Integrated Manure and Fertilizer Application: A Pathway to Enhanced Rice Yield and Soil Health

ABSTRACT

A balanced incorporation of both synthetic and organic nutrient sources is necessary to maintain soil fertility. Effective implementation of integrated nutrient management plays a crucial role in preserving soil fertility yet the optimal combination and application rates remain unclear. A research study was carried out in theSoil Science field laboratory of Bangladesh Agricultural University, Mymensingh during the Aman season of 2023 to examine the effect of various manure and fertilizer combinations for optimizing the growth and yield of rice. The experiment employed a Randomized Complete Block Design (RCBD) with 3 replications across eight treatments. The treatment combinations were: T_1(Control), T_2(100% Recommended Fertilizer Dose (RFD)), T_3(75% RFD + Cowdung (CD) @ 5 t ha^{-1}), T_4(75% RFD + Poultry manure (PM) @ 3 t ha^{-1}), T_5(75% RFD + Compost @ 5 t ha^{-1}), T_6(75% RFD + Dhaincha Green Manure (GM) @ 10 t ha^{-1}), T_7(50% RFD +CD @ 2.5 t ha^{-1} +PM @ 1.5 t ha^{-1}) and T_8(50% RFD + Compost @ 2.5 t ha^{-1} + Dhaincha GM 5 t ha^{-1}).The findingsshowed that T_6 markedly improved growth metrics and yield-related traits, leading to a 12.2% rise in grain yield and a 13.24% rise in straw yield compared to T_2, where only chemical fertilizers were applied. This treatment also achieved the greatest macronutrient content and uptake, outperforming other treatments (T_3, T_4, and T_5) with equal nutrient amounts. Therefore, application of 75% recommended fertilizer dose along with dhaincha green manure (10 t ha^{-1}) offers a promising strategy for successfully cultivatingBRRI dhan71 with a good soil health.

Keywords: *Cowdung, Poultry Manure, Dhaincha Green Manure, Rice Yield, BRRI dhan71*

1.INTRODUCTION

Rice serves as a primary dietary component for over half the global population and is cultivated in over a hundred nations, with Asia contributing to 90% of the worldwide yield [1]. Among the three rice seasons, T. Aman rice covers about 40.85% of the total rice area in Bangladesh [2]. Despite its extensive cultivation, rice yield has plateaued, falling short of its production potential, possibly due to imbalanced fertilizer application. The excessive or inappropriate use of chemical fertilizers significantly disrupts nutrient equilibrium in the soil, resulting in substantial nitrogen (N) losses. Specifically, N recovery rates are low (around 30%), and N use efficiency remains at approximately 35% in rice cultivation [3]. Furthermore, the use of chemical fertilizers detrimentally affects crop quality and leads to environmental issues like water contamination, greenhouse gas release, and nitrogen leaching [4].

Conversely, nutrients from organic fertilizers are released gradually over time, allowing for natural plant assimilation and avoiding the risks of over-fertilization, while also reducing soil acidity, supporting soil microorganisms, and enhancing soil structure for better air circulation and nutrient availability[5]. However, employing organic fertilizers without sufficient insight into their characteristics can lead to suboptimal yields or environmental harm due to incorrect application rates [6]. The lower nutrient concentration in organic fertilizers means that larger quantities are needed to effectively provide nutrients for plant growth. In consequence, the exclusion of inorganic fertilizers presents challenges for large-scale agriculture [7].

For sustainable agricultural practices that guarantee high-quality food production, it is essential to employ a balanced mix of organic and inorganic nutrient sources. Reganold and colleagues (1990) emphasized the importance of this approach for enhancing the quality of agricultural output. Similarly, the proposal by

Nambiar (1991) to integrate organic manures and chemical fertilizers is endorsed by Aktar et al. [8], indicating significant potential for stabilizing crop yields and enhancing soil fertility. Despite the known benefits, the optimal combination and application rates of manures and fertilizers remain elusive. This study seeks to illuminate this gap by focusing on BRRI dhan71. This study aimed to investigate the combined impact of manures and fertilizers on the yield and nutrient uptake of BRRI dhan71.

2. MATERIALS AND METHODS

2.1. Experimental Site and Soil

The research was conducted at the Soil Science Field Laboratory of Bangladesh Agricultural University, Mymensingh, located at 24.0°N, 90.0°E, during the Aman season of 2021. The soil, classified under the Sonatala series within the Agro-Ecological Zone (AEZ) of the Old Brahmaputra Floodplain, was characterized as silt loam. The soil analysis revealed a pH of 6.93, indicating slight acidity. Organic carbon content was measured at 1.24%, signifying a moderate level of soil organic matter. Total N was found to be 0.1%, available phosphorus (P) was 6.92 ppm, exchangeable potassium (K) was 6.77 ppm, and available sulfur (S) was 13.89 ppm.

