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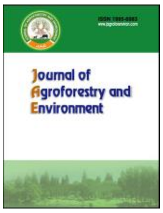

Assessing the Impact of Tillage Systems and Organic Amendments on Rice Productivity

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Abstract: Food security depends on rice (*Oryza sativa* L.), the foundation of billions of Asian and African people. The loss of soil organic matter reduces rice growth and productivity by lowering soil structure and water-holding capacity. Thus, a field experiment examined how tillage regimes and organic additions affect rice growth and productivity. Two-factor Split Plot Designs were used in the investigation. Tillage systems (CT1= Conservation tillage and CT2=Conventional tillage) in the main plot and organic amendments (CD=Cow dung 5t/ha, PM=Poultry manure 3t/ha, and Cow dung Slurry 1.5 t/ha) in the sub plot were the determining factors. Grain and straw yields were higher in CT1 than CT2. In organic amendments, PM (3 t/ha) consistently maximized growth and production. With the CT1+ PM treatment, total tillers (15.89), effective tillers (15.08), and plant height (100.46 cm) were highest, while CT2 × CD combination had the lowest values (12.56, 12.22, and 92.37 cm, respectively). In grain, CT1+ PM treatment had P (0.35%) and K (0.39%) and S (0.40%). For grain and straw nutrient content, organic additions were also beneficial. The lowest nutritional levels were found in CD. The combination of CT1 and PM outperformed CT2 and PM. Compared to CT2 and other organic amendments, CT1+PM (3 t/ha) improved BRRI dhan89 (boro rice) growth features, grain and straw yield, and nutrient status. These findings suggested that using CT1+PM (3 t/ha) in the soil might be effective for high yield and nutritional conditions for rice.

Keywords: Conservation tillage; Conventional tillage; Organic amendments (OMs); Nutrition; Yield.

INTRODUCTION

More than half of the world's population, especially in Asia and Africa, relies on rice (*Oryza sativa* L.) as their main sustenance (Mohapatra & Sahu, 2022). Bangladeshis depend heavily on rice for their nutrition and caloric intake. According to the latest data, Bangladesh produced 40.3 million metric tons (MT) (paddy equivalent) of rice in Fiscal Year 2022-23 (BBS, 2023). Given the country's expected population growth of over 30 million in the next decades, it will need over 47 MMT of rice by 2050 to maintain food security, making sustainable yield improvements on a given or declining land area difficult. Bangladesh's rice yield is below average at 4.32 t/ha. The low yield may be due to diminishing soil fertility, measured by critically low Soil Organic Matter (SOM) content and incorrect tilling and management methods that erode soil structure. Conventional Tillage (CT) forms a restrictive plough pan that degrades soil structure over time (John Anurag & Singh, 2007). Compaction physically hinders root growth and limits soil water infiltration. Synthetic chemical fertilizers increase soil deterioration and microbial loss while temporarily increasing yield (Iqbal et al., 2020). This extensive use of chemicals affects the farming system and renders it unsustainable. Organic inputs alone cannot maximize agricultural production (Nambiar, 1998). Thus, soil management must incorporate organic and chemical inputs.

Minimum tillage (MT) strengthens soil and facilitates farming. As digging decreases, MT prevents the plough pan, a hard layer under CT. Protecting soil protects its structure and porosity. Porosity enhances air and water flow in soil quickly. Safe, open soil is essential for strong root growth.

Strong root growth helps the plant absorb nutrients and generate better panicles, which boosts crop yield. Improving soil structure and fertility, especially Soil Organic Matter, are necessary. To rebuild the soil ecosystem, organic additions like cow dung, bio-slurry, and poultry manure are essential. Plant growth is boosted by these widely available macro and micronutrients. They increase SOM, which increases soil aggregation and beneficial microbial activity (Ayoola & Makinde, 2007). These soil enhancements boost agricultural output significantly and sustainably. Managing soil structure and fertility together maximizes rice yield. Research suggests that combining Conservation Tillage (MT) with Organic Amendments (OMs) yields better than either strategy alone (Li et al., 2022).

Global agricultural literature recognizes the contributions of CT/MT to soil physical structure and organic additions like cow dung and slurry to soil fertility (Li et al., 2022). Additionally, their interaction effects are little understood. Bangladesh's soil and climate make integrated management findings unsuitable for the boro rice ecosystem. The combined effects of improved soil physical conditions and biologically enriched soil through amendments on key physiological traits like root growth and panicle formation under local field conditions are not well studied (Chandra et al., 2023). In order to develop sustainable ways for farmers to get the highest yields in the region, this study is crucial. Thus, this study is crucial to developing sustainable strategies for farmers to obtain the region's highest yields.

MATERIALS AND METHODS

Experimental Site

The investigation was conducted at the Soil Science Field Laboratory of Bangladesh Agricultural University (BAU) in Mymensingh. The experimental site is situated at 24°N latitude and 90°E longitude, 18 meters above sea level. It is located in AEZ-9, which is the Old Brahmaputra Floodplain. The experiment was conducted during the Rabi season (Boro) December 30, 2023, to May 16, 2024, a period of arid, consistent weather, during which temperatures fluctuated between 10°C and 25°C, humidity ranged from 50% to 70%, and rainfall was minimal.

Experimental Soil

Soil samples were collected from experimental plot at BAU's Soil Science Field Laboratory in Mymensingh. Ten random soil samples from 0–15 cm across the experimental plot, a single unit, were taken for representativeness. Physicochemical testing of the composite sample was complete. Table 1 shows initial soil analysis results.

Test Crop

BRRI Dhan89 rice, which yields well, was employed in this study. It produces 8.0 tons per hectare in ordinary farming, outperforming the renowned check variety BRRI Dhan29. Importantly, it produces 9.7 tons per hectare under ideal conditions. BRRI Dhan89 grows at 106 cm with robust plant architecture. A strong stem prevents lodging. While grain panicles mature, "stay-green" stems and flag leaves are ideal for agriculture. Extension of photosynthesis improves panicle grain fullness, especially at the bottom. A 24.4-gram 1000-grain weight suggests good grain. Early cultivars struggled with common illnesses and insect pests, but BRRI Dhan89 did well in the field. Following the preparation of the seedbed, seeds were sown on December 26, 2023, and the 35-day-old seedlings were transplanted into the field on January 30, 2024.

Land Preparation

The land was prepared by ploughing and cross ploughing with power tiller followed by country plough. Then the land was laddered with traditional tools. All kinds of weeds and stubbles were removed from the field before final ploughing and levelling.

Layout of the Experiment

Split plot design was used for the experiment. There were two experimental treatments: two tillage treatments (CT1= Conservation Tillage, CT2= Conventional Tillage) as the main plot and organic amendments CD = Cowdung (5 t /ha), PM= Poultry Manure (3 t/ha), S= Cowdung Slurry (1.5 t/ha) were allocated into subplots. Treatments were repeated three times. The plot count was 18. The unit plot was 3 m × 2 m with 0.5 m plot-to-plot and 1 m block-to-block spacing.

Application of Fertilizers

For each plot, N, P, K, S, zinc, and boron were calculated. Each experiment plot received Urea-125, TSP-40, MoP-48, Gypsum-18, Zinc Sulphate-2 g plot^{-1}. During final land preparation, all TSP, MoP, gypsum, and zinc sulfate were applied. The first urea dose was given 15 days after transplanting (DAT), followed by 30 and 45 DAT doses.

Intercultural operations

Intercultural operations were done as needed to keep crops growing normally. The following were done:
The plots received deep tube well irrigation to meet crop water needs. More irrigation was needed in boro season. Several noxious weeds were uprooted and removed from the experimental plots three times. A moderate grasshopper infestation occurred during boro season. This was controlled by using 67 g Brifur 5G per plot mixed with urea at the second split. No major diseases were found all season.

Harvesting and Threshing

Each plot harvested mature crops on May 16, 2024. Each plot's crops were packaged, marked, and taken to the threshing floor. Sun-dried, threshed, and winnowed bundles. Five samples were randomly selected and uprooted from each plot for data collection before harvesting. Straw and grain yields were measured plot-wise and expressed in t ha^{-1}. Sun-dried yields were adjusted to 14% moisture.

Data Collection

Main data collecting began at 30 DAT. Three measurements were conducted during the growing period and one on harvest day to capture plant height and tiller count at 30-day intervals. At 30-day intervals, soil pH and redox potential (Eh) were measured. Another growth and yield characteristic was assessed after harvesting.

Recording of Yield and Yield Components

Panicle length was measured from rachis basal node to apex. On average, each observation had 5 hills. The number of tillers per hill during growth was recorded for 10 random

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hills from each plot. In addition, five hills from each plot were counted for effective and non-effective tillers. Tillers with grains on the panicle were effective; those without were not. Five panicles from each hill were randomly picked, and filled and empty grains were counted and averaged for number of grains panicle^{-1}. After harvest, 1,000 cleaned and dried grains with 14% moisture were randomly selected from the seeds. These grains were weighed in grams using an electric balance for thousand seeds weight. For grain yield each plot had a 1 m^2 area for grain yield measurements at 14% moisture. These measurements were then converted to a yield of tons per hectare. Sun-dried straw from the grain yield sample was weighed. The weight was converted to tons/ha for straw yield. Yoshida (1981)'s formula estimated the biological yield, which is the grain and straw yields.

Biological Yield= Grain Yield + Straw Yield

Harvest Index

The harvest index, which represents the proportion of economic yield to biological yield, was calculated using the formula provided by Yang and Zhang (2010).

$$\%\,Harvest\ Index\ (HI) = \frac{Grain\ yield}{Biological\ yield} \times 100$$

Preparation of Plant Samples

Representative grain and straw samples were pulverized in a grinder after drying in a 65°C oven for 24 hours. Ziplock bags held the samples for analysis.

Plant Sample Digestion for Total N Determination

A digestion tube contained 0.1 g of oven-dry ground plant sample (grain or straw) for N determination. Catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Se = 100:10:1)1.1 g, 2 ml 30% H_2O_2, and 3 ml H_2SO_4 were added. After swirling and waiting 30 minutes, the slurry was heated in a digesting block at 360°C for 45 minutes until colorless. The digest was diluted to the mark with distilled water in a 100 ml volumetric flask after cooling. Similar reagent blanks were made. N was determined from the digest.

Plant Sample Digestion for P, K, and S Determination

Grain or straw of 0.5 g was placed in a dry, clean digestive tube. Ten ml of a 2:1 di-acid combination (HNO_3: $HClO_4$) was added to the tube. The tube was heated at 180°C in a digesting block until the solution became clear and colorless after reacting. The digest was diluted to the mark with distilled water in a 50 ml volumetric flask after cooling. The digest was used to measure P, K, and S.

Plant sample N, P, K, and S determination

The digests' N content was measured using the same procedure as soil analysis. Phosphorus (P) was measured using the Olsen method (Olsen, 1954), using 1 cc of digest from a 50 ml extract. The ascorbic acid reduction of the phosphomolybdate complex produced a blue hue that was detected spectrophotometrically at 890 nm to quantify the isolated P. Five ml of digest was taken and diluted to 50 ml volume to achieve the desired concentration for K. The emission was measured by a flame photometer. To assess S content, 5 ml of digest from a 50 ml extract was employed and a spectrophotometer was used at 420 nm (Hunter, 1984).

Nutrient Uptake

Nutrient uptake by grain and straw was calculated using the following equation (Islam *et al.,* 2021):

Nutrient uptake (kg ha^{-1}) =

$$\frac{\text{Nutrient content} \times \text{Dry mass production (kg/ha)}}{100}$$

Soil Sample Collection

Subsurface soil samples were taken 0-15 cm deep. The materials were air-dried and passed through a 2 mm sieve after removing weeds, plant roots, stubbles, stones, and waste. The produced samples were stored in clean plastic bags for chemical and mechanical investigation.

Soil Sample Analysis

Using Michael Peech's (1965) method, a glass electrode pH meter assessed soil pH in a 1:2.5 soil-to-water suspension ratio. As described by Walkley and Black (1934), moist oxidation determined organic carbon. Over 1N $K_2Cr_2O_7$, conc. H_2SO_4, and conc. H_3PO_4 were used to oxidize organic C. The excess solution was titrated with 1N $FeSO_4$. A Van Bammelen factor of 1.73 was applied to organic carbon to calculate organic matter.

Total N

One gram of oven-dried soil, 1.1 g of catalyst combination (K_2SO_4: $CuSO_4.5H_2O$: Se = 100:10:1), 2 ml of 30% H_2O_2, and 5 ml of H_2SO_4 were placed in a digestion tube. The mixture was heated at 360°C until clear and colorless after whirling and waiting 10 minutes. Cooled digest was diluted with distilled water in a 100 ml volumetric flask. Additionally, a reagent blank was made. Distillation with 40% NaOH determined N. Trapped ammonia in 4% H_3BO_3 solution with 5 drops of bromocresol green and methyl red indicator. After titrating with 0.01 N H_2SO_4, the distillate turned pink from green (Bremner and Mulvaney, 1982). Formula determined N content:

$$\%N = \frac{(T-B)\times N\times 0.014\times 100}{S}$$

Where,

T= Sample titration value (ml) of standard H_2SO_4

B= Blank titration value (ml) of standard H_2SO_4

N= Strength of H_2SO_4

S= Sample weight in gram

Available P,K and S determination

According to Olsen, (1954), soil samples were shaken with 0.5 M NaHCO3 solution at pH 8.5 to extract P. SnCl2 reduction of phosphomolybdate complex produced a blue color, which was measured spectrophotometrically at 660 nm wavelength and calibrated to the standard P curve to quantify the extracted P. Exchangeable K was extracted from soil samples with 1.0 N ammonium acetate, pH 7 NH4OAc, and measured directly by a flame photometer (Black, 1965) and calibrated using a standard curve. According to Sahrawat et al., (2009), soil samples were extracted with 0.15% calcium chloride to determine S. The extract's S concentration was determined turbidimetrically with a 420 nm spectrophotometer.

Statistical Analysis

The data were initially checked for normality using boxplots, histograms, and the Shapiro-Wilk test ($p > 0.05$). Following a two-factor split plot design, RStudio statistically evaluated normally distributed data. Based on F-statistics, crop and soil factors were analyzed using ANOVA. All

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parameters had mean values, and the Tukey HSD test at 5% significance was used to compare means (Gomez and Gomez, 1984). Kruskal-Wallis compared non-parametric data. Gplot2 and Metan in RStudio (V-2024.04.0+735) were used to show the data and a correlation matrix.

RESULTS AND DISCUSSIONS

Interaction effect of different tillage and organic amendments on the yield attributes of *boro* rice

The interaction of different tillage methods and organic amendments did not influence boro rice yield metrics, with the exception of non-effective tillers, panicle length, and non-filled grains (Table 2). The poutry manure treatment yielded the most tillers (15.89 t ha^{-1}) in both conventional and conservation tillage, whereas the conventional tillage+ cowdung treatment yielded the least (12.56 t ha^{-1}). Tiller effectiveness ranged from 12.22 to 15.08, with conservation tillage utilizing poultry manure yielding the highest and conventional tillage using cowdung yielding the lowest. Statistics show that conservation tillage with poultry manure yielded 19% more than conventional tillage with cowdung. Plant height ranged from 92.37 to 100.46 cm, with conservation + poultry manure combination having the highest and conventional + cowdung combination was having the lowest. The combination of conservation and poultry manure resulted in 8% higher seed weight than conventional + cowdung, as with plant height. Conventional + cowdung combination yielded the most unfilled grains (41.19), followed by conventional + cowdung slurry (33.83), and lowest with poultry manure treatment through conservation (23.47). While conservation + poultry manure outperformed conventional + cowdung, the interaction effects were mostly insignificant. Poultry manure supplies nitrogen, P, K, S, Ca, Mg, and micronutrients like Fe and Zn, which are absent in conventional chemical fertilizers (Ashworth et al., 2020). After 365 days, 85% of poultry manure remains, providing continuous nutrients that boost growth and grain production during reproductive stages (Pitta et al., 2012). The addition of poultry manure to soil affects microbiological activity, transforming, moving, and accumulating materials and energy (Abdel-Hamid et al., 2020; Cheng, 2021). Higher soil microbial activity increases N, P, and K mineralization, plant growth-promoting chemicals, and nutrient cycling (Dai et al., 2016; Smith, 2018). Cow dung provides fewer vital nutrients than chemical fertilizers, which can limit the immediate availability of nutrients required for optimal plant growth (Islam et al., 2021). Cowdung alone may lack micronutrients, reducing yield and nutrient content compare to poultry manure (Islam et al., 2021). Conservation tillage with organic management results in increased plant height, dry matter accumulation, and grain yield than conventional approaches (Meena et al., 2023).

