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Growth Stage-Specific Response Of Basmati Rice To Organic Nutrient Sources: Nutrient Dynamics And Uptake Patterns

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Abstract
The Field experiment was conducted during the kharif seasons of 2022 and 2023 at the Crop Research Center, Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, to study the impact of various organic nutrient sources on soil quality and the productivity of basmati rice in light-textured soils. The ten treatments consisting combination of different organic nutrient sources such as green manure (Dhaicha), farmyard manure (FYM), vermicompost, microbial consortia, and biostimulants were compared with chemical fertilizer (Recommended dose of NPK) and unfertilized (control). Nitrogen content was highest at tillering under with the application of RDF (1.82-1.86%), integration of organic treatments with consortia and biostimulants (T_4, T_8) maintained higher N at later stages. Phosphorus and potassium showed similar trends, with T_2 and T_4 consistently superior. Straw performed as the main sink for K. Total nutrient uptake was maximum under RDF (84.94 kg N, 23.36 kg P, 110.29 kg K/ha), closely followed by T_4 (82.04, 21.51, and 100.89 kg/ha). Integrated organics with biological amendments proved effective in sustaining nutrient supply and enhancing soil fertility in basmati rice.
Keywords: *Basmati Rice, Organic Sources, RDF, Nutrient Content and Uptake*

INTRODUCTION

Rice (*Oryza sativa* L.) the most important cereal crop is the primary source of food security for people all over the world. Rice occupies about 43.82 million hectares of land in India, where it produces 112.44 million tons annually with an average productivity of 2850 kg/ha (Anonymous, 2023). In tropical and sub-tropical Asia, where 60% of the world's population lives, about 90% of rice is produced. Around twenty percent of the world's population and thirty-one percent of the Indian population get their calories from rice. In an average human diet, it provides protein and carbohydrates. Rice has industrial and economic significance in addition to grains. Rice hulls and straw can be used for insulation, packing, mulching and animal feed, among other things.

In terms of basmati rice production, basmati has become India's pride since it was originally introduced to the Middle East by Indian traders. More than 70 percent of the world's supply of basmati rice is currently produced in India. The major states- J & K, Himachal Pradesh, Punjab, Haryana, Delhi, Uttarakhand and western Uttar Pradesh represent the area used for basmati rice (APEDA, 2023-24; Singh et al., 2023). Natural and organic farming are the emerging concepts in modern agriculture. Government is promoting these two practices. Organic farming consists use of different organic sources of plant nutrients while natural farming does not use organic fertilizers and relives on natural processes and on farm resources.

The holistic production management approach of organic farming supports and improves the health of the agro-ecosystem, including biological cycles, biodiversity and soil biological activity. It highlights the use of possible agronomic, biological and mechanical techniques rather than synthetic materials to perform a particular system function by increasing the amount of biologically readily available soil organic matter and the activity of beneficial soil microbes and insects. These methods enhance the physical characteristics of the soil, reduce the risk of disease and promote plant health (Ngbenka *et al.*, 2015;

Subash et al., 2023). The organic farming approach considers soil health, which is demonstrated by its active participation in nutrient delivery and breakdown processes, as the foundation of agriculture.

Conventional agriculture methods and organically maintained soils have quite distinct approaches to nutrient management. Organic farming can produce a healthy ecosystem and natural environment for both the current and future generations (Singh et al., 2023a; Ghazaryan et al., 2024). *Sesbania aculeata* L is one of the most significant components of organic farming and contributes about 60–80 kg of nitrogen per hectare when added to the soil (Paikary *et al.*, 2001). After decomposition green manure lowers the soil's C: N ratio, increases humus and available nitrogen. By partially supplying the crop's nitrogen needs, green manuring improves soil quality and fertility. Releasing nitrogen gradually, organic manures increase rice output and improving nutrient utilization (Sharma 2000). Farm yard manure is the most often used organic manure.

