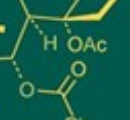
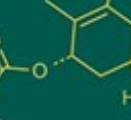
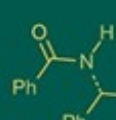


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Ganesh Kumar

Research Scholar, Department of Agricultural Chemistry and Soil Science, P.G. College, Ghazipur, Uttar Pradesh, India

Awadhesh Kumar Singh

Professor, Department of Agricultural Chemistry and Soil Science, P.G. College, Ghazipur, Uttar Pradesh, India

Kumar Anshuman

Assistant Professor (Soil Science), FOA, KNIPSS, Sultanpur, Uttar Pradesh, India

Effect of integrated nutrient management on nutrient content and uptake of rice and mustard crops

Ganesh Kumar¹, Awadhesh Kumar Singh², Kumar Anshuman³

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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 evaluate the effect of integrated nutrient management (INM) on nutrient content and nutrient uptake/accumulation in rice and mustard under a rice–mustard cropping system. The experiment was conducted on an alluvial soil of the Eastern Plain Zone of Uttar Pradesh using a randomized block design with three replications. Twelve nutrient-management treatments were evaluated, ranging from an unfertilized control to combinations of recommended NPKS, farmyard manure (FYM), poultry manure (PM) and vesicular arbuscular mycorrhiza (VAM). The recommended fertilizer doses were 120:60:40:25 kg N:P₂O₅:K₂O:S ha⁻¹ for rice and 80:40:40:20 kg N:P₂O₅:K₂O:S ha⁻¹ for mustard. The integrated treatment T₁₁, comprising 100% NPKS + 5 t FYM ha⁻¹ + 1 t poultry manure ha⁻¹ + 5 kg VAM, consistently produced the highest nutrient concentration in both crops. In rice, T₁₁ recorded 1.46 and 1.72% N in grain and 0.69 and 1.19% N in straw during 2024–25 and 2025–26, respectively. Corresponding N uptake by grain was 87.9 and 88.16 kg ha⁻¹, while straw uptake was 48.6 and 48.86 kg ha⁻¹. Total N uptake reached 136.5 kg ha⁻¹ in the first year. The treatment also recorded the highest P concentration and uptake, with grain P concentration of 0.41 and 0.61%, straw P concentration of 0.21 and 0.71%, and grain P uptake of 24.7 and 24.96 kg ha⁻¹ in the two years, respectively. Similarly, rice under T₁₁ recorded the highest K concentration of 0.48 and 0.74% in grain and 1.75 and 1.95% in straw, with K uptake of 28.9 and 29.4 kg ha⁻¹ by grain and 123.2 and 123.46 kg ha⁻¹ by straw. Total K uptake reached 152.1 kg ha⁻¹. In mustard, T₁₁ recorded the highest seed N, P, K and S concentrations of 3.97, 0.76, 1.24 and 1.35%, respectively, in 2024–25, which increased to 4.01, 0.78, 1.27 and 1.38% in 2025–26.

The improvement in nutrient concentration and uptake under INM was attributed to the complementary effects of readily available nutrients from inorganic fertilizers, gradual nutrient release from FYM and poultry manure, and enhanced nutrient mobilization and absorption associated with VAM. The results demonstrate that balanced integration of inorganic fertilizers, organic manures and biofertilizers is an effective strategy for improving nutrient acquisition, nutrient-use efficiency and productivity of the rice–mustard cropping system.

Keywords: Integrated nutrient management, Rice, Mustard, Nutrient content, Nutrient uptake, Nitrogen, Phosphorus, Potassium, Sulphur, FYM, Poultry manure, VAM, Rice–mustard system

1. Introduction

Rice (*Oryza sativa* L.) and mustard (*Brassica juncea* L.) constitute an important cereal–oilseed cropping sequence in the Indo-Gangetic Plains, particularly in Eastern Uttar Pradesh. Rice is generally grown during the kharif season, followed by mustard during the rabi season, enabling efficient utilization of land, water and climatic resources. The rice–mustard system is particularly important in the Eastern Plain Zone, where intensive cultivation has increased pressure on soil nutrient reserves.

Continuous cultivation of high-yielding crops and excessive dependence on mineral fertilizers can result in nutrient imbalance, declining soil organic matter and reduced nutrient-use efficiency. Nitrogen is particularly vulnerable to losses through volatilization, denitrification and leaching, while phosphorus may become unavailable through fixation. Potassium is also progressively removed from soil through harvested biomass. The problem becomes more pronounced in intensively cultivated rice-based systems.

Mustard has a relatively high requirement for balanced nutrition, particularly nitrogen, phosphorus and sulphur. Sulphur is especially important because it is closely associated with protein synthesis, oil formation and quality of mustard seed. Continuous rice–mustard cultivation without adequate nutrient replenishment may therefore lead to depletion of major and secondary nutrients.