Effect of different tillage systems and organic amendments on nutrient concentrations in the grain of *boro* rice

Combining conservation and poultry manure yielded the highest total N (1.28%) in grain (Figure 1). Conservation × cowdung (1.18%) had the lowest results. Boro rice had a range of available P (0.10% to 0.35%), with the maximum being attained with conservation and poultry manure. Boro rice grain had a K of 0.35–0.39. Similar to K, boro rice S ranged from 0.48-0.52%, with poultry manure yielding the greatest amount of S than others treatments. Conservation and poultry outperformed traditional poultry manure in terms of grain available N, straw P, and K. Martín-Lammerding et al. (2021) found that organic additions increase topsoil nutrient content, especially nitrogen, phosphorus, and potassium. Poultry manure enhances soil structure, accelerates microbiological activity, and releases nutrients slowly (Li et al., 2022). Poultry manure raised soil pH and nutrient concentrations, especially phosphorus and sulfur, improving soil fertility (Khan et al., 2017). Poultry manure increased soil total nitrogen, accessible phosphorus, exchangeable potassium, calcium, and magnesium, and nutrient concentration more than control and complete NPK treatments (Hossain et al., 2013). Cow dung decomposes slowly, delaying nutrient release and potentially disrupting crop nutrient uptake (Akhter et al., 2015). Reduced tillage and straw retention improve organic carbon and total nitrogen, improving crop nutrient availability (Calistru et al., 2024). Compared to conventional approaches, conservation tillage with organic amendments enhances grain and straw nutrient content (Whitmore et al., 2017). Malhi & Lemke (2007) found that conservation tillage with straw retention (R) increased nitrogen (N) and carbon (C) in seed, straw, and chaff, improving crop nutrient concentration. Conservation tillage increased soil organic matter, nitrogen, phosphate, and potassium (Ahmad et al., 2022).

Effect of different tillage systems and organic amendments on nutrient concentrations in the straw of *boro* rice

Tillage systems and organic amendments interacted significantly on total N and S (Figure 2). The combination of conservation and poultry manure yielded the highest total N and S values (0.56% and 0.15%, respectively). Lowest value of total N and S was found with conventional and cowdung combination (0.45% and 0.11% respectively). The K value of boro rice straw ranged from 1.35 to 1.70 meq/100g soil, with conservation+poultry manure as the greatest and conventional cowdung as the lowest. Similarly to K, boro rice straw's P ranged from 0.10% to 0.16%, with poultry manure providing the greatest and conventional+ cowdung yielding the lowest. The highest yields were achieved with conservation tillage and poultry manure, while conventional tillage and cowdung slurry yielded the lowest. Conservation tillage improves soil structure and porosity (Sarker et al., 2022). Conservation tillage increased rice yield by 9.2% in Bangladesh (Sarker et al., 2022). Organic manure offers many benefits due to its balanced macro and micronutrients. This may boost soil nutrients by increasing microbial activity and physical and chemical characteristics (Adekiya et al., 2018). Plant growth requires soil organic carbon and nutrients, which organic amendments boost (Das et al., 2024). poultry manure increases soil organic matter by 24%, improving soil quality and health, while mineral fertilizer offers plant nutrients. Manure improves soil fertility and

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crop productivity by decomposing organic matter (Biswas & Kole, 2017). Poultry manure changed soil microbiology, transforming, moving, and accumulating materials and energy (Abdel-Hamid et al., 2020; Cheng, 2021). The soil receives a lot of nutritional substrate, energy, and foreign microbes, including harmful ones. Poultry manure offers organic matter and vital nutrients, while fertilizers provide urgent nutrient needs, improving root development and nutrient absorption and yielding more than solo fertilizer treatment (Bilkis et al., 2018). Cowdung slowly releases nutrients improves soil characteristics, but its nutrient content may not meet crop growth needs as quickly as other organic amendments (Akhter et al., 2015). Organic amendments enhance rice yields by 5.1% to 6.1% over traditional approaches (Qui et al., 2024). Conservation tillage, integrated nutrient management, and residue retention increased rice output over conventional methods. Conservation tillage boosted straw, root, and biomass yield in wet and dry season rice (Yadav et al., 2017). Conservation tillage with organic amendments yields higher than conventional tillage (Whitmore et al., 2016).

Table 1: Physical, and chemical characteristics of the initial soil

Physical characteristics		**Chemical characteristics**	
Characteristics	**Value**	**Textural Class**	**Results**
pH (soil: water 1:2.5)	6.28	Particle size analysis	
OC (%)	1.13	Sand (%)	22.00
TN (%)	0.172	Silt (%)	64.00
Available P (mg kg^{-1})	4.36	Clay (%)	14.00
Exchangeable K (meq 100 g^{-1} soil)	0.060	Textural class	Silt loam
Available Sulphur (mg kg^{-1})	10.5		
Available Zinc (mg kg^{-1})	0.9		
CEC (meq 100 g^{-1} soil)	15		

Interaction effect of different tillage and organic amendments on the properties of the post-harvest soils of *boro* rice

Tillage systems and organic amendments affected P availability (Figure 3). The maximum total N was recorded with conservation tillage and poultry manure (0.28%) and the lowest with conventional tillage and cowdung (0.20%). The combination of conventional and poultry manure yielded the greatest P (ppm) (8.84), followed by conservation and poultry manure (7.78), conventional and cowdung slurry (7.51), conservation and cowdung (6.30), and conservation and cowdung (5.93). Conversely, conventional × cowdung yielded the lowest P (5.09). Conservation and conventional poultry manure had similar K values (0.18 meq/100g soil), with conventional + cowdung having the lowest (0.15 meq/100g soil). Treatments using conservation tillage and poultry manure had the highest available sulphur (24.6 ppm) compared to others. The interaction only affected available P, with conventional × poultry manure yielding the most (8.84 ppm) and conservation × cowdung yielding the lowest (5.93 ppm). Depending on quantity and quality, organic additions can increase soil OM. Organic amendments increase SOM, TN, P, K, S, and CEC through nutrient cycling, microbial activity, and water retention, improving soil health post-harvest (Omokaro et al., 2024). McConnell et al. (1993) observed that 18–146 t ha-1 compost increased soil organic matter by 6–163%. Agegnehu et al. (2016) found that organic compounds increase SOM by 23–34%. Organic matter in poultry manure increased 2.76% (Islam & Raihan, 2024). FYM and poultry manure improve plant nutrient availability organically (Hue and Silva et al., 2000). Mineralization by microorganisms converts organic nitrogen to inorganic (Abdelhafez et al., 2018). Applying composts and manures consistently raises soil P levels (Mohamed et al., 2007). Zero-tillage improves root growth and water infiltration by lowering bulk density and increasing overall porosity. Poultry manure improves soil aggregate stability and minimizes compaction, which is essential for soil health. Conservation tillage and poultry manure improve soil moisture retention, which boosts crop output in drought-prone locations (Saha et al., 2013).

Table 2: Interaction effect of different tillage and organic amendments on the yield attributes of *boro* rice

Tillage	**Treatment**	**Total Tillers**	**Effective Tillers**	**Non-Effective Tillers**	**Plant Height (cm)**	**Panicle Length (cm)**	**Filled Grains**	**Unfilled Grains**	**1000-Grain Weight (g)**
CT1	Poultry Manure	15.89±0.21 a	15.08±0.29 a	0.36±0.06	100.46±2.42 a	28.43±0.27	124.7±2.98	23.47±0.33 c	24.13±0.19 a

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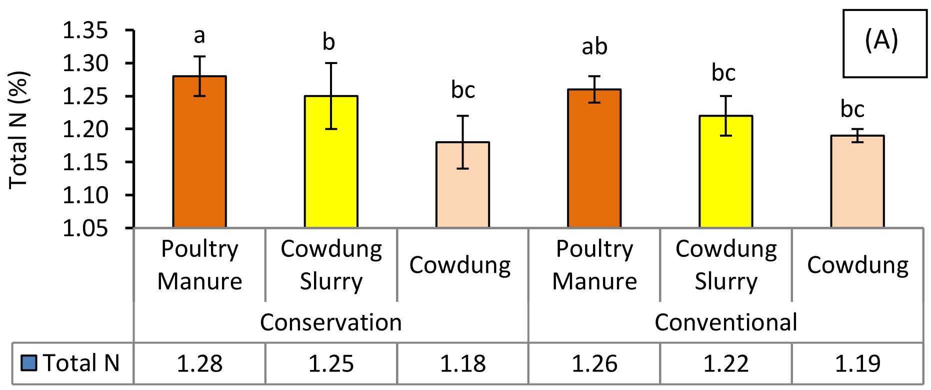
	Cowdung Slurry	15.00±0.31 ab	14.66±0.10 abc	0.38±0.23	95.93±0.30 bc	26.41±1.29	108.2±5.54	30.73±1.06 b	23.29±0.46 ab
	Cowdung	13.22± 0.33 bc	12.33±0.33 b	0.37 ±0.09	92.71±0.46 cd	23.50±0.56	102.3±2.04	31.87±2.34 b	22.76 ±0.30 bc
CT2	Poultry Manure	15.59±0.77 ab	14.82±0.51 ab	0.23±0.40	99.23±1.27 ab	26.35±0.28	121.6 ±2.25	28.08±2.13 bc	23.85±0.31 ab
	Cowdung Slurry	12.88±0.22 bc	12.33±0.03 bc	0.55±0.38	95.53±0.87 cd	23.76±0.90	106.9±1.45	33.83±3.07 b	23.08±0.13 abc
	Cowdung	12.56±1.82 c	12.22±1.61 b	0.33±0.33	92.37±1.02 d	23.62±0.85	102±2.44	41.19±3.81 a	22.16±0.65 c
CV(%)		8.00	8.01	17.73	1.95	25.18	5.38	10.46	3.00
Level of significance		*	*	NS	*	NS	NS	*	*

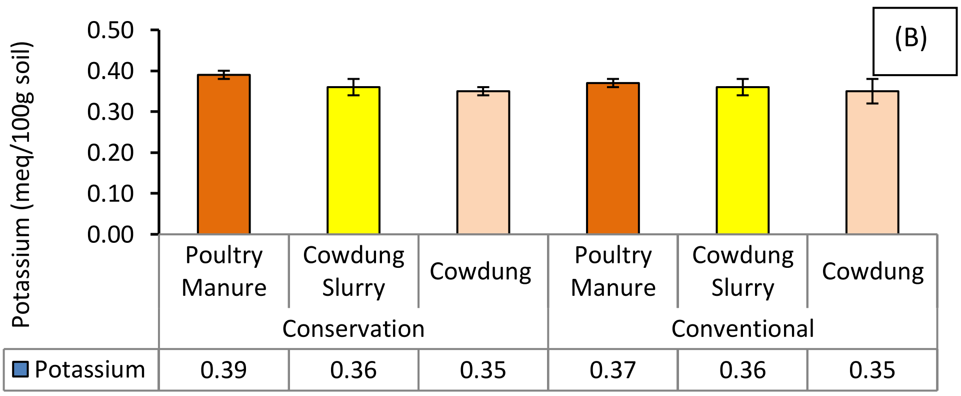
Means with the same letters or without letters within the same column do not differ significantly

* = Significant at 5% level of probability, ** = Significant at 1% level of p robability, NS = Non-significant

Interaction effect of different tillage systems and organic amendments on grain and straw yield of *boro* rice

Tillage systems and organic amendments affected P availability (Figure 4). The maximum total N was recorded with conservation tillage and poultry manure (0.28%) and the lowest with conventional tillage and cowdung (0.20%). The combination of conventional and poultry manure yielded the greatest P (ppm) (8.84), followed by conservation and poultry manure (7.78), conventional and cowdung slurry (7.51), conservation and cowdung (6.30), and conservation and cowdung (5.93). Conversely, conventional × cowdung yielded the lowest P (5.09). Conservation and conventional poultry manure had similar K values (0.18 meq/100g soil), with conventional × cowdung having the lowest (0.15 meq/100g soil). Treatments using conservation tillage and poultry manure had the highest available sulphur (24.6 ppm) compared to others.





