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Comparative Performance of Different Fertilizer Recommendation Methods on Growth and Yield of Rice (*Oryza sativa*) in Old Brahmaputra Floodplain Soils

Shadia Akter [a], Md Hosenuzzaman [a], Md Anwarul Abedin [a] and Md Anamul Hoque [a*]

[a] Department of Soil Science, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh.

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

Improving rice productivity is the challenge for the farmer due to rapid soil health deterioration in intensive agricultural system. Therefore, the present study was conducted to evaluate comparative performance of different nutrient management practices in rice production in Bangladesh. The experiment was laid out in a randomized complete block design with three replications. There were six treatments namely, T1 (Control-no fertilizer), T2 (Farmer's Practice), T3 (Fertilizer Recommendation Guide-2018), T4 (BAU Soil Testing Kit), T5 (Soil Test Basis) and T6 (Rice Crop Manager). The results revealed that all the treatments showed better performances over control (T1). Treatment T4 (BAU Soil Testing Kit) produced the highest value of plant height (90.18 cm), panicle length (24.90), filled grains panicle^{-1} (122.60) and 1000-grain weight (26.67g) while T5 (Soil Test Basis) produced maximum effective tillers hill^{-1} (12.80). The highest grain yield (6.29 t ha^{-1}) and

**Corresponding author: E-mail: anamul71@bau.edu.bd;*

straw yield (7.73 t ha^{-1}) were recorded in treatment T4 (BAU Soil Testing Kit). Treatment T4 (BAU Soil Testing Kit) also showed the highest grain yield increase (61.49%) and straw yield increase (90.49%) over control. The highest total N, P and K uptake (108.84 kg ha^{-1}, 24.54 kg ha^{-1} and 128.17 kg ha^{-1}) were obtained in the treatment T4 (BAU Soil Testing Kit). Control treatment T1 (No fertilizers) showed minimum performances in all the cases compared to other treatments. The overall result demonstrated that the application of fertilizers following BAU Soil Testing Kit method of fertilizer application system is a better option for rice production.

Keywords: Fertilizer recommendation; methods; rice; Bangladesh.

1. INTRODUCTION

Rice serves as a staple for over three billion people worldwide [1]. Rice provides a significant portion of calorie and dietary protein for about 520 million people living in poverty in Asia [2]. Bangladesh is heavily reliant on intensive rice cultivation, ranking third globally in both area and production of rice. In 2019, Bangladesh produced 37.4 million tons of rice, contributing significantly to the national economy and food security. However, the country faces challenges such as a low average rice yield of 3.92 t ha^{-1} compared to other nations like China and Japan [3].

With an annual per capita consumption of 198 kg, rice is a vital commodity in Bangladesh, utilizing 84.67% of total cropped land. Despite the country's efforts to increase production to meet the growing population's demands, challenges such as diminishing cultivable land persist. Experts anticipate a potential increase in rice production to 46.7 million tons by 2050 [4].

Fertilizer and the recommendation methods play a crucial role in sustaining high crop production. But the heavy dependence on NPKS fertilizers pose environmental and food safety concerns. Continuous use accelerates soil degradation, affecting physical and chemical properties. Constituting 20% of rice production costs, fertilizer expenses prompt substantial government subsidies, reaching 119 billion Taka in 2012–2013 [5]. Crop scientists around the world are searching for sustainable farming techniques to keep the soil healthy and decrease the amount of fertilizer needed for per kg of rice produced [6].

This study aims to compare different fertilizer recommendation methods to achieve maximum production in the current agricultural landscape of Bangladesh. The objectives include:

1. Compare fertilizer recommendation methods and identify the best.
2. Assess the impact of methods on rice growth and yield.
3. Examine the effect of different fertilizer treatments on nutrient uptake by the rice crop.

2. MATERIALS AND METHODS

The experiment was conducted at Bangladesh Agricultural University's Soil Science Field Laboratory in Mymensingh (24.75º N latitude, 90.45º E longitude, 18.978 m above the sea level) during the boro season (February-May, 2020) on BRRI dhan29, a widely used HYV boro rice variety in Bangladesh. The climate is sub-tropical with distinct seasonal variations. The soil, categorized as non-calcareous Dark Grey Floodplain under AEZ-9, is moderately well-drained silt loam.

Land preparation involved ploughing, cross ploughing with a power tiller, and laddering. After levelling and puddling, experimental plots were arranged per treatments. Soil sampling, conducted at 0-15 cm depth before ploughing, produced composite samples from 10 spots in each plot. These samples underwent meticulous cleaning and were stored in plastic containers for subsequent physical and chemical analyses (Table 1).

