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Effect of efficient nutrient management on nutrient content and their uptake on Transplanted rice (*Oryza sativa* L.) and soil health in North West plain zone

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ABSTRACT

Rice (*Oryza sativa* L.) is a major staple food crop in India and a key contributor to food and nutritional security. However, low nutrient-use efficiency and declining soil fertility threaten its sustainable production. Integrated nutrient management (INM), combining inorganic fertilizers with organic amendments and micronutrients, is recognized as an effective strategy to improve crop performance and soil health. A field experiment was conducted during the *kharif* seasons of 2023 and 2024 to study the effect of INM on nutrient content and uptake in transplanted rice. Treatments included different levels of NPK with or without zinc, pressmud, and NPK consortia. Grain and straw samples were analyzed for nitrogen, phosphorus, and potassium content and uptake. The results revealed that INM significantly improved nutrient content and uptake compared to the control. The treatment 125% NPK + 5 kg Zn recorded the highest nutrient concentrations in grain (N: 1.39%, P: 0.38%, K: 0.38%) and straw (N: 0.48%, P: 0.16%, K: 1.36%). Similarly, nutrient uptake was highest under the same treatment, with total uptake of 91.0 kg ha^{-1} nitrogen, 26.7 kg ha^{-1} phosphorus, and 83.9 kg ha^{-1} potassium, showing a substantial increase over the control (42.1, 10.3, and 55.3 kg ha^{-1}, respectively). Treatments integrating pressmud and NPK consortia also enhanced nutrient uptake and were superior to 100% NPK alone. The findings suggest that INM not only improves nutrient availability and uptake but also sustains soil fertility and productivity, offering a viable strategy for sustainable rice production.

Key words: *Efficient nutrient management, Soil health, Transplanted rice*

Introduction

Rice (*Oryza sativa L.*) is the most important staple food crop, consumed daily by over 60% of the global population, making it central to food security worldwide, particularly in Asia where more than 90% of rice is produced and consumed (USDA-ERS, 2025). India is the second-largest rice producer after China, cultivating around 29.0 million ha with production exceeding 145 million tonnes, though its productivity 7.15 tonnes per hectare. Rice-based farming systems support more than 50 million households in

India and contribute significantly to rural livelihoods and the national economy (MoAFW, 2025). In India, rice is cultivated on about 51.4 million hectares of land, with an estimated production of nearly 149 million tonnes during 2024–25. The average productivity of rice in the country stands at around 2,899 kilograms per hectare (H" 2.9 tonnes/ha) (USDA-FAS, 2025; Ministry of Agriculture and Farmers Welfare, 2025; Mishra, 2025).

Within India, Uttar Pradesh holds a prominent position in rice cultivation. The state accounts for about 5.6–5.7 million hectares under rice, producing roughly 15.3 to 15.7 million tonnes annually. The productivity in Uttar Pradesh ranges between 2,749 and 2,809 kilograms per hectare, which is slightly below the national average (MoAFW, 2025). This indicates that while Uttar Pradesh contributes significantly in terms of area and total production, there is still scope to improve yields through efficient nutrient and crop management practices.

Future demand for rice in India is projected to reach 121 million tonnes by 2030 and 137 million tonnes by 2050, but this faces challenges due to limited land availability, urbanization, and declining profitability for resource-poor farmers (Durand-Morat *et al.,* 2020). Excessive reliance on chemical fertilizers to increase yields has led to soil acidification, nutrient imbalance, heavy metal accumulation, and environmental issues such as salinity, water pollution, and greenhouse gas emissions (Yadav *et al.,* 2000).

Integrated Nutrient Management (INM) offers a sustainable solution by combining inorganic fertilizers with organic sources like farmyard manure (FYM), crop residues, green manures, pressmud (a sugar industry byproduct), and biofertilizers (Yadav *et al.,* 2000; Dotaniya *et al.,* 2025). This approach improves soil fertility, enhances nutrient availability, prevents multiple nutrient deficiencies, and supports long-term productivity while minimizing ecological damage. Pressmud, in particular, shows promise in reclaiming degraded soils. Continuous use of organics with inorganics under INM has also been shown to enhance micronutrient availability and improve soil health (Dotaniya *et al.,* 2025).

Thus, adopting INM in rice-based systems is critical for achieving sustainable production, restoring soil fertility, reducing environmental risks, and meeting future food demands in India and globally (USDA-ERS, 2025; Durand-Morat *et al.,* 2020).