2.2. Experimental Design and Treatments

The present study utilized the modern, high-yielding T. Aman rice variety, BRRI dhan71, developed by the Bangladesh Rice Research Institute (BRRI) in Gazipur. The experiment was laid out following a Randomized Complete Block Design (RCBD), with the experimental plot segmented into three blocks to serve as replications. A total of eight distinct treatments were applied including T_1(Control), T_2(100% Recommended Fertilizer Dose (RFD)), T_3(75% RFD + Cowdung (CD) @ 5 t ha^{-1}), T_4(75% RFD + Poultry manure (PM) @ 3 t ha^{-1}), T_5(75% RFD + Compost @ 5 t ha^{-1}), T_6(75% RFD + Dhaincha Green Manure (GM) @ 10 t ha^{-1}), T_7(50% RFD +CD @ 2.5 t ha^{-1} +PM @ 1.5 t ha^{-1}) and T_8(50% RFD + Compost @ 2.5 t ha^{-1} + Dhaincha GM 5 t ha^{-1}). Each experimental plot measured 4 m x 2.5 m, with 30 cm aisles separating them, and a 1 m wide drain delineating the blocks.

Table 1. Nutrient content of manures

	Nutrient contents			
Manure	%N	%P	%K	%S
Cowdung	0.57	0.47	0.69	0.23
Compost	0.89	0.30	0.45	0.46
Poultry manure	1.18	1.13	0.81	0.35
Dhaicha GM	3.30	0.70	1.30	0.20

2.3. Crop Management

For Aman rice cultivation, the prescribed fertilizer rates consist of 90 kg N, 8 kg P, 50 kg K, 4 kg S, and 1 kg Zn per hectare. These doses were further adjusted according to various treatments. A week before transplanting, organic fertilizers were introduced into the soil. One day in advance of transplanting, the entirety of Triple Super Phosphate (TSP), Muriate of Potash (MOP), Gypsum, and Zinc Sulphate doses were applied to the soil. Urea was strategically divided into three equal portions: urea was split thrice: 15 DAT (Day After Transplanting), 35 DAT (maximum tillering), and after 60 DAT (panicle initiation).Seedlings that had reached thirty days of age were attentively removed from the nursery bed and transplanted into the experimental plots. A spacing of 20 cm × 20 cm was maintained, with three seedlings carefully arranged in each hill. Essential intercultural practices, including timely moisture managementand regular weeding, were conducted to maintain optimal growing conditions. The crop was fortunate to experience no significant insect pests or disease infestations throughout the cultivation period. Upon reaching full maturity, 1 m^2 was harvested from each plot, with the produce being individually bundled to facilitate precise yield assessment.

2.4. Data Collection on Plant Growth Parameters

Yield measurements were carefully conducted, with grain yield adjusted to a 14% moisture basis and straw yield evaluated based on sun-dried conditions. Data collection was conducted for each plot to ensure precision. Key yield components—plant height, panicle length, number of effective tillers per hill, grains per panicle, and 1000-grain weight.

2.5. Analysis of Soil Samples

The soil analysis at the beginning and end of the study involved assessing physical and chemical properties using established methods. Organic matter was determined by the Walkley and Black method [9], soil pH was measured at a 1:2.5 soil-water ratio using a glass electrode pH meter [10], total N was quantified by the semi-micro Kjeldahl method[11], available P was evaluated using the Olsen method [12], exchangeable K was assessed by Flame Photometry after extraction with 1N NH_4OAc at pH 7.0 [13], available S was determined by turbidity measurement in a spectrophotometer [14].

2.6. Analysis of Grain and Straw Samples

The grain and straw samples were analyzed for their N, P, K, and S contents adhering to standard laboratory procedures. To quantify the nutrient uptake by the grain and straw, the following formula was employed as per (Malika et al., n.d.) [15]:

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

2.7. Statistical Analysis

The statistical analysis of the data involved an F-test to assess treatment effects. Subsequently, the Tukey HSD Test at a 5% level was employed to determine mean differences, with rankings indicated by letters.The data analysis was conducted using the R programming language.