Table 1. Physico-chemical properties of the initial soil

Physical characteristics	
% Sand	10.92
% Silt	77.98
% Clay	11.10
Textural class	Silt loam
Chemical characteristics	
pH	6.60
Organic matter (OM) (%)	1.16
Total N (%)	0.15
Available P (mg/kg)	10.80
Exchangeable K (meq/100 g soil)	0.14
Available S (mg/kg)	11.50

The experiment was comprised of six treatments including control.

T1: Control (No fertilizer)
T2: Farmer's practice
T3: Fertilizer Recommendation Guide (FRG)-2018
T4: BAU soil testing kit
T5: Soil Test Basis (STB)
T6: Rice crop manager

Fertilizer rates and sources of NPKS fertilizers for 10 m^2 area following different recommendation methods are presented in Table 2 and Table 3.

Seedlings of BRRI dhan29 rice were carefully uprooted from the seedbed before transplanting, with the transplantation occurring on February 13, 2020. Thirty-five-day-old seedlings were transplanted into the plots. The experiment employed a randomized complete block design with three replications, incorporating six treatments, including a control. Each block was subdivided into unit plots, resulting in a total of 18 plots. The unit plot size was 4×2.5 m, with 1 m spacing between blocks and 0.5 m between plots. To ensure proper crop growth, various intercultural operations were undertaken such as weeding, pest control, irrigation, drainage etc.

Harvesting occurred at full maturity, with crops bundled, threshed, cleaned, and processed. Grain and straw yields were recorded based on 14% moisture content. Sample analysis involved collecting 100 grams from each plot, oven drying, and grinding for chemical analysis. Various plant characteristics, including plant height, panicle length, number of effective tillers, number of filled grains per panicle, weight of 1000 grains, and grain and straw yields, were measured and recorded. After sun drying, straw and grain samples underwent digestion and analysis for nitrogen, phosphorus, potassium, and sulfur content using standard methods [7]. To calculate nutrient uptake with grain and straw the following equation was used.

$$\text{Nutrient uptake (kg ha}^{-1}) = (Gy \times Ngr)/100 + (Sty \times Nst)/100$$

Where,

Gy= Grain yield (kg ha^{-1}), Sty= Straw yield (kg ha^{-1}), Ngr = Nutrient content in grain (%), Nst = Nutrient content in Straw (%)

Data were analysed statistically by ANOVA to examine whether treatment effects were significant [8]. Mean values were compared by Duncan's Multiple Range Test (DMRT). Software package, Statistix10 was followed for statistical analysis.

Table 2. Fertilizer rates of the treatments following different recommendation methods used for the experiment

Treatments	Name of the fertilizers			
	Urea (g 10 m^{-2} $split^{-1}$)	TSP (g 10 m^{-2})	MoP (g 10 m^{-2})	Gypsum (g 10 m^{-2})
T_1	0.00	0	0	0.00
T_2	82.00	100	86	61.00
T_3	103.68	105	120	44.40
T_4	130.00	20	226	44.40
T_5	135.00	35	180	94.00
T_6	90.00	80	36	31.00

T_1: Control (No fertilizer), T_2: Farmer's practice, T_3: Fertilizer Recommendation Guide (FRG)-2018, T_4: BAU soil testing kit, T_5: Soil Test Basis (STB) and T_6: Rice crop manager (RCP)

Table 3. Nutrients and their sources used for the experiment

Nutrient	Sources
Nitrogen (N)	Urea
Phosphorus (P)	Triple super phosphate
Potassium (K)	Muriate of potash
Sulphur (S)	Gypsum

3. RESULTS AND DISCUSSION

Yield contributing characteristics of rice consists of plant height, effective tillers hill^{-1}, panicle length, filled grains panicle^{-1}, and 1000-grain weight (Table 4). The effects of NPK fertilizers on the plant height of BRRI dhan29 has been ranked in order of $T_2 > T_6 > T_3 > T_4 > T_5 > T_1$, the number of effective tillers hill^{-1} has been ranked in order of $T_5 > T_4 > T_3 > T_6 > T_2 > T_1$, panicle length has been ranked in order of $T_4 > T_6 > T_5 > T_3 > T_2 > T_1$, filled grain panicle^{-1} has been ranked in the order of $T_4 > T_5 > T_3 > T_2 > T_6 > T_1$ and the values of 1000-grains weight for treatments T_1, T_2, T_3,T_4, T_5 and T_6 has been recorded as 25.00g, 26.00g, 26.50g, 26.67g, 26.67g and 26.133g respectively. The grain yield has been recorded in the rank of $T_4 > T_5 > T_3 > T_2 > T_6 > T_1$ (Table 5). The results indicated that all the treatments with fertilizer recommendation methods gave significantly higher value over the control (T_1) (Fig. 1) and in terms of straw yield the treatment has been ranked in order of $T_4 > T_5 > T_3 > T_6 > T_2 > T_1$. Ali et al. [9] found in his experiment that farmer's practice of fertilizer recommendation result in higher plant growth. Mamun et al. [10] reported that using Soil Test Basis (STB) fertilizer recommendation method give more effective tillers hill^{-1}. Akhter [11] carried out a series of experiment about the effect of different fertilizer recommendation methods on rice and confirmed that fertilizer recommended through BAU soil testing kit gave highest panicle length, filled grains panicle^{-1}, 1000-grain weight, and yield.