Materials and Methods

The experiment was conducted at the Crop Research Centre, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.) during Kharif seasons of 2023 and 2024. The variety was used in the research is "Pusa Basamati 1718". The design of the experiment was a Randomized Block Design (RBD) with three replications and twelve treatment combinations. Throughout the course of the study, a total of twelve treatments were included, including including biofertilizers (NPK Consortia), organic manures (Pressmud), and inorganic fertilizers. Details of the treatment allocation are as follows: T – Control (no fertilizer application); T – 100% recommended dose of NPK; T – 125% of the recommended dose of NPK; T – 100% NPK + 5 kg Zn ha^{-1}; T – 125% NPK + 5 kg Zn ha^{-1}; T – 75% N + 100% PK with 25% N substituted through pressmud; T – 75% N + 100% PK with 25% N through pressmud + NPK consortia; T – 75% N + 100% PK with 25% N through pressmud + NPK consortia + 5 kg Zn ha^{-1}; T – 50% N + 100% PK with 50% N through pressmud; T – 50% N + 100% PK with 50% N through pressmud + NPK consortia; T – 50% N + 100% PK with 50% N through pressmud + 5 kg Zn ha^{-1}; and T – 50% N + 100% PK with 50% N through pressmud + NPK consortia + 5 kg Zn ha^{-1}.

The experimental crop was transplanted rice (*Oryza sativa* L., variety PB-1718). Seedlings were raised in a nursery bed and transplanted at 25 – 30 days after sowing with a spacing of 20 × 10 cm. The recommended fertilizer dose for rice was 120-150 kg N, 60-70 kg PO, and 40-50 kg KO ha^{-1}, applied as per treatment schedule. Nitrogen was supplied in three splits-basal, tillering, and panicle initiation—while phosphorus, potassium, zinc, and pressmud were applied at transplanting. Standard agronomic practices for irrigation, weeding, and plant protection were uniformly followed across all plots. Nutrient analysis in Grain and straw were tested for N, P, K, and Zn. Nitrogen was measured by the Kjeldahl method, phosphorus by the vanadomolybdate colorimetric method, potassium with a flame photometer, and zinc using an AAS. Soil analysis in Post-harvest soil was analyzed for available N, P, K, Zn, organic carbon, and pH following standard procedures.

Results and Discussion

The primary objective of this investigation was to evaluate the influence of nutrient management on nutrient content and uptake in transplanted rice. Accordingly, the results are presented treatment-wise and discussed with reference to relevant literature.

Nitrogen content (%) and their uptake (kg ha^{-1}) by crop

The application of integrated nutrient management practices had a significant influence on the nitrogen concentration of both grain and straw across the two years of study. The highest grain nitrogen content (1.34% and 1.39% in 2023 and 2024, respectively) was observed under the treatment comprising 125% NPK + 5 kg Zn, followed by 125% NPK**,** 75% N + 100% PK + 25% N through pressmud + NPK consortia + 5 kg Zn, and 75% N + 100% PK + 25% N through pressmud + NPK consortia. Similarly, the maximum nitrogen content in straw (0.46% and 0.48% during 2023 and 2024, respectively) was also recorded with 125% NPK + 5 kg Zn, followed by the same set of treatments. On the other hand, the lowest nitrogen content in both grain (0.98% and 1.01%) and straw was consistently observed under the control treatment during both years. In addition to this, Nitrogen uptake in grain and straw was greater in 2024 than in 2023, and integrated nutrient management treatments significantly enhanced uptake in both years. The treatment 125% NPK + 5 kg Zn consistently recorded the highest nitrogen uptake in both grain (57.4 and 61.4 kg ha^{-1}) and straw (27.1 and 29.6 kg ha^{-1}) during 2023 and 2024, showing a significant advantage over other treatments. On average, this treatment enhanced nitrogen uptake by 173.7% in grain and 57.5% in straw compared to the control. The lowest uptake was observed in the control, with values of 20.8 and 22.6 kg ha^{-1} for grain and 17.2 and 18.8 kg ha^{-1} for straw. Total nitrogen uptake increased significantly under integrated nutrient management across both years. The highest uptake (84.5 and 91.0 kg ha^{-1}) was recorded with 125% NPK + 5 kg Zn, which was at par with 125% NPK and pressmud-based treatments, and markedly higher than the rest. This treatment showed a 121% increase over 100% NPK. The lowest uptake (38.5 and 42.1 kg ha^{-1}) was observed in the control during 2021 and 2022. To better understand these results, they are compared with earlier studies, which provide supporting evidence for the observed trends. Singh *et al*. (2024) reported that higher nitrogen doses significantly enhanced nitrogen uptake in rice grain and straw.

Sethi *et al*. (2024) found that integrated nutrient management with chemical nitrogen and organic manures improved uptake compared to chemical fertilizers alone. Similarly, Ram *et al*. (2024) observed that replacing 50% of nitrogen with vermicompost maintained uptake levels comparable to full chemical fertilization, while also supporting soil health.