Applying FYM improves soil structure, nutrient exchange and soil health, making it ideal for organic or INM farming. FYM is a heterogeneous decomposing organic material that includes household comprehensive, crop residue and manure in different stages of decomposition (Kumar *et al.*, 2023; Singh et al., 2024). Addition of FYM stimulates microbial population and activity in soil. Soil microorganisms decompose the organic components of FYM, release nutrients, produce growth-promoting compounds, and improve soil health (Singh *et al.*, 2012, Kumar *et al.*, 2023 and Prashar *et al.*, 2025).

Vermicomposting often known as worm composting, is a straight forward technique that uses earthworms to turn waste into organic manure. Vermicompost is a well-decomposable form of organic fertilizer produced by earthworms (such as *Eisenia fetida*) from agricultural and household waste. Various organic fertilizer sources enhance soil organic carbon, provide all the nutrients needed by plants and enhance soil properties. In agriculture, organic manures enrich the soil with much-needed organic and mineral content. The effectiveness of both native and added nutrients especially through the use of organic manure can increased yield and sustainability with the right management. Proper use of organic manure also improves nutrient use efficiency and reduces production costs while addressing some micro and secondary nutrient deficiencies. Microbial activity, soil physical characteristics and soil organic matter are all strongly correlated with the activities of soil enzymes, which are the main contributors in the biochemical processes of organic matter recycling in the soil system.

Soil enzymes are essential catalysts to the breakdown of soil organic matter, cycling of nutrients and they have a significant impact on agronomic production, environmental quality and energy transformation. Soil organic carbon and biological characteristics, such as microbial biomass and enzymatic activity are enhanced by the addition of organic matter and the use of balanced fertilizers. The activity of the dehydrogenase enzyme, which is thought to be a measure of the oxidative activity of soil microorganisms, rises noticeably when balanced fertilizer is applied (Rao *et al.*, 2014 and Dixit *et al.*, 2024).

Experimental site and location

The field experiments were conducted at Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.) during *kharif* season 2022 and 2023. Meerut is located on the Delhi - Dehradun National Highway-58 at latitude of 290.40' North and longitude of 770. 42' East and at an altitude of 237 meter above mean sea level (MSL) and from 28.40 South and 28.00 North latitude and between 77.00 and 78.00 longitude of the District of Meerut. The climate of this region is semi-arid and sub-tropical characterized with hot summers and extremely cold winters. The mean maximum temperature is noticed in June, which is the hottest month of the year, ranges from 40^0C to 45^0C while very low temperature (4^0C) accompanied by frost may be experienced in December - January.

2.2 **Experimental design and Treatment details**

The experiment was conducted using a Randomized Complete Block Design replicated three times comprising of ten treatments viz. T1- Control, T2- Recommended dose of fertilizers NPK (120:60:40), T3- 50 % N through Dhaincha + 25 % N through FYM + 25 % N through Vermicompost, T4- 50 % N through Dhaincha + 25 % N through FYM + 25 % N through Vermicompost + Consortia + Biostimulant, T5- 25 % N through Dhaincha + 25 % N through FYM + 50 % N through Vermicompost, T6- 25 % N through Dhaincha + 25% N through FYM + 50 % N through Vermicompost + Consortia + Biostimulant, T7- 1/3 N through Dhaincha + 1/3 N through FYM + 1/3 N through Vermicompost, T8- 1/3 N through Dhaincha + 1/3 N through FYM + 1/3 N through Vermicompost + Consortia + Biostimulant, T9- 50

% N through FYM + 50 % N through Vermicompost, T10- 50 % N through FYM + 50 % N through Vermicompost + Consortia + Biostimulant, respectively.

Plant analysis

Preparation of plant samples

The plant sample were dried in an oven at 60^0 C for about 48 hours and then grounded by a grinding mill to pass through a 20- mesh sieve. The ground plant materials (grain and straw) were stored in paper bags kept in desiccators. The grain and straw samples were analyzed for determination of N, P, K, S and Zn concentrations.

