

INCREASED SOIL FERTILITY AND RICE YIELD USING ORGANIC MATTER AMENDMENTS IN BANGLADESH

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Abstract

Organic matter amendments significantly improve soil fertility and increase rice yields. The study was conducted to investigate the effects of integrating organic amendments with chemical fertilizers on soil fertility and yields of T. aman and Boro rice. Field experiments were conducted, employing five treatments: T₁: Native soil fertility (Control), T₂: 100% chemical fertilizers (100% CF), T₃: CF+2.5 t ha⁻¹ rice straw (CF+RS, Integrated Plant Nutrient System (IPNS)), T₄: CF+4 t ha⁻¹ cowdung (CF+CD (IPNS)), T₅: CF+3 t ha⁻¹ poultry manure (CF+PM (IPNS)). The results indicated that integrating organic amendments with reduced rate of chemical fertilizers significantly improved rice yield and soil fertility compared to the only application of chemical fertilizers. The treatment T₄, incorporating cowdung with chemical fertilizers exhibited the highest grain yield, surpassing even the 100% chemical fertilizer treatment. This superior performance may be attributed to the soil fertility parameters, including increased organic matter content and nutrient availability (N, P, K, S). Furthermore, all the treatments of organic amendments demonstrated comparatively higher yields than the 100% chemical fertilizer alone, suggesting a viable strategy for reducing reliance on chemical fertilizers and promoting sustainable rice production. This study underscores the crucial role of organic matter in maintaining soil health and productivity, advocating for the adoption of integrated nutrient management practices to ensure both agricultural sustainability and environmental protection in Bangladesh.

Key words: Chemical fertilizer, organic amendment, Soil Fertility, T. aman rice, Boro rice, yields

Introduction

Rice (*Oryza sativa* L.) constitutes the single most important food crop in Bangladesh, serving as a staple food source for the majority of the population (Ferdous *et al.*, 2021). Sustaining and enhancing rice production is crucial for ensuring food security in the country (Hossain *et al.*, 2019). Traditionally, rice production has mainly relied on chemical fertilizers to meet the demands of a growing population (Naher *et al.*, 2019). This practice has raised concerns about its long-term sustainability due to adverse impacts on soil health, biodiversity and the environment (Rahman and Barmon, 2019). However, continuous rice cultivation, coupled with intensive farming practices, has led to a decline in soil fertility across Bangladesh (Biswas *et al.*, 2019; Haque *et al.*, 2021). This decline in soil fertility presents a significant challenge to achieving optimal rice yields. To address these concerns, exploring alternative approaches to enhance soil fertility and rice productivity while minimizing reliance on chemical fertilizers is paramount.

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Organic matter amendments, derived from various sources like crop residues and animal manure, have emerged as a promising avenue to improve soil health and crop yield (Nayak *et al.*, 2020). These amendments offer multiple benefits, including enhanced nutrient cycling, improved soil structure, and increased water retention capacity (Urta *et al.*, 2019). Several studies have highlighted the potential of organic matter amendments to enhance soil fertility and rice productivity in Bangladesh (Adda and Sriramachandrasekharan, 2020; Urmi *et al.*, 2022; Hasnain *et al.*, 2020). Chemical fertilizers have been extensively used to increase crop yields, but this practice has led to a depletion of soil organic matter and degradation of soil health over time (Hoque *et al.*, 2018). Organic matter is a key component of soil fertility, providing nutrients, improving soil structure, and enhancing water-holding capacity (Tahat *et al.*, 2020). Studies have shown that organic amendments, such as poultry manure (Urmi *et al.*, 2022), cow dung, rice straw and biosolids (Haque *et al.*, 2021), can improve soil fertility (Hussainy and Arivukodi, 2020). These amendments can enhance soil physical properties like water holding capacity and soil structure, as well as increase nutrient availability (Wang *et al.*, 2022; Iqbal *et al.*, 2022). Moreover, organic matter amendments can promote beneficial microbial activity in the soil, further contributing to nutrient cycling and overall soil health (Aytenew and Bore, 2020; Urta *et al.*, 2019; Duddigan *et al.*, 2022).

Integrated application of organic amendments alongside chemical fertilizers has demonstrated superior agronomic efficacy compared to the sole use of chemical fertilizers, by enhancing nutrient availability, improving soil health, and promoting sustainable crop productivity (Anik *et al.*, 2017). The integrated nutrient management approach can lead to improve soil fertility, enhanced nutrient availability for plants, and ultimately, increased crop yields. This study aims to assess the effectiveness of this integrated nutrient management approach for increased soil fertility and sustainable rice production in Bangladesh.

