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

ABSTRACT

A research study was carried out in theSoil Science field laboratory of Bangladesh Agricultural University, Mymensingh during the Aman season of 2021to 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}).Statistical analysis conducted using R programming revealed thatT_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.This approach offers farmers a cost-effective method to boost productivity and support long-term soil fertility, and policymakers could promote it to enhance agricultural sustainability.

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.

Table 1 Chemical characteristics of initial soil

Characteristics	Value
pH (soil: water 1:2.5)	6.93
OC (%)	1.24
Total N (%)	0.1
Available P (ppm)	6.92
Exchangeable K (ppm)	6.77
Available S (ppm)	13.89
Available Zinc (ppm)	0.90
CEC (meq 100 g^{-1} soil)	15
EC (µS cm^{-1})	348

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.

2.3 Collection of Different Manures and Their Chemical Composition

CD and PM were obtained from the dairy and poultry farms at Bangladesh Agricultural University, Mymensingh-2202. The materials underwent fermentation for 6 months (CD) and 1 month (PM) in piles before use. To prepare the compost for the experiment, these fermented materials were layered in a composting pit, with proper aeration and moisture levels maintained. The compost was regularly turned to enhance microbial activity and accelerate decomposition. After 3-4 months, the fully decomposed compost was sieved and used as a soil amendment in the field. Additionally, Dhaincha was collected from the Agronomy field at Bangladesh Agricultural University, Mymensingh-2202.

Table 2. 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

2.4. 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.

2.5. 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.

2.6. 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].

2.7. 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 (Godebo et al.) [15]:

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

2.8. 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 and Appendix 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).

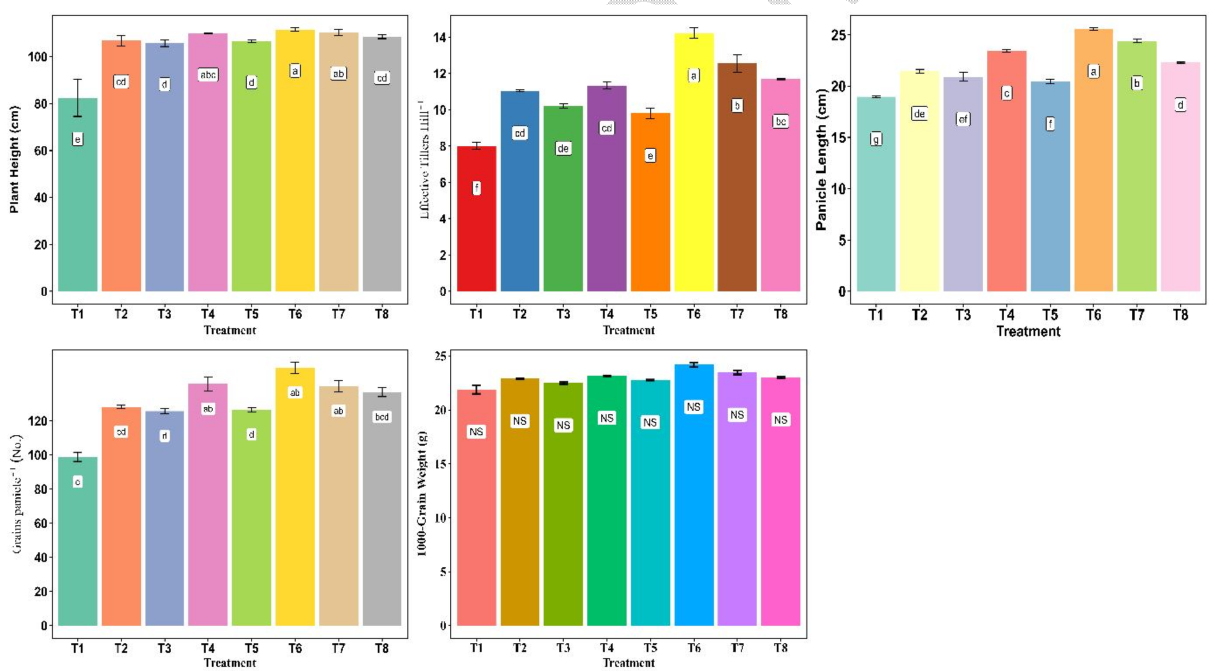

Fig. 1. Yield contributing characters of BRRI dhan71 as influenced by organic and inorganic fertilizers*(Data are mean±SE, n=3)*

