + 10 kg Biofertilizer (VAM)	5.02	5.12	6.28	6.4	11.30	11.06	44.4	44.7
T ₇ 100% NPKS + 5 t FYM ha ⁻¹ + 5 kg Biofertilizer (VAM)	5.74	6.24	6.82	6.88	12.56	11.42	45.7	45.58
T ₈ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	5.20	5.3	6.46	6.76	11.66	12.62	44.6	44.62
T ₉ 100% NPKS + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	5.56	6.06	6.68	6.71	12.24	11.96	45.4	45.47
T ₁₀ 50% NPKS + 10 t FYM ha ⁻¹ + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	5.68	5.6	6.74	7.24	12.42	12.27	45.7	46.6
T ₁₁ 100% NPKS + 5 t FYM ha ⁻¹ + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	6.02	6.52	7.04	7.3	13.06	12.92	46.1	46.3
S.Em ±	0.15	1.05	0.18	1.13	0.24	1.19	0.92	1.81
CD (P=0.05)	0.44	1.44	0.53	1.73	0.71	1.91	2.70	4

Table M1: Effect of Integrated Nutrient Management on Plant Height (cm) at Different Growth Stages of Mustard Crop

Treatment	30 DAS		60 DAS		90 DAS		At Harvest	
	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26
T ₀ Control (no fertilizer)	42.1	41.7	78.4	77.6	108.5	108.44	120.4	120.6
T ₁ 100% NPKS (Recommended Dose of Fertilizer)	54.3	54.5	101.2	101.29	139.8	139.82	155.2	155.22
T ₂ 50% NPKS (RDF) + 10 t FYM ha ⁻¹	56.8	56.87	105.9	105.96	146.2	146.13	162.3	162.6
T ₃ 100% NPKS + 5 t FYM ha ⁻¹	59.5	59.45	110.8	111.1	153.0	153.09	169.9	169.81
T ₄ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹	57.8	58.0	107.6	107.7	148.6	148.66	165.0	165.2
T ₅ 100% NPKS + 1 t Poultry Manure ha ⁻¹	62.4	61.9	116.2	116.7	160.5	160.8	178.1	177.34
T ₆ 50% NPKS + 10 t FYM ha ⁻¹ + 10 kg Biofertilizer (VAM)	58.9	59.02	109.7	110.0	151.5	151.6	168.2	168.32
T ₇ 100% NPKS + 5 t FYM ha ⁻¹ + 5 kg Biofertilizer (VAM)	60.2	60.26	112.1	111.98	154.8	155.3	171.8	171.86
T ₈ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	58.5	58.8	109.0	109.02	150.6	150.7	167.2	167.5
T ₉ 100% NPKS + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	63.0	63.03	117.4	117.47	162.0	162.5	179.8	179.83
T ₁₀ 50% NPKS + 10 t FYM ha ⁻¹ + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	63.6	64.1	118.5	119.4	163.7	163.62	181.7	182.2
T ₁₁ 100% NPKS + 5 t FYM ha ⁻¹ + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	66.5	66.76	123.9	124.1	171.0	171.5	189.8	190.06
SEm ±	2.8	3.0	3.5	3.6	4.2	4.6	4.0	4.25
CD (P=0.05)	8.1	8.7	10.2	10.5	12.3	13.2	11.7	12.45

Table M2: Effect of Integrated Nutrient Management on Primary Branches Plant⁻¹ at Different Growth Stages of Mustard Crop

Treatment	30 DAS		60 DAS		90 DAS		At Harvest	
	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26
T ₀ Control (no fertilizer)	0.0	0.0	2.1	2.2	4.2	4.4	4.8	5.0
T ₁ 100% NPKS (Recommended Dose of Fertilizer)	0.0	0.0	3.4	3.6	5.8	6.1	6.6	6.9
T ₂ 50% NPKS (RDF) + 10 t FYM ha ⁻¹	0.0	0.0	3.8	4.0	6.4	6.7	7.3	7.6
T ₃ 100% NPKS + 5 t FYM ha ⁻¹	0.0	0.0	4.1	4.3	7.0	7.3	7.9	8.2
T ₄ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹	0.0	0.0	3.9	4.1	6.6	6.9	7.5	7.8
T ₅ 100% NPKS + 1 t Poultry Manure ha ⁻¹	0.0	0.0	4.6	4.8	7.6	7.9	8.5	8.9
T ₆ 50% NPKS + 10 t FYM ha ⁻¹ + 10 kg Biofertilizer (VAM)	0.0	0.0	4.0	4.2	6.7	7.0	7.6	7.9
T ₇ 100% NPKS + 5 t FYM ha ⁻¹ + 5 kg Biofertilizer (VAM)	0.0	0.0	4.3	4.5	7.2	7.5	8.1	8.4
T ₈ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	0.0	0.0	3.9	4.1	6.6	6.9	7.5	7.8
T ₉ 100% NPKS + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	0.0	0.0	4.7	4.9	7.8	8.1	8.7	9.1
T ₁₀ 50% NPKS + 10 t FYM ha ⁻¹ + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	0.0	0.0	4.9	5.1	8.1	8.4	9.0	9.4
T ₁₁ 100% NPKS + 5 t FYM ha ⁻¹ + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	0.0	0.0	5.2	5.4	8.5	8.8	9.5	9.9
SEm ±	0.0	0.0	0.18	0.19	0.26	0.28	0.28	0.30
CD (P=0.05)	NS	NS	0.53	0.56	0.76	0.82	0.82	0.88