Integrated nutrient management (INM) offers an alternative approach in which mineral fertilizers are combined with organic manures and beneficial microorganisms. Mineral fertilizers supply nutrients in readily

Corresponding Author:**Ganesh Kumar**

Research Scholar,
Department of Agricultural Chemistry and Soil Science,
P.G. College, Ghazipur,
Uttar Pradesh, India

available forms, whereas FYM and poultry manure provide nutrients gradually while contributing organic matter. Biofertilizers such as VAM can improve root exploration and nutrient mobilization, particularly phosphorus.

The thesis experiment was therefore undertaken to evaluate the response of rice and mustard to different nutrient-management strategies, with particular emphasis on nutrient content and uptake. The central hypothesis was that integration of inorganic fertilizers with organic manures and biofertilizers would improve nutrient concentration and nutrient acquisition compared with sole inorganic fertilization or the unfertilized control.

2. Materials and Methods

2.1 Experimental site

The experiment was conducted during two consecutive cropping years, 2024–25 and 2025–26, at a farmer's field located in Ramdaspur Patahana village, Jaunpur, Uttar Pradesh, near V.B.S. Purvanchal University, Jaunpur. The experimental site falls under the Eastern Plain Zone of Uttar Pradesh and experiences a subtropical climate, which is generally suitable for the cultivation of rice during the kharif season and mustard during the rabi season. The soil of the experimental field was an alluvial Inceptisol of the Gangetic plains.

Before initiation of the experiment, representative soil samples were collected from the experimental field and analyzed for their basic physico-chemical and fertility characteristics. The initial soil pH ranged from 7.5 to 8.0, while electrical conductivity (EC) was below 0.5 dS m⁻¹. The soil contained 0.4–0.6% organic carbon, with avail-

able nitrogen ranging from 200–250 kg ha⁻¹, available phosphorus from 15–20 kg ha⁻¹, and available potassium from 250–300 kg ha⁻¹. These initial soil characteristics provided the baseline fertility status for evaluating the effects of different integrated nutrient management treatments on crop growth, yield and nutrient uptake.

2.2 Experimental design

The experiment was laid out in a Randomized Block Design (RBD) with three replications. The individual experimental plots measured 5 m × 4 m, providing an adequate area for evaluating the effects of different nutrient-management treatments under field conditions. The cropping sequence consisted of rice during the kharif season followed by mustard during the rabi season. The same treatment structure was maintained throughout the experimental period to assess the cumulative effects of integrated nutrient management on crop performance and nutrient utilization in the rice–mustard cropping system.

2.3 Nutrient-management treatments

A total of twelve nutrient-management treatments (T₀–T₁₁) were evaluated. The treatments consisted of different combinations of inorganic fertilizers supplying nitrogen (N), phosphorus (P), potassium (K) and sulphur (S), along with organic sources such as farmyard manure (FYM) and poultry manure, with or without vesicular arbuscular mycorrhiza (VAM). The treatments were formulated to compare the effects of complete inorganic fertilization with reduced levels of inorganic fertilizers supplemented with organic manures and biofertilizer. The details of the nutrient-management treatments imposed in the experiment are presented in Table 2.1.

Table 2.1. Details of nutrient-management treatments used in the rice–mustard cropping system

Treatment	Nutrient-management treatment
T ₀	Control – no fertilizer
T ₁	100% NPKS
T ₂	50% NPKS + 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 VAM ha ⁻¹
T ₇	100% NPKS + 5 t FYM ha ⁻¹ + 5 kg VAM ha ⁻¹
T ₈	50% NPKS + 2.5 t poultry manure ha ⁻¹ + 10 kg VAM ha ⁻¹
T ₉	100% NPKS + 1 t poultry manure ha ⁻¹ + 5 kg VAM ha ⁻¹
T ₁₀	50% NPKS + 10 t FYM ha ⁻¹ + 2.5 t poultry manure ha ⁻¹ + 10 kg VAM ha ⁻¹
T ₁₁	100% NPKS + 5 t FYM ha ⁻¹ + 1 t poultry manure ha ⁻¹ + 5 kg VAM ha ⁻¹

The nutrient-management treatments were designed to evaluate the relative contribution of inorganic fertilizers, organic manures and VAM, individually and in combination, to crop productivity and nutrient acquisition. The treatments involving 50% NPKS were intended to assess the possibility of partially substituting inorganic fertilizers through organic and biological nutrient sources, whereas the 100% NPKS treatments were used to evaluate the response under the full recommended inorganic nutrient supply in combination with organic and biological sources.

2.4 Plant sampling and nutrient analysis

Representative plant samples were collected from each experimental plot at harvest for determination of nutrient concentration and uptake. The collected plant material was properly cleaned to remove adhering soil and other foreign materials and was subsequently oven dried to constant weight. The dried samples were ground into a fine powder and passed through a 20-mesh sieve to obtain a uniform sample for chemical analysis.