Materials and Methods

Site description

The study was conducted at the BINA substation farm at Jamalpur, Bangladesh. The station is fall the agro-ecological zone (AEZ) of Young Brahmaputra and Jamuna Floodplain (AEZ 8).

Treatments, experimental design and fertilization

The study consisted of five treatments: T₁: Native soil fertility (Control), T₂: 100% Chemical fertilizers (100% CF), T₃: CF+2.5 t ha⁻¹ Rice straw (CF+RS (IPNS)), T₄: CF+4 t ha⁻¹ cow dung (CF+CD (IPNS)), T₅: CF+3 t ha⁻¹ poultry manure (CF+PM (IPNS)). The experiment was laid out in a randomized complete block design with three replications. The size of individual plot was 12 m² (4 m × 3 m). A 0.5 m irrigation channel separated the

blocks from each other, while each plot was separated by a 0.5 m wide levee to prevent horizontal seepage of water and fertilizer between the plots.

Initial soil samples were collected from 0-15 cm depth before the experiment started and analyzed to determine chemical fertilizer doses (Table 1). Besides this, rice straw, cowdung and poultry manure, used in the experiment were analyzed (Table 2).

Table 1. Initial soil properties

Soil pH	Total N (%)	Organic matter (%)	Exchangeable K (meq100g ⁻¹)	Available P (ppm)	Available S (ppm)	Zn (ppm)	B (ppm)
6.3	0.088	1.72	0.1	7.16	10.01	2.01	0.17
Neutral	V. Low	Low	Low	Low	Low	Medium	Medium

Table 2. Nutrient contents in rice straw, cowdung and poultry manure

Name of manures	%N	%P	%K	%S
Rice straw	0.682	0.18	1.46	0.15
Cowdung	0.66	0.33	0.49	0.25
Poultry manure	1.15	1.06	0.62	0.29

The experiment was conducted across two distinct rice-growing seasons like T. Aman in 2022 and Boro in 2023. Based on soil test results, N was applied in three equal splits, whereas P, K, and S were applied as basal and mixed with soil on the day of transplanting in all treatments, including the zero-N control (Tables 3 and 4). Triple super phosphate (TSP), muriate of potash (MoP), and gypsum were used as sources of P, K, and S.

Table 3. Amount of fertilizers and organic matter applied in T. aman (Binadhan-17) rice as treatment plan

Treatments	Chemical Fertilizer (CF) (Kg ha ⁻¹)			
	N	P	K	S
T ₁ = Native soil fertility (Control)	-	-	-	-
T ₂ = 100% Chemical fertilizers (100% CF)	90	15	50	9
T ₃ = CF+2.5 t ha ⁻¹ Rice straw (CF+RS (IPNS)	73	11	15	6
T ₄ = CF+4 t ha ⁻¹ cow dung (CF+CD (IPNS)	63	3	30	-
T ₅ = CF+3 t ha ⁻¹ poultry manure (CF+PM (IPNS)	55	-	31	2

Table 4. Amount of fertilizers and organic matter applied in Boro (Binadhan-24) rice as treatment plan

Treatments	Chemical Fertilizer (CF) (Kg ha ⁻¹)			
	N	P	K	S
T ₁ = Native soil fertility (Control)	-	-	-	-
T ₂ = 100% Chemical fertilizers (100% CF)	100	20	60	8
T ₃ = CF+2.5 t ha ⁻¹ Rice straw (CF+RS (IPNS)	40	12.5	18	5
T ₄ = CF+4 t ha ⁻¹ cow dung (CF+CD (IPNS)	28	11	54	2
T ₅ = CF+3 t ha ⁻¹ poultry manure (CF+PM (IPNS)	81	13	48	4

The study was conducted in two different growing seasons. The variety Binadhan-17 was used in the first season (T. Aman rice) from July 20 to October 22, 2022, while the variety Binadhan-24 was used in the second season (Boro rice) from November 20 to April 17, 2023. Crop and plot management practices were uniform across all plots, encompassing consistent approaches to irrigation, weed control, and pest management.

Soil sampling and analysis

Before starting the experiment and after the two-season rice harvest, an auger was used to collect random composite soil samples (3 per plot) from 0-15 cm depth. The soil samples were left to dry naturally in a shaded area and then pulverized with a mortar and ground to attain a particle size capable of passing through a 2 mm sieve. Soil parameters were determined by following methods such as soil pH (Richards 1954), organic matter content (Walkley and Black 1934), total nitrogen (Bremner, 1965), available potassium (Jackson 1958), phosphorus (Olsen 1954), and sulfur (Williams, *et al.*, 1959), as well as the levels of zinc (Lindsay *et al.*, 1978) and boron (Berger & Truog (1939).

