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Organic and Inorganic Fertilizer Management for *Boro* Rice Cultivation in a Single *Boro* Cropping Area

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Authors' contributions

This work was carried out in collaboration among all authors. Author MAAG designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors SF and MKHT managed the analyses of the study. Author TC helps in data collection. Authors MTH and MTJE managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: In any agricultural production system, combining organic and chemical fertilizers into the soil is regarded as a useful management practice since it boosts soil fertility and crop growth. The goal of the current study was to ascertain the effects of combined organic and inorganic fertilizer treatment on the yield contributing traits, yield, nutrient uptake and nutrient use efficiency of BRRI dhan89 in a single *Boro* cropping area.
Study Design: With three replications, the experiment was set up in a two factor RCB design. Organic fertilizer treatment was regarded as Factor-a, while inorganic fertilizer as Factor-b.

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Place and Duration of Study: The experiment was conducted in a farmer's field in Nagarkanda, Faridpur, Bangladesh from December 2021 to May 2022.
Methodology: Factor-a comprises two treatments named cowdung (CD) and poultry manure (PM). Factor-b comprises five treatments named T_0 (control), T_1, T_2, T_3, and T_4. In the main field, organic fertilizers were used just two weeks prior to transplanting. In all inorganic fertilizer treatments, Urea top dressed in three installments at 15 DAT, 30 DAT and 5 days before panicle initiation. In T4 treatment, MoP split at two installments, one during final land preparation and another 5 days before panicle initiation.
Results: The highest no. of effective tillers, yield contributing traits, grain yield, straw yield, nutrient concentration (%) in both grain and straw, nutrient uptake by grain and straw observed in organic fertilizer treatment PM, inorganic fertilizer treatment T_4 and treatment interaction PM × T_4 whereas the lowest found in CD, T_0 and CD × T_0. The maximum nutrient use efficiency was recorded by PM × T_4 treatment interaction and minimum in CD × T_1.
Conclusion: Comparing all of the treatments employed in the current study, the treatment interaction PM × T_4 generated the best results for BRRI dhan89 in a single Boro cropping area.

Keywords: Boro rice; cowdung; poultry manure; inorganic fertilizer; nutrient use efficiency.

1. INTRODUCTION

The most fitting motto for the world is "Rice is life," as this grain is essential to the security of our national food supply and a source of income for millions of rural residents [1]. Additionally, rice is the main crop grown in Bangladesh, covering up about 78 percent of the nation's net cropped area [2]. From its 11.55 million hectares of cultivated gross area, the nation manages to obtain self-sufficiency in order to supply the rice need for its 169.04 million citizens [3]. Although the vast area under cultivation in rice, productivity is low as a result of a variety of connected issues. An imbalanced fertilizer use is one of the major contributors to low yields, and the prolonged use of inorganic fertilizers has decreased soil fertility. The maximum grain and straw yields were obtained when inorganic fertilizers were combined with organic resources [4]. Combining organic manure with chemical fertilizers has a lot of potential for boosting soil fertility as well as yield stability [5].

Inorganic, organic, and biofertilizers are the main sources of resupplying plant nutrients in agricultural soils [6]. However, organic manuring is a major element of environmentally friendly, sustainable farming. Organic matter prevents nutrient leaching by acting as a reservoir for plant nutrients, particularly N, P, and S and micronutrients [7]. In addition to helping to fertilize the soil, applying organic fertilizers has other advantages such as enhancing environmental quality, lowering the cost of agricultural production, and enhancing crop quality [8]. The most well-known and potential solid and liquid farm animal excretions are cowdung and poultry manure. The basic nutrients needed for plant growth and development are present in significant concentrations in them. In order to maintain the soil organic matter and increase soil fertility, it is crucial to add a significant amount of cowdung and poultry manure to agricultural fields.

Continual and extensive application of inorganic fertilizers has led to environmental degradation [9] a decrease in soil fertility [10], changes in the behavior of soil organisms [11], and an increase in the cost of agricultural production. Additionally, nitrate accumulation in the plant's edible sections is accelerated as a result of using excess amount of nitrate in synthetic fertilizer (urea), which is detrimental for human health [12]. Therefore, applying organic fertilizers or combining them with inorganic fertilizers can be an alternate strategy to decrease the use of inorganic fertilizers [13]. The application of both organic and inorganic fertilizers together is anticipated to meet all of the nutritional requirements of plants, which can boost and accelerate plant growth and yields [14].

Faridpur region of Bangladesh comprises four districts namely Faridpur, Rajbari, Madaripur, and Shariatpur. The maximum area of Faridpur region has floodplain and basin type soil. Because of the frequent flooding in this area, sedimentation accumulates every year. Therefore, the soils in this area are fertile, allowing a wide variety of crops to be cultivated all year. In the Faridpur region, 141 cropping patterns were identified, six of which were rice-based and covered over 35.16% of the NCA (Net cropped area) [15]. Among them Boro-Fallow-

Fallow cropping pattern had the maximum coverage (24.41%), and was found in 28 of the 29 upazillas [15]. The major problems of this region are flash flood, deep flood, slow drainage, peat soils, perennial weeds, and heavy basin clays, have an impact on the production of several crops [16].

Since organic manure has a relatively low nutrient content, using it alone may not be enough to meet the plant's needs. The combined application of organic and inorganic fertilizer stimulates the soil microbial activity, improves nutrient use efficiency, and boosts the availability of nutrients to the plants leading to higher nutrient uptake [1]. Therefore, organic manure must be used in conjunction with inorganic fertilizer in order to maintain soil health as well as achieve the best yield. Thus, the goal of the current research work was to improve an appropriate integrated dose of inorganic fertilizers mixed with various manures and figure out the combined effect of both organic and inorganic fertilizers on yield components and yield of BRRI dhan89.

2. MATERIALS AND METHODS

2.1 Location

The experiment was carried out at farmer's field of Nagarkanda, Faridpur in Bangladesh from December 2021 to May 2022 to observe the effect of organic and inorganic fertilizer on the growth and yield of BRRI dhan89. The geographical location of the experiment site was 23.454457 N latitude, 89.89363 E longitude, with the elevation of 7 m above sea level.

2.2 Soil

The experiment site belongs to Calcaric gleysols under Active Ganges River Floodplain (AEZ-10) and the soil of the research plot was silt loam in texture. Table 1 showed the physico chemical characteristics of soils in the experimental soil.

2.3 Planting Material

BRRI dhan89 a high yielding BRRI (Bangladesh Rice Research Institute) released rice variety was used in the experiment as a planting material.

2.4 Experimental Design and Treatments

The experiment was laid out in a two factor RCB design with three replications. Organic fertilizers (Cowdung and poultry manure) were considered as Factor-a (Table 2) whereas the inorganic fertilizers such as Urea, TSP, MoP, Gypssum, and Zinc were considered as Factor-b (Table 3).

2.5 Application of Organic and Inorganic Fertilizer

The organic fertilizers were applied in the main field one week before transplanting (Table 2). All the inorganic fertilizer were applied during final land preparation, except Urea and Muriate of Potash (MoP). In treatments 2, 3 and 4, the crop was top dressed with Urea in split applications at 15 and 30 days after transplanting (DAT), and at 5 days before panicle initiation. In all inorganic fertilizer treatments, MoP was applied during final land preparation except in treatment 4 where MoP was applied in split applications, during final land preparation 5 days before panicle initiation (Table 3). Nutrient concentration of the manures applied in this research are shown in Table 4.

2.6 Transplanting

Seedlings were transplanted at forty days from germination in the research plots, with 2-3 seedlings per hill and 25 cm × 15 cm plant spacing were maintained.

2.7 Intercultural Operations

Intercultural operations like weeding, irrigation, drainage, insect and pest management, and other plant protection actions were taken when necessary [25].

2.8 Measurements and Calculations

Five hills were selected randomly in each plot for counting the number of effective tillers per hill at a fifteen-day interval from transplanting to maturity. During tillering, maximum tillering, heading, and maturity stage, five hills in each plot was selected randomly, clipped at ground level, and dried in an oven at 70^{o}C until the weight became constant. For counting the number of effective tillers per hill and measuring the shoot dry weight, each hill per plot was chosen excluding the border line. At maturity, the crop was harvested and the data on plant height, number of tillers m^{-2}, number of panicles m^{-2}, panicle length, filled grains panicle^{-1}, unfilled grains panicle^{-1} and 1000-grain weight were recorded. Rice plants from 5 m^2 previously marked area of the middle of each plot was harvested at ground level and threshed.

Table 1. Physical and chemical properties of the experimental soil sample (0-20 cm)

Soil properties	Value	Methods
Sand (%)	12.77	Pipette Method [17]
Silt (%)	47.72	
Clay (%)	39.51	
pH	6.54	Glass Electrode pH Meter [18]
Organic matter (%)	2.23	Walkley and Black Method [19]
Total nitrogen (%)	0.20	Semi-micro Kjeldahl Method [20]
Available phosphorus (µg/g soil)	6.63	Olsen method [21]
Exchangeable potassium (meq/100 g soil)	0.25	Flame Photometer [22]
Available sulfur (µg/g soil)	15.38	Spectrophotometer [23]
Textural class	Silt loam	Finger Feel Method [24]

Table 2. Organic fertilizer management (Factor-a) under the experiment

Organic fertilizer	Application time	Amount (tha^{-1})
Cowdung (CD)	1 weeks before transplanting	5.00
Poultry manure (PM)	1 weeks before transplanting	3.00

Table 3. Inorganic fertilizer management (Factor-b) under the experiment)

Treatments	Urea ($kgha^{-1}$)			TSP ($kgha^{-1}$)	MoP ($kgha^{-1}$)		Gypsum ($kgha^{-1}$)	$ZnSO_4$ ($kgha^{-1}$)
	15 DAT	**30 DAT**	**5 DBPI**	**FLP**	**FLP**	**5 DBPI**	**FLP**	**FLP**
T_0 (Control)	No fertilizer application							
T_1 (-N)	No urea			97.11	165.00	-	112.67	11.80
T_2 (STB)	90.84	90.84	90.84	78.14	147.20	-	112.67	11.80
T_3 (BRRI recommended)	99.60	99.60	99.60	97.11	165.00	-	112.67	11.80
T_4	100.00	106.50	106.50	97.11	82.50	82.50	112.67	11.80

STB: Soil test-based fertilizer management, DAT: Days after transplanting, 5 DBPI: 5 days before panicle initiation, FLP: During final land preparation

Table 4. Nutrient contents in cow dung, and poultry manure

Organic fertilizer	Nutrient contents (%)					
	Organic C	N (%)	P (%)	K (%)	S (%)	C:N
Cow dung (CD)	18.4	0.55	0.44	0.67	0.24	33.45
Poultry manure (PM)	23.5	1.20	1.15	0.84	0.37	19.58

The grains were dried in sunlight and winnowed before weighing and yield were adjusted to 14% moisture content (MC) and straw yield was recorded at sun dry basis.

Grain yield at 14% MC = $\frac{100-\text{sample MC}}{100-14}$ × grain weight at harvest

Nitrogen concentration in grains and straw was determined by the standard micro-kjeldahl procedure [20] and calculated by the following formulae:

Nutrient uptake by grain ($kgha^{-1}$) = $\frac{\%\ \text{Nutrient in grain} \times \text{grain yield}\ (\text{kgha}^{-1})}{100}$

Nutrient uptake by straw ($kgha^{-1}$) = $\frac{\%\ \text{Nutrient in straw} \times \text{straw yield}\ (\text{kgha}^{-1})}{100}$

Nutrient use efficiency (NUE) was calculated using the following formula [26]:

Nutrient use efficiency (NUE) = (Gy_{+N} – Gy_{0N}) / FR

GY_{+N} = Grain yield in treatment with nutrient application (kg ha^{-1}), GY_{0N} = Grain yield in treatment without nutrient application (kg ha^{-1}) and FR = Fertilizer (N, P, K, S) rate applied (kg ha^{-1}).

2.9 Statistical Analysis

All the data were statistically analysed by Statistix10 software using Analysis of Variance (ANOVA). Treatments were compared with least significant difference (LSD) at the $p < 0.05$ level of significance and the mean differences were ranked by DMRT at 5% level [27].

3. RESULTS AND DISCUSSION

3.1 Number of Effective Tillers per Hill

Number of effective tillers per hill at 30-day intervals had significant variations among the treatments and its interaction (Table 5). At 30, 60, 90, and 120 DAT the maximum number of effective tillers per hill was found in PM treatment whereas the lowest in CD. Similarly, the highest number of effective tillers per hill was recorded by T_3 at 30 DAT (7.04) and 60 DAT (17.41), T_4 at 60 DAT (16.76) and 120 DAT (15.65) while the lowest number of effective tillers (5.13, 15.96, 15.23 and 12.88) was recorded by T_0 at 30, 60, 90, and 120 DAT, respectively. The results showed that the highest number of effective tillers per hill (8.67 and 17.82) were obtained by the treatment interaction (PM × T_3) at 30 and 60 DAT. The highest number of effective tillers per hill were obtained from the treatment interaction (PM × T_4) at 90 DAT (17.13) and 120 DAT (16.57). On the other hand, the treatment interaction (CD × T_0) showed the lowest number of effective tillers per hill (4.42, 15.75, 14.98 and 12.08) at 30, 60, 90, and 120 DAT, respectively. A sharp increase in effective tiller number was observed from 30 to 60 DAT and subsequently tiller growth rate was slowed up to maturity. For the first 15 DAT, the rice plant grew slowly, then increased faster at 30 DAT, and then accelerated, but remain reasonably constant at 60 DAT, when the stem and leaf ceased developing and allowed to enter the reproductive stage [28]. Chongkid [29] reported that tiller number increased with age, notably at 60 DAT, but then began to fall and stopped at 90 days which was in line with the present study. Nitrogen promoted vegetative development in terms of tiller production, and thus the number of tillers per hill rose with increasing nitrogen rate and organic manure application compared to a control treatment with no organic and inorganic fertilizers. These findings are consistent with those of Paul et al. [30] and Ali et al. [31] observed that the combine application of both organic and inorganic fertilizers had a significant effect on the number of effective tillers per hill.

3.2 Effects of Organic Manure, Inorganic Fertilizer and their Interaction on Yield Components and Yield of BRRI dhan89

The yield contributing traits and yield of BRRI dhan89 differed significantly due to the effect of organic manure and inorganic fertilizer as well as their interaction (Table 6). The results showed that poultry manure (PM) had the highest plant height (112.96 cm), number effective of tillers m^{-2} (249.95), number of panicles m^{-2} (230.49), panicle length (24.79 cm), number of filled grains per panicle (142.15), 1000 grain weight (24.12 g), grain yield (7.96 tha^{-1}) and straw yield (8.40 tha^{-1}) except number of unfilled grains per panicle when compared to cowdung (CD). Among inorganic fertilizer treatments, the highest yield contributing traits like plant height (114.57 cm), number effective of tillers m^{-2} (261.50), number of panicles m^{-2} (250.17), panicle length (25.16 cm), number of filled grains per panicle (152.10), number of unfilled grains per panicle (46.15), 1000 grain weight (24.50 g) as well as grain yield (9.22 tha^{-1}) and straw yield (9.68 tha^{-1}) were observed in treatment T_4. The lowest plant height (108.90 cm), number effective of tillers m^{-2} (228.00), number of panicles m^{-2} (201.83), panicle length (24.04 cm), number of filled grains per panicle (130.22), 1000 grain weight (23.19 g) as well as grain yield (6.18 tha^{-1}) and straw yield (6.50 tha^{-1}) were observed in treatment T_0 but the lowest number of unfilled grains per panicle (4.78) observed in T_3. In case of treatment interaction, the highest plant height (115.21 cm), number effective of tillers m^{-2} (263.33), number of panicles m^{-2} (251.67), panicle length (25.18 cm), number of filled grains per panicle (152.34), 1000 grain weight (24.85 g) as well as grain yield (9.38 tha^{-1}) and straw yield (9.70 tha^{-1}) were obtained in treatment interaction (PM × T_4) whereas the lowest plant height (106.80 cm), number effective of tillers m^{-2} (212.67), number of panicles m^{-2} (200.67), panicle length (23.97 cm), number of filled grains per panicle (129.00), 1000 grain weight (22.76 g) as well as grain yield (5.99 tha^{-1}) and straw yield (6.29 tha^{-1}) were obtained in treatment interaction (CD × T_0). Moreover, the maximum number of unfilled grains per panicle (47.93) was recorded in treatment interaction (PM × T1) while the minimum number (42.47) was found by PM × T_1 treatment interaction (Table 6).

Plant height is one of the important yield components which indicates plants better growth and yield. The split application of urea and potassium accelerated vegetative growth in the plants, which may have been the main factor contributing to the increased plant height [32]. Our findings are similarly consistent with those of [33], who found that using manure in combination with inorganic fertilizer enhanced rice growth and yield considerably as compared to using chemical fertilizer separately.

Table 5. No. of effective tillers per hill at thirty days interval after transplanting

Organic fertilizer (OF)	30 DAT	60 DAT	90 DAT	120 DAT
CD	5.87 a	16.33 a	15.81 a	13.69 b
PM	6.07 a	16.94 a	16.32 a	14.89 a
LSD (<0.05)	0.57	1.76	0.76	0.19
Inorganic fertilizer (IF)				
T_0	5.13 b	15.96 b	15.23 c	12.88 c
T_1	5.17 b	16.21 ab	15.46 bc	13.50 c
T_2	6.17 ab	17.18 ab	16.39 ab	14.55 b
T_3	7.04 a	17.41 a	16.46 ab	14.87 ab
T_4	6.33 ab	17.18 ab	16.76 a	15.65 a
LSD (<0.05)	1.63	1.27	1.03	0.89
Interaction effect (OF × IF)				
CD × T_0	4.42 bc	15.75 c	14.98 d	12.08 f
CD × T_1	5.92 bc	15.76 c	15.26 cd	13.42 e
CD × T_2	5.75 bc	17.67 a	16.46 abc	14.20 cde
Cd × T_3	5.42 bc	17.00 b	15.93 abcd	14.00 cde
CD × T_4	6.83 ab	17.00 b	16.39 abcd	14.74 bcd
PM × T_0	5.42 c	16.17 bc	15.48 cd	13.67 cde
PM × T_1	5.83 bc	16.67 b	15.67 bcd	13.58 de
PM × T_2	6.58 abc	16.68 b	16.33 abcd	14.90 bc
PM × T_3	8.67 a	17.82 a	16.98 ab	15.74 ab
PM × T_4	5.83 bc	17.35 ab	17.13 a	16.57 a
LSD (<0.05)	2.29	1.78	1.46	1.25
CV (%)	22.26	6.16	5.24	5.06