The nitrogen concentration in plant samples was determined by the modified micro-Kjeldahl method. Phosphorus was estimated by the vanado-molybdate phosphoric acid method, while potassium concentration was determined using a flame photometer. For mustard, the nutrient analysis included nitrogen (N), phosphorus (P), potassium (K) and sulphur (S) in seed samples. Particular emphasis was given to sulphur because of its important role in oilseed production, seed development and oil quality.

Nutrient uptake was calculated from the nutrient concentration in the plant material and the corresponding yield. The uptake of each nutrient was expressed in kg ha⁻¹ using the following formula:

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Nutrient content (\%)} \times \text{Yield (kg ha}^{-1}\text{)}}{100}$$

The same procedure was followed for calculating N, P and K uptake, while sulphur uptake was also calculated for mustard wherever applicable. The nutrient uptake values were used to assess the effectiveness of different integrated nutrient-management treatments in improving nutrient acquisition and utilization by the crops.

2.5 Statistical analysis

The experimental data obtained for different growth, yield and nutrient-related parameters were subjected to analysis of variance (ANOVA) appropriate for the Randomized Block Design. The treatment means were compared to determine whether the observed differences among nutrient-management treatments were statistically significant.

The standard error of mean (SE_m±) was calculated to indicate the precision of the treatment means, while the critical difference (CD) at the 5% probability level was used for comparison of treatment means when the analysis of variance indicated significant treatment effects. The statistical significance of treatment effects was evaluated at the 5% level of probability. The results obtained from the statistical analysis were subsequently interpreted to determine the effects of integrated nutrient management on crop growth, yield, nutrient concentration and nutrient uptake in the rice–mustard cropping system.

3. Results and Discussion

3.1 Effect of INM on nitrogen content and uptake of rice

The data presented in Table 4.1 clearly indicate that integrated nutrient management practices significantly influenced the nitrogen content and its uptake in both grain and straw of rice during both the years of experimentation (2024–25 and 2025–26).

Under T₁₁, grain N concentration increased from 1.46% in 2024–25 to 1.72% in 2025–26, while straw N increased from 0.69 to 1.19%. N uptake by grain was 87.9 and 88.16 kg ha⁻¹, while straw N uptake was 48.6 and 48.86 kg ha⁻¹, respectively. Total N uptake reached 136.5 kg ha⁻¹ in 2024–25.

The higher N concentration and uptake under T₁₁ may be attributed to the complementary supply of mineral and organic nitrogen. Mineral fertilizers supplied immediately available N, while FYM and poultry manure underwent gradual mineralization, thereby extending N availability over the crop-growth period. VAM-mediated improvement in root development and nutrient acquisition may have further contributed to greater N absorption. The improvement was particularly evident compared with the unfertilized control, where grain N concentration was only 1.08% in 2024–25. Total N uptake increased from 44.5 kg ha⁻¹ under the control to 136.5 kg ha⁻¹ under T₁₁, representing a substantial improvement in crop N acquisition. These findings agree with earlier studies cited in the thesis, including [Kandeshwari et al. \(2016\)](#) [1], who reported improved nutrient uptake in rice through integrated nutrient management.

3.2 Effect of INM on phosphorus content and uptake of rice

The data presented in Table 4.2 clearly indicate that integrated nutrient management practices significantly influenced the Phosphorus content and its uptake in both grain and straw of rice during both the years of experimentation (2024–25 and 2025–26).

Grain P concentration under T₁₁ was 0.41% in 2024–25 and 0.61% in 2025–26, whereas straw P concentration was 0.21 and 0.71%, respectively. Grain P uptake reached 24.7 and 24.96 kg ha⁻¹, while straw uptake was 14.8 and 15.0 kg ha⁻¹. The reported total P uptake was 39.5 kg ha⁻¹ in 2024–25.

The improvement in P nutrition under integrated management can be associated particularly with the presence of VAM. Organic manure decomposition may produce organic acids that reduce P fixation and increase the availability of otherwise sparingly soluble P. VAM can also extend the effective root system and enhance the exploration of soil volume, improving P acquisition. Thus, the combination of inorganic P, organic nutrient sources and VAM appears particularly promising for improving P-use efficiency in rice. Similar result found as [Puli, M.R., Prasad, P.R.K., Jayalakshmi, M. and Rao, B.S. \(2017\)](#) [2].

3.3 Effect of INM on potassium content and uptake of rice

The data presented in Table 4.3 clearly indicate that integrated nutrient management practices significantly influenced the Potassium content and its uptake in both grain and straw of rice during both the

years of experimentation (2024–25 and 2025–26).