Yield data

At the time of harvesting, fifteen consecutive hills were chosen for assessing the panicle count per hill. From each plot, ten representative hills were gathered to analyse yield components, encompassing spikelets per panicle, filled grain and 1000-grain weight. Grain and straw yields were calculated from a 4 m² area situated at the centre of each plot. The moisture content of the grain was adjusted to 13%. Biological yield was calculated by adding grain and straw dry weight and harvest index was calculated as grain dry weight/biological yield.

Statistical analysis

Statistix version 10.0 statistical software was used for the statistical analysis of the data. ANOVA and univariate analyses were conducted to assess all parameters, and the separation of treatment means was accomplished through the least significant difference (Gomez and Gomez *et al.*, 1984).

Results and Discussions

Yield contributing characters

The integration of organic matter amendments with chemical fertilizers exhibited significant positive effects on the yield contributing characters of T. man and Boro rice compared to the control and sole chemical fertilizer application. In both the T. Aman and Boro season application of organic matter and chemical fertilizer exhibited significant variations in the yield-contributing characteristics of rice (Tables 4 and 5). In the both Aman and Boro season, the T₅ treatment displayed the tallest plant height (96.21 cm and 99 cm). Conversely, the control treatment recorded the lowest plant height (84.20 cm and 85.55 cm).

The T₄ treatment also showed the highest number of effective tillers per hill (12.53 and 15.38), a value statistically similar to the T₃ and T₅ treatment in the both T. Aman and Boro season. In contrast, the control treatment exhibited the lowest number of effective tillers per hill (9.00 and 9.05). Regarding panicle length, the highest panicle length was recorded (23.97 cm and 25.75 cm) in T₄ treatment, followed by T₃ and T₅ treatment in the both seasons. The lowest panicle length was recorded from control treatment (19.18 cm and 19.96 cm).

Table 4. Effect of different organic amendments with chemical fertilizers on yield and yield contributing characters of T. aman rice (Binadhan-17)

Treatment	Plant height (cm)	Effective tiller hill ⁻¹	Panicle length (cm)	Filled grains panicle ⁻¹	Unfilled grain panicle ⁻¹	1000-seed weight (g)
T ₁	84.20e	9.00c	19.18c	102.87c	20.43b	20.47d
T ₂	94.25d	10.44b	21.57b	150.33b	27.33a	21.20c
T ₃	95.70b	11.63a	22.52b	181.67a	18.67bc	23.13a
T ₄	95.40c	12.53a	23.97a	187.33a	17.33c	22.10b
T ₅	96.21a	12.29a	22.22b	174.00a	17.00c	21.67bc
CV	0.12	5.02	2.92	5.87	5.53	1.42
S.E. (±)	0.09	0.46	0.52	7.63	0.91	0.25

Note: Control: Native soil fertility (T₁), 100% CF: 100% Chemical fertilizers (T₂), CF+CD (IPNS): Chemical fertilizers + 2.5 t ha⁻¹ Rice straw (IPNS) (T₃), CF+CD (IPNS): Chemical fertilizers + 4 t ha⁻¹ cow dung (IPNS) (T₄) and CF+PM (IPNS): Chemical fertilizers + 3 t ha⁻¹ poultry manure (IPNS) (T₅).

Table 5. Effect of different organic amendments with chemical fertilizers on yield contributing characters of Boro rice (Binadhan-24)

Treatment	Plant height (cm)	Effective tiller hill ⁻¹	Panicle length (cm)	Filled grains panicle ⁻¹	Unfilled grain panicle ⁻¹	1000-seed weight (g)
T ₁	85.55e	9.05c	19.96c	100.95c	23.60b	22.75d
T ₂	97.05d	13.29b	23.35b	154.10b	29.50a	23.78c
T ₃	98.20c	14.48a	24.00b	184.35a	20.95bc	24.65b
T ₄	98.50b	15.38a	25.75a	190.00a	19.15c	25.70a
T ₅	99.00a	15.14a	24.30b	176.67a	19.50c	24.25bc
CV	0.21	5.12	2.96	5.95	5.62	1.56
S.E. (±)	0.15	0.38	0.51	7.65	0.95	0.31

Note: Control: Native soil fertility (T₁), 100% CF: 100% Chemical fertilizers (T₂), CF+CD (IPNS): Chemical fertilizers + 2.5 t ha⁻¹ Rice straw (IPNS) (T₃), CF+CD (IPNS): Chemical fertilizers + 4 t ha⁻¹ cow dung (IPNS) (T₄) and CF+PM (IPNS): Chemical fertilizers + 3 t ha⁻¹ poultry manure (IPNS) (T₅).