Nitrogen

Nitrogen content in grain and straw of rice plant was determined by Kjeldahl method. 0.5 g finely ground, plant sample wrap in a tissue paper was drop into digestion tube. To this 1 g of the digestion accelerator mixture (20 part of anhydrous Na_2SO_4 with one part of $CuSO_4$. $5H_2O$) and 10 ml of Conc. H_2SO_4 was added. Tubes were placed in a digestion block and digestion was performed until yellow or dark colour totally disappears. After cooling tubes were removed from the block and distillation was performed with 40% NaOH in auto N- analyzer and liberated ammonia was trapped in 25 ml of 4 % H_3BO_3 containing mixed indicator. A blank sample (without plant sample) was also run identically. Distillate was titrated with $0.02H_2SO_4$ until purple color just appears.

Digestion of plant sample for phosphorus, potassium, and zinc determination

For the release of mineral elements from plant tissues, dry as hing and wet oxidation are two widely adopted methods. Wet oxidation with tri or di acid mixture is generally followed. One-gram plant sample was digested with di acid mixture (HNO_3: $HClO_4$) and after complete digestion the aliquot was transferred to 100 ml volumetric flask with repeated washing/ rinse and finally volume was made up to 100ml.

Determination of phosphorus

Phosphorus in aliquot was determined by using the method based on vanadomolybdophosphoric yellow color method and color intensity was measured at 420 nm.

Determination of potassium

Potassium is the aliquot of plant samples was determined using flame photometer exactly in the same manner as described for available soil K.

Calculated parameters

Nutrient Uptake kg/ha

Total uptake of nitrogen, phosphorus, potassium and Zinc by rice was calculated from dry matter obtained at tillering, panicle initiation, flowering and harvesting (grain and straw) as:

$$\text{Nutrient uptake (kg/ha)} = \frac{\text{Nutrient content (\%) X Dry matter of crop (Kg/ha)}}{100}$$

Experimental Result

Effect of different treatments on nutrients content at different growth stages of basmati rice

Nitrogen content (%)

Tillering Stage

During the tillering stage, nitrogen content was highest across all treatments compared to subsequent growth stages showed in table 1. In 2022, treatment maximum nitrogen content (1.82%), statistically at par with T_4 (1.78%), T_3 (1.74%) and T_8 (1.69%) was found in T_2 (Recommended dose of NPK). The control treatment (T_1) comparable to T_9 (1.54%) showed significantly lower nitrogen content (1.53%). A similar trend was observed in 2023, with T_2 recording the highest value (1.86%), which was statistically at par with T_4 (1.82%), T_3 (1.79%), T_8 (1.76%) and T_7 (1.72%). The integrated organic management treatments containing consortia and biostimulant (T_4, T_8) generally exhibited improved nitrogen content compared to their counterparts without biological amendments. Among the organic treatment T_3 and T_4 showed comparable higher N content than the other treatments.

Panicle Initiation Stage

At the panicle initiation stage, nitrogen content decreased across all treatments compared to the tillering stage. During 2022, The highest nitrogen content 1.29% recorded with application of RDF was found statistically at par with T_4 (1.27%), T_3 (1.25%), T_8 (1.23%), T_7 (1.21%) and T_6 (1.19%). The control treatment T_1 showed significantly lower nitrogen content than the rest of the treatments. A similar trend was observed during 2023, with T_2 recording the highest value (1.37%), closely followed by T_4 (1.33%), T_3 (1.31%), T_8 (1.28%) and T_7 (1.25%) while lower value (1.15%) was recorded under treatment T_1. The treatments consisting equal amount of N application through different organic sources (T_7 and T_8) performed moderately well. The beneficial effect of adding consortia and biostimulant was also evident.

Flowering Stage

During the flowering stage, a notable shift occurred in nitrogen content patterns. Treatment T4 recorded the highest nitrogen content during both years (1.03% in 2022 and 1.06% in 2023), surpassing the chemical fertilizer treatment (T_2). Treatment T_3 also performed exceptionally well (0.95% and 1.00%). This indicates that integrated organic treatments became more effective at later growth stages, possibly due to the gradual release of nutrients from organic sources. The control treatment continued to show the lowest values (0.67% and 0.71%). The overall nitrogen content declined considerably compared to earlier growth stages.