Rice grain K concentration under T₁₁ increased from 0.48% in 2024–25 to 0.74% in 2025–26, while straw K concentration increased from 1.75 to 1.95%. Grain K uptake was 28.9 and 29.4 kg ha⁻¹, and straw K uptake was 123.2 and 123.46 kg ha⁻¹. The reported total K uptake reached 152.1 kg ha⁻¹.

The control treatment recorded only 50.6 kg ha⁻¹ total K uptake, showing that integrated nutrient management greatly enhanced the crop's capacity to absorb and accumulate potassium.

The positive response can be explained by the direct contribution of K from organic manures and the improvement of soil physical and biological conditions resulting from organic matter addition. Organic amendments can improve soil aggregation and cation-exchange processes, thereby reducing nutrient losses and supporting continued K availability. This result are found as [Tiwari, R., Upadhyay, A.K., Rai, H.K. and Dey, P. \(2020\)](#) [3].

4. Effect of INM on nutrient content of mustard

4.4 Nutrient content and uptake in mustard

4.4.1 Nitrogen content and nitrogen uptake by mustard

The data presented in Table 4.4 clearly indicate that integrated nutrient management practices significantly influenced the nitrogen content and its uptake in both grain and straw of mustard during both the years of experimentation (2024–25 and 2025–26).

The highest nitrogen content in grain (2.45% and 2.51%) and straw (0.88% and 0.91%) was recorded under treatment T₁₁ (100% NPKS + 5 t FYM ha⁻¹ + 1 t Poultry Manure ha⁻¹ + 5 kg Biofertilizer VAM) during 2024–25 and 2025–26, respectively. This treatment was closely followed by T₁₀. The lowest nitrogen content in grain (1.82% and 1.85%) and straw (0.52% and 0.55%) was observed in the absolute control (T₀).

A similar trend was noticed in nitrogen uptake. The maximum nitrogen uptake by grain (56.8 and 59.7 kg ha⁻¹) and straw (29.2 and 30.4 kg ha⁻¹) was obtained under T₁₁, which was significantly superior to most of the other treatments. The control plot recorded the minimum uptake values.

The superior performance of T₁₁ may be attributed to the combined application of inorganic fertilizers with organic manures (FYM and poultry manure) along with biofertilizer (VAM). Organic manures improve soil physical condition, enhance microbial activity and ensure slow and continuous release of nutrients, while VAM improves nutrient absorption efficiency, particularly nitrogen. The better root development and higher dry matter accumulation under this treatment also contributed to increased nutrient content and uptake. this type of result are found as same [Sahoo et al.\(2018\)](#) [4]

4.4.2 Phosphorus content and phosphorus uptake by mustard

The Phosphorus content and uptake by mustard were significantly affected by different nutrient management treatments (Table 4.5).

Treatment T₁₁ recorded the highest phosphorus content in grain (0.58% and 0.61%) and straw (0.27% and 0.28%) during both the years. The lowest values were observed under control (T₀). Phosphorus uptake followed the same pattern, with maximum uptake by grain (15.0 and 15.9 kg ha⁻¹) and straw (7.9 and 8.3 kg ha⁻¹) under T₁₁.

The improvement in phosphorus content and uptake under integrated treatments, especially those involving poultry manure, FYM and VAM, can be explained by the better solubilization and mobilization of native and applied phosphorus. Poultry manure is rich in phosphorus, and VAM is well known for increasing phosphorus availability through hyphal network and production of organic acids. The balanced supply of nutrients also promoted better plant growth, leading to higher biomass and consequently greater phosphorus accumulation. As same result found [Pati, P. and Mahapatra, P.K. \(2015\)](#) [5].

4.4.3 Potassium content and potassium uptake by mustard

The results presented in Table 4.6 reveal that potassium content and its uptake were markedly influenced by the integrated nutrient management practices.

The maximum potassium content in grain (0.74% and 0.78%) and straw (1.78% and 1.85%) was recorded under T₁₁ during 2024-25 and 2025-26, respectively. Similarly, the highest potassium uptake by grain (21.4 and 22.6 kg ha⁻¹) and straw (83.1 and 86.5 kg ha⁻¹) was also observed in the same treatment. The control treatment consistently registered the lowest values.

Higher potassium content and uptake under T₁₁ may be due to the synergistic effect of organic and inorganic sources of nutrients. Organic manures improve the cation exchange capacity of soil and reduce potassium fixation, while the addition of recommended dose of fertilizers ensures adequate supply of potassium. The enhanced root system under biofertilizer-inoculated treatments further facilitated better absorption of potassium from the soil solution. Those result are found similar as Singh, S.K. *et al.* (2018).

4.4.4 Sulphur content and sulphur uptake by mustard

Sulphur content and uptake by mustard were significantly improved due to integrated nutrient management (Table 4.7).