Both T. Aman and Boro seasons, the highest number of filled grains panicle⁻¹ (187.33 and 190.0) was observed in T₄ treatment, which is statically similar with T₃ and T₅ treatment and the lowest number of filled grains panicle⁻¹ (102.87 and 100.0) was observed from the control treatment. The highest 1000-seed weight was observed in T₄ treatment and other treatments showed statically lower 1000-seed weight. T. Aman and Boro rice showed significant variation when compared across treatments for each yield-contributing

characteristic under different treatments of organic amendments with chemical fertilizers. The T₄ treatment consistently shows relatively higher values in most of the parameters, suggesting potentially better growth and yield outcomes compared to other treatments. The control treatment generally exhibits lower values in most parameters.

The application of organic matter amendments with chemical fertilizers had a significant impact on soil fertility and rice production compared to the sole use of chemical fertilizers or the native soil fertility. These findings reveal that the application of organic matter, particularly cow dung, can significantly enhance the vegetative growth and yield potential of T. Aman and Boro rice when combined with chemical fertilizers. The combined application of organic and inorganic fertilizers improved soil organic matter, nutrient status, and microbial activities, resulting in enhanced nutrient use efficiency and higher rice yields (Urmi *et al.*, 2022). Organic materials, when used in conjunction with chemical fertilizers, can significantly increase rice yields by 15-20% compared to the exclusive use of chemical fertilizers (Urmi *et al.*, 2022). The integration of organic and inorganic fertilizers can lead to a more balanced supply of nutrients, improved soil physical properties, and enhanced nutrient use efficiency, ultimately resulting in higher rice yields compared to the sole application of chemical fertilizers (Hasnain *et al.*, 2020). The combined application of organic and inorganic fertilizers significantly enhances rice productivity, nutrient uptake efficiency, and soil physical attributes relative to exclusive chemical fertilizer use (Iqbal *et al.*, 2019).

Yields

In both the T. Aman and Boro seasons, the application of organic matter and chemical fertilizers showed significant variations in the grain, straw, and biological yield of rice. (Fig. 1). In both T. Aman and Boro rice, the highest grain yield (6.50 t ha⁻¹ and 7.53 t ha⁻¹) was recorded in T₄ treatment and the lowest grain yield (3.96 t ha⁻¹ and 3.99 t ha⁻¹) was recorded in the control treatment. Similarly, the highest straw yield (7.31 t ha⁻¹ and 8.25 t ha⁻¹) was recorded in T₄ and the lowest straw yield (4.94 t ha⁻¹ and 5.04 t ha⁻¹) was observed from control treatment. In case of biological yield, the highest biological yield (13.81 t ha⁻¹ and 15.78 t ha⁻¹) was also recorded in T₄ treatment and the lowest grain yield (8.90 t ha⁻¹ and 9.03 t ha⁻¹) was recorded in the control treatment in both the T. Aman and Boro rice. Comparing the yield values across the treatments, it was evident that the T₄ treatment consistently yielded the highest values in all three categories: straw yield, grain yield and biological yield. Conversely, the control treatment consistently demonstrated the lowest values in all three categories of yields. Meanwhile, the remaining treatments, including 100% Chemical fertilizers (T₂), chemical fertilizers + 4 t ha⁻¹ cow dung (IPNS) (T₄) and Chemical fertilizers + 3 t ha⁻¹ poultry manure (IPNS) (T₅), exhibited intermediate values, showing varying degrees of enhancement compared to the control treatment.

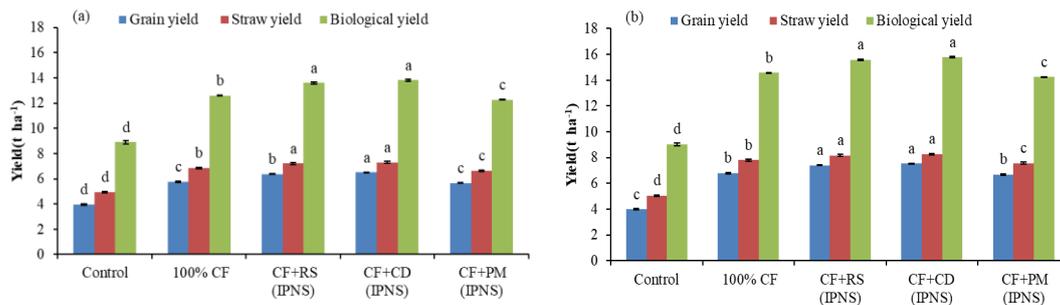


Fig. 1. Effect of different organic amendments with chemical fertilizers on grain, straw and biological yield of (a) T. Aman rice, 2022 and (b) Boro rice, 2023.