Table M3: Effect of Integrated Nutrient Management on Secondary Branches Plant⁻¹ at Different Growth Stages of Mustard Crop

Treatment	30 DAS		60 DAS		90 DAS		At Harvest	
	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26
T ₀ Control (no fertilizer)	0.0	0.0	0.0	0.0	4.8	5.0	8.4	8.7
T ₁ 100% NPKS (Recommended Dose of Fertilizer)	0.0	0.0	0.0	0.0	8.2	8.6	12.6	13.1
T ₂ 50% NPKS (RDF) + 10 t FYM ha ⁻¹	0.0	0.0	0.0	0.0	9.8	10.2	14.3	14.9
T ₃ 100% NPKS + 5 t FYM ha ⁻¹	0.0	0.0	0.0	0.0	11.2	11.7	15.8	16.4
T ₄ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹	0.0	0.0	0.0	0.0	10.4	10.8	14.8	15.4
T ₅ 100% NPKS + 1 t Poultry Manure ha ⁻¹	0.0	0.0	0.0	0.0	12.8	13.3	17.4	18.1
T ₆ 50% NPKS + 10 t FYM ha ⁻¹ + 10 kg Biofertilizer (VAM)	0.0	0.0	0.0	0.0	10.6	11.0	15.2	15.8
T ₇ 100% NPKS + 5 t FYM ha ⁻¹ + 5 kg Biofertilizer (VAM)	0.0	0.0	0.0	0.0	11.8	12.3	16.4	17.0
T ₈ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	0.0	0.0	0.0	0.0	10.5	10.9	15.0	15.6
T ₉ 100% NPKS + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	0.0	0.0	0.0	0.0	13.2	13.7	17.8	18.5
T ₁₀ 50% NPKS + 10 t FYM ha ⁻¹ + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	0.0	0.0	0.0	0.0	13.8	14.3	18.4	19.1
T ₁₁ 100% NPKS + 5 t FYM ha ⁻¹ + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	0.0	0.0	0.0	0.0	14.6	15.2	19.7	20.5
SEm ±	0.0	0.0	0.0	0.0	0.42	0.44	0.54	0.56
CD (P=0.05)	NS	NS	NS	NS	1.23	1.29	1.58	1.64

Table M4: Effect of Integrated Nutrient Management on Dry Matter Accumulation (g m⁻²) at Different Growth Stages of Mustard Crop

Treatment	30 DAS		60 DAS		90 DAS		At Harvest	
	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26
T ₀ Control (no fertilizer)	48.2	48.14	182.5	182.42	412.8	412.4	582.4	581.6
T ₁ 100% NPKS (Recommended Dose of Fertilizer)	72.5	72.52	298.6	299.1	682.4	682.6	962.8	962.89
T ₂ 50% NPKS (RDF) + 10 t FYM ha ⁻¹	78.9	78.83	328.4	328.8	748.6	748.67	1056.2	1056.26
T ₃ 100% NPKS + 5 t FYM ha ⁻¹	85.3	85.39	358.2	359.1	812.5	812.45	1148.9	1149.2
T ₄ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹	80.6	80.66	338.1	338.19	768.4	768.6	1084.3	1084.4
T ₅ 100% NPKS + 1 t Poultry Manure ha ⁻¹	92.8	93.1	392.5	392.56	892.6	892.1	1260.4	1260.9
T ₆ 50% NPKS + 10 t FYM ha ⁻¹ + 10 kg Biofertilizer (VAM)	82.4	82.5	345.6	345.9	785.2	785.32	1108.6	1108.9
T ₇ 100% NPKS + 5 t FYM ha ⁻¹ + 5 kg Biofertilizer (VAM)	88.1	88.6	369.4	369.5	838.9	838.96	1184.7	1184.58
T ₈ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	81.7	81.8	342.8	343.3	778.3	778.6	1098.4	1098.42
T ₉ 100% NPKS + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	94.6	95.1	398.7	398.8	906.4	906.43	1279.2	1279.27
T ₁₀ 50% NPKS + 10 t FYM ha ⁻¹ + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	96.8	96.72	408.2	408.4	928.6	929.1	1310.5	1311.4
T ₁₁ 100% NPKS + 5 t FYM ha ⁻¹ + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	102.4	102.9	432.8	432.82	984.2	984.46	1389.6	1389.8
SEm ±	2.1	2.3	6.4	6.6	14.3	14.5	18.2	18.4
CD (P=0.05)	6.1	6.7	18.7	19.3	41.8	42.4	53.2	53.8

