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Optimizing Nutrient Uptake in Rice Crops through Integrated Organic Manure Application: A Comprehensive Analysis of Grain and Straw Composition

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Rice (*Oryza sativa L.)* is the staple food of more than 60 percent of the world's population and is considered the "global grain". It is the main staple food in the Asia and the Pacific region. This study was conducted to ascertain the Impact of Various Treatment Combinations on the Nutrient Uptake of rice grains and straw. The field experiments were carried out at the research Farm of Acharya

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Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya (U.P.) during Kharif, 2021-22. The experiment was laid out in randomized block design with 3 replications having 8 treatments. The eight treatments combinations were: T1(Absolute Control), T2 (Bio decomposed compost 1q/ha+50%RDF), T3 (Bio decomposed compost 1.5 q/ha+50%RDF), T4 (Bio decomposed compost 1q/ha+50% RDF + Root dipping with bio decomposed compost wash 10 ml/ lit of water), T5 (Bio decomposed compost 1.5 q/ha+50%RDF + Root dipping with bio decomposed wash 10 ml/lit of water), T6 (Bio decomposed compost 1q/ha+50%RDF+foliar application of bio decomposed compost wash of 10 ml/ lit of water), T7 (Bio decomposed compost 1.5 q/ha+50%RDF + foliar application of bio decomposed compost wash of 10 ml/ lit of water), T8 (100% RDF). As per findings, Nutrient uptake of N, P and K by grain of Rice varied from 44.32 kg ha-1 to 77.03 kg ha-1, 11.90 kg ha-1 to 20.85 kg ha-1, and 22.16 kg ha-1 to 45.17 kg ha-1. In Rice straw, N, P and K uptake varied from 20.16 kg ha-1 to 36 kg ha-1, 8.17 kg ha-1 to 15.62 kg ha-1, and 66.67 kg ha-1 to 100.55 kg ha-1. The application of organic manures significantly influenced nutrient uptake, attributed to enhanced photosynthesis, increased biomass, and improved nutrient availability. The findings align with previous research, emphasizing the positive impact of organic manure on nutrient uptake in rice crops. These studies contribute valuable insights into optimizing agricultural practices for enhanced nutrient management and sustainable crop production.

Keywords: Nutrient uptake; biodynamic compost; organic manures; biomass.

1. INTRODUCTION

Rice (*Oryza sativa L.*) is the staple food and main source of energy for more than three billion people around the globe, mostly consisting of South Asia and India whereas, it is the main source of dietary carbohydrate for 65% of the Indian population" (Patra et al., 2020). "Moreover, rice accounts for more than 40% of food-grain production in India, providing direct employment to 70% of people in rural areas. Rice cultivation accounts for more than 80% of the North–Eastern Himalayan region's total cultivated area (7.8% of India's total rice cultivation area) and contributes significantly to domestic rice production" (Patra et al., 2020). "At the global level, rice is grown in an area of about 165 million ha with production of 519 million tonnes respectively" [1]. "In India, rice is the most important and extensively grown food crop occupying 46.38 m ha area with a production of 130.29 mt and productivity of 28.09 q ha^{-1}" [2]. Agriculture faces the dual challenge of meeting increasing global food demands while minimizing environmental impact. Traditional farming practices often rely on synthetic fertilizers, contributing to soil degradation and environmental pollution. Bio-dynamic compost is a promising alternative, leveraging a holistic approach to soil fertility and plant nutrition. The integration of various organic manures resulted in higher NPK uptake, potentially due to increased microbial activity and the release of organic acids.