3. RESULT

3.1. Yield Contributing Characters of Rice

The application of both manures and chemical fertilizers had a marked effect on yield-contributing factors of BRRI dhan71 (Fig. 1). T_6 displayed the tallest plants (111.58 cm) and the most effective tillers (14.22), with T_7 and T_4 exhibiting statistically equivalent performance. The control treatment yielded the shortest plants (82.45 cm) and the fewest effective tillers (8.01). Panicle length was greatest in T_6 (25.57 cm), with the control showing the least (18.96 cm). Similarly, T_6 produced the most grains per panicle (151.09), a count comparable to T_4 and T_7, while the control had the lowest (98.85). The 1000-grain weight was also highest in T_6 (24.20 g) compared to the control (21.90 g).

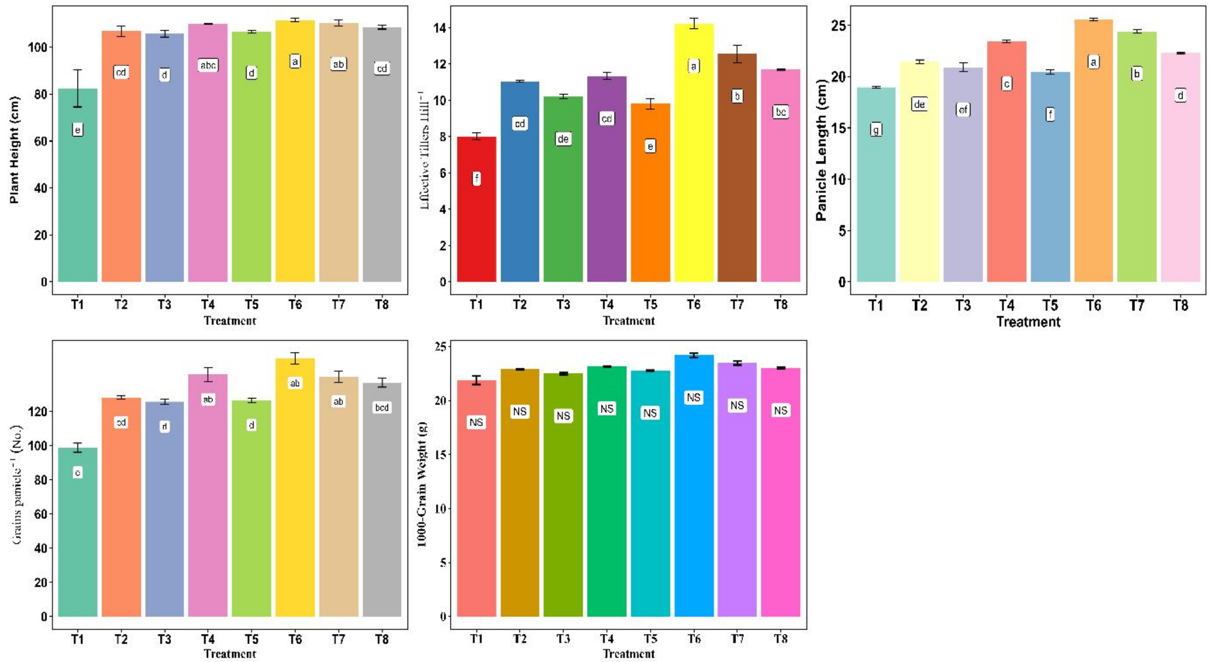

Fig. 1. Yield contributing characters of BRRI dhan71 as influenced by organic and inorganic fertilizers*(Data are mean±SE, n=3)*

3.2. Yield Parameters of Rice

The integration of manures with fertilizers led to marked yield enhancements, as depicted in Fig. 2. Grain yield varied from 3.07 t ha^{-1} in T_1 to 5.61 t ha^{-1} in T_6. The results showed that T_6 achieved a 12.2% increase in grain yield and a 13.24% increase in straw yield compared to T_2, where only chemical fertilizers were applied. Additionally, yield was enhanced in T_6 compared to T_3, T_4, and T_5, which received similar amounts of chemical fertilizers.