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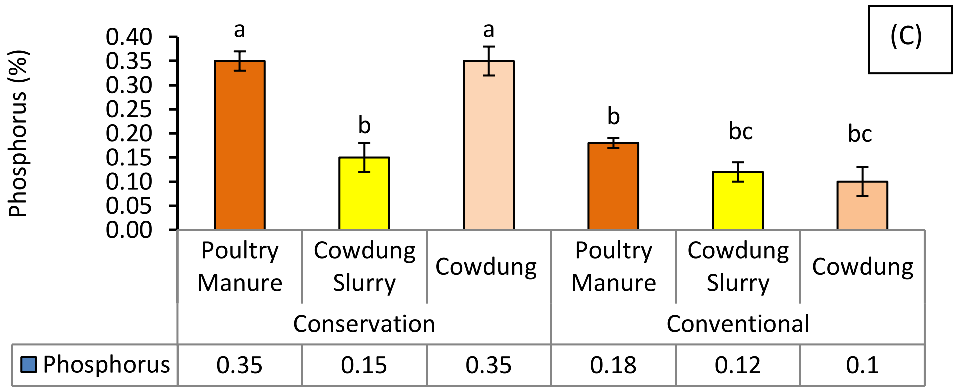


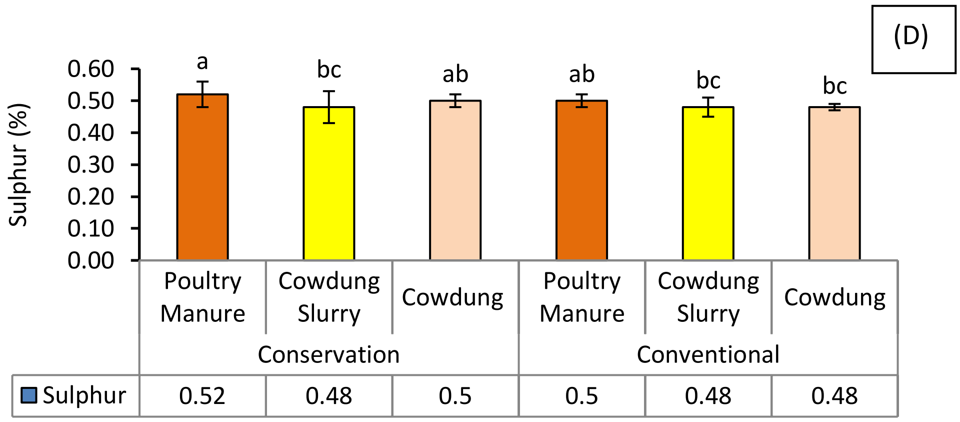
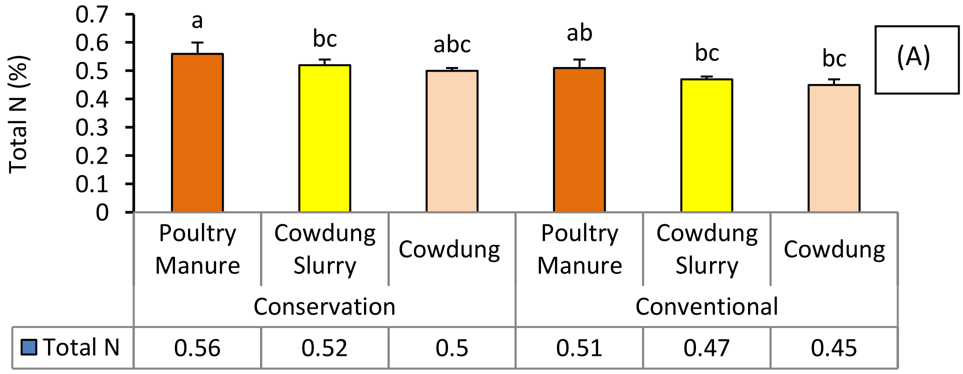


Figure 1: Interaction effect of different tillage systems and organic amendments on the (A) Total N, (B) Potassium, (C) Phosphorus and (D) Sulphur of the grain of *boro* rice. Means with the same letters or without letters within the same column do not differ significantly



(B)

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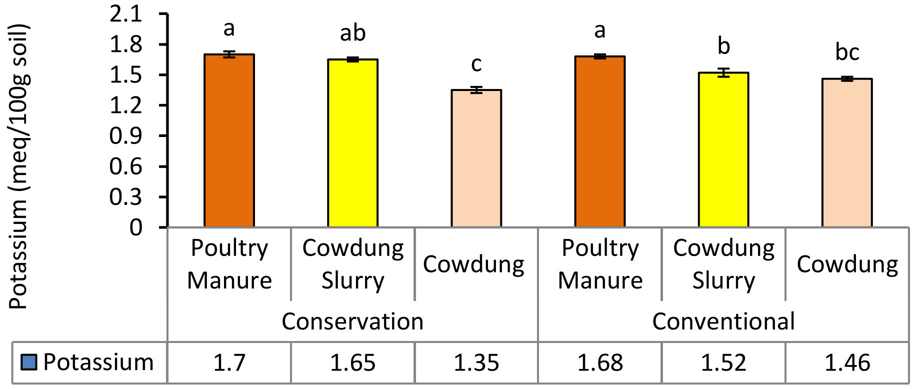
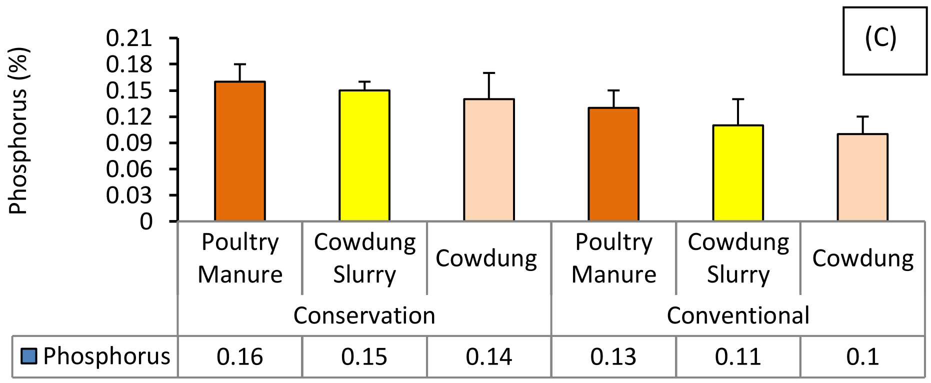




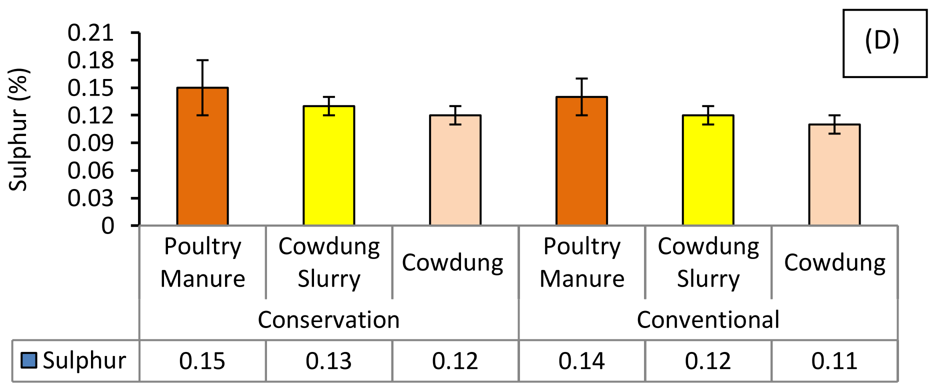
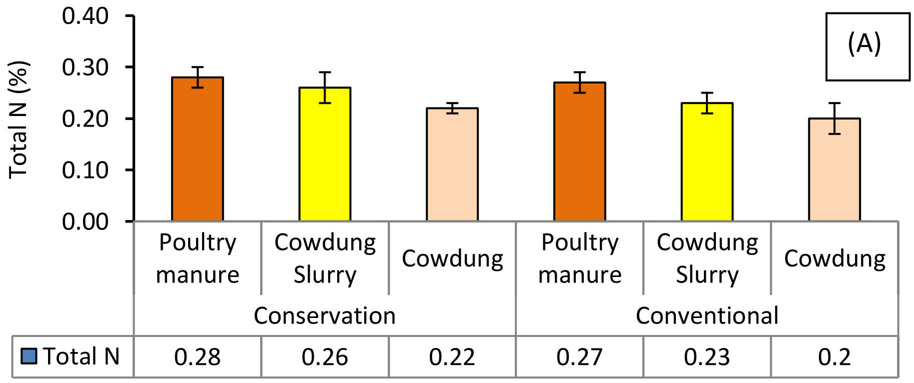


Figure 2: Interaction effect of different tillage systems and organic amendments on the (A) Total N, (B) Potassium, (C) Phosphorus and (D) Sulphur of the straw of *boro* rice. Means with the same letters or without letters within the same column do not differ significantly



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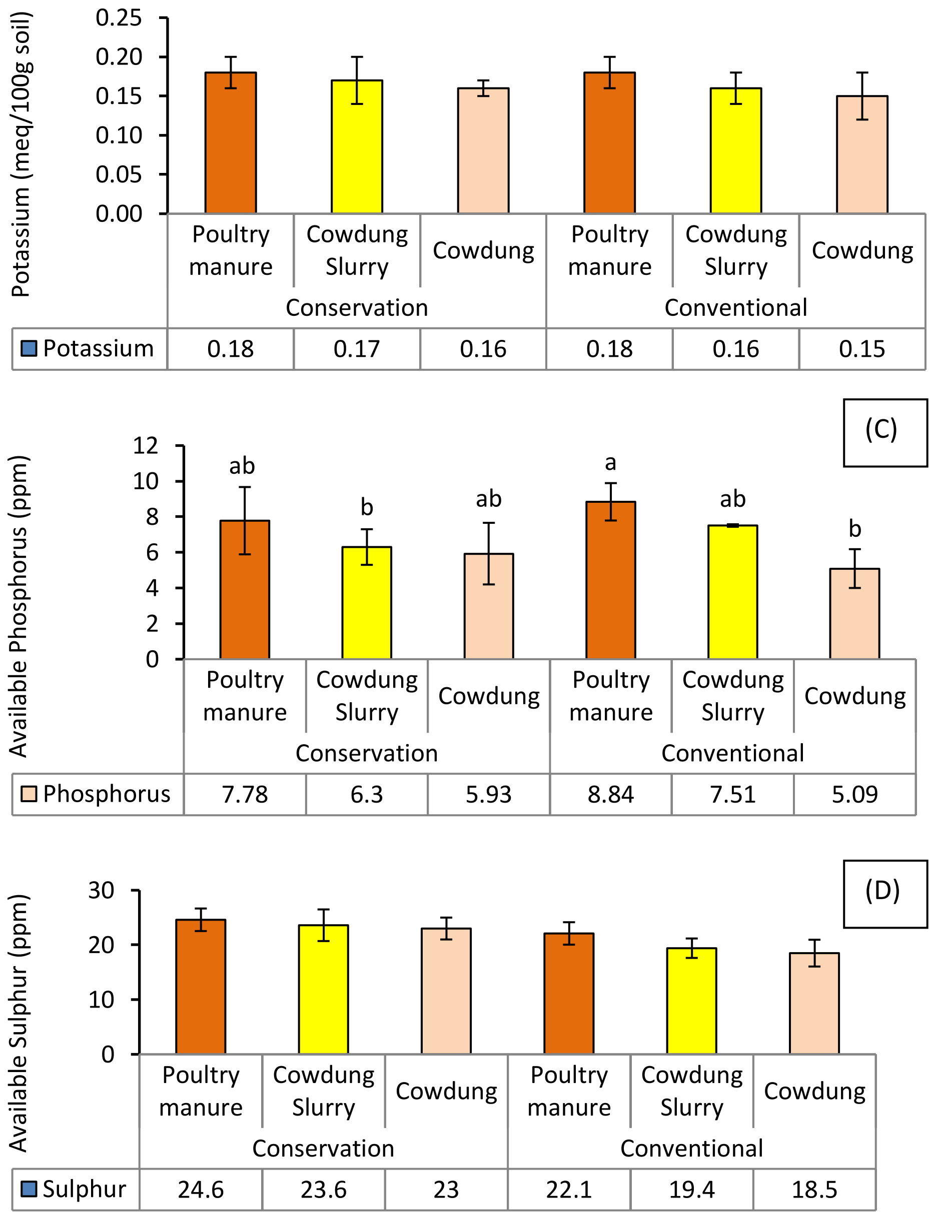

Figure 3: Interaction effect of different tillage systems and organic amendments on the (A) Total N, (B) Potassium, (C) Phosphorus and (D) Sulphur of the post-harvest soils of *boro* rice. Means with the same letters or without letters within the same column do not differ significantly

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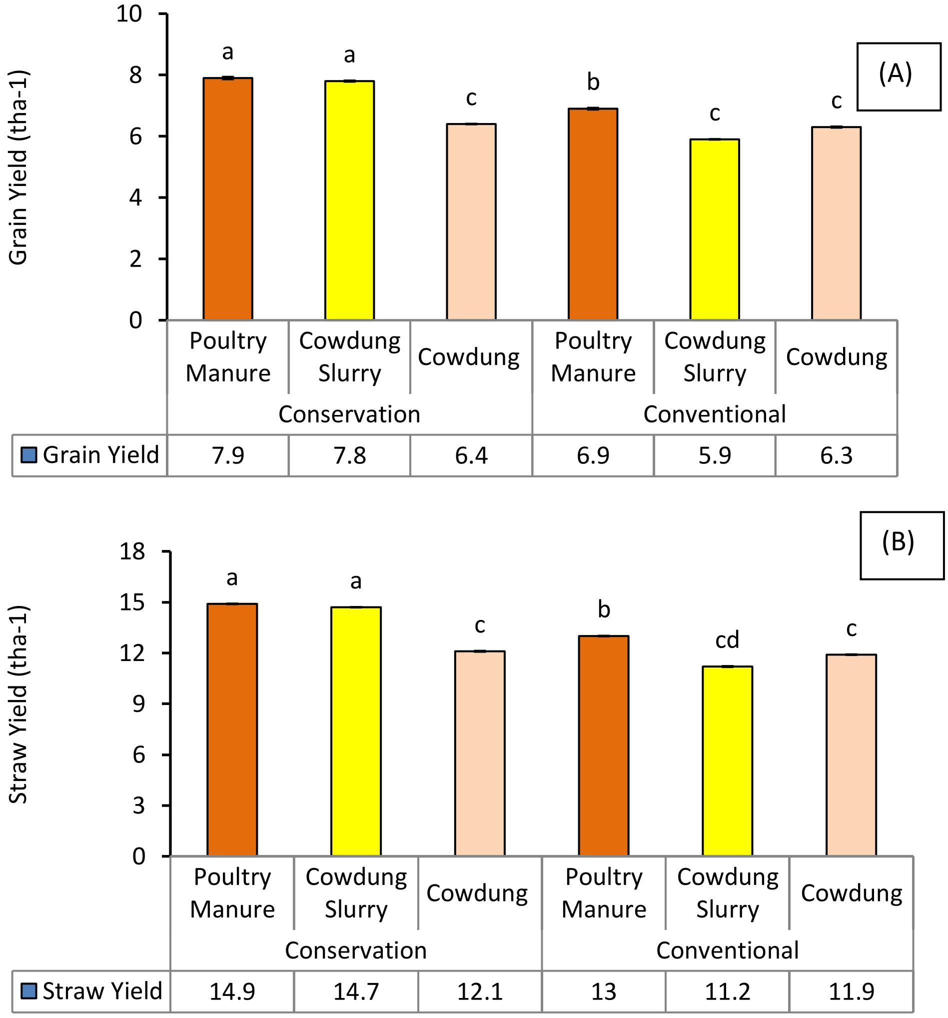

Figure 4: Interaction effect of different tillage systems and organic amendments on the (A) grain and (B) straw yields of *boro* rice. Means with the same letters or without letters within the same column do not differ significantly

CONCLUSION

The research on boro rice BRRI dhan89 cultivation demonstrated that while different tillage systems had a statistically non-significant effect on most yield attributes and soil properties, conservation tillage showed a numerical advantage, resulting in higher grain and straw yield compared to conventional methods. Among the organic treatments, Poultry Manure proved superior, consistently maximizing all critical yield attributes (total tillers, effective tillers, 1000-grain weight) and delivering the overall highest grain yield. Conversely, cow dung performed poorly across most parameters, likely due to its slow nutrient release rate and lower concentration. In terms of grain quality, the poultry manure excelled by providing the highest concentrations of N, P, K, and S in the grain. The interaction analysis clearly established that the optimal management practice is the combination of Conservation Tillage and Poultry Manure, which produced the highest yields. To draw a final conclusion, long-term experimentation in different locations with other rice varieties is necessary.

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Conflict of Interest

There is no conflicts of interest declared by the authors.

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