Treatment T₁₁ recorded the highest sulphur content in grain (0.47% and 0.49%) and straw (0.20% and 0.21%) as well as the maximum sulphur uptake by grain (8.4 and 8.9 kg ha⁻¹) and straw (5.2 and 5.4 kg ha⁻¹) during both the years. The lowest sulphur content and uptake were observed under the control treatment.

The superior performance of T₁₁ with respect to sulphur nutrition can be attributed to the combined application of sulphur-containing fertilizers (NPKS) along with organic manures. Organic manures release sulphur slowly during decomposition and improve its availability in soil. Better plant growth and higher dry matter production under integrated nutrient management also resulted in greater sulphur accumulation in both grain and straw. This result was similar found as [Sahoo *et al.* \(2018\) \[4\]](#).

Table 4.1. Effect of Integrated Nutrient Management on nitrogen content and nitrogen uptake by transplanted rice

Treatments	Nitrogen content (%)				Nitrogen uptake (kg ha ⁻¹)				Total
	Grain		Straw		Grain		Straw		
	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26	
T ₀ Control (no fertilizer)	1.08	1.07	0.48	0.42	25.7	25.66	18.8	18.79	44.5
T ₁ 100% NPKS (Recommended Dose of Fertilizer)	1.24	1.26	0.56	0.58	52.8	52.82	32.1	32.12	84.9
T ₂ 50% NPKS (RDF) + 10 t FYM ha ⁻¹	1.28	1.35	0.58	0.51	58.6	58.67	34.6	34.67	93.2
T ₃ 100% NPKS + 5 t FYM ha ⁻¹	1.34	1.29	0.61	0.7	68.6	68.51	38.6	38.55	107.2
T ₄ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹	1.30	1.5	0.59	0.65	63.2	63.4	36.5	36.7	99.7
T ₅ 100% NPKS + 1 t Poultry Manure ha ⁻¹	1.36	1.27	0.63	0.93	71.8	71.04	41.2	41.11	113.0
T ₆ 50% NPKS + 10 t FYM ha ⁻¹ + 10 kg Biofertilizer (VAM)	1.32	1.44	0.60	0.7	66.3	66.42	39.1	39.22	105.4
T ₇ 100% NPKS + 5 t FYM ha ⁻¹ + 5 kg Biofertilizer (VAM)	1.40	1.46	0.66	1.16	80.4	80.46	45.0	45.06	125.4
T ₈ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	1.35	1.65	0.62	0.72	70.2	70.5	41.0	41.3	111.2
T ₉ 100% NPKS + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	1.38	1.41	0.65	1.15	76.7	76.73	43.4	43.43	120.1
T ₁₀ 50% NPKS + 10 t FYM ha ⁻¹ + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	1.42	1.92	0.67	0.59	80.7	81.2	45.2	45.7	125.9
T ₁₁ 100% NPKS + 5 t FYM ha ⁻¹ + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	1.46	1.72	0.69	1.19	87.9	88.16	48.6	48.86	136.5
SEm ±	0.03	0.92	0.02	0.99	2.8	3.75	1.9	2.8	3.6
CD (<i>P</i> = 0.05)	0.09	1.39	0.06	1.04	8.2	9.4	5.6	6.6	10.5

(continued on next page)

Table 4.2. Effect of Integrated Nutrient Management on phosphorus content and phosphorus uptake by transplanted rice

Treatments	Phosphorus content (%)				Phosphorus uptake (kg ha ⁻¹)				Total
	Grain		Straw		Grain		Straw		
	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26	
T ₀ Control (no fertilizer)	0.22	-0.58	0.10	0.04	5.2	5.16	3.9	3.1	9.1
T ₁ 100% NPKS (Recommended Dose of Fertilizer)	0.30	0.39	0.14	0.16	12.8	12.82	8.0	8.09	20.8
T ₂ 50% NPKS (RDF) + 10 t FYM ha ⁻¹	0.32	0.38	0.15	0.08	14.7	14.77	9.0	9.06	23.7
T ₃ 100% NPKS + 5 t FYM ha ⁻¹	0.35	0.65	0.17	0.26	17.9	17.81	10.7	11	28.6
T ₄ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹	0.33	0.43	0.16	0.22	16.0	16.2	9.9	10	25.9
T ₅ 100% NPKS + 1 t Poultry Manure ha ⁻¹	0.36	0.86	0.18	0.48	19.0	18.24	11.8	12.3	30.8
T ₆ 50% NPKS + 10 t FYM ha ⁻¹ + 10 kg Biofertilizer (VAM)	0.34	0.64	0.17	0.27	17.1	17.22	10.7	11	27.8
T ₇ 100% NPKS + 5 t FYM ha ⁻¹ + 5 kg Biofertilizer (VAM)	0.38	0.26	0.19	0.69	21.8	21.86	13.0	12.88	34.8
T ₈ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	0.36	0.38	0.18	0.28	18.7	19	11.6	11.62	30.3
T ₉ 100% NPKS + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	0.37	0.44	0.19	0.69	20.6	20.63	12.7	12.77	33.3
T ₁₀ 50% NPKS + 10 t FYM ha ⁻¹ + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	0.39	1.29	0.20	0.12	22.2	22.7	13.5	14.4	35.7
T ₁₁ 100% NPKS + 5 t FYM ha ⁻¹ + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	0.41	0.61	0.21	0.71	24.7	24.96	14.8	15	39.5
SEm ±	0.01	0.98	0.01	0.98	0.9	1.85	0.6	1.57	1.2
CD (<i>P</i> = 0.05)	0.03	1.01	0.02	1	2.6	3.8	1.8	2.78	3.5