Table 4. Effect of different fertilizer application methods on several plant characteristics of BRRI dhan29

Treatments	Plant height (cm)	No. of effective tillers hill^{-1} (no.)	Panicle length (cm)	Filled grains panicle^{-1} (no.)	1000- grain weight (g)
T_1	78.47b	9.27c	20.20b	83.07c	25.00b
T_2	90.97a	10.87bc	22.84a	122.53ab	26.00ab
T_3	90.63a	12.13ab	23.43a	114.77ab	26.50a
T_4	90.18a	12.14ab	24.90a	122.60a	26.67a
T_5	90.17a	12.80a	23.50a	116.5ab	26.67a
T_6	90.64a	11.53ab	23.60a	111.53b	26.13a
SE ±	2.03	0.86	1.04	3.96	0.497
CV (%)	2.81	9.2	5.54	4.41	2.33

The figure (s) having common letter (s) in a column do not differ significantly at 5% level of significance. SE (±) = Standard Error of Means, CV (%) = Co-efficient of variance

T_1: Control (No fertilizer), T_2: Farmers practice, T_3: Fertilizer Recommendation Guide (FRG)-2018, T_4: BAU soil testing kit, T_5: Soil Test Basis (STB) and T_6: Rice crop manager (RCP)

Table 5. Influence of different fertilizer recommendation methods on grain and straw yields of BRRI dhan29

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
T_1	4.01c	4.07d
T_2	5.18b	6.15c
T_3	5.50ab	6.96b
T_4	6.29a	7.73a
T_5	5.81ab	7.08ab
T_6	5.17b	6.43bc
SE ±	0.44	0.33
CV (%)	10.15	6.45

The figure (s) having common letter (s) in a column do not differ significantly at 5% level of significance. SE (±) = Standard Error of Means, CV (%) = Co-efficient of variance

T_1: Control (No fertilizer), T_2: Farmer's practice, T_3: Fertilizer Recommendation Guide (FRG)-2018, T_4: BAU soil testing kit, T_5: Soil Test Basis (STB) and T_6: Rice crop manager (RCP)

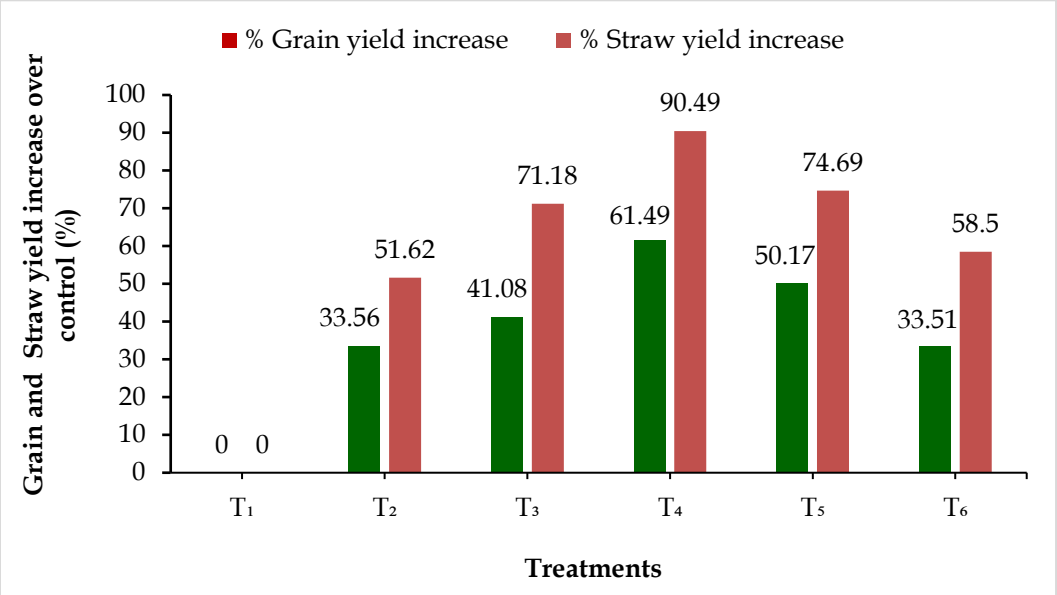

Fig. 1. Effect of applying fertilizers through different fertilizer recommendation methods on %grain and %straw yield increase over control of BRRI dhan29

[T_1: Control (No fertilizer), T_2: Farmer's practice, T_3: Fertilizer Recommendation Guide (FRG)-2018, T_4: BAU soil testing kit, T_5: Soil Test Basis (STB) and T_6: Rice crop manager (RCP)]

In rice grain, the highest N content (1.288%) was observed with BAU Soil Testing Kit (T4), while all treatments showed significantly higher nitrogen content compared to the control (Table 6). In case of rice straw, the highest N content of 0.364% was recorded in the treatment T_5 which was statistically similar with T_4. The highest nitrogen uptake in grain and straw was in T_4 (80.86 kg $ha^{-1}$and 27.98 kg ha^{-1}). The highest total nitrogen uptake by rice has also found in treatment T_4 (108.84 kg ha^{-1}). Akhter [11] reported that the plots treated by fertilizer recommended through BAU soil testing kit show higher content and N uptake in rice. The higher N uptake might be attributed to higher N application in BAU soil testing kit based fertlizer recommendation method.

Phosphorus content varied at different ranges with the application of P fertilizer through different fertilizer recommendation methods in rice grain of BRRI dhan29 (Table 7). The highest phosphorus content in grain and straw of was recorded in the treatment T_3 (0.258% and 0.123%). Phosphorus (P)uptake by rice grain, straw and total uptake has been recorded in the treatment T_4 (15.57 $kgha^{-1}$, 8.965 $kgha^{-1}$ and 24.54 $kgha^{-1}$). All the treatments with fertilizer recommendations gave significantly higher value over the control (T_1). Akhter [11] found that the plots using fertilizers through BAU soil testing kit recommendation have significantly higher P uptake.

Potassium content varied at different ranges with the application of K fertilizer through different fertilizer recommendation methods in rice grain of BRRI dhan29 (Table 8). The highest potassium content in grain and straw of was recorded in the treatment T_4 (0.339% and 1.383%). Potassium (K) uptake by rice grain, straw and total uptake has been recorded in the treatment T_4 (21.282 kg ha^{-1}, 106.89 kg ha^{-1} and 128.17 kg ha^{-1}). All the treatments with fertilizer recommendations gave significantly higher value over the control (T_1). Akhter [11] confirmed that the plots treated by fertilizer recommended through BAU soil testing kit resulted in significantly highest K uptake [12].

Sulphur content and uptake varied at different ranges with the application of S fertilizer through different fertilizer recommendation methods in rice grain of BRRI dhan29 (Table 9). The highest Sulphur (S) uptake by rice grain, straw and total uptake has been recorded in the treatment T_4 (14.124 kg ha^{-1}, 17.466 kg ha^{-1} and 31.590 kg ha^{-1}). All the treatments with fertilizer recommendations gave significantly higher value over the control (T_1). Akhter [11] reported that using fertilizers through BAU soil testing kit resulted in significant S uptake.

Table 6. Effect urea fertilizer through different fertilizer recommendation methods on nitrogen concentration and uptake by BRRI dhan29

Treatments	Content		Uptake (kg ha^{-1})		
	% N (Grain)	% N (Straw)	N (Grain)	N (Straw)	Total
T_1	1.101d	0.328c	44.20c	13.35e	57.54d
T_2	1.128c	0.352b	58.37b	21.70d	80.07c
T_3	1.176b	0.352b	64.82b	24.52bc	89.34bc
T_4	1.288a	0.362a	80.86a	27.98a	108.84a
T_5	1.178b	0.364a	68.50b	25.74ab	94.23b
T_6	1.176b	0.353b	60.76b	22.69cd	83.45bc
SE ±	0.0026	0.0013	4.97	1.22	5.51
CV (%)	0.27	0.44	9.69	6.59	7.89

The figure (s) having common letter (s) in a column do not differ significantly at 5% level of significance.
SE (±) = Standard Error of Means, CV (%) = Co-efficient of variance
T_1: Control (No fertilizer), T_2: Farmer's practice, T_3: Fertilizer Recommendation Guide (FRG)-2018, T_4: BAU soil testing kit, T_5: Soil Test Basis (STB) and T_6: Rice crop manager (RCP)

Table 7. Effect of P fertilizer through different fertilizer recommendation methods on phosphorus concentration and uptake by BRRI dhan29

Treatments	Content		Uptake (kg ha^{-1})		
	% P (Grain)	% P (Straw)	P (Grain)	P (Straw)	Total
T_1	0.242f	0.115d	9.714c	4.679c	14.39c
T_2	0.255b	0.121b	13.196ab	7.458b	20.65b
T_3	0.358a	0.123a	14.220ab	8.566a	22.79ab
T_4	0.248e	0.116d	15.570a	8.965a	24.54a
T_5	0.249d	0.116d	14.477ab	8.201ab	22.68ab
T_6	0.254c	0.119c	13.123b	7.650b	20.77b
SE ±	0.00045	0.00052	1.082	0.405	1.273
CV (%)	0.22	0.53	9.9	6.54	7.44

The figure (s) having common letter (s) in a column do not differ significantly at 5% level of significance.
SE (±) = Standard Error of Means, CV (%) = Co-efficient of variance
T_1: Control (No fertilizer), T_2: Farmer's practice, T_3: Fertilizer Recommendation Guide (FRG)-2018, T_4: BAU soil testing kit, T_5: Soil Test Basis (STB) and T_6: Rice crop manager (RCP)

Table 8. Effect of K fertilizer through different fertilizer recommendation methods on potassium concentration and uptake by BRRI dhan29

Treatments	Content		Uptake (kg ha^{-1})		
	% K (Grain)	% K (Straw)	K (Grain)	K (Straw)	Total
T_1	0.308f	1.227d	12.363d	49.96e	62.32e
T_2	0.329d	1.290c	17.026bc	79.51d	96.54d
T_3	0.333c	1.295c	18.354abc	90.19bc	108.54bc
T_4	0.339a	1.838a	21.282a	106.89a	128.17a
T_5	0.337b	1.352b	19.594ab	95.60b	115.20b
T_6	0.315e	1.274c	16.274c	81.90cd	98.18cd
SE ±	0.00067	0.0125	1.405	4.39	5.11
CV (%)	0.25	1.17	9.85	6.40	6.17

The figure (s) having common letter (s) in a column do not differ significantly at 5% level of significance.
SE (±) = Standard Error of Means, CV (%) = Co-efficient of variance
T_1: Control (No fertilizer), T_2: Farmer's practice, T_3: Fertilizer Recommendation Guide (FRG)-2018, T_4: BAU soil testing kit, T_5: Soil Test Basis (STB) and T_6: Rice crop manager (RCP)

Table 9. Effect of S fertilizer through different fertilizer recommendation methods onsulphur concentration and uptake by BRRI dhan29

Treatments	Content		Uptake (kg ha^{-1})		
	% S (Grain)	% S (Straw)	S (Grain)	S (Straw)	Total
T_1	0.201e	0.218d	8.068c	8.179e	16.25d
T_2	0.223c	0.225b	11.540b	13.867d	25.41c
T_3	0.225b	0.226b	12.401ab	15.739bc	28.14bc
T_4	0.225b	0.226b	14.124a	17.466a	31.59a
T_5	0.231a	0.230a	13.372ab	16.264ab	29.64ab
T_6	0.219d	0.223c	11.317b	14.336cd	25.65c
SE ±	0.00076	0.00051	0.9296	0.7641	1.377
CV (%)	0.42	0.29	9.65	6.54	6.46

The figure (s) having common letter (s) in a column do not differ significantly at 5% level of significance. SE (±) = Standard Error of Means, CV (%) = Co-efficient of variance
T_1: Control (No fertilizer), T_2: Farmer's practice, T_3: Fertilizer Recommendation Guide (FRG)-2018, T_4: BAU soil testing kit, T_5: Soil Test Basis (STB) and T_6: Rice crop manager (RCP)

4. CONCLUSION

The experiment, conducted from February to May 2020, assessed the impact of different fertilizer recommendation methods on rice (BRRI dhan29) in Old Brahmaputra floodplain soils. Employing a randomized complete block design with six treatments, BAU Soil Testing Kit (T4) demonstrated superior performance, significantly increasing plant height, effective tillers, panicle length, filled grains, 1000-grain weight, grain yield (6.29 t ha^{-1}), straw yield (7.73 t ha^{-1}), and nutrient uptake. The control (T1) exhibited inferior results in all aspects. Using BAU Soil Testing Kit for fertilizer application emerged as the most efficient and contributing to higher rice yield and improved nutrient uptake compared to other methods, emphasizing the importance of adopting proper fertilizer recommendation methods in sustainable crop production in Bangladesh. Further studies are encouraged to validate these findings.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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