3.2. Yield Parameters of Rice

The integration of manures with fertilizers led to marked yield enhancements, as depicted in Fig. 2. and Appendix 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.

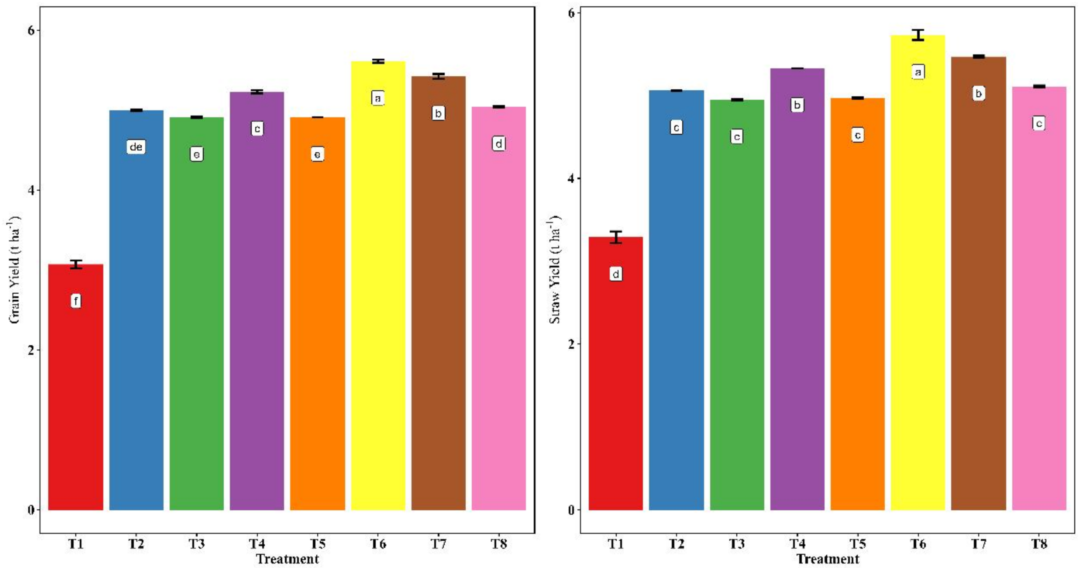

Fig. 2. Grain and straw yield variation in rice due to various treatment combinations *(Data are mean±SE, n=3).*

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.