Grain

Nitrogen content in grains showed recovery compared to the flowering stage. The highest grain nitrogen content (1.19 % during 2022 and 1.21 % during 2023 was observed in treatment T_2 (recommended dose of fertilizer), followed by T_4 (1.17% and 1.19%) and T_3 (1.13% and 1.15%). Among the organic treatments, treatments consisting equal amount of N application through different organic sources (T_7 and T_8) also performed well. The significantly lower values in control T_1 (0.91% and 0.99%) highlight the importance of adequate nutrient management for grain quality. The addition of consortia and biostimulant slightly improved grain nitrogen content across comparable treatments.

Straw

Straw nitrogen content was substantially lower than grain nitrogen content across all treatments. Treatment T_2 (Recommended dose of NPK) showed the highest values 0.53 % in 2022 and 0.55 % in 2023. Interestingly, T_7 (equal proportions of organic inputs) performed exceptionally well for straw nitrogen content, especially in 2023. The control treatment had the lowest straw nitrogen content in both years (0.40% and 0.42%). Straw N content in T_9 and T_{10} was comparatively lower that the straw N content found in rest of the organic treatments. Effect of different treatments on phosphorus content (%) at different growth stages of Rice.

Phosphorus content (%)

Tillering Stage

Phosphorus content (%) of basmati rice at different growth stages as influenced by different treatments is shown in Table 2. At the tillering stage, phosphorus content showed non-significant differences among treatments in both years. Treatment T_2 (Recommended dose of NPK) recorded the highest phosphorus content (0.332% in 2022 and 0.345% in 2023), Among the organic sources T_4 (50% N through Dhaicha + 25% N through FYM + 25% N through Vermicompost + Consortia + Biostimulant) showed the higher phosphorus content (0.328% in 2022 and 0.342% in 2023). The control treatment (T_1) recorded the lowest phosphorus content (0.294% and 0.305%) during both growing season. All treatments showed slightly higher phosphorus content in 2023 compared to 2022.

Panicle Initiation Stage

At the panicle initiation stage, phosphorus content decreased across all treatments compared to the tillering stage. The effect of the different treatments on plant phosphorus content was more or less similar to the P content found at tillering stage and ranged from 0.244 to 0.252 percent during 2022 and 2023. The control treatment (T_1) continued show the lowest values (0.244% and 0.252%). The treatments application of consortia and biostimulant showed slight advantages over without biological amendments.

Flowering Stage

At the flowering stage, phosphorus content further declined in all treatments during both the years. In 2022 treatment T_2 recorded the highest phosphorus content (0.213%). Among the organic sources T_4 (50% N through Dhaicha + 25% N through FYM + 25% N through Vermicompost + Consortia + Biostimulant) recorded maximum phosphorus content (0. 208%). Treatment T_1 (control) recorded the lowest value (0.173%). A similar trend was observed during 2023, with T_2 recording the highest value (0.219%). The control treatment (T_1) showed the lowest values (0.179%). The overall reduction in phosphorus content from panicle to flowering stage was approximately 25-30% across treatments.

Grain

Phosphorus content in grains showed a slightly increase compared to the flowering stage and ranged from 0.198 to 0.246 during 2022 and 0.213 to 0.260 during 2023. In 2022, The highest phosphorus content in grain was observed under treatment T_2 (0.246%). Among the organic sources treatment T_4 recorded the higher value (0.240%). The control treatment (T_1) recorded the lowest value (0.198%). A similar pattern was recorded during 2023, with T_2 (Recommended dose of NPK) recording the highest value (0.260 %). Among the organic sources T_4 (50% N through Dhaicha + 25% N through FYM + 25% N through Vermicompost + Consortia + Biostimulant) recorded the higher value (0.257 %). The control treatment (T_1) showed the lowest values (0.213 %).