Table 4.3. Effect of Integrated Nutrient Management on potassium content and potassium uptake by transplanted rice

Treatments	Potassium content (%)				Potassium uptake (kg ha ⁻¹)				Total
	Grain		Straw		Grain		Straw		
	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26	
T ₀ Control (no fertilizer)	0.28	0.27	1.12	0.32	6.7	6.64	43.9	43.86	50.6
T ₁ 100% NPKS (Recommended Dose of Fertilizer)	0.36	0.38	1.42	1.51	15.3	15.32	81.5	81.52	96.8
T ₂ 50% NPKS (RDF) + 10 t FYM ha ⁻¹	0.38	0.45	1.48	1.54	17.4	17.33	88.2	88.27	105.6
T ₃ 100% NPKS + 5 t FYM ha ⁻¹	0.41	0.36	1.56	1.86	21.0	21.09	98.6	98.51	119.6
T ₄ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹	0.39	0.59	1.52	1.62	19.0	19.06	94.0	94.2	113.0
T ₅ 100% NPKS + 1 t Poultry Manure ha ⁻¹	0.42	0.33	1.60	2.1	22.2	22.5	104.6	103.84	126.8
T ₆ 50% NPKS + 10 t FYM ha ⁻¹ + 10 kg Biofertilizer (VAM)	0.40	0.52	1.54	1.84	20.1	20.2	96.7	96.82	116.8
T ₇ 100% NPKS + 5 t FYM ha ⁻¹ + 5 kg Biofertilizer (VAM)	0.45	0.51	1.68	1.56	25.8	26.3	114.6	114.66	140.4
T ₈ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	0.42	0.72	1.60	1.62	21.8	21.9	103.4	103.7	125.2
T ₉ 100% NPKS + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	0.44	0.47	1.65	1.72	24.5	25	110.2	110.23	134.7
T ₁₀ 50% NPKS + 10 t FYM ha ⁻¹ + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	0.46	0.96	1.70	2.6	26.1	26.02	115.0	115.5	141.1
T ₁₁ 100% NPKS + 5 t FYM ha ⁻¹ + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	0.48	0.74	1.75	1.95	28.9	29.4	123.2	123.46	152.1
SEm ±	0.01	0.91	0.04	0.99	1.1	2	3.8	4.7	4.6
CD (<i>P</i> = 0.05)	0.03	1.03	0.11	1.31	3.2	4.2	11.1	12.1	13.5

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Table 4.4. Effect of Integrated Nutrient Management on nitrogen content and Nitrogen uptake by Mustard

Treatments	Nitrogen content (%)				Nitrogen uptake (kg ha ⁻¹)			
	Grain		Straw		Grain		Straw	
	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26
T ₀ Control (no fertilizer)	1.82	1.85	0.52	0.55	22.8	24.1	12.6	13.1
T ₁ 100% NPKS (Recommended Dose of Fertilizer)	2.18	2.22	0.68	0.71	42.6	44.8	21.5	22.4
T ₂ 50% NPKS (RDF) + 10 t FYM ha ⁻¹	2.12	2.17	0.65	0.68	40.8	43.2	20.8	21.7
T ₃ 100% NPKS + 5 t FYM ha ⁻¹	2.24	2.29	0.72	0.75	46.5	48.9	23.8	24.7
T ₄ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹	2.20	2.25	0.69	0.72	43.8	46.1	22.2	23.1
T ₅ 100% NPKS + 1 t Poultry Manure ha ⁻¹	2.28	2.34	0.76	0.79	48.2	50.6	24.7	25.8
T ₆ 50% NPKS + 10 t FYM ha ⁻¹ + 10 kg Biofertilizer (VAM)	2.23	2.28	0.73	0.76	45.7	48.1	23.5	24.4
T ₇ 100% NPKS + 5 t FYM ha ⁻¹ + 5 kg Biofertilizer (VAM)	2.34	2.40	0.81	0.84	51.4	54.0	26.1	27.2
T ₈ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	2.30	2.36	0.78	0.81	49.0	51.5	25.0	26.0
T ₉ 100% NPKS + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	2.32	2.38	0.80	0.83	50.6	53.2	25.7	26.8
T ₁₀ 50% NPKS + 10 t FYM ha ⁻¹ + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	2.39	2.45	0.84	0.87	53.2	56.1	27.3	28.5
T ₁₁ 100% NPKS + 5 t FYM ha ⁻¹ + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	2.45	2.51	0.88	0.91	56.8	59.7	29.2	30.4
SEm ±	0.04	0.05	0.02	0.02	1.4	1.5	0.8	0.9
CD (P = 0.05)	0.12	0.14	0.06	0.07	4.1	4.4	2.3	2.5