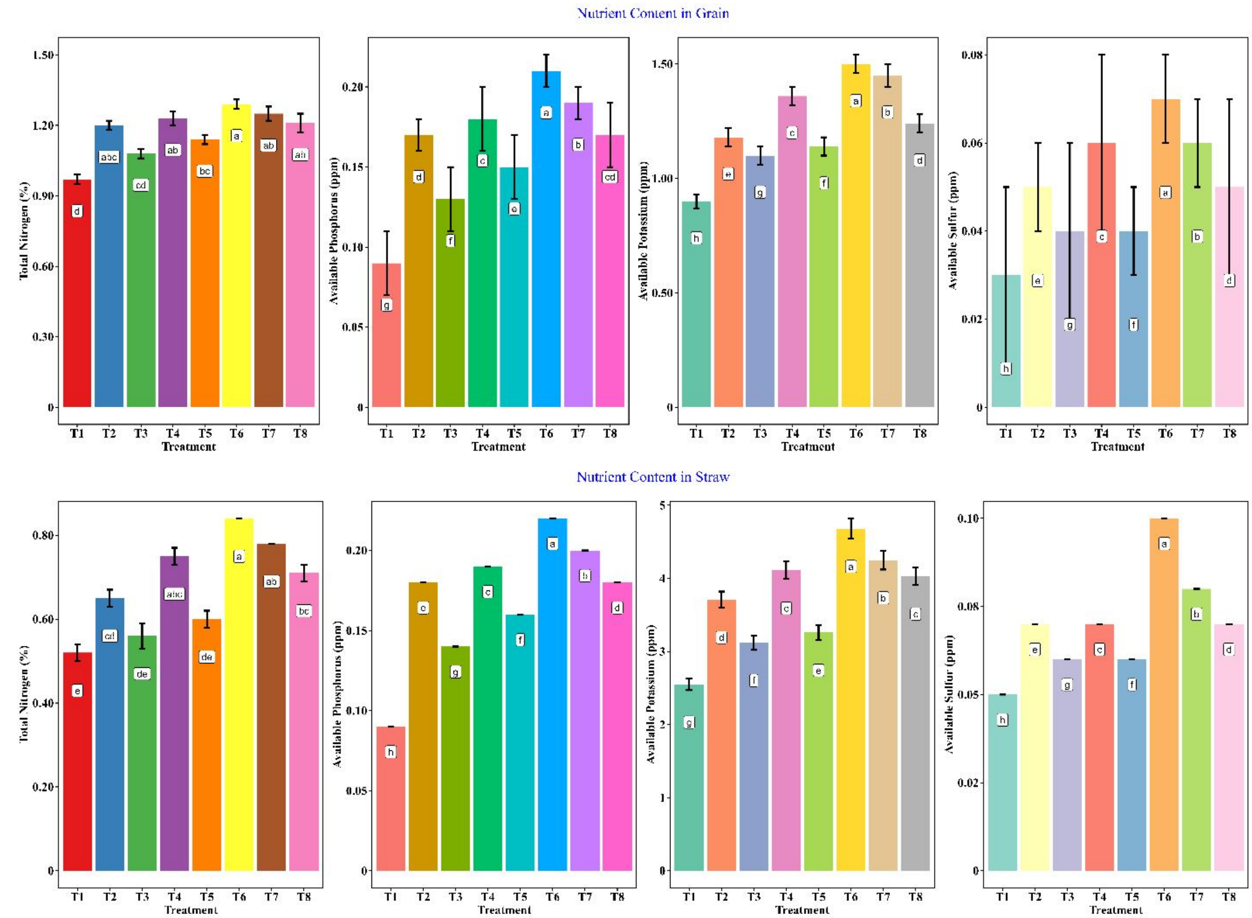

Fig. 3. Nutritional composition of rice grain and straw as affected by organic and inorganic fertilizers*(Data are mean±SE, n=3)*

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.

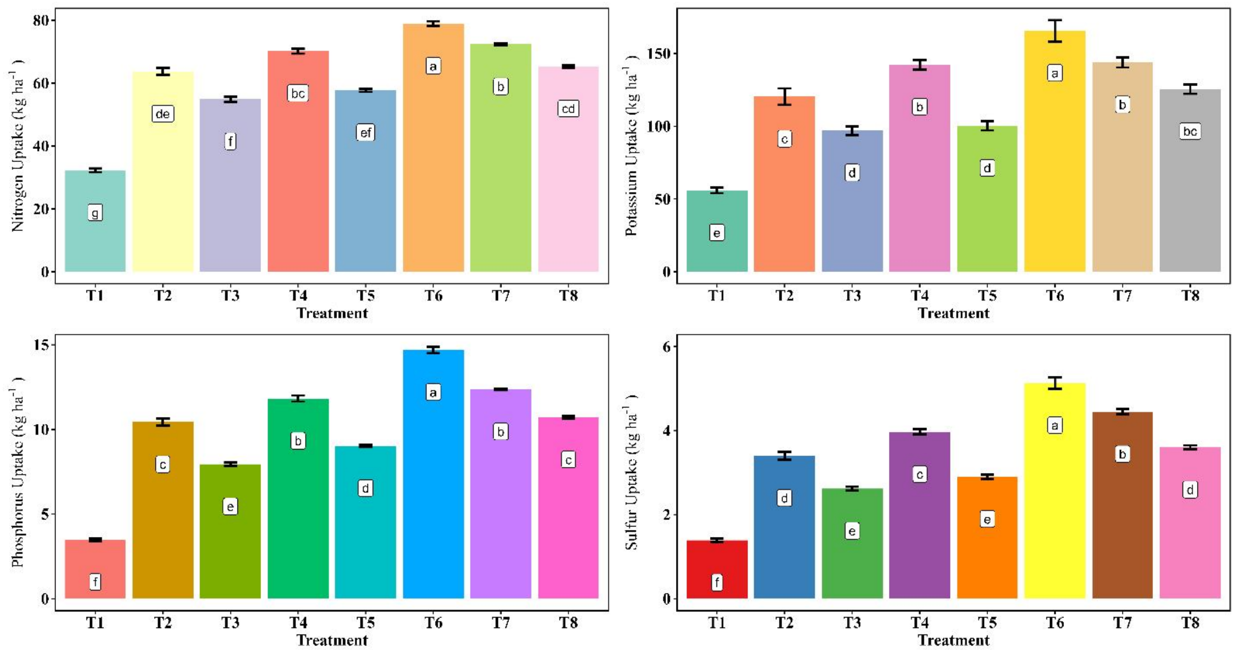

Fig. 4. Nutrient uptake in rice grain and straw influenced by organic and inorganic fertilizers*(Data are mean±SE, n=3)*

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.

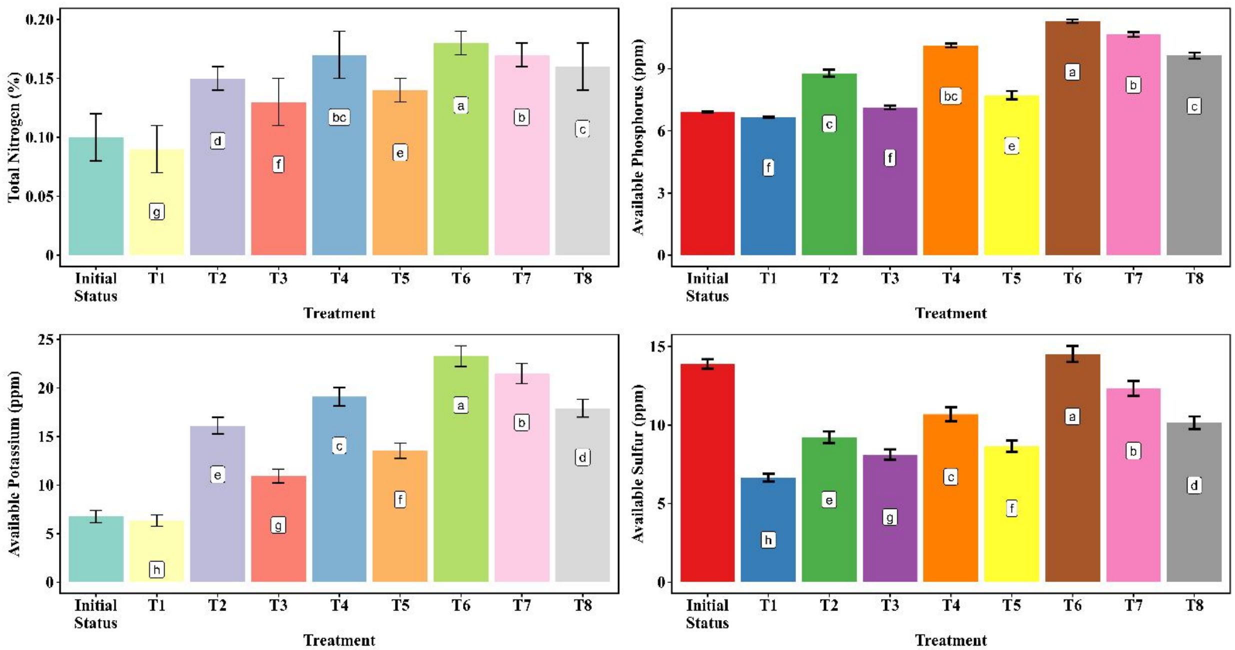

Fig. 5. Chemical properties of post-harvest soils *(Data are mean±SE, n=3)*

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.

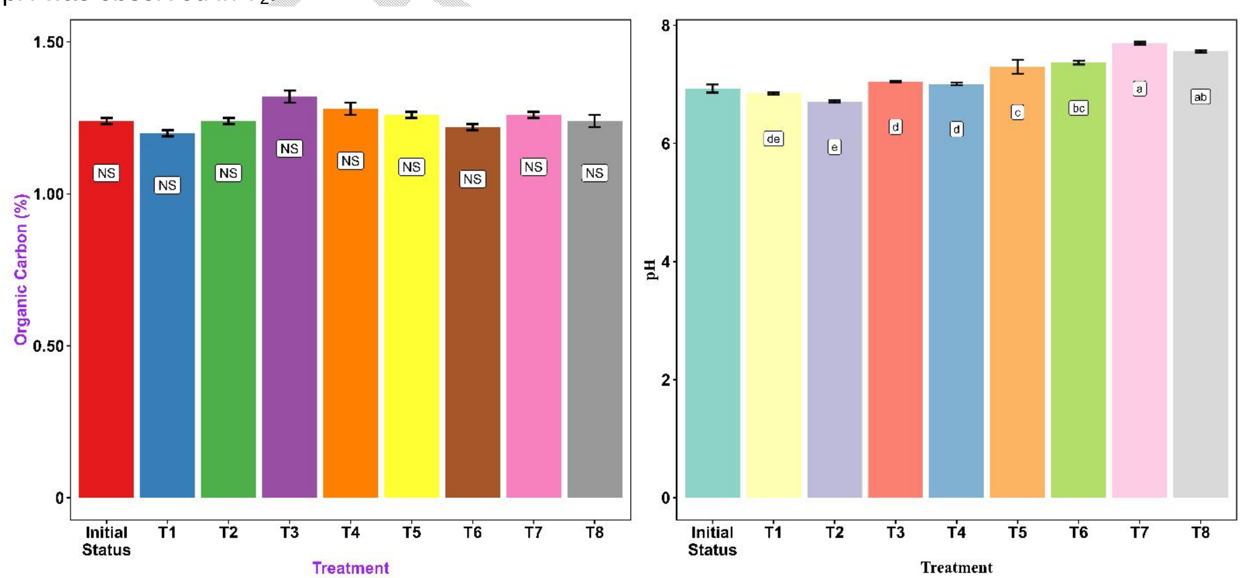

Fig. 6. Organic carbon and pH of post-harvest soils*(Data are mean±SE, n=3).*

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.

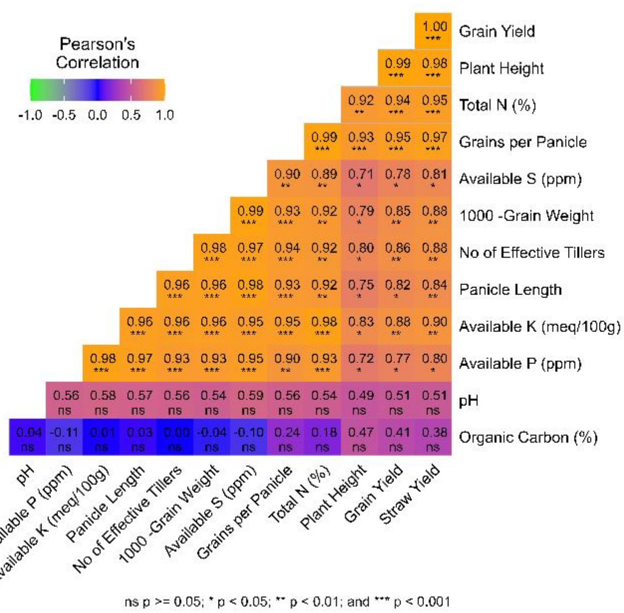

Fig. 7. Pearson's correlation between yield-contributing traits and soil chemical properties.*(Data are mean±SE, n=3)*

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 Liton Mia et al. [16] and Singh et al. [17]. 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. [18]. The concurrent use did not significantly alter the 1000-grain weight, corroborating Moe et al. [3] 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. [19].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. [20].

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. [21]; Noor A-Jannat et al. [22]), while in India, GM application increased high-yielding rice varieties' yields from 0.65 to 3.1 t ha^{-1} [23].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 Mahey et al. [24]. GM crops positively impact soil structure, texture, water-holding capacity, nutrient retention, plant fertilizer use, and microbial populations, as well as nitrogen (N) concentrations. These findings are consistent with the research of Hlaing et al. [20].

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. [25] and Khan et al. [26].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. [20].

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. Future research should explore the long-term effects of integrated nutrient management on soil health and crop sustainability, including impacts on soil nutrient dynamics and environmental outcomes over multiple growing seasons.

6. Disclaimer (Artificial Intelligence):

Author(s) hereby declare that NO generative AI technologies have been used during the writing or editing of the manuscript.

7. REFERENCES

1. Fukagawa NK, Ziska LH. Rice: Importance for Global Nutrition. J NutrSciVitaminol (Tokyo). 2019;65(Supplement):S2-S3. doi: 10.3177/jnsv.65.S2. PMID: 31619630.
2. Bangladesh Rice Research Institute. (2023). *About BRRI: A Very Short Introduction* (p. 15). Retrieved from https://brri.portal.gov.bd/sites/default/files/files/brri.portal.gov.bd/page/6af533b2_278e_4e30_9e27_0626f3448845/2024-02-12-05-24-3785a1a0e574fd36c6a543e2839d6052.pdf
3. Moe, K., Moh, S. M., Htwe, A. Z., Kajihara, Y., & Yamakawa, T. (2019). Effects of Integrated Organic and Inorganic Fertilizers on Yield and Growth Parameters of Rice Varieties. *Rice Science*, *26*(5), 309–318. https://doi.org/10.1016/J.RSCI.2019.08.005

4. Wan, L. J., Tian, Y., He, M., Zheng, Y. Q., Lyu, Q., Xie, R. J., Ma, Y. Y., Deng, L., & Yi, S. L. (2021). Effects of chemical fertilizer combined with organic fertilizer application on soil properties, citrus growth physiology, and yield. *Agriculture (Switzerland)*, *11*(12). https://doi.org/10.3390/agriculture11121207
5. Assefa, S. (2019). The Principal Role of Organic Fertilizer on Soil Properties and Agricultural Productivity -A Review. *Agricultural Research & Technology: Open Access Journal*, *22*(2). https://doi.org/10.19080/artoaj.2019.22.556192
6. El-Sayed, A.-F. M. (2020). Semi-intensive culture. In *Tilapia Culture* (pp. 69–101). Elsevier. https://doi.org/10.1016/B978-0-12-816509-6.00005-7
7. Roba, T. B. (2018). Review on: The Effect of Mixing Organic and Inorganic Fertilizer on Productivity and Soil Fertility. *Journal*, *5*, 4618. https://doi.org/10.4236/oalib.1104618
8. Aktar, S., Islam, M., Hossain, M., Akter, H., Maula, S., & Hossain, S. (2018). Effects of municipal solid waste compost and fertilizers on the biomass production and yield of BRRI dhan 50. *Progressive Agriculture*, *29*(2), 82–90. https://doi.org/10.3329/pa.v29i2.38291
9. Walkley, A., & Black, I. A. (1934). An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science*, 37(1), 29-38.
10. Michael, A. M. (1965). Determination of soil pH by glass electrode pH meter. *Journal of Agricultural Science*, 65(2), 143-145.
11. Bremner, J. M., & Mulvaney, C. S. (1982). Nitrogen-total. In A. L. Page, R. H. Miller, & D. R. Keeney (Eds.), *Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties* (pp. 595-624). American Society of Agronomy, Soil Science Society of America.
12. Olsen, S. R., Cole, C. V., Watanabe, F. S., & Dean, L. A. (1954). Estimation of available phosphorus in soils by extraction with sodium bicarbonate. *U.S. Department of Agriculture Circular*, (939).
13. Knudsen, D., Peterson, G. A., & Pratt, P. F. (1982). Lithium, sodium, and potassium. In A. L. Page, R. H. Miller, & D. R. Keeney (Eds.), *Methods of Soil Analysis. Part 2. Chemical and Microbiological Properties* (pp. 225-246). American Society of Agronomy, Soil Science Society of America.
14. Williams, C. H., & Steinbergs, A. (1959). Soil sulphur fractions as chemical indices of available sulphur in some Australian soils. *Australian Journal of Agricultural Research*, 10(3), 340-352.
15. Godebo, T., Laekemariam, F., & Loha, G. (2021). Nutrient uptake, use efficiency and productivity of bread wheat (Triticum aestivum L.) as affected by nitrogen and potassium fertilizer in KeddidaGamelaWoreda, Southern Ethiopia. *Environmental Systems Research*, *10*(1), 12. https://doi.org/10.1186/s40068-020-00210-4
16. Liton Mia, M., Begum, M., Neshe, F. A., & Monira, S. (2023). *EFFECT OF INTEGRATED NUTRIENT MANAGEMENT ON THE YIELD PERFORMANCE OF INBRED AND HYBRID RICE. International Journal of Sustainable Crop Production*. www.ggfjournals.com
17. Singh, A., Singh, N. K., Sushma, H. A., Jayhoon, A. S., Ravinder, Raghavan, M., Pandey, A., & Singh, K. V. (2023). Effects of Integrated Use of Organic Manure and Bio-fertilisers on Crop Productivity: A Case Study of Rice (Oryza sativa L.) Crop. *International Journal of Environment and Climate Change*, *13*(8), 820–825.https://doi.org/10.9734/ijecc/2023/v13i82016
18. Iqbal, A., Ali, I., Yuan, P., Khan, R., Liang, H., Wei, S., & Jiang, L. (2022). Combined Application of Manure and Chemical Fertilizers Alters Soil Environmental Variables and Improves Soil Fungal Community Composition and Rice Grain Yield. *Frontiers in Microbiology*, *13*.https://doi.org/10.3389/fmicb.2022.856355
19. Shrestha, J., Karki, T. B., & Hossain, M. A. (2022). Application of Nitrogenous Fertilizer in Rice Production: A Review. *Journal of Nepal Agricultural Research Council*, *8*, 16–26.https://doi.org/10.3126/jnarc.v8i.44815
20. Hlaing, T., Moe, K., Kyaw, E., Ngwe, K., Hlaing, M., & Oo, H. (2024). Assessment of Green Manure Crops and their Impacts on Mineralizable Nitrogen and Changes of Nutrient Contents in the Soil. *Asian Soil Research Journal*, *8*, 29–38. https://doi.org/10.9734/asrj/2024/v8i2149

21. Ehsan, S., Niaz, A., Saleem, I. & Mehmood, K. (2014). Substitution of major nutrient requirement of rice wheat cropping system through Sesbania green manuring. Sci.Agri., 8(3): 99-102. DOI:10.15192/PSCP.SA.2014.4.3.99102
22. Noor-A-Jannat, Ahmed, S., Abuyusuf, M., Hassan, M.Z., Lipi, N.J. & Biswas, K.K. (2015). Nitrogen fertilizer after green manuring on the yield of T. Aman rice. American Res.Thoughts, 1: 2898-2909.
23. Singh, Y., Khind, C.S. & Singh, B. (1991). Efficient management of leguminous green manures in wetland rice. *Adv.Agron*., 45: 135 189.
24. Mahey, H. K., Sharma, K., Singh, A., Rampal, V. K., & Kaushik, P. (2024). *Green Manuring Crop Plants: Harnessing Natural Processes to Enhance Soil Health and Promote Sustainable Agricultural Practices*. https://doi.org/10.20944/preprints202406.0340.v1
25. Kaisar, N., Moslehuddin, A. Z. Md., Tarafder, Md. M. A., & Rahman, Md. S. (2020). Combined Effects of Nutrient Management on Nutrient Content and Uptake of Transplant Aus Rice (BRRI Dhan48). *Agricultural Science*, *2*(1), p282. https://doi.org/10.30560/as.v2n1p282
26. Khan, M. A., Rabin, M. H., & Barman, A. (2018). *Effect of Fertilizer and Manure on the Change of Nutrient Availability of T. Aman Rice in Different Soil*. https://doi.org/10.9790/2380-1105021721

8. APPENDIX

Appendix 1 Yield contributing characters of BRRI dhan71 as influenced by different treatments (Data are Mean±SE)

Treatment	Plant height (cm)	Effective tillers hill^{-1} (No.)	Panicle length (cm)	Grains panicle^{-1} (No.)	1000-grain weight (g)
T_1	82.45±1.58e	8.01±0.20f	18.96±0.07g	98.85±2.61e	21.90±0.40
T_2	106.92±0.45cd	11.05±0.05cd	21.44±0.20de	128.22±0.91cd	22.90±0.00
T_3	105.75±0.28d	10.21±0.11de	20.90±0.43ef	125.76±1.40d	22.50±0.10
T_4	109.88±0.03abc	11.33±0.19cd	23.44±0.15c	141.66±4.19ab	23.17±0.03
T_5	106.60±0.10d	9.81±0.29e	20.44±0.20f	126.59±1.31d	22.77±0.03
T_6	111.58±0.14a	14.22±0.29a	25.57±0.10a	151.09±3.22a	24.20±0.21
T_7	110.36±0.25ab	12.56±0.48b	24.41±0.15b	140.41±3.46ab	23.47±0.18
T_8	108.54±0.16bcd	11.69±0.03bc	22.31±0.07d	136.90±2.65bcd	23.00±0.06
CV%	1.00	3.55	1.41	3.39	1.05
Level of Significance	**	**	**	**	NS

** Significant at 1% level of probability, *Significant at 5% level of probability
Figure (s) having common letter (s) in a column do not differ significantly at 5 % level of significance by Tukey's HSD.
CV (%) = Coefficient of variation

Appendix 2 Integrated effect of manures and fertilizers on grain and straw yields of BRRI dhan71 (Data are Mean±SE)

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1	3.07±0.05f	3.29±0.07d
T_2	5.00±0.01de	5.06±0.00c
T_3	4.91±0.01e	4.95±0.01c
T_4	5.23±0.02c	5.33±0.00b
T_5	4.91±0.00e	4.97±0.01c
T_6	5.61±0.02a	5.73±0.06a
T_7	5.42±0.03b	5.47±0.01b
T_8	5.04±0.01d	5.11±0.01c
CV%	0.92	1.24
Level of Significance	**	**

** Significant at 1% level of probability, *Significant at 5% level of probability
Figure (s) having common letter (s) in a column do not differ significantly at 5 % level of significance by Tukey's HSD.
CV (%) = Coefficient of variation