Straw

Straw phosphorus content was substantially lower than grain phosphorus content across all treatments. Same as all the stages, Treatment T_2 showed the highest values (0.187% in 2022 and 0.195% in 2023), Among the organic sources treatment T_4 (50% N through Dhaicha + 25% N through FYM + 25% N through Vermicompost + Consortia + Biostimulant) also performed well (0.181% and 0.191%) and treatment T_1 (Control) recorded the lowest value (0.119 % and 0.127 %) during both the year.

Potassium content (%)

Tillering Stage

Potassium content (%) of basmati rice at different growth stages as influenced by different treatments is shown in Table 3. At the tillering stage, potassium content showed significant variations among treatments during both growing seasons. In 2022. treatment T_2 (Recommended dose of NPK) recorded the highest potassium content (1.76%) which was statistically at par with exception of T_1, T_5, T_9 and T_{10}. Treatments T_1 (Control) recorded the lower value (1.32%). Same trend was seen during 2023 T_2 recording the highest value (1.78%) which was statistically at par to the treatments with exception of T_1, T_9 and T_{10}.The treatment T_1 (Control) recorded the lowest value (1.37%). Among the organic treatments addition of consortia and biostimulant consistently improved potassium content, integration of dhaicha along with organic sources resulted high K content while integration of organic sources FYM and vermicompost showed higher K content.

Panicle Initiation Stage

During the panicle Initiation stage, potassium content decreased across all treatments compared to the tillering stage. Treatment T_2 again recorded the highest potassium content (1.64% in 2022 and 1.66% in 2023), which was statistically similar to T_4 (1.58% and 1.62%) and T_3 (1.51% and 1.58%). The control treatment (T_1) continued to show the lowest values (1.18% and 1.20%), along with T_9 (1.21% and 1.34%). The statistical groupings were more distinct at this stage, with clear separation between high-performing treatments (T_2, T_3, T_4, T_8) and the lower-performing ones (T_1, T_9, T_{10}). The beneficial effect of biostimulant, consortia and dhaicha application remained evident, with enhanced potassium content in treatments including these biological amendments and dhaicha.

Flowering Stage

At the flowering stage, potassium content further decreased across all treatments. Treatment T2 recorded the highest potassium content (1.48% in 2022 and 1.51% in 2023), closely followed by T_4 and T_3 during 2022 and T_3, T_4, T_7, T_8 during 2023. The control treatment (T_1) recorded the lowest values (1.03% and 1.13%), along with T_9 (1.18% and 1.21%) and T_{10} (1.21% and 1.26%). The statistical groupings remained pronounced, with T_2, T_3, and T_4 consistently in the highest performance category.

Grain

Grain potassium content was lower than straw potassium content across all treatments, reflecting the lower potassium translocation to grains. During both the year treatment T_2 (Recommended dose of NPK) showed the highest values (0.47% in 2022 and 0.49% in 2023), followed by T_4 (0.45% and 0.47%) and T_3 (0.44% and 0.45%) which were statistically at par. The control treatment (T_1) exhibited the lowest values (0.32% and 0.34%), along with T_9 (0.33% and 0.37%). The effect of biostimulant and consortia was particularly evident in grain potassium content, with consistent improvements across comparable treatments. Application of dhaicha also improved the grain K content.

Straw

Straw potassium content was higher than grain potassium content, highlighting the role of straw as a major sink for potassium in rice. Treatment T_2 recorded the highest values (1.40% in 2022 and 1.48% in

2023), closely followed by T_4 (1.28% and 1.39%). The control treatment (T_1) showed the lowest values (1.02% and 1.08%), along with T9 (1.06% and 1.12%). Statistical groupings were distinct, with T_2 and T_4 consistently in the highest performance category. The difference between the highest (T_2) and lowest (T_1) potassium content in straw was approximately 37% in 2022 and 37% in 2023, indicating the effect of potassium application on potassium accumulation in straw.

Effect of different treatments on total nutrients uptake of basmati rice

Total Nitrogen Uptake

Total Uptakes of N, P and K was affected different by different treatments of basmati rice showed in Table 4. Total nitrogen uptake showed highly significant differences among treatments in both growing seasons. Treatment T_2 (79.38 kg/ha) recorded the highest nitrogen uptake in 2022. Among the organic treatments T_4 recorded the higher nitrogen uptake (71.91 kg/ha). The control treatment (T_1) showed the lowest nitrogen uptake (32.48 kg/ha). During the 2023 treatment T_2 (Recommended dose of NPK) recorded the maximum nitrogen uptake 84.94 kg/ha closely followed by treatment T_4 (82.04 kg/ha). Treatment T_1 recorded the lower nitrogen uptake (37.25 kg/ha). The application of consortia and biostimulant consistently enhanced nitrogen uptake in all organic treatment.

Phosphorus Uptake

Total phosphorus uptake recorded a similar pattern to nitrogen uptake. Chemical fertilization recorded the highest phosphorus uptake (21.49 kg/ha) during 2022. Among the organic sources treatment T_4 (19.16 kg/ha) statistically at par with treatment T_3 (18.23 kg/ha). The control treatment (T_1) showed the lowest values (8.32 kg/ha). During the 2023 the treatment T_2 also recorded the maximum phosphorus uptake (23.36 kg/ha). Among the organic sources treatment T_4 recorded maximum value (21.51 kg/ha) closely followed with treatment T_3 (20.82 kg/ha). The control treatment (T_1) showed the lowest values (9.52 kg/ha). Most treatments demonstrated higher phosphorus uptake in 2023 compared to 2022, with increases ranging from 8-14%, suggesting improved soil phosphorus availability in the second year.

Potassium Uptake

Potassium uptake showed the highest absolute values among macronutrients, reflecting the high potassium requirement of rice. In the session 2022 treatment T_2 recorded the highest potassium uptake (104.10 kg/ha). Among the organic treatment T_4 recorded the higher potassium uptake (91.19 kg/ha) closely followed by T_3 (87.02 kg/ha). Treatment T_1 recorded the lowest value (46.32 kg/ha). Same trend was seen during 2023 with T_2 (110.29 kg/ha). Among the treatment T_4 recorded the maximum value (100.89). The control treatment (T_1) lowest the lowest values (8.32 kg/ha). The enhancement of potassium uptake by biostimulant and consortia was evident across all organic treatment combinations, with increases ranging from 4-5%.

DISCUSSION

The nitrogen content across different growth stages of rice revealed distinct patterns of influence by fertilization treatments, with significant implications for crop nutrition and grain quality. The highest nitrogen content observed during the tillering stage (1.53-1.86%) across all treatments aligns with established knowledge that early vegetative growth requires substantial nitrogen for leaf and tiller development (Xu *et al.*, 2012). The recommended NPK treatment (T_2) consistently maintained the highest nitrogen content during early growth stages (1.82-1.86% at tillering, 1.29-1.37% at panicle initiation), reflecting the immediate availability of mineral nitrogen, which supports findings that inorganic fertilizers provide rapid nutrient release for early plant establishment (Fageria *et al.*, 2003; Dutta et al., 2024).

The phosphorus content in plant at different growth stages of rice remain unaffected with the application of different treatments non-significant treatment effect on plant P content may be suppressed due to almost similar P availability in soil under different treatments. The highest phosphorus content observed during the tillering stage (0.294-0.345%) across all treatments reflects the critical role of phosphorus in early root development, tillering, and photosynthetic establishment in rice (Fageria *et al.*, 2011; Mugabo et al., 2024). The recommended NPK treatment (T_2) consistently maintained the highest phosphorus content across all growth stages (0.332-0.345% at tillering, 0.213-0.219% at flowering, 0.246-0.260% in grain in 2022 and 2023), demonstrating the immediate availability of mineral phosphorus, which supports findings that inorganic phosphorus fertilizers provide readily available P for plant uptake (Richardson *et al*., 2009).

Plant potassium content at various growth stages of rice differ significantly under the influence of different treatments. The highest potassium content was observed during the tillering stage (1.32-1.78%) across all treatments during 2022 and 2023 respectively. The recommended NPK treatment (T_2) consistently maintained the highest potassium content across all growth stages (1.76-1.78% at tillering, 1.64 - 1.66 % at Panicle initiation, 1.48-1.51% at flowering, 0.47-0.49% in grain, 1.40-1.48% in straw during 2022 and 2023), demonstrating the immediate availability of mineral potassium, which get support from the findings that inorganic potassium fertilizers provide readily available K for plant uptake and translocation (Romheld & Kirkby, 2010). The superior performance of T_4 (50% N through dhaicha + 25% each through FYM and vermicompost + consortia + biostimulant) among organic treatments, achieving plant potassium level comparable to T_2 during panicle initiation (1.58-1.62%) and flowering stages (1.40-1.45%), demonstrates the effectiveness of integrated organic management with microbial enhancement in maintaining adequate potassium nutrition throughout the crop cycle.

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CONCLUSION

The study found that various nutrition management techniques had a significant impact on the nutrient content of basmati rice. The highest levels of nitrogen, phosphate, and potassium were consistently found in grain and straw at various growth stages when the recommended fertilizer dose (T_2) was applied. Integrated organic treatments T_3 and T_4 came in second and third, respectively. The use of Dhaicha, FYM, and Vermicompost (T_4) together outperformed RDF among organic sources, demonstrating its potential as a sustainable substitute. From tillering until blooming, the N, P, and K content generally decreased, with a minor recovery in grain at harvest. For N and P, grain continued to have a higher nutritional content than straw, whereas straw had a higher K content throughout all treatments. The control consistently showed the lowest nutrient concentrations. These findings clearly emphasize that integrated organic nutrient management, particularly the inclusion of green manuring and organic amendments along with recommended fertilizers, is effective in maintaining balanced nutrient dynamics and enhancing total nutrient uptake in basmati rice under light-textured soils.

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Nitrogen content (%)										
							Harvest			
	Tillering		Panicle Initiation		Flowering		Grain		Straw	
Treatments	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
T_1	1.53	1.57	1.08	1.15	0.67	0.71	0.93	1.00	0.40	0.42
T_2	1.82	1.86	1.29	1.37	0.85	0.90	1.19	1.21	0.53	0.55
T_3	1.74	1.79	1.25	1.31	0.95	1.00	1.13	1.15	0.50	0.52
T_4	1.78	1.82	1.27	1.33	1.03	1.06	1.17	1.19	0.52	0.53
T_5	1.60	1.64	1.16	1.20	0.84	0.86	1.02	1.10	0.47	0.49
T_6	1.63	1.67	1.19	1.23	0.87	0.89	1.05	1.15	0.46	0.51
T_7	1.66	1.72	1.21	1.25	0.89	0.91	1.08	1.12	0.48	0.54
T_8	1.69	1.76	1.23	1.28	0.91	0.97	1.11	1.15	0.49	0.53
T_9	1.54	1.59	1.13	1.16	0.80	0.82	0.96	1.04	0.44	0.45
T_{10}	1.57	1.61	1.16	1.20	0.82	0.84	1.03	1.08	0.45	0.47
C.D. at 5%	**0.14**	**0.16**	**0.11**	**0.13**	**0.09**	**0.10**	**0.11**	**0.12**	**0.05**	**0.06**
S.E.(m)±	**0.05**	**0.05**	**0.04**	**0.04**	**0.03**	**0.03**	**0.04**	**0.04**	**0.02**	**0.02**

Table 1. Effect of different treatments on nitrogen content (%) at different growth stages of basmati rice

Table 2. Effect of different treatments on phosphorus content (%) at different growth stages of basmati rice