Note: Control: Native soil fertility (T₁), 100% CF: 100% Chemical fertilizers (T₂), CF+CD (IPNS): Chemical fertilizers + 2.5 t ha⁻¹ Rice straw (IPNS) (T₃), CF+CD (IPNS): Chemical fertilizers + 4 t ha⁻¹ cow dung (IPNS) (T₄) and CF+PM (IPNS): Chemical fertilizers + 3 t ha⁻¹ poultry manure (IPNS) (T₅).

Chemical properties of post-harvest soil

The application of organic amendments with chemical fertilizer has made a positive change on chemical properties of post-harvest soil (Table 6). Soil pH of the post-harvest soils varied among different treatments. The soil pH, soil OM (%), total N (%), exchangeable K, available P, available S were significantly higher in CF+RS (IPNS) treatment (T₃), which is statistically similar with CF+CD (IPNS) treatment (T₄). Zinc (Zn) and Boron (B) content were significantly higher in CF+CD (IPNS) treatment (T₄), which is statistically similar to CF+RS (IPNS) and CF+PM (IPNS) treatments.

Table 6. Effect of different organic amendment with chemical fertilizers on physio-chemical characteristics of post-harvest soil

Treatment	Soil pH	Soil OM (%)	Total soil N (%)	Exchangeable K (meq 100g ⁻¹)	Available P (ppm)	Available S (ppm)	Zn (ppm)	B (ppm)
Control	6.10c	1.73c	0.08c	0.10d	6.93d	9.37c	1.92b	0.13c
100% CF	5.95d	1.79bc	0.09bc	0.11c	8.14cd	14.16b	2.19b	0.18b
CF+RS (IPNS)	6.40a	1.98a	0.10a	0.14a	10.93a	18.04a	2.49a	0.23a
CF+CD (IPNS)	6.30ab	1.95a	0.09ab	0.14ab	9.98ab	15.60b	2.53a	0.24a
CF+PM (IPNS)	6.22b	1.84b	0.09ab	0.13b	9.27bc	14.21b	2.49a	0.21a
CV	0.89	2.38	5.01	5.51	8.24	7.45	6.37	7.47
S.E. (±)	0.045	0.036	0.004	0.006	0.609	0.868	0.121	0.012

Note: Control: Native soil fertility, 100% CF: 100% Chemical fertilizers, CF+CD (IPNS): Chemical fertilizers + 2.5 t ha⁻¹ Rice straw (IPNS), CF+CD (IPNS): Chemical fertilizers + 4 t ha⁻¹ cow dung (IPNS) and CF+PM (IPNS): Chemical fertilizers.

The application of organic matter amendments with chemical fertilizers had a significant impact on soil fertility compared to the sole use of chemical fertilizers or the native soil fertility. The findings from this study corroborate with previous research that has

shown the positive impacts of organic matter amendments on soil properties (Adda and Sri Rama Chandrasekharan, 2020; Dhiman and Dubey, 2017). The integration of organic amendments and chemical fertilizers enhanced soil fertility by increasing soil organic carbon, total nitrogen, and available phosphorus compared. Soil organic carbon content increased by 12-18% in the organic matter amendment treatments compared to the chemical fertilizer-only treatment (Adda and Sriramachandrasekharan, 2020). Similarly, total nitrogen, available phosphorus, and exchangeable potassium were significantly higher in the organic matter amendment treatments (Urmi *et al.*, 2022).

Conclusions

The study indicated the significant role of organic matter amendments in improving soil fertility and enhancing rice production in Bangladesh. The integration of organic materials, such as cow dung, rice straw, and poultry manure, with chemical fertilizers significantly enhanced soil physico-chemical properties, including increased organic carbon, total nitrogen, available phosphorus, and exchangeable potassium. Consequently, the treatments with organic matter amendments exhibited higher rice grain yields than with the chemical fertilizers alone. The application of organic matter can be a viable strategy for marginal farmers in Bangladesh to increase soil fertility and rice production in a sustainable manner.

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