Here, CD: Cowdung, PM: Poultry manure, DAT: Days after transplanting

Many researchers have also discovered the influence of organic manures and inorganic fertilizer mixtures on rice plant height [34,35]. Tillering is another important element of crop yields as well as a key component in rice production. The number of effective tillers (tillers that carry panicles) contributes more than the total number of tillers when determining rice yield. Many researchers [36,37] reported that tiller production of rice was influenced by the application of organic manure and inorganic fertilizer mixture. Increased nitrogen availability, which is essential for cell division, could be connected to a significant increase of tillers per square meter [38]. Organic sources supply a more complete diet for plants, especially micronutrients, which have a positive effect on the number of tillers in plants [39]. Nayak et al. [40] found that mixing chemical fertilizer with organic manure resulted in a significant increase in effective tillers m^{-2}. The number of panicles m^{-2} is the most prominent traits of rice growth in order to enhance grain yield. The number of panicles m^{-2} increased as NPK rates increased [41]. Organic and inorganic fertilizers resulted in the most productive tillers as well as the higher panicle number [42]. The present findings showed that the application of organic manure and inorganic fertilizers caused significant increase in panicle length of BRRI dhan89 (Table 6). Previous research [3,43] stated that the application of organic manure and inorganic fertilizers to rice plants increased panicle length significantly which support the present study. The use of organic manures as fertilizers provided growth-regulating compounds that promoted grain filling and enhanced the soil physical, chemical, and microbiological attributes [44]. The application of organic manures and inorganic fertilizers increased the number of grains per panicle significantly [13]. Iqbal et al. [45] agreed with these findings. The application of organic manure and inorganic fertilizers in combination increased 1000 grain weight of rice [46,47]. The availability of nutrients during the reproductive stage enhanced grain filling and, consequently, higher grain weight [48]. Yang et al. [49] discovered that combining chemical fertilizer with organic manure boosted 1000-grain weight. It was observed that all the treatments significantly gave a higher grain and straw yield over the control (Table 6). Grain yield is the expression of yield contributing traits. Organic manure has been shown to improve photosynthetic activity and availability of nutrients [50]. According to Rahman et al. [51], the use of organic and inorganic fertilizers boosted rice grain and straw yields. It is obvious that mixing organic manure with inorganic fertilizers boosted plant vegetative growth and thus rice straw yield [52]. These findings are consistent with those of Moe et al. [43] and Armin et al. [53].

3.3 Plant Nutrient Concentration

The various degrees of fertilizer and manure application and their interaction had a significant impact on the nitrogen (N), phosphorous (P), potassium (K), and sulphur (S) content in grain and straw of BRRI dhan89 (Table 7). The treatment PM showed the maximum concentration of N, P, K, and S in both grain and straw of BRRI dhan89 when compared to treatment CD. Among the inorganic fertilizer treatments, the highest concentration of N, P, K, S were observed in both grain and straw by the treatment T_4 whereas the lowest concentration of N, P, K, S was recorded by treatment T_0. Among the treatment interaction the highest concentration of N (1.39%), P (0.37%), K (0.21%), and S (0.17%) were found in grain by PM × T_4. On the other hand, the lowest concentration of N (0.75%), P (0.16%), K (0.12%), and S (0.08%) were found in grain by CD× T_0. In case of straw, treatment combination PM × T_4 had the highest N (0.66%), P (0.18%), K (1.34%), and S (0.08%) content and the treatment combination CD × T_0 had the lowest N (0.36%), P (0.0.08%), K (0.63%), and S (0.03%) content. These results are somewhat similar to those of Schmidt and Knoblauch [54]; Moe et al. [55], who applied poultry manure along with inorganic fertilizers to increase the concentration of nutrients including N, P, K and S in rice. The application of both inorganic and organic fertilizers clearly enhanced plant vegetative growth and increased the yield of straw [1]. According to Farid et al. [56], the use of organic sources of nitrogen and potassium had a significant impact on chemical characteristics such organic matter content, CEC, total N, exchangeable K, available P, and S, whereas inorganic sources typically had a negative impact. The findings made it clear that poultry manure accumulated more P in both rice grain and straw than cowdung. Vennila et al. [57] found that the phosphorus content of rice increased after being fertilized with both chemical and organic fertilizers. Sohel et al. [58] reported that the application of both chemical and organic fertilizers boosted the S concentrations in grain and straw of rice.

Table 6. Effects of organic fertilizer, inorganic fertilizer and its interaction on yield components and yield of BRRI dhan89

Organic fertilizer (OF)	PH	TN	PN	PL	FGP	UFG	TGW	GY	SY
CD	110.59 a	238.40 b	226.93 a	24.70 a	140.89 a	45.39 a	23.75 b	7.66 a	8.15 a
PM	112.96 a	249.95 a	230.49 a	24.79 a	142.15 a	44.63 a	24.12 a	7.96 a	8.40 a
LSD (<0.05)	3.78	2.44	7.43	0.82	8.31	5.91	0.30	0.45	0.75
Inorganic fertilizer (IF)									
T0	108.90 c	228.00 c	201.83 e	24.04 c	130.22 c	45.52 a	23.19 bc	6.18 c	6.50 c
T1	109.18 c	229.67 c	215.50 d	24.73 b	130.39 c	44.48 a	23.21 c	6.53 c	6.90 c
T2	112.13 b	247.00 b	233.80 c	24.82 ab	144.78 b	46.10 a	24.29 ab	8.23 b	8.85 b
T3	114.10 ab	254.72 a	242.26 b	24.98 ab	150.12 ab	42.78 a	24.48 a	8.91 a	9.44 ab
T4	114.57 a	261.50 a	250.17 a	25.16 a	152.10 a	46.15 a	24.50 ab	9.22 a	9.68 a
LSD (<0.05)	2.16	7.32	5.85	0.43	5.62	4.83	0.89	0.59	0.73
Interaction effect (OF × IF)									
CD × T0	106.80 c	212.67 f	200.67 e	23.97 d	129.00 b	44.93 a	22.76 d	5.99 d	6.29 b
CD × T1	108.33 c	224.33 e	213.33 d	25.08 a	130.00 b	46.50 a	23.32 bcd	6.42 d	6.82 b
CD × T2	110.81 bc	244.33 d	231.67 c	24.93 ab	144.20 a	44.67 a	24.29 ab	8.12 c	8.71 a
CD × T3	112.98 b	251.00 bcd	240.33 b	24.78 b	149.38 a	42.90 a	24.25 abc	8.71 abc	9.25 a
CD × T4	114.03 b	259.67 ab	248.67 a	25.18 a	151.86 a	47.93 a	23.94 abcd	9.05 ab	9.65 a
PM × T0	109.47 c	231.67 d	203.00 e	24.11 c	130.43 b	46.10 a	24.03 abcd	6.36 d	6.70 b
PM × T1	111.56 b	246.67 e	217.67 d	24.38 c	131.77 b	42.47 a	23.11 cd	6.63 d	6.99 b
PM × T2	113.45 b	249.67 cd	235.94 bc	24.72 b	145.35 a	47.53 a	24.29 abc	8.33 bc	8.98 a
PM × T3	115.11 a	258.44 abc	244.18 ab	25.13 a	150.85 a	42.67 a	24.71 a	9.10 ab	9.64 a
PM × T4	115.21 a	263.33 a	251.67 a	25.18 a	152.34 a	44.37 a	24.85 ab	9.38 a	9.70 a
LSD (<0.05)	3.05	10.35	8.28	0.60	7.94	6.83	1.26	0.84	1.03
CV (%)	1.58	2.45	2.09	1.41	3.24	26.28	3.03	6.21	7.21

Here, CD: Cowdung, PM: Poultry manure, PH: Plant height (cm), TN: Effective tillers m^{-2}, PN: Number of panicles m^{-2}, PL: Panicle length (cm), FGP: Number of filled grains per panicle, UGP: Number of unfilled grains per panicle, TGW: 1000 grain weight (g), GY: Grain yield (tha^{-1}), and SY: Straw yield (tha^{-1})

Table 7. Nutrient content (%) in grain and straw of BRRI dhan89 affected by organic and inorganic fertilizers

Organic fertilizer (OF)	Nutrient concentration in grain (%)				Nutrient concentration in straw (%)			
	N	P	K	S	N	P	K	S
CD	1.08 b	0.32 a	0.16 a	0.13 b	0.50 a	0.14 b	1.13 b	0.06 a
PM	1.12 a	0.34 a	0.17 a	0.14 a	0.52 a	0.15 a	1.16 a	0.06 a
LSD (<0.05)	0.01	0.02	0.03	2.87	0.03	0.03	0.03	0.02
Inorganic Fertilizer (IF)								
T0	0.77 d	0.17 d	0.13 d	0.09 c	0.36 d	0.09 d	0.65 e	0.03 b
T1	0.78 d	0.33 c	0.17 bc	0.14 b	0.38 d	0.13 c	1.27 c	0.06 a
T2	1.24 c	0.35 b	0.16 c	0.14 b	0.56 c	0.16 b	1.19 d	0.06 a
T3	1.34 b	0.35 ab	0.18 b	0.15 b	0.62 b	0.17 ab	1.31 b	0.07 a
T4	1.38 a	0.37 a	0.19 a	0.17 a	0.65 a	0.17 a	1.33 a	0.08 a
LSD (<0.05)	0.03	0.01	0.01	0.02	0.02	0.01	0.02	0.02
Interaction Effect (OF × IF)								
CD × T0	0.75 g	0.16 e	0.12 d	0.08 d	0.36 f	0.08 f	0.63 g	0.03 c
CD × T1	0.76 g	0.32 d	0.17 bc	0.13 c	0.37 ef	0.12 d	1.25 d	0.07 ab
CD × T2	1.22 e	0.34 bc	0.16 c	0.14 bc	0.55 d	0.15 c	1.19 e	0.06 ab
CD × T3	1.31 c	0.35 bc	0.18 b	0.15 bc	0.61 c	0.16 bc	1.28 c	0.07 a
CD × T4	1.36 b	0.36 abc	0.19 b	0.16 ab	0.64 ab	0.16 abc	1.31 bc	0.07 a
PM × T0	0.80 f	0.17 e	0.13	0.09 d	0.37 ef	0.10 e	0.67 f	0.04 bc
PM × T1	0.80 f	0.34 cd	0.17 bc	0.15 b	0.39 e	0.13 d	1.28 c	0.06 abc
PM × T2	1.26 d	0.35 bc	0.17 bc	0.14 bc	0.57 d	0.16 bc	1.19 e	0.06 abc
PM × T3	1.36 b	0.36 ab	0.17 bc	0.16 ab	0.63 bc	0.17 ab	1.33 ab	0.06 abc
PM × T4	1.39 a	0.37 a	0.21 a	0.17 a	0.66 a	0.18 a	1.34 a	0.08 a
LSD (<0.05)	0.04	0.02	0.02	0.02	0.02	0.02	0.03	0.03
CV (%)	1.88	3.62	6.14	8.22	2.73	6.44	1.35	26.94

Here, CD: Cowdung, PM: Poultry manure

Table 8. Effects of organic and inorganic fertilizers and its interaction on nutrient uptake by BRRI dhan89

Organic fertilizer (OF)	Nutrient uptake in grain ($kgha^{-1}$)				Nutrient uptake in straw ($kgha^{-1}$)			
	N	**P**	**K**	**S**	**N**	**P**	**K**	**S**
CD	58.44 b	16.35 b	8.67 a	7.07 b	30.32 b	8.11 b	67.08 a	3.67 a
PM	63.06 a	17.75 a	9.41 a	7.92 a	32.29 a	9.07 a	71.02 a	3.53 a
LSD (<0.05)	2.59	0.20	1.85	0.34	1.03	0.90	7.46	1.32
Inorganic Fertilizer (IF)								
T0	32.51 d	7.01 d	5.25 e	3.58 e	16.69 c	4.24 d	29.95 d	1.54 d
T1	34.63 d	14.66 c	7.62 d	6.21 d	18.48 c	6.13 c	62.01 c	3.12 c
T2	69.31 c	19.31 b	9.14 c	8.04 c	35.17 b	9.85 b	74.69 b	3.76 bc
T3	80.87 b	21.40 a	10.70 b	9.18 b	41.58 a	11.07 a	87.52 a	4.46 ab
T4	86.42 a	22.88 a	12.47 a	10.45 a	44.65 a	11.66 a	91.07 a	5.12 a
LSD (<0.05)	5.54	1.67	1.22	1.03	3.17	0.99	6.47	1.25
Interaction Effect (OF × IF)								
CD × T0	30.41 e	6.53 e	4.89 d	3.26 f	15.93 e	3.57 f	28.18 f	1.33 d
CD × T1	33.05 e	13.99 d	7.42 c	5.66 e	17.63 e	5.81 de	60.37 e	3.26 abc
CD × T2	67.44 d	18.79 c	8.65 c	7.94 cd	34.19 d	9.48 c	73.30 cd	3.95 ab
CD × T3	77.58 bc	20.51 bc	10.67 b	8.66 bc	40.04 bc	10.52 bc	84.05 ab	4.80 ab
CD × T4	83.71 ab	21.95 ab	11.71 ab	9.83 ab	43.85 ab	11.17 ab	89.51 a	5.03 a
PM × T0	34.61 e	7.49 e	5.62 cd	3.90 f	17.44 e	4.90 ef	31.71 f	1.75 cd
PM × T1	36.22 e	15.32 d	7.81 c	6.77 de	19.32 e	6.45 d	63.66 de	2.98 bcd
PM × T2	71.18 cd	19.83 c	9.63 c	8.14 cd	36.15 cd	10.22 bc	76.08 bc	3.58 ab
PM × T3	84.16 ab	22.30 ab	10.74 b	9.70 ab	43.12 ab	11.62 ab	90.99 a	4.12 ab
PM × T4	89.13 a	23.80 a	13.24 a	11.07 a	45.45 a	12.15 a	92.63 a	5.23 a
LSD (<0.05)	7.84	2.36	1.72	1.46	4.49	1.41	9.15	1.77
CV (%)	7.45	7.98	11.01	11.25	8.28	9.51	7.65	28.36

Here, CD: Cowdung, PM: Poultry manure

3.4 Plant Nutrient Uptake

The nutrient (N, P, K, S) uptake by grain and straw as well as the total nutrient uptake by BRRI dhan89 was significantly influenced by organic manure, inorganic fertilizer and their interaction (Table 8). In case of organic manure, the highest nutrient (N, P, K, S) uptake by grain and straw were recorded in PM while the lowest nutrient (N, P, K, S) uptake by grain and straw were recorded in CD. In case of inorganic fertilizer, the highest amount of nutrient (N, P, K, S) uptake by grain and straw were obtained in T_4 while the lowest in T_0. The findings showed that the maximum amount of nutrient (N, P, K, S) uptake by grain (89.13, 23.80, 13.24 and 11.07 tha^{-1}) and straw (45.45, 12.15, 92.63 and 5.23 tha^{-1}) were recorded in the treatment combination PM × T_4. However, the minimum amount of nutrient (N, P, K, S) uptake by grain (33.41, 6.53, 4.89 and 3.26 tha^{-1}) and straw (15.93, 3.59, 28.18 and 1.333 tha^{-1}) were recorded in the treatment combination CD × T_0. The findings of our study partially corroborated those of previous related studies by many other investigators [59,60], who found that rice uptake more N, P, K, and S as a result of the application of poultry manure along with inorganic fertilizers.

3.5 Nutrient Use Efficiency

Chemical fertilizers are widely used in modern agriculture, particularly in the production of cereals. In addition to raising production costs, excessive fertilizer use has negative environmental effects. Macronutrients play a key role in determining the grain production of rice, particularly nitrogen (N), and phosphorus (P). However, zinc (Zn) and sulphur (S) are two micronutrients that are essential for crop health [61]. As a result, one of the most practical strategies to boost grain yield and nutritional quality with less fertilizer input is regarded to be through breeding rice varieties with enhanced nutrient use efficiency (NUE). Nutrient use efficiency is measured as the increase in grain yield expressed in kg for each kg of supplied nutrients [62]. To compare the use efficiency of nutrients by crop, NPKS use efficiency for various treatments with organic and inorganic fertilizers was computed. The use efficiency of NPKS was maximum in PM × T_4 and the minimum value was recorded in CD × T_1 and PM × T_1 for N, CD × T_1 for P, PM × T_1 for K and CD × T_1 for S. Recently, it was investigated that applying a balanced amount of N fertilizer at various growth stages of rice known as transplanting, active tillering, tillering, and panicle initiation will increase the transplanted rice's ability to use nitrogen [63]. Murthy et al. [64] also clarified that efficiency of N, P, K, and S in rice was gradually improved with increasing amounts of the corresponding nutrients.

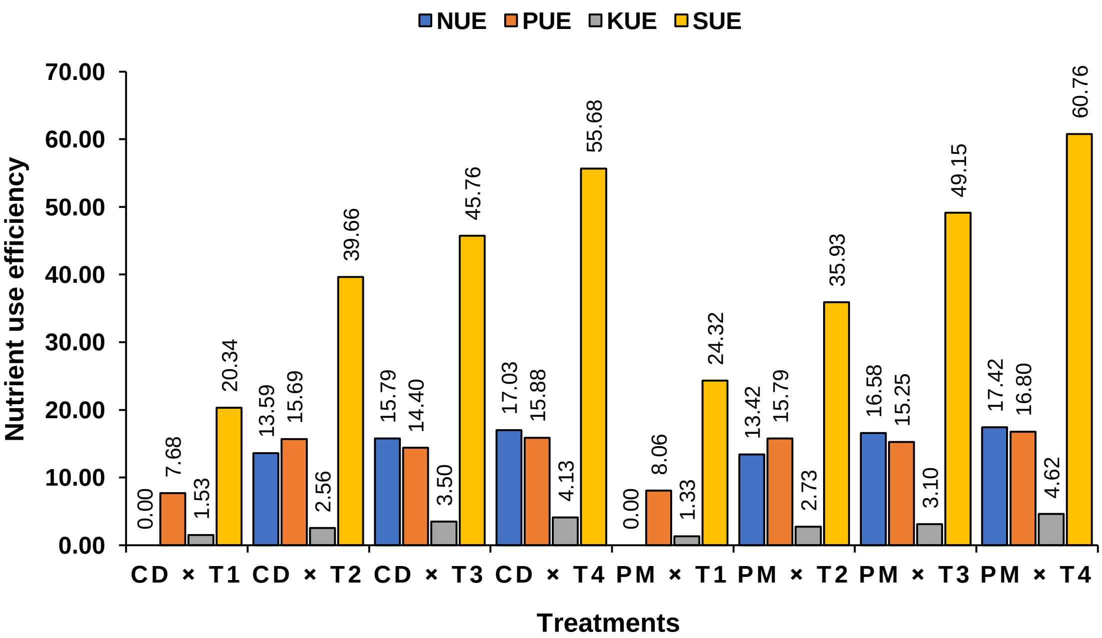

Fig. 1. Effects of organic and inorganic fertilizers on nutrient use efficiency (%) of BRRI dhan89

4. CONCLUSION

In modern agriculture, the most important factors influencing plant growth, yield contributing parameters and yield are nutrient management and fertilizer application. The findings of this study showed that the combined application of organic and inorganic fertilizer as well as the split application of urea and MoP enhanced yield contributing traits performance, yield, nutrient concentration in plant, nutrient uptake capacity and nutrient use efficiency of BRRI dhan89. Among the treatments studied, the treatment interaction PM × T_4 has a more favourable and beneficial effect on enhancing growth, yield contributing traits and yield of BRRI dhan89. In comparison to the traditional, and imbalanced fertilizer suggestion, such nutrient and fertilizer management technique (PM × T_4) will be more beneficial to meet the requirements of winter rice in a single *Boro* cropping system.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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