Table M5: Effect of Integrated Nutrient Management on Number of Siliqua Plant⁻¹, Seeds Siliqua⁻¹, Test Weight (g) of Mustard Crop

Treatment	Number of Siliqua Plant ⁻¹		Seeds Siliqua ⁻¹		Test Weight (g)	
	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26
To Control (no fertilizer)	172	178	11.4	11.8	4.32	4.38
T ₁ 100% NPKS (Recommended Dose of Fertilizer)	268	275	15.0	15.5	5.05	5.12
T ₂ 50% NPKS (RDF) + 10 t FYM ha ⁻¹	302	312	16.0	16.6	5.20	5.28
T ₃ 100% NPKS + 5 t FYM ha ⁻¹	338	348	16.8	17.4	5.35	5.43
T ₄ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹	318	328	16.2	16.8	5.26	5.34
T ₅ 100% NPKS + 1 t Poultry Manure ha ⁻¹	382	394	18.0	18.7	5.55	5.63
T ₆ 50% NPKS + 10 t FYM ha ⁻¹ + 10 kg Biofertilizer (VAM)	322	332	16.4	17.0	5.28	5.36
T ₇ 100% NPKS + 5 t FYM ha ⁻¹ + 5 kg Biofertilizer (VAM)	358	368	17.2	17.8	5.42	5.50
T ₈ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	320	330	16.3	16.9	5.27	5.35
T ₉ 100% NPKS + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	398	410	18.4	19.1	5.60	5.68
T ₁₀ 50% NPKS + 10 t FYM ha ⁻¹ + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	418	430	18.8	19.5	5.66	5.74
T ₁₁ 100% NPKS + 5 t FYM ha ⁻¹ + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	442	456	19.6	20.3	5.80	5.88
SEm ±	12.8	13.2	0.44	0.46	0.11	0.12
CD (P=0.05)	37.4	38.6	1.29	1.35	0.32	0.35

Table M6: Effect of Integrated Nutrient Management on Seed Yield Plant⁻¹ (g), Stover Yield Plant⁻¹ (g) and Harvest Index (%) of Mustard Crop

Treatment	Seed Yield Plant ⁻¹ (g)		Stover Yield Plant ⁻¹ (g)		Harvest Index (%)	
	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26
To Control (no fertilizer)	7.2	7.5	11.2	11.7	39.1	39.4
T ₁ 100% NPKS (Recommended Dose of Fertilizer)	12.8	13.4	15.8	16.4	44.8	45.0
T ₂ 50% NPKS (RDF) + 10 t FYM ha ⁻¹	14.6	15.3	17.8	18.5	45.1	45.3
T ₃ 100% NPKS + 5 t FYM ha ⁻¹	16.2	16.9	19.6	20.3	45.3	45.5
T ₄ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹	15.2	15.9	18.5	19.2	45.1	45.3
T ₅ 100% NPKS + 1 t Poultry Manure ha ⁻¹	18.6	19.4	20.6	21.4	47.5	47.7
T ₆ 50% NPKS + 10 t FYM ha ⁻¹ + 10 kg Biofertilizer (VAM)	15.6	16.3	19.0	19.7	45.1	45.3
T ₇ 100% NPKS + 5 t FYM ha ⁻¹ + 5 kg Biofertilizer (VAM)	17.2	18.0	20.0	20.8	46.2	46.4
T ₈ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	15.4	16.1	18.7	19.4	45.2	45.4
T ₉ 100% NPKS + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	19.4	20.3	21.1	21.9	47.9	48.1
T ₁₀ 50% NPKS + 10 t FYM ha ⁻¹ + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	20.6	21.5	21.5	22.3	48.9	49.1
T ₁₁ 100% NPKS + 5 t FYM ha ⁻¹ + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	22.8	23.8	22.8	23.7	50.0	50.2
SEm ±	0.70	0.73	0.65	0.68	0.88	0.91
CD (P=0.05)	2.05	2.14	1.90	1.99	2.57	2.66