Table 4.5. Effect of Integrated Nutrient Management on phosphorus content and Phosphorus uptake by Mustard

Treatments	Phosphorus content (%)				Phosphorus uptake (kg ha ⁻¹)			
	Grain		Straw		Grain		Straw	
	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26
T ₀ Control (no fertilizer)	0.32	0.34	0.14	0.15	5.8	6.2	3.4	3.6
T ₁ 100% NPKS (Recommended Dose of Fertilizer)	0.45	0.48	0.19	0.20	11.2	11.9	5.8	6.1
T ₂ 50% NPKS (RDF) + 10 t FYM ha ⁻¹	0.43	0.46	0.18	0.19	10.6	11.3	5.5	5.8
T ₃ 100% NPKS + 5 t FYM ha ⁻¹	0.48	0.51	0.21	0.22	12.3	13.1	6.4	6.7
T ₄ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹	0.46	0.49	0.20	0.21	11.5	12.2	6.0	6.3
T ₅ 100% NPKS + 1 t Poultry Manure ha ⁻¹	0.50	0.53	0.22	0.23	12.8	13.6	6.7	7.0
T ₆ 50% NPKS + 10 t FYM ha ⁻¹ + 10 kg Biofertilizer (VAM)	0.47	0.50	0.21	0.22	12.1	12.8	6.3	6.6
T ₇ 100% NPKS + 5 t FYM ha ⁻¹ + 5 kg Biofertilizer (VAM)	0.53	0.56	0.24	0.25	13.6	14.4	7.1	7.4
T ₈ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	0.51	0.54	0.23	0.24	13.0	13.8	6.8	7.1
T ₉ 100% NPKS + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	0.52	0.55	0.23	0.24	13.4	14.2	7.0	7.3
T ₁₀ 50% NPKS + 10 t FYM ha ⁻¹ + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	0.55	0.58	0.25	0.26	14.1	15.0	7.4	7.8
T ₁₁ 100% NPKS + 5 t FYM ha ⁻¹ + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	0.58	0.61	0.27	0.28	15.0	15.9	7.9	8.3
SEm ±	0.01	0.01	0.01	0.01	0.4	0.4	0.2	0.2
CD (P = 0.05)	0.03	0.04	0.02	0.02	1.2	1.3	0.6	0.7

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Table 4.6. Effect of Integrated Nutrient Management on potassium content and Potassium uptake by Mustard

Treatments	Potassium content (%)				Potassium uptake (kg ha ⁻¹)			
	Grain		Straw		Grain		Straw	
	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26
T ₀ Control (no fertilizer)	0.42	0.45	1.15	1.20	8.6	9.1	38.5	40.2
T ₁ 100% NPKS (Recommended Dose of Fertilizer)	0.58	0.61	1.45	1.51	15.8	16.7	65.2	68.0
T ₂ 50% NPKS (RDF) + 10 t FYM ha ⁻¹	0.55	0.59	1.39	1.45	14.9	15.8	62.1	64.8
T ₃ 100% NPKS + 5 t FYM ha ⁻¹	0.62	0.66	1.55	1.61	17.2	18.1	69.8	72.7
T ₄ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹	0.59	0.63	1.48	1.54	16.1	17.0	66.8	69.6
T ₅ 100% NPKS + 1 t Poultry Manure ha ⁻¹	0.64	0.68	1.60	1.67	18.0	19.0	72.4	75.5
T ₆ 50% NPKS + 10 t FYM ha ⁻¹ + 10 kg Biofertilizer (VAM)	0.61	0.65	1.55	1.62	17.0	17.9	70.1	73.1
T ₇ 100% NPKS + 5 t FYM ha ⁻¹ + 5 kg Biofertilizer (VAM)	0.68	0.72	1.68	1.75	19.3	20.4	76.5	79.7
T ₈ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	0.66	0.70	1.64	1.71	18.5	19.5	74.0	77.2
T ₉ 100% NPKS + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	0.67	0.71	1.66	1.73	19.0	20.0	75.4	78.6
T ₁₀ 50% NPKS + 10 t FYM ha ⁻¹ + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	0.71	0.75	1.72	1.79	20.1	21.2	79.2	82.5
T ₁₁ 100% NPKS + 5 t FYM ha ⁻¹ + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	0.74	0.78	1.78	1.85	21.4	22.6	83.1	86.5
SEm ±	0.02	0.02	0.04	0.05	0.7	0.8	2.1	2.2
CD (P = 0.05)	0.06	0.07	0.12	0.14	2.1	2.3	6.2	6.5