Bio-decomposed compost wash is produced by repeatedly spraying water on compost, allowing it to seep through and collecting the washed water. This process is repeated until only a minimal amount of washed water remains, which is then utilized as compost wash. This method, known as biodynamic composting, is an expedited approach to compost production conducted on the surface rather than in traditional pits. The compost heap is energized using specific preparations to enhance nutrient content and accelerate decomposition. Built on a flat site, away from tree shade and waterlogging, the compost heap takes the form of a rectangle, typically 2m wide and 4m long, depending on biomass availability. A wind tunnel of logs is placed lengthwise in the middle of the rectangle. It is a specially prepared organic material infused with diverse microorganisms. These microorganisms play a pivotal role in enhancing soil structure, fostering water retention, and increasing nutrient availability. Humic acid, a key component of humic compounds, plays a vital role in this process. Humic substances, created through the biological activity of microorganisms and the humification of plant and animal materials, influence plant development. The effects of humic chemicals on plant growth are determined by factors such as their source, concentration, molecular weight, and molecular fraction. By adding humic and fulvic acids to the soil, it is possible to see the beginning of root augmentation and improved root development [3] "Macro nutrients, such as nitrogen (N), phosphorus (P), and potassium (K), are present in organic manure in varying proportions. These nutrients are crucial for plant growth, as nitrogen is essential for leaf and stem development, phosphorus promotes root growth and flowering, and potassium supports overall plant vigour and disease resistance. The balanced supply of these macronutrients in organic manure helps provide plants with the necessary elements for optimal growth and productivity. This can enhance soil nutrients due to enhanced soil microbial activity, improving soil physical and chemical properties" [4]. "The slow and gradual release of N from organic manure is an advantage over sole chemical fertilization for achieving higher NUE, grain yield, and quality of rice. Organic manures are fractionated based on their solubility characteristics to extract humic and fulvic acids from humus" [5,6] and (Ramalakshmi et al., 2013). This research aims to investigate the impact of diverse treatment combinations on nutrient uptake in rice crops. The study focuses on nitrogen, phosphorus, potassium, and protein content in rice grains and straw. With the rising global population, understanding the relationships between different treatments and nutrient composition is crucial for informed agricultural practices, aimed at improving nutrient utilization and ensuring sustainable crop production. Keeping these in view, the research was carried out to find out the use of urban solid waste compost as a source of nutrients for rice crop present research was conducted.

2. MATERIALS AND METHODS

The field experiment was conducted during the Kharif season 2021 Agricultural Research Farm of Acharya Narendra Deva University of Agriculture & Technology, Kumarganj, Ayodhya (U.P.). The experiment was laid out in randomized block design having 8 treatments (Table 1) as per the recommended dose fertilizer (RDF) applied through Urea, DAP and MOP as per treatments. Half dose of nitrogen and full dose of phosphorus and potassium were applied basally. The remaining half N dose was applied in two equal splits once at tillering and rest panicle initiation stages. However, biodynamic compost was applied at root dipping just before transplanting and foliar application at 30 DAT (Days After Transplanting) in standing crop.

2.1 Nutrient Analysis

Available nitrogen in soil was determined using the alkaline potassium permanganate method by Subbaiah and Asija [7]. The procedure involved distilling 20g of soil with 0.32% $KMnO_4$ and 2.5% NaOH, absorbing ammonia gas in 4% boric acid (pH 4.5), and back titrating with 0.02 N H_2SO_4. Results were converted to kg ha^{-1}. Available phosphorus was assessed following Olsen et al., [8] method. In a 150 ml flask, 2.5g of air-dry soil was mixed with P-free activated charcoal, Olsen's reagent ($NaHCO_3$, pH 8.5), and shaken. Color development was measured at 660 nm using a spectrophotometer, with values converted to kg ha^{-1}. For available potassium determination, soil extraction utilized neutral ammonium acetate (pH 7.0) following Hanway and Heidal [9]. Potassium levels in the extract were measured using a flame photometer, and results were converted to kg ha^{-1}.

2.2 Protein Content (%)

Protein content (%) in grain was worked out by multiplying the nitrogen content in grain by factor 6.25 [10].

2.3 Nutrient Uptake

For the analysis of nutrient uptake, plant shoot samples endured diacid extraction for nitrogen estimation, following Humphries' micro Kjeldahl method (1956), expressed as a percentage on a dry weight basis. For phosphorus, the triple acid extraction method by Jackson et al., [11] was employed, and results were presented as a percentage on a dry weight basis. Potassium levels were determined using flame photometry on a triple acid extract, as per Jackson et al., [11], expressed as a percentage on dry weight basis. Nutrient uptake/removal in grain and straw of the crops were calculated in kg ha^{-1} about yield ha^{-1} by using the following formula [12] Nutrient uptake (kg/ha) = Nutrient content (%) × yield (q/ha).

2.4 Statistical Analysis

The observations recorded during the investigation were tabulated and analyzed statistically to draw a valid conclusion. The data were analyzed as per the standard procedure for "Analysis of Variance" (ANOVA) as described by Gomez and Gomez [13]. The standard error of mean (SEm±) was computed in all cases. The difference in the treatment mean was tested by using critical difference (CD) or least significant difference (LSD) at 5% level of probability.

Table 1. Details of treatment

Treatment No.	Treatment details
T_1	Absolute Control
T_2	Bio Dynamic Compost 1q/ha+50%RDF
T_3	Bio Dynamic compost 1.5 q/ha+50%RDF
T_4	T2+Root dipping with Bio Dynamic compost wash 10 ml/ lit of water
T_5	T3 + Root dipping with Bio Dynamic compost wash 10 ml/lit of water
T_6	T2+foliar application of Bio Dynamic compost wash of 10 ml/ lit of water
T_7	T3 +foliar application of Bio Dynamic compost wash of 10 ml/ lit of water
T_8	100%RDF

3. RESULTS AND DISCUSSION

3.1 Nitrogen Content in Grain and Straw (%)

The concentration of nitrogen in both grains and straw of Rice, as presented in Table 2. The N concentration of grain varied from 1.12 to 1.33%. The highest grain N concentration 1.33% was observed in treatment T_7. Conversely, the lowest nitrogen content (1.12%) in grains was observed in treatment T_1 (Control). These findings align with those reported by Bisht et al*.* [14]. In straw, the N concentration ranged from 0.37 to 0.47%. The highest nitrogen content in straw (0.47%) was observed in treatment T_7. These findings are consistent with the research of Satish et al*.* [15] and Ramalakshmi et al*.* [16].

3.2 Nitrogen Uptake by Grain and Straw (Kg ha^{-1})

The nitrogen uptake in rice grains exhibited a range from 44.32 Kg ha^{-1} to 77.03 Kg ha^{-1}, as indicated in Table 3. The highest nitrogen uptake in rice grains was observed in treatment T_7 (77.03 Kg ha^{-1}), statistically comparable to T_5 (74.41 Kg ha^{-1}). Conversely, the lowest nitrogen uptake in rice grains was recorded in the control plot T_1 (44.32 kg/ha). In the case of rice straw, nitrogen uptake ranged from 20.16 Kg ha^{-1} to 37.6 Kg ha^{-1}. The highest nitrogen uptake in rice straw occurred in T_5 (37.6 Kg ha^{-1}), statistically at par with T_7 (35.36 Kg ha^{-1}), while the lowest nitrogen uptake was observed in the control plot T_1 (20.16 Kg ha^{-1}). The variation in nitrogen uptake in both grains and straw across different treatments was primarily attributed to yield differences and, to some extent, to the nitrogen content in grains and straw. The application of organic manures provided sufficient nutrients for enhanced photosynthesis, resulting in increased nitrogen uptake in both grains and straw, contributing to the overall nitrogen uptake. The higher NPK uptake can be attributed to increased yields in treatments, as reported by Kumari et al*.* [17] and supported by similar findings from Satish et al*.* [15] and Ramalakshmi et al*.* [16].

3.3 Protein Content in Grain (%)

The examination of data concerning protein content in grains, as presented in Table 2, indicates that various treatment combinations influenced the outcomes. The Protein concentration of grain varied from 7.0 to 8.3%. The highest protein content in grains (8.31%) was associated with treatment T_7, significantly surpassing T_1 and statistically comparable to T_5 and T_6. In contrast, the lowest protein content (7.00%) was noted in treatment T_1 (Control). Additionally, Balasubramaniam et al*.* [18] reported a significant increase in protein content in groundnuts with the application of humic acid (HA).

3.4 Phosphorus Content in Grain and Straw (%)

The data presented in Table 2 concerning phosphorus content in grains as well as straw indicates the influence of various treatment combinations. The Phosphorous content in grain varied from 0.30 to 0.36%. The maximum phosphorus content in grains (0.36%) was observed with treatment T_7, significantly exceeding T_1 and statistically comparable to T_5 and T_6. In contrast, the minimum phosphorus content (0.30%) in grains was noted in treatment T_1 (Control). These results are consistent with the findings of Mondal et al*.* [19]. In straw, the P concentration varied from 0.15 to 0.19%. The highest P content in straw (0.19%) was observed in treatments T_7 and T_5 in statistically comparable to T_4 and T_6.

3.5 Phosphorous Uptake by Grain and Straw (kg ha^{-1})

The phosphorus uptake in rice grains displayed a range from 11.90 kg ha^{-1} to 20.85 kg ha^{-1}, as presented in Table 3. The highest phosphorus uptake in rice grains was observed in treatment

T_7 (20.85 kg ha^{-1}), statistically comparable to T_5 (20.60 kg ha^{-1}), while the lowest phosphorus uptake occurred in the control plot T_1 (11.90 kg ha^{-1}). In the case of rice straw, phosphorus uptake varied from 8.17 kg ha^{-1} to 15.62 kg ha^{-1}. The highest phosphorus uptake in rice straw was recorded in T_7 (15.62 kg ha^{-1}), statistically at par with T_5 (15.53 kg ha^{-1}), and the lowest phosphorus uptake was found in the control plot T_1 (8.17 kg ha^{-1}). "The increased nutrient uptake observed with organic manure application can be attributed to the solubilization of native nutrients, chelation of complex intermediate organic molecules produced during the decomposition of added organic manures, and the mobilization and accumulation of different nutrients in various plant parts". Mohapatra et al. [20]. Additionally, the application of bio-fertilizers further facilitates the increased availability of nitrogen and phosphorus in the soil, enhancing their uptake by plants.

3.6 Potassium Content in Grain and Straw (%)

The analysis of data about potassium content in grains as well as straw, presented in Table 2, highlights the influence of various treatment combinations. The Potassium content in grain varied from 0.61 to 0.79%. The maximum potassium content in grains (0.79%) was observed with treatment T_5, significantly surpassing T_1 and statistically comparable to T_7 and T_6. Conversely, the minimum potassium content in grains (0.61%) was noted in treatment T_1. In straw, the Potassium content in straw varied from 1.15 to 1.28%. The maximum potassium content in straw (1.28%) was observed with treatment T_7, significantly surpassing T_1 and statistically comparable to T_5, and statistically comparable to T_6. In contrast, the minimum potassium content in straw (1.15%) was noted in treatment T_1. These findings are consistent with the results reported by Kumari et al. [17].

3.7 Potassium Uptake by Grain and Straw (kg ha^{-1})

The potassium uptake in rice grains exhibited a range from 22.16 kg ha^{-1} to 45.17 kg ha^{-1}, as outlined in Table 3. The highest potassium uptake in rice grains was observed in treatment T_7 (45.17 kg ha^{-1}), statistically comparable to T_5 (44.41 kg ha^{-1}), while the lowest potassium uptake occurred in the control plot T_1 (22.16 kg ha^{-1}). In the case of rice straw, potassium uptake ranged from 66.67 kg ha^{-1} to 105.28 kg ha^{-1}. The highest potassium uptake in rice straw was found in T_7 (105.28 kg ha^{-1}), statistically at par with T_5 (103.81 kg ha^{-1}) and the lowest potassium uptake was recorded in the control plot T_1 (66.67 kg ha^{-1}), The increased uptake of potassium in both grain and straw may be attributed to the application of organic nitrogen sources, which released more NH_4^+ and NO_3^{-} in the soil. This, in turn, occupied the selective exchange sites in the 2:1 layer clay mineral, replacing the K^+ ions from these exchange sites. Consequently, this led to the highest available potassium concentration in the soil solution, resulting in greater absorption by rice. The similarity in ionic radii of nitrogen and potassium ions could contribute to this phenomenon. The control treatment exhibited the lowest nitrogen, phosphorus, and potassium uptake. Bindra and Thakur [21] reported increased nitrogen, phosphorus, and potassium uptake in grain and straw due to manuring [22-28].

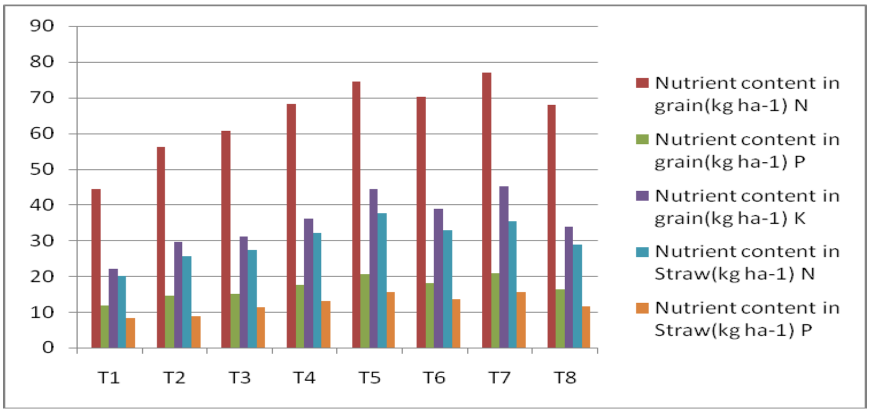

Fig. 1. Effect of different treatments on uptake of nitrogen, phosphorus, and potassium (kg ha^{-1}) in grain and straw of rice

Table 2. Effect of different treatments on N, P and K concentration by grain and straw of rice crop

S. No.	Treatment combination	Content/Concentration (%)						
		Grain				Straw		
		N	P	K	Protein	N	P	K
1	Control	1.12	0.3	0.61	7	0.37	0.15	1.15
2	Biodynamic compost 1q ha^{-1} + 50 % RDF	1.19	0.31	0.63	7.4	0.38	0.14	1.18
3	Bio dynamic compost 1.5 q ha^{-1} + 50 % RDF	1.24	0.31	0.64	7.7	0.39	0.16	1.18
4	T2 + Root dipping with Biodynamic compost wash 10 ml lit^{-1} of water	1.28	0.33	0.68	8	0.42	0.17	1.21
5	T3 + Root dipping with Biodynamic wash 10 ml lit^{-1} of water	1.32	0.35	0.79	8.2	0.46	0.19	1.27
6	T2 + foliar application of Biodynamic compost wash of 10 ml lit^{-1} of water	1.28	0.33	0.71	8	0.43	0.17	1.23
7	T3 + foliar application of Biodynamic compost wash of 10 ml lit^{-1} of water	1.33	0.36	0.78	8.3	0.47	0.19	1.28
8	100 % RDF	1.25	0.32	0.66	7.81	0.4	0.16	1.2
SEm±		0.017	0.005	0.009	0.109	0.006	0.002	0.016
C.D at 5 %		0.051	0.016	0.029	0.332	0.017	0.006	0.049

Table 3. Effect of different treatments on total nutrient uptake by rice crop

S. No.	Treatments combination	Nutrient uptake (Kg ha^{-1})					
		Grains			Straw		
		N	P	K	N	P	K
T_1	Control	44.32	11.9	22.16	20.16	8.17	66.67
T_2	Bio dynamic compost 1q ha^{-1} + 50 % RDF	56.05	14.6	29.67	25.57	8.86	79.43
T_3	Bio dynamic compost 1.5 q ha^{-1} + 50 % RDF	60.78	15.07	31.12	27.23	11.17	72.57
T_4	T_2 + Root dipping with Biodynamic compost wash 10 ml lit^{-1} of water	68.09	17.55	36.17	31.99	12.95	92.17
T_5	T_3 + Root dipping with Biodynamic wash 10 ml lit^{-1} of water	74.41	20.6	44.41	37.6	15.53	103.81
T_6	T_2 + foliar application of Biodynamic compost wash of 10 ml lit^{-1} of water	70.2	18.1	38.94	32.74	13.45	100.55
T_7	T_3 + foliar application of Biodynamic compost wash of 10 ml lit^{-1} of water	77.03	20.85	45.17	35.36	15.62	105.28
T_8	100% RDF	67.97	16.35	33.73	28.8	11.55	86.66
SEm±		0.891	0.226	0.47	0.407	0.163	1.178
C.D.		2.728	0.693	1.439	1.246	0.498	3.609

4. CONCLUSION

In conclusion, the study underscores the significant positive impact of organic manure application, particularly in treatment T_7, on nutrient composition and uptake in rice grains and straw. The results emphasize the efficacy of integrated organic manure strategies in enhancing nitrogen, phosphorus, potassium, and protein content. The observed variations in nutrient uptake are linked to increased yield and improved nutrient availability facilitated by organic manure. The competitive uptake of nitrogen and potassium ions further contributes to the overall nutrient enhancement. These findings offer crucial insights for advancing sustainable agricultural practices and optimizing nutrient management in rice cultivation.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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