Table M7: Effect of Integrated Nutrient Management on Oil Content (%) in Mustard Seed

Treatment	Oil Content (%)	
	2024-25	2025-26
To Control (no fertilizer)	36.4	36.7
T ₁ 100% NPKS (Recommended Dose of Fertilizer)	40.0	40.4
T ₂ 50% NPKS (RDF) + 10 t FYM ha ⁻¹	40.8	41.2
T ₃ 100% NPKS + 5 t FYM ha ⁻¹	41.6	42.0
T ₄ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹	41.1	41.5
T ₅ 100% NPKS + 1 t Poultry Manure ha ⁻¹	42.7	43.1
T ₆ 50% NPKS + 10 t FYM ha ⁻¹ + 10 kg Biofertilizer (VAM)	41.3	41.7
T ₇ 100% NPKS + 5 t FYM ha ⁻¹ + 5 kg Biofertilizer (VAM)	42.0	42.4
T ₈ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	41.2	41.6
T ₉ 100% NPKS + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	43.0	43.4
T ₁₀ 50% NPKS + 10 t FYM ha ⁻¹ + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	43.4	43.8
T ₁₁ 100% NPKS + 5 t FYM ha ⁻¹ + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	44.0	44.4
SEm ±	0.40	0.42
CD (P=0.05)	1.17	1.23

Table M8: Effect of Integrated Nutrient Management on Nutrient Content (%) in Mustard Seed (at Harvest)

Treatment	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Sulphur (%)	
	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26
T ₀ Control (no fertilizer)	2.45	2.48	0.39	0.41	0.74	0.77	0.70	0.73
T ₁ 100% NPKS (Recommended Dose of Fertilizer)	3.20	3.24	0.55	0.57	0.94	0.97	0.94	0.97
T ₂ 50% NPKS (RDF) + 10 t FYM ha ⁻¹	3.37	3.41	0.59	0.61	1.00	1.03	1.04	1.07
T ₃ 100% NPKS + 5 t FYM ha ⁻¹	3.50	3.54	0.63	0.65	1.06	1.09	1.12	1.15
T ₄ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹	3.42	3.46	0.60	0.62	1.02	1.05	1.07	1.10
T ₅ 100% NPKS + 1 t Poultry Manure ha ⁻¹	3.74	3.78	0.69	0.71	1.14	1.17	1.24	1.27
T ₆ 50% NPKS + 10 t FYM ha ⁻¹ + 10 kg Biofertilizer (VAM)	3.44	3.48	0.61	0.63	1.03	1.06	1.09	1.12
T ₇ 100% NPKS + 5 t FYM ha ⁻¹ + 5 kg Biofertilizer (VAM)	3.57	3.61	0.65	0.67	1.08	1.11	1.16	1.19
T ₈ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	3.43	3.47	0.60	0.62	1.02	1.05	1.08	1.11
T ₉ 100% NPKS + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	3.80	3.84	0.71	0.73	1.17	1.20	1.27	1.30
T ₁₀ 50% NPKS + 10 t FYM ha ⁻¹ + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	3.87	3.91	0.73	0.75	1.20	1.23	1.30	1.33
T ₁₁ 100% NPKS + 5 t FYM ha ⁻¹ + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	3.97	4.01	0.76	0.78	1.24	1.27	1.35	1.38
SEm ±	0.10	0.11	0.02	0.02	0.03	0.04	0.04	0.05
CD (P=0.05)	0.29	0.32	0.06	0.06	0.09	0.11	0.12	0.14

4. Conclusion

The two-year investigation demonstrated that integrated nutrient management substantially improved the growth, yield attributes, yield and quality of rice and mustard compared with the unfertilized control.

In rice, the treatment T₁₁ (100% NPKS + 5 t FYM ha⁻¹ + 1 t poultry manure ha⁻¹ + 5 kg biofertilizer/VAM) produced the highest dry matter accumulation, yield attributes and grain yield, whereas T₁₀ showed particularly strong performance for plant height and tillering.

In mustard, T₁₁ consistently produced the highest growth, yield attributes, seed yield and oil content. The maximum mustard oil content of 44.0 and 44.4% was recorded under T₁₁ during 2024-25 and 2025-26, respectively.

Therefore, under the experimental conditions, integrated application of recommended NPKS with FYM, poultry manure and VAM, particularly T₁₁, was an effective nutrient-management strategy for improving productivity and quality of the rice-mustard cropping system. 5. Tables.

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