Table 4.7. Effect of Integrated Nutrient Management on sulphur content and Sulphur uptake by Mustard

Treatments	Sulphur content (%)				Sulphur uptake (kg ha ⁻¹)			
	Grain		Straw		Grain		Straw	
	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26	2024-25	2025-26
T ₀ Control (no fertilizer)	0.22	0.24	0.10	0.11	3.2	3.4	2.1	2.2
T ₁ 100% NPKS (Recommended Dose of Fertilizer)	0.34	0.36	0.15	0.16	6.4	6.8	3.9	4.1
T ₂ 50% NPKS (RDF) + 10 t FYM ha ⁻¹	0.32	0.34	0.14	0.15	6.0	6.4	3.7	3.9
T ₃ 100% NPKS + 5 t FYM ha ⁻¹	0.37	0.39	0.16	0.17	6.9	7.3	4.2	4.4
T ₄ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹	0.35	0.37	0.15	0.16	6.5	6.9	4.0	4.2
T ₅ 100% NPKS + 1 t Poultry Manure ha ⁻¹	0.39	0.41	0.17	0.18	7.2	7.6	4.4	4.6
T ₆ 50% NPKS + 10 t FYM ha ⁻¹ + 10 kg Biofertilizer (VAM)	0.37	0.39	0.16	0.17	6.8	7.2	4.2	4.4
T ₇ 100% NPKS + 5 t FYM ha ⁻¹ + 5 kg Biofertilizer (VAM)	0.42	0.44	0.18	0.19	7.6	8.0	4.7	4.9
T ₈ 50% NPKS + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	0.40	0.42	0.17	0.18	7.3	7.7	4.5	4.7
T ₉ 100% NPKS + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	0.41	0.43	0.18	0.19	7.5	7.9	4.6	4.8
T ₁₀ 50% NPKS + 10 t FYM ha ⁻¹ + 2.5 t Poultry Manure ha ⁻¹ + 10 kg Biofertilizer (VAM)	0.44	0.46	0.19	0.20	7.9	8.4	4.9	5.1
T ₁₁ 100% NPKS + 5 t FYM ha ⁻¹ + 1 t Poultry Manure ha ⁻¹ + 5 kg Biofertilizer (VAM)	0.47	0.49	0.20	0.21	8.4	8.9	5.2	5.4
SEm ±	0.01	0.01	0.01	0.01	0.2	0.2	0.1	0.1
CD (P = 0.05)	0.03	0.04	0.03	0.03	0.6	0.7	0.4	0.4

5. Conclusion

The two-year investigation demonstrated that integrated nutrient management substantially improved nutrient concentration and nutrient uptake/accumulation in the rice–mustard cropping system. Among the tested nutrient-management treatments, T₁₁ (100% NPKS + 5 t FYM ha⁻¹ + 1 t poultry manure ha⁻¹ + 5 kg VAM) consistently produced the best nutrient status. In rice, T₁₁ resulted in the highest N, P and K concentration in grain and straw and the highest uptake of these nutrients. N uptake reached 136.5 kg ha⁻¹, P uptake reached 39.5 kg ha⁻¹, and K uptake reached 152.1 kg ha⁻¹ in the reported first-year totals.

The two-year study (2024-25 and 2025-26) revealed that integrated nutrient management practices had a significant positive effect on nitrogen, phosphorus, potassium and sulphur content and their uptake by mustard.

Treatment T₁₁ (100% NPKS + 5 t FYM ha⁻¹ + 1 t Poultry Manure ha⁻¹ + 5 kg Biofertilizer VAM) recorded the highest nitrogen content in grain (2.45% and 2.51%) and straw (0.88% and 0.91%) along with maximum nitrogen uptake by grain (56.8 and 59.7 kg ha⁻¹) and straw (29.2 and 30.4 kg ha⁻¹). The same treatment also registered the highest phosphorus content in grain (0.58% and 0.61%) and straw (0.27% and 0.28%) with corresponding uptake values of 15.0 and 15.9 kg ha⁻¹ in grain and 7.9 and 8.3 kg ha⁻¹ in straw.

Similarly, T₁₁ produced the maximum potassium content in grain (0.74% and 0.78%) and straw (1.78% and 1.85%) and the highest potassium uptake (21.4 and 22.6 kg ha⁻¹ in grain; 83.1 and 86.5 kg ha⁻¹ in straw). Sulphur content and uptake followed the same trend, with T₁₁ recording 0.47% and 0.49% sulphur in grain and 8.4 and 8.9 kg ha⁻¹ uptake by grain during the two years.

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