Table 1. Effect of nitrogen content in grain and straw in rice

Treatment	Nitrogen content (%)				Nitrogen uptake (kg ha^{-1})				Total N uptake (kg ha^{-1})	
	Grain		Straw		Grain		Straw			
	2023	2024	2023	2024	2023	2024	2023	2024	2023	2024
T1	0.98	1.01	0.28	0.30	20.8	22.6	17.2	18.8	38.0	41.4
T2	1.31	1.36	0.43	0.45	47.7	51.5	24.4	26.1	72.1	77.6
T3	1.34	1.39	0.45	0.47	56.4	59.9	26.2	28.6	82.6	88.5
T4	1.31	1.36	0.43	0.45	50.4	54.0	24.5	26.1	74.9	80.1
T5	1.34	1.39	0.46	0.48	57.4	61.4	27.1	29.6	84.5	91.0
T6	1.32	1.37	0.44	0.46	52.0	55.5	25.1	27.0	77.2	82.5
T7	1.33	1.38	0.44	0.46	53.3	57.4	25.4	27.4	78.7	84.8
T8	1.33	1.38	0.45	0.47	54.0	58.4	26.2	28.4	80.2	86.8
T9	1.26	1.31	0.41	0.43	38.6	41.5	22.6	24.2	61.2	65.7
T10	1.27	1.32	0.41	0.43	41.5	44.4	23.2	24.6	64.7	69.0
T11	1.28	1.33	0.42	0.44	43.3	46.4	23.8	25.3	67.1	71.7
T12	1.28	1.33	0.42	0.44	46.0	48.4	23.8	25.4	69.8	73.8
SEM±	0.05	0.05	0.02	0.02	1.67	1.78	0.8	0.9	2.52	2.70
CD (P=0.05)	0.13	0.14	0.04	0.05	4.79	5.12	2.4	2.6	7.23	7.74

Phosphorus content and their uptake by crop

Across both years, phosphorus concentration remained higher in grain than in straw. The maximum grain phosphorus content (0.36% and 0.38%) was obtained with 125% NPK + 5 kg Zn, closely followed by 125% NPK and 50% N + 100% PK + 50% N through pressmud + NPK consortia + 5 kg Zn during 2023 and 2024. The highest phosphorus content in straw (0.15% and 0.16%) was observed with 125% NPK + 5 kg Zn, which remained statistically at par with 125% NPK and 75% N + 100% PK + 25% N through pressmud + NPK consortia + 5 kg Zn in both years. In contrast, the lowest phosphorus content was recorded under the control, with 0.24% and 0.25% in grain and 0.09% and 0.10% in straw. Total phosphorus uptake in rice was significantly influenced by integrated nutrient management across both years. The highest uptake (24.2 and 26.7 kg ha^{-1}) was achieved with 125% NPK + 5 kg Zn, followed by 125% NPK and pressmud- based treatments, and was markedly higher than the other treatments. On average, this treatment increased total phosphorus uptake by 161% over the control, where the lowest values (9.2 and 10.3 kg ha^{-1}) were recorded in 2023 and 2024, respectively. The present study showed maximum phosphorus uptake with 125% NPK + 5 kg Zn, which is consistent with earlier findings. Rath *et al.* (2022) observed that applying 25% extra phosphorus improved uptake and productivity in a rice–greengram system. Similarly, Shahane and Shivay (2022) reported higher phosphorus uptake in rice–wheat cropping when zinc was combined with microbial inoculants. Ramulu *et al.* (2024) also found that integrated nutrient management raised phosphorus uptake in Kharif rice to 27.3 kg ha^{-1} compared to 17.8 kg ha^{-1} in control. These studies confirm that balanced fertilization with zinc and organic inputs enhances phosphorus use efficiency.

Potassium content in both grain and straw was significantly influenced by integrated nutrient management compared to the control during both years. The highest potassium concentration in grain (0.36 and 0.38%) and straw (1.32 and 1.36%) was recorded with 125% NPK + 5 kg Zn, which was statistically similar to 125% NPK and 75% N + 100% PK + 25% N through pressmud + NPK consortia + 5 kg Zn. In contrast, the control plot showed the lowest values with 0.28 and 0.30% in grain and 1.15 and 1.18% in straw. These results highlight the role of integrated nutrient management, particularly the inclusion of zinc and organic inputs, in enhancing potassium accumulation in rice. Potassium uptake in both grain and straw was significantly improved by integrated nutrient management compared to the control. The treatment 125% NPK + 5 kg Zn recorded the highest uptake, with 15.4 and 16.8 kg ha^{-1} in grain and 77.7 and 83.9 kg ha^{-1} in straw during the two years. This treatment outperformed all others and showed mean increases of 155.5% in grain and 50.4% in straw uptake over the control. The lowest uptake was observed in the control plots, with only 5.9 and 6.7 kg ha^{-1} in grain and 52.1 and 55.3 kg ha^{-1} in straw.