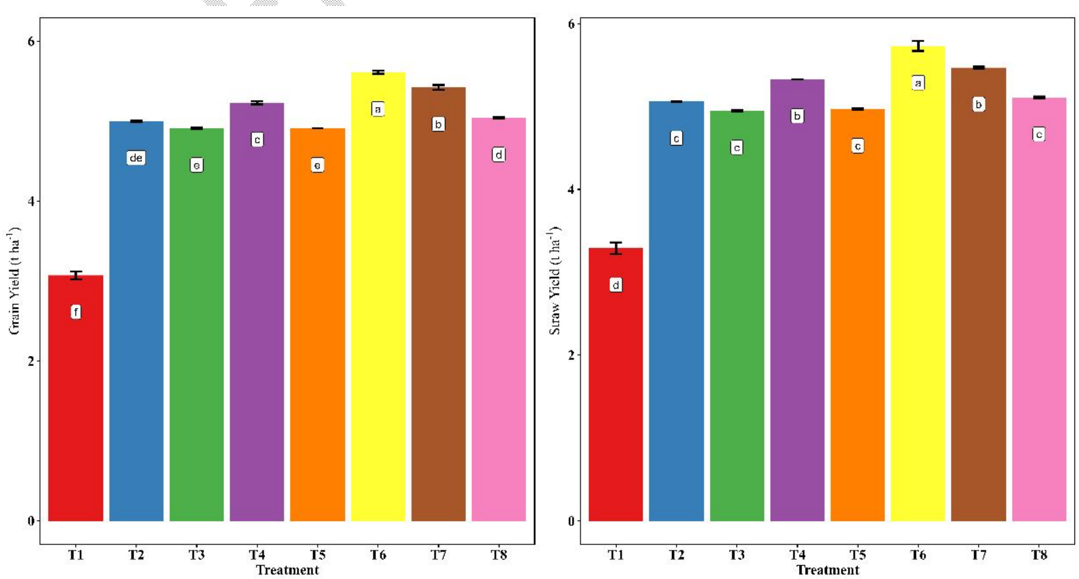

Fig. 2. Grain and straw yield variation in rice due to various treatment combinations *(Data are mean±SE, n=3).*

3.3. Nutritional CompositionGrain and Straw

Both grain and straw nutrient levels of BRRI dhan71 were significantly influenced by the simultaneous use of organic and inorganic fertilizers (Fig. 3). The grain exhibited N levels spanning from 0.97% to 1.29%, with the peak concentration found in T_6, which was comparable to treatments T_4, T_7, and T_8. Straw N level also peaked in T_6, ranging from 0.52% to 0.84%. P content saw a similar trend, with grain P between 0.09% and 0.21%, and straw P content from 0.09% to 0.22%, both highest in T_6.The amount of K in grain was notably higher in T_6 at 1.50%, with straw K content reaching up to 4.68%. Lastly, S content in the grain and straw of T_6 was the greatest, measuring at 0.07% and 0.10%, respectively.

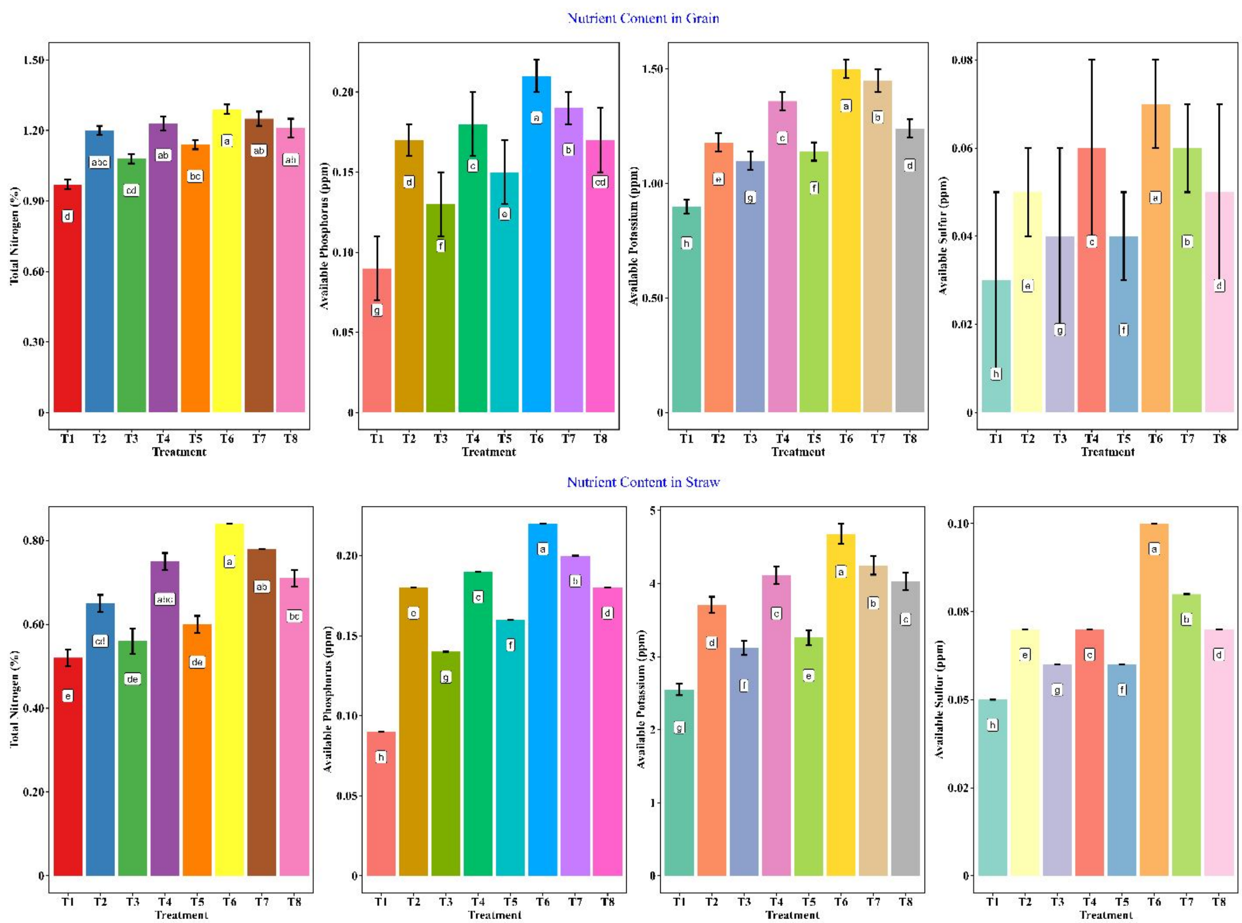

Fig. 3. Nutritional composition of rice grain and straw as affected by organic and inorganic fertilizers*(Data are mean±SE, n=3)*

3.4. Grain and Straw Nutrient Assimilation in Rice

The uptake of macronutrients by grain and strawof BRRI dhan71 were significantly affected by various treatments (Fig. 4). Treatment T_6 consistently resulted in the highest nutrient uptake across all elements.

Treatment T_6 resulted in peak nutrient absorption, with N levels reaching 62.19 kg ha^{-1} in the grain and 16.69 kg ha^{-1} in the straw. P assimilation was recorded at 10.33 kg ha^{-1} for the grain, complemented by 4.37 kg ha^{-1} in the straw. K uptake showed a notable rise, with grain and straw values at 72.39 kg ha^{-1} and 93.77 kg ha^{-1}, respectively. Lastly, S uptake was measured at 1.99 kg ha^{-1} for the grain and 1.91 kg ha^{-1} for the straw. Conversely, the control treatment (T_1) exhibited minimal nutrient absorption. Notably, the uptake by straw was higher than that by grain forK, while grain uptake was more pronounced for N, P, and S.

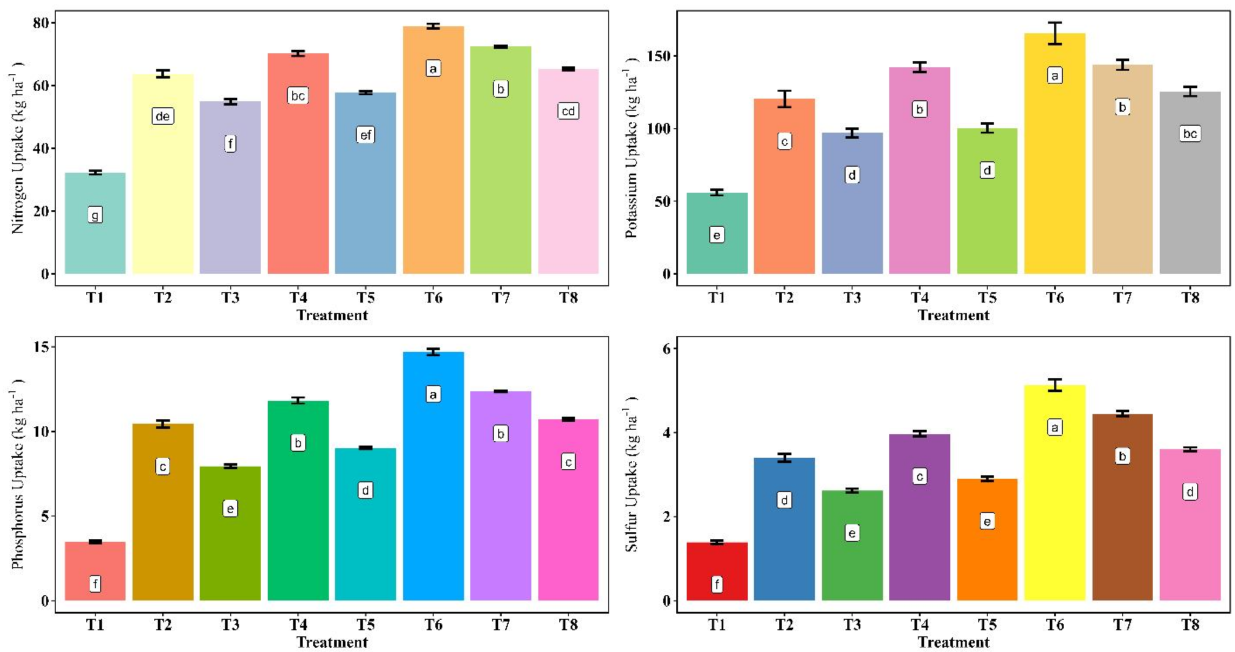

Fig. 4. Nutrient uptake in rice grain and straw influenced by organic and inorganic fertilizers*(Data are mean±SE, n=3)*

3.5. Chemical Properties of Post-Harvest Soils

Significant variations in soil nutrient content were observed across treatments.N ranged from 0.09% in T_1 to 0.18% in T_6, a 20% increase over T_2, which only received chemical fertilizers. T_7 had the second-highest N content, showing a 13.33% increase over T_2, statistically identical to T_4.P content varied from 6.66 ppm (T_1) to 11.28 ppm (T_6), with T_6 displaying a 44.42% increase and T_7 showing a 33.31% increase over T_2, both similar to T_4.K ranged from 6.33 ppm in T_1 to 23.28 ppm in T_6, a 44.42% increase over T_2, followed by T_4 with 19.10 ppm, an 18.49% increase over T_2. S varied from 0.053 ppm (T_1) to 0.096 ppm (T_6), a 43.28% increase over T_2, with T_7 having the second-highest S content, also statistically similar to T_4. Overall, treatment T_6 significantly enhanced post-harvest soil nutrient levels compared to control and other treatments.