Phosphorus content (%)										
							Harvest			
	Tillering		Panicle Initiation		Flowering		Grain		Straw	
Treatments	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
T_1	0.294	0.305	0.244	0.252	0.173	0.179	0.198	0.213	0.119	0.127
T_2	0.332	0.345	0.294	0.299	0.213	0.219	0.246	0.260	0.187	0.195
T_3	0.320	0.337	0.284	0.291	0.204	0.210	0.234	0.253	0.177	0.187
T_4	0.328	0.342	0.290	0.295	0.208	0.214	0.240	0.257	0.181	0.191
T_5	0.306	0.320	0.264	0.268	0.188	0.195	0.219	0.232	0.158	0.167
T_6	0.311	0.324	0.270	0.273	0.191	0.198	0.222	0.238	0.162	0.171
T_7	0.313	0.331	0.274	0.279	0.195	0.203	0.226	0.244	0.167	0.179
T_8	0.316	0.334	0.280	0.285	0.200	0.205	0.231	0.249	0.171	0.183
T_9	0.298	0.310	0.252	0.258	0.181	0.188	0.210	0.221	0.147	0.158
T_{10}	0.302	0.316	0.258	0.263	0.185	0.193	0.214	0.227	0.152	0.165
C.D. at 5%	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**	**NS**
S.E.(m)±	**0.02**	**0.02**	**0.02**	**0.02**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**	**0.01**

Table 3. Effect of different treatments on potassium content (%) at different growth stages of basmati rice

Potassium Content (%)	
	Harvest

	Tillering		Panicle Initiation		Flowering		Grain		Straw	
Treatments	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
T_1	1.32	1.37	1.18	1.20	1.03	1.13	0.32	0.34	1.02	1.08
T_2	1.76	1.78	1.64	1.66	1.48	1.51	0.47	0.49	1.40	1.48
T_3	1.67	1.71	1.51	1.58	1.38	1.45	0.44	0.45	1.22	1.29
T_4	1.71	1.75	1.58	1.62	1.44	1.47	0.45	0.47	1.28	1.39
T_5	1.48	1.52	1.29	1.38	1.26	1.31	0.37	0.40	1.14	1.21
T_6	1.53	1.57	1.34	1.42	1.29	1.34	0.39	0.41	1.13	1.21
T_7	1.58	1.62	1.39	1.47	1.34	1.38	0.41	0.43	1.14	1.22
T_8	1.63	1.67	1.46	1.53	1.36	1.41	0.42	0.44	1.18	1.26
T_9	1.39	1.43	1.21	1.34	1.18	1.21	0.33	0.37	1.06	1.12
T_{10}	1.43	1.47	1.26	1.35	1.21	1.26	0.35	0.38	1.09	1.18
C.D. at 5%	**0.25**	**0.28**	**0.17**	**0.18**	**0.11**	**0.14**	**0.04**	**0.05**	**0.12**	**0.13**
S.E.(m)±	**0.08**	**0.09**	**0.06**	**0.06**	**0.04**	**0.04**	**0.01**	**0.02**	**0.04**	**0.04**

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Total Nutrient Uptake						
	Nitrogen (kg/ha)		Phosphorus (kg/ha)		Potassium(kg/ha)	
Treatments	**2022**	**2023**	**2022**	**2023**	**2022**	**2023**
T_1	32.48	37.25	8.32	9.52	46.32	50.96
T_2	79.38	84.94	21.49	23.36	104.10	110.29
T_3	67.04	77.94	18.30	20.82	87.02	95.13
T_4	71.91	82.04	19.16	21.51	91.19	100.89
T_5	52.77	60.70	14.55	16.52	72.54	81.51
T_6	55.17	65.59	15.47	17.51	75.60	84.12
T_7	59.66	71.51	16.39	18.86	78.57	87.88
T_8	64.28	74.23	17.55	19.78	83.97	91.14
T_9	45.19	51.23	12.74	14.42	65.08	72.03
T_{10}	49.58	56.20	13.57	15.63	68.52	77.27
C.D. at 5%	**4.03**	**4.61**	**1.10**	**1.24**	**5.36**	**5.65**
S.E.(m)±	**1.36**	**1.54**	**0.36**	**0.41**	**1.79**	**1.88**

Table 4. Effect of different treatments on Total Nutrient Uptake of N, P and K