Table 2. Effect of phosphorus content and uptake in grain and straw in rice

Treatments	Phosphorus content(%)				Phosphorus uptake (kg ha^{-1})				Total P uptake (kg ha^{-1})	
	Grain		Straw		Grain		Straw			
	2023	2024	2023	2024	2023	2024	2023	2024	2023	2024
T1	0.24	0.25	0.09	0.10	5.1	5.6	4.1	4.7	9.2	10.3
T2	0.30	0.32	0.11	0.12	10.9	12.1	6.2	6.9	17.1	19.0
T3	0.33	0.35	0.14	0.15	13.5	14.7	8.2	9.1	21.7	23.8
T4	0.30	0.32	0.12	0.13	11.6	12.7	6.8	7.6	18.4	20.3
T5	0.36	0.38	0.15	0.16	15.4	16.8	8.8	9.9	24.2	26.7
T6	0.31	0.33	0.12	0.13	12.2	13.4	6.8	7.6	19.0	21.0
T7	0.31	0.33	0.13	0.14	12.4	13.7	7.5	8.3	19.9	22.0
T8	0.32	0.34	0.13	0.14	13.0	14.4	7.6	8.5	20.6	22.9
T9	0.27	0.28	0.10	0.11	8.3	8.9	5.5	6.2	13.8	15.1
T10	0.28	0.29	0.10	0.11	9.2	9.7	5.7	6.3	14.9	16.0
T11	0.28	0.29	0.11	0.12	9.5	10.1	6.2	6.9	15.7	17.0
T12	0.29	0.30	0.11	0.12	10.4	10.9	6.2	6.9	16.6	17.8
SEm±	0.01	0.01	0.001	0.01	0.38	0.42	0.2	0.3	0.62	0.68
CD (P=0.05)	0.03	0.03	0.003	0.03	1.10	1.20	0.6	0.8	1.77	1.94

Potassium content and their uptake by crop

Table 3. Effect of potassium content in grain and straw in rice

Treatments	Potassium content (%)				Potassium uptake (kg ha^{-1})				Total K uptake (kg ha^{-1})	
	Grain		Straw		Grain		Straw			
	2023	2024	2023	2024	2023	2024	2023	2024	2023	2024
T1	0.28	0.30	1.15	1.18	5.9	6.7	52.1	55.3	58.0	62.0
T2	0.32	0.34	1.27	1.31	11.6	12.9	72.1	75.8	83.7	88.7
T3	0.34	0.36	1.31	1.35	14.3	15.5	76.4	82.1	90.7	97.6
T4	0.32	0.34	1.28	1.32	12.3	13.5	72.8	76.7	85.1	90.2
T5	0.36	0.38	1.32	1.36	15.4	16.8	77.7	83.9	93.1	100.7
T6	0.33	0.35	1.28	1.32	13.0	14.2	73.0	77.5	86.0	91.7
T7	0.33	0.35	1.29	1.33	13.2	14.6	74.4	79.3	87.6	93.9
T8	0.34	0.36	1.30	1.34	13.8	15.2	75.7	80.9	89.5	96.1
T9	0.30	0.32	1.24	1.28	9.2	10.1	68.4	71.9	77.6	82.0
T10	0.30	0.32	1.25	1.29	9.8	10.8	70.6	73.9	80.4	84.7
T11	0.30	0.32	1.26	1.30	10.1	11.2	71.3	74.9	81.4	86.1
T12	0.31	0.33	1.27	1.31	11.1	12.0	72.0	75.6	83.1	87.6
SEm±	0.02	0.02	0.05	0.05	0.41	0.45	2.92	3.09	2.95	3.13
C.D.(P=0.05)	0.05	0.06	0.13	0.14	1.18	1.29	8.38	8.86	8.46	8.99

Recent Indian research corroborates the observed improvements in potassium uptake under integrated nutrient management in this study. In Telangana, Ch. Ramulu *et al.* (2024) showed that INM treatments achieved a potassium uptake of about 96.66 kg ha^{-1}, significantly higher than control (56.31 kg ha^{-1}) and other farming systems. Similarly, in the rice-wheat cropping system, Shahane and Shivay (2022) found that combining recommended dose of nutrients with zinc fertilization and microbial inoculants substantially increased potassium uptake compared to lower input or control treatments.

Conclusion

The study demonstrated that integrated nutrient management practices significantly enhanced nutrient content and uptake in both grain and straw of transplanted rice compared to the control. Among the treatments, 125% NPK + 5 kg Zn consistently recorded the highest values for nitrogen, phosphorus, and potassium content and uptake, followed by combinations involving pressmud and NPK consortia. The results highlight that balanced application of chemical fertilizers supplemented with zinc and organic sources not only improves nutrient use efficiency but also contributes to sustainable soil fertility management. Therefore, adopting integrated nutrient management strategies can be a viable approach to maximize rice productivity while ensuring long-term soil health and resource sustainability.

Conflict of interest - No

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