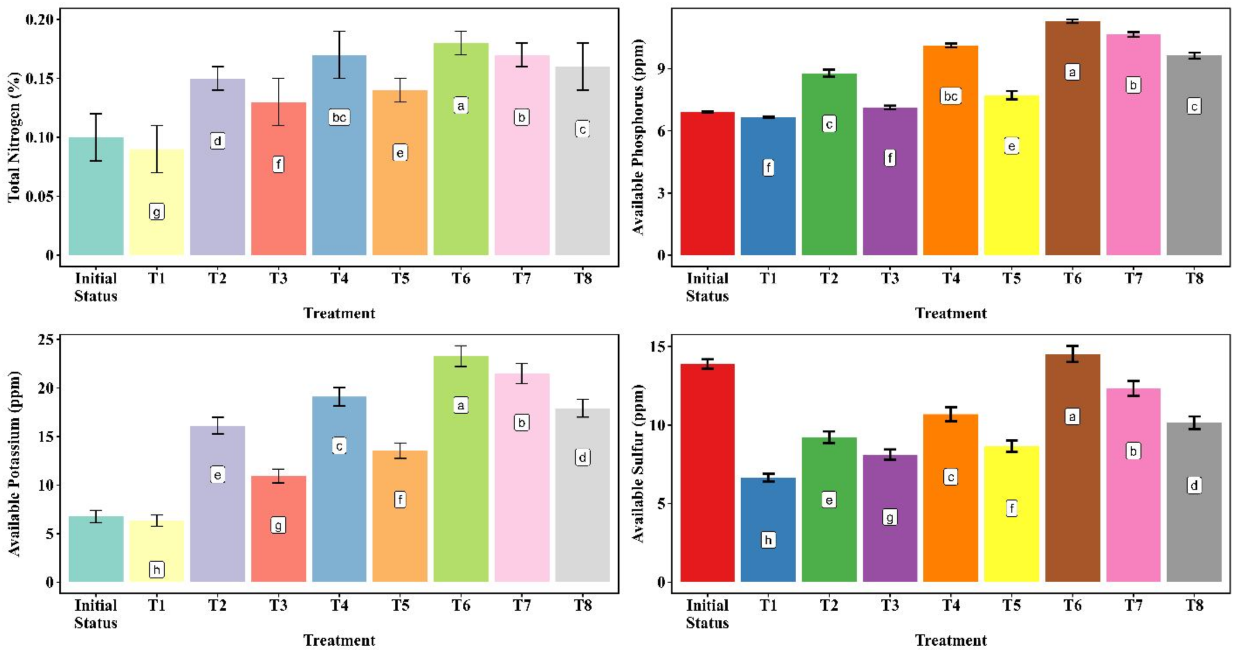

Fig. 5. Chemical properties of post-harvest soils *(Data are mean±SE, n=3)*

3.5.1 Organic Carbon and Soil pH

The post-harvest soils exhibited a range of soil organic carbon (SOC) content, varying from 1.20% to 1.32% (Fig. 6). Among the treatments, T_3had the highestSOC content at 1.32%, resulting in a significant 9.78% increase in total SOC compared to the control (T_1). Additionally, T_4 showed the second-highest SOC content (1.26%), contributing to a 6.52% increase in total SOC.Regarding pH, the post-harvest soils displayed a range from 6.71 to 7.70. Notably, T_7 exhibited the highest pH value of 7.70, while the lowest pH was observed in T_2.

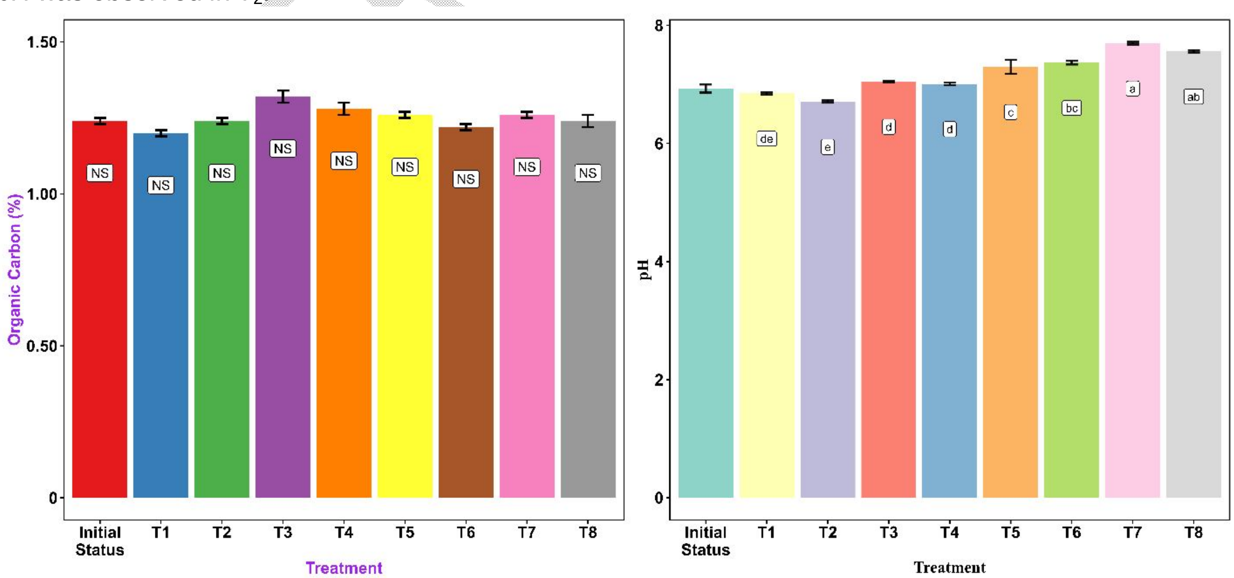

Fig. 6. Organic carbon and pH of post-harvest soils*(Data are mean±SE, n=3).*

3.6. Correlation Matrix among Growth Parameters, YieldParameters, and Chemical Properties of Soil

The heatmap (Fig.7) illustrates the Pearson correlation coefficients between various yield-contributing characters and soil chemical properties. The color gradient from green to red represents the correlation strength, with significant correlations marked by asterisks. Grain yield demonstrates a strong, statistically meaningful positive correlation with plant height, total N, and grains per panicle, indicating these factors are crucial in influencing yield. Other strong correlations include plant height with total Nand panicle length. Conversely, soil pH exhibits weak or non-significant correlations with most variables, such as plant height and total N, suggesting a limited impact on yield components.

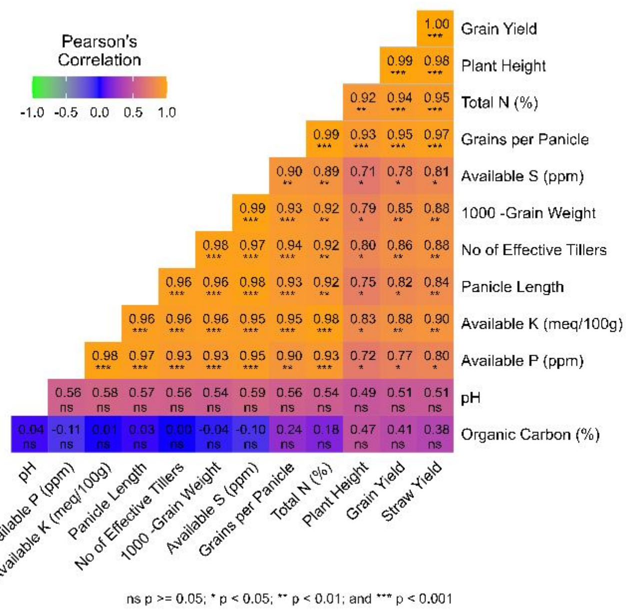

Fig. 7. Pearson's correlation between yield-contributing traits and soil chemical properties.*(Data are mean±SE, n=3)*

4. DISCUSSION

The experimental data showed a substantial enhancement in the yield-contributing traits of rice when subjected to synergistic utilization of manures and fertilizers, consistent with the findings of Islam et al. [16], Liton Mia et al. [17] and Singh et al. [18]. This enhancement likely results from soil biochemical characteristics and microbial communities, enabling plant roots to better compete with nutrient loss mechanisms, as supported by Iqbal et al. [19] and Naher & Poul [20]. The concurrent use did not significantly alter the 1000-grain weight, corroborating Islam et al. [16] suggesting that the factor influencing grain size remained unaffected, possibly due to genetic constraints or already optimal conditions. Additionally, the correlation heatmap revealed a strong positive correlation between the yield-contributing features and total N, which increased during integrated nutrient management. This highlights the pivotal role of nitrogen in enhancing rice yield characteristics, as the increased total N likely facilitated better vegetative growth, tillering, grain formation, and grain filling, contributing significantly to the observed yield improvements consistent with Shrestha et al. [21].Dhaincha GM, when combined with NPKS fertilizers, resulted in superior growth factors compared to other manures. This improvement may be attributed to the incorporation of green manures into the soil, which enhances soil N, P_2O_5, andK_2O content, along with increased mineralizable N, following the findings of Hlaing et al. [22].

The treatment T_6, which combined dhainchaGM with chemical fertilizers, yielded the highest grain and straw output. Previous research indicated that incorporating dhaincha with varying chemical fertilizer doses boosted rice grain yields by 32% to 77% over the control (Ehsan et al. [23]; Noor A-Jannat et al. [24]), while in India, GM application increased high-yielding rice varieties' yields from 0.65 to 3.1 t ha^{-1} [25].The observed enhancement likely results from increased total N in the soil, facilitated by GM crops' ability for nodule formation and N fixation. GM crops also contribute to higher organic matter production. These beneficial effects stem from the mineralization of soil nutrients derived from organic matter, aligning with Bar et al. [26] and Mahey et al. [27]. Furthermore, GM crops positively impact soil structure, texture, water-holding capacity, nutrient retention, plant fertilizer use, and microbial populations, consistent with Hlaing et al. [22]. In a similar vein, prior research by Islam et al. [28] supports the favorable influence of GM crops on N concentrations.

The synergistic interaction of manure and fertilizer notably affected the uptake of macronutrients viz. N, P, K, andS by the plants. These results encompass both the total nutrient uptake and their available forms in the soil, validating the findings of Kaisar et al. [29], Khan et al. [30], and Sohel et al. [31].The increased nutrient uptake can be attributed to the enhanced nutrient availability from both the mineralization of organic matter and the immediate nutrient supply from fertilizers, which together improve the overall nutrient absorption efficiency of the rice plants.T_6 exhibited the highest NPKS content and uptake, significantly surpassing other treatments. This effect may be due to the lower C:N ratio in GM crops, resulting in higher mineralizable N. As a consequence, GM crops can enhance the content of N, P, and K, in accordance with Hlaing et al. [22].

5. CONCLUSION

The experimental findings underscore the benefits of integrating organic manures with chemical fertilizers, which significantly enhanced the growth and yield parametersof rice compared to the exclusive use of chemical fertilizers. Specifically, when used alongside chemical fertilizers (T_6), Dhaincha GM notably improved yield-contributing factors, as well as grain and straw yields of rice. Therefore,itcan be recommended that T_6can achieve maximum rice yield, effectively offsetting a 25% reduction in chemical fertilizers.

9. REFERENCES

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