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Effects of tillage and fertilizers on soil and yield characteristics of brri dhan97 rice

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ABSTRACT

A field study was conducted at the Soil Resource Development Institute Research Field, Mymensingh, Bangladesh from January to May 2024 to evaluate the impact of tillage intensity and use of chemical fertilizer on soil and yield attributes of Boro rice (cv. BRRI Dhan97). The study was conducted in a randomized complete block design with 3 replications. The treatments were: T_1 +C = 1 passing of power tiller + chemical fertilizer, T_2 +C = 2 passing of power tiller + chemical fertilizer, and T_3 +C = 3 passing of power tiller + chemical fertilizer. Fertilizers were utilized @ 124 kg N ha^{-1}, 23 kg P ha^{-1}, 68 kg K ha^{-1}, 12 kg S ha^{-1}, 7 kg Zn ha^{-1} as Urea, TSP, MOP, Gypsum ($CaSO_4 \cdot 2H_2O$), and ZnO forms. The results revealed that soil physical parameters were substantially affected by tillage and chemical fertilizer treatments. Three passing of power tiller in combination with chemical fertilizer presented substantially lower ($p<0.01$) bulk density than all other treatments. T_1+C and T_2+C treatments are significantly higher than T_3+C treatment. The maximum soil moisture content of 49.78% was measured in the T_3+C treatment which was significantly higher ($p<0.01$) than all other treatments were statistically different. The highest air-filled porosity of 11.95% was measured in the T_3+C treatment which was substantially higher ($p<0.01$) than T_1+C and T_2+C treatments where they were statistically different. Considering the plant attributes, the maximum number of effective tillers hill^{-1} (16.84) and 1000 grain weight (22.58 g) were observed in T_3+C treatment which was significantly higher ($p<0.05$). The maximum grain (7.33 t ha^{-1}) and straw (9.83 t ha^{-1}) yields were documented in T_3+C treatment which was substantially higher ($p<0.01$) than other treatments. Considering the soil and rice yield attributes T_3+C treatment proved the best results.

Key words: BRRI dhan97, Chemical fertilizer, Soil physical properties, Tillage, Yield characteristics

INTRODUCTION

Rice is one of the most significant essential cereal foods in human nutrition and a main food grain for approximately 75% of the people of the world (Tagliapietra *et al.*, 2024). Rice provides 91% of the overall grain production and covers 74% of the overall calorie consumption of the people of Bangladesh (BBS, 2019; FPMU, 2020). Food scarcity in Bangladesh might be alleviated by cultivating additional land or enhancing rice production per unit area. Amongst the 3 kinds of paddy, Boro rice contains approximately 57% of the overall rice area, which influences 43% of the overall rice production in the country (BBS, 2019). The overall area and production of rice in Bangladesh is around 11.3 million hectares and 31.2 million metric tons (t) correspondingly with the mean production of about 2.4 tons per hectare (BBS, 2019). Rice is substantially cultivated in Bangladesh comprising around 80% of agricultural land. Unluckily, rice yields are poor in Bangladesh when compared to other rice-growing countries such as Japan and China, where mean yields are 6.7 and 6.3 t ha^{-1}, respectively (Bangladesh Rice Journal, 2022). Crop productivity is primarily influenced by soil, management, and ecological conditions.

Gondal *et al.* (2021) described tillage as the physical, chemical, and biological management of soil to strengthen environments for seed germination, emergence, and seedling establishment.

Tillage is stated to be the most ancient, most primitive farm operation, and the initial stage in crop production. Distinct tillage actions may affect the physical characteristics of soil like soil bulk density, soil moisture, soil porosity, and air-filled porosity (Polizeli *et al.*, 2024). Tillage also influences the physical and chemical characteristics of the soil by influencing the aggregate size distribution which in turn affects plant growth by enhancing soil moisture content, and air-filled porosity and reducing the bulk density (Modiba *et al.*, 2024). Tillage activities are required to clear weeds and avoid crust development. Diverse tillage activities provide organic matter into the soil, improving its physical state and bringing out more effective nutrient and water relationships. It also plays an important role in root growth and development by regulating air and water circulation to some level, as well as nutrient availability to the roots of developing plants. As a result, the soil remains more porous, aerated, and physically suitable for crop development. A judicious use of inorganic fertilizers can help achieve sustainable agriculture that produces high-quality food. However, it's important to consider environmental and soil health impacts, and to use fertilizers responsibly (Mahmud *et al.*, 2016; Shanmugavel *et al.*, 2023; Jote, 2023; Wang *et al.*, 2024; Wato *et al.*, 2024). Chemical fertilizers provide essential nutrients for optimal crop growth, yield, and quality. It can be customized to meet specific needs and can help farmers maximize productivity and meet food demand (Shanmugavel *et al.*, 2023; Jote, 2023; Wang *et al.*, 2024; Wato *et al.*, 2024). This study is planned to observe the impact of distinct tillage practices and judicious application of inorganic fertilizer on the soil physicochemical characteristics such as bulk density, air-filled porosity, soil moisture, and yield of Boro Rice under climate conditions.

The current research was conducted relating the effect of tillage intensity and chemical fertilizer with the following objectives: (i) To assess the interaction effects of tillage operations and inorganic fertilizer application on soil and yield attributes of Boro rice (cv.BRRI dhan97). (ii) To examine the relationships between soil physical properties and rice plant (cv.BRRI dhan97) attributes and (iii) To find out the best treatment in this study.

MATERIAL AND METHODS

Location of the experimental field

The study was carried out at the Soil Resource Development Institute Research Field, Mymensingh throughout the Boro season from January to May 2024. The topographical location of the place was around between the latitudes of 24°42´9" North and the longitudes of 90°19´40" East at an altitude of 18 m above the mean sea level. The soil belongs to the “Old Brahmaputra Floodplain” and Agro-Ecological Zone-9 (FAO and UNDP, 1988).

Vol. 27, Issue: 4, p. 11-20, 2025
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Climate

The climate of the region is being practiced through comparatively high temperature, high humidity, and heavy rainfall with infrequent gusty winds throughout the kharif season and low temperature and low humidity throughout the rabi season. The highest (34°C), lowest (12°C) and average temperature (27°C), highest (202.7 mm), lowest (0.00 mm) and average rainfall (101.35 mm), highest (83.6%), lowest (71.6%) and average relative humidity (77.6%), highest (7.64 hours day^{-1}), lowest (3.2 hours day^{-1}) and average sunshine (5.43 hours day^{-1}), as well as highest (138.2 mm), lowest (63.5 mm) and average evaporation (100.85 mm) throughout the investigational time were documented through the Weather Yard, Bangladesh Meteorological Department, Dhaka.

Agro- ecological zone

The Soil Resource Development Institute Research Field belongs to the agro-ecological zone of Old Brahmaputra Flood Plain "AEZ 9" (FAO and UNDP, 1988).

Soil

The soil in the investigational place belongs to the Sonatola series of the Old Brahmaputra Flood Plain. Soil samples of 0-10 cm depth were taken from the investigational location after harvesting the trial crop (cv. BRRI dhan97). Morphological attributes and physical characteristics of the soil were collected from diverse locations of research at 10-20 cm depth and have been described in Table 1.

Taxonomic and morphological features of the investigational area

Taxonomic and morphological features of the investigational area have been described in Table 2 & 3.

Test crop

The suggested high-yielding Boro variety BRRI dhan97 was utilized as a trial crop. This variety was developed by the Bangladesh Rice Research Institute, Joydebpur, Gazipur after regional and zonal tests and assessment. It is suggested as an appropriate variety for cultivation under the climatic situation of Bangladesh. These high-yielding varieties are suitable for Boro season, the grains were medium fine, and tasty. Growth duration of: 146-151 days (from seedling to harvest).

Land preparation

The land was initially tilled on 9 January 2024 with the aid of a power tiller. It was again tilled followed through laddering on 16 and 17 January 2024 as per tillage treatment to arrange land lastly for transplanting of rice seedlings.

Design of the trial

The study was carried out in a Randomized complete block design (RCBD). The treatments were replicated 3 times. Consequently, the overall number of plots was (6*3) 18. The unit plot size was 4m×2.5m having spacing of the plot to plot 0.5 m and block to block 1.0 m. The design of the trial is exposed in Fig. 1.

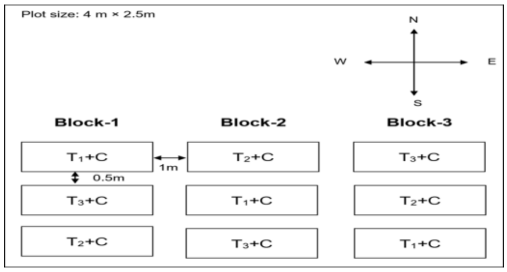

Fig. 1. Layout of the experiment

Treatment of the study

The study comprised of 3 treatments. The treatments were given in Table 4.

Rates and origins of fertilizers

Rates and origins of fertilizers were given in Table 5.

Fertilizers application

The total amount of TSP, MOP, gypsum, and zinc oxide was utilized throughout the last land preparation but urea was utilized in the 2 identical splits. The initial split was utilized, throughout the last land preparation, and the 2nd split at the crown root introduction (CRI) phase.

Transplanting

Forty-five-day-old seedlings of BRRI dhan97 were transplanted on 22 January 2024 in 20 cm at a space rows retaining 20 cm hill to hill space and 3 seedlings per hill. Required gap filling was completed 8 days after transplanting.

Weeding, pest and diseases management

Weeding was completed and when essential but no insecticides and pesticides were needed to utilize since the crop was free from insects and pathogens attack.

Harvesting

The crop was reaped on 04 May 2023 at full maturity. For data collection, five hills from each plot were collected randomly from the central portion of the plot at a one-meter square area. The crop was cut at the ground level. Threshing, cleaning, and drying of grain were done distinctly plot-wise. The weights of grain and straw were documented plot-wise.

Table 1. Particle size analysis of the initial soil

Soil depth (cm)	Particle size fractions			Textural class	Bulk density (g cm^{-3})
	% sand(0.2-0.02 mm)	% silt(0.02-0.002 mm)	% clay (<0.002 mm)		
0-10	9.6	79.8	10.6	Silt loam	1.3
10-20	10.4	80.3	9.3	Silt loam	1.5

Table 2. Taxonomic properties of soil

Order	Inceptisol
Sub-Order	Aquept
Sub-Group	Aeric Haplaquet
Series	Sonatola

Table 3. Morphological features of the investigational area

Location	Soil Resource Development Institute Research Field, Mymensingh
Agro-ecological zone	Old Brahmaputra Floodplain (AEZ-9)
Land type	Medium high land
General soil type	Non-calcareous dark grey floodplain soil
Topography	Fairly level
Field Level	Above flood level
Drainage	Fairly good
Firmness (Consistency)	Friable when dry
Cropping pattern	Fallow-wheat

Table 4. Treatment of the study

Treatment code	Treatments utilized to the experimental field
T_1+C	One passing of power tiller + chemical fertilizer
T_2+C	Two passing of power tiller + chemical fertilizer
T_3+C	Three passing of power tiller + chemical fertilizer

Table 5. Name, rates and origins of the diverse fertilizers

Fertilizers	Rate	Sources
N	124 kg ha^{-1}	Urea (46%N)
P	23 kg ha^{-1}	TSP (20%P)
K	68 kg ha^{-1}	MOP (50%)
S	12 kg ha^{-1}	Gypsum (18%S)
Zn	7 kg ha^{-1}	ZnO (78%Zn)

Collection and preparation of soil samples for measuring physical characteristics of soil

Original soil sample

The original soil sample (0-10 cm soil depth) was taken before complete land preparation. The samples were collected utilizing an auger from eighteen diverse random locations involving the entire investigational areas. The soil samples were properly combined to form a composite sample, and undesirable items like stubbles and weeds were eliminated. The composite soil sample was air-dried and sieved using a 10-mesh sieve. This composite soil sample was kept in a fresh plastic pot for consequent physical investigation.

Procedures for measuring physical characteristics of soil

Soil texture

Bouyoucos (1927) described the hydrometer technique for determining textural groups. 50 g of air-dried soil was placed in a dispersion cup, and 10 ml of 5% Calgon solution was supplied. The sample was permitted to rinse for 15 minutes before being filled with 90 milliliters of distilled water. The solution was then agitated using an electric stirrer for 10 minutes. The contents of the dispersion cup were then moved to a 1000 ml suspension cylinder, and distilled water was applied to fill the capacity to the level. A cork was put at the mouth of the cylinder, and the cylinder was turned upside down numerous times till the entire dirt mass was suspended. The cylinder was positioned standing up, and hydrometer measurements were collected after 40 seconds and two hours of sedimentation. The temperature of the solution was also measured utilizing a thermometer after 40 seconds and 2 hours of precipitation.

The amendments of hydrometer readings were completed as the hydrometer was standardized at 68 °F. The percentage of sand, silt, and clay was measured as follows:

$$\%\,(\text{Silt}+\text{Clay}) = \frac{\text{C.H.R. after 40 seconds of sedimentation}}{\text{W}} \times 100$$

$$\%\,(\text{Clay}) = \frac{\text{C.H.R. after 2 hours of sedimentation}}{\text{W}} \times 100$$

Where,

C.H.R = Corrected hydrometer reading

W = Weight of soil (g)

% sand = 100 -% (silt + clay)

% silt = % (silt + clay) - % clay

% clay = % (silt + clay) - % silt

Bulk density

The bulk density was measured with the aid of a core sampler made of a metal cylinder of identified volume (Black, 1965).

Bulk density was assessed by utilizing the below equation:

$$\text{Bulk density,} \quad Db = \frac{Ms}{Vt} \ \text{g cm}^{-3} \quad \text{.................................} (1)$$

Where,

Db = Bulk density g cm^{-3} (g cm^{-3})

Ms= Mass of soil solid (g)

Vt = Total volume of soil (cm^3)

Air filled porosity

Air-filled porosity was measured through utilizing the below equation:

$$\text{Air filled porosity (\%)} = \frac{[\text{Volume of the air (cm}^3)}{\text{Total volume of the soil (cm}^3)} \times 100 \quad \text{..........} (2)$$

Volume of air (cm^3) = Total volume of soil (cm^3) – volume of water (cm^3) - volume of soil solids (cm^3)

$$\text{Volume of water (cm}^3) = \frac{\text{Mass of water (g)}}{\text{Density of water (g cm}^{-3})}$$

$$\text{Volume of solid (cm}^3) = \frac{\text{Mass of soil}}{\text{Density of soil solid (g cm}^{-3})}$$

Soil moisture

The soil moisture was assessed through gravimetric system and was measured through utilizing the below equation:

$$\text{Soil moisture (\%)} = \frac{(W - W_1)}{W_1} \times 100 \ \text{(oven dry basis)} \quad \text{..................} (3)$$

Where,

W = Weight of moist soil (g)

W_1 = Weight of oven dry soil (g)

Yield promoting characteristics and yield data

Plant length

Five hills were randomly selected from each unit plot and the length of every plant from each hill was recorded in terms of cm with the aid of a meter scale. In this way, the mean length of plants was assessed.

Active tillers hill^{-1}

Five hills were collected randomly from each plot and the overall numbers of tillers were calculated, the mean of which was measured as an overall number of tillers hill^{-1}.

Non-active tillers hill^{-1}

Measurement was taken from the bottom node of the rachis to the top of each panicle (cm). The panicle length was stated by averaging the data from 5 plants.

Panicle length

Five hills were randomly nominated from each plot and the number of filled and unfilled grain panicle^{-1} from each hill was calculated in number. Then the mean number of grains panicle^{-1} was calculated in number.

1000-grain weights

The grain samples were calculated from each plot and dried the sample in an oven at 65° C for 24 hours and then documented their weight in gm with the aid of an electrical balance.

Grain and straw yields

The rice crops were harvested at full maturity on 04 May 2024. The harvested crop of each plot was bundled distinctly and carried to the threshing floor for threshing by hand. The detached grains were dried in the sun for 5 days to achieve moisture up to 14%. The grains were taken in paper bags plot-wise and were documented in kg. Likewise, the straw yield was documented in kg. Lastly, the plot-wise yield of grain and straw was converted into t ha^{-1}.

Correlation and regression study

Correlation and regression among soil characteristics, yield attributes, and yields were calculated.

Statistical investigation

Data on diverse parameters under the experiment were statistically investigated to determine the significance of the investigational findings. The average data for all the treatments were measured and analysis of the variance of all the properties calculated was done through F-test.

The significance of the variance between the pair of means was assessed at a 5% level of significance through the Least Significant Difference (LSD) utilizing the MSTAT-C computer package system (Gomez and Gomez, 1984).

RESULTS

Influences of tillage intensity and poultry manure on some soil physical characteristics

Bulk density (Before panicle opening phase)

The bulk density of soil presented substantial differences under 3 tillage treatments due to increasing soil moisture content and air-filled porosity (Table 6). Three passing of power tiller in combination with chemical fertilizer showed significantly lower ($p<0.01$) bulk density (0.79 g cm^{-3}) than all other treatments. T_1+C and T_2+C treatments being significantly higher than other treatment. The maximum bulk density (1.08 g cm^{-3}) was measured in T_1+C (one passing of power tiller+ chemical fertilizer application) treatment at 0-10 cm soil depth.

Soil moisture (Before panicle opening phase)

The moisture content of soil presented substantial differences under 3 tillage treatments (Table 6). The maximum soil moisture content of 49.78% was measured in T_3+C (3 passing of power tiller + chemical fertilizer application) treatment at 0-10 cm soil depth which was suggestively higher ($p<0.01$) than all other treatments where T_1+C and T_2+C were statistically different and the lowermost moisture content of 43.14% was measured in T_1+C (1 passing of power tiller+ chemical fertilizer application) treatment at 0-10 cm soil depth (Table 6).

Air-filled porosity (Before panicle opening phase)

The air-filled porosity of the soil revealed substantial differences under 3 tillage treatments (Table 6). The highest air-filled porosity of 11.95% was measured in T_3+C (3 passing of power tiller + chemical fertilizer application) treatment at 0-10 cm soil depth which was suggestively higher ($p<0.01$) than T_2+C and T_1+C treatments (Table 6).

Impact of tillage intensity and application of poultry manure on yield and yield promoting characteristics of Boro rice

Plant length

The plant length of BRRI dhan97 was not so different due to diverse tillage treatments. Though they were statistically similar, some numerical variation was found among the treatments. The maximum plant height (80.40 cm) was measured in T_3+C (3 passing of power tiller + chemical fertilizer application) treatment and the minimum plant length (79.67 cm) was detected under T_1+C (1 passing of a power tiller+ chemical fertilizer) treatment (Table 7).

Active tillers hill^{-1}

The number of active tillers hill^{-1} of BRRI dhan97 was suggestively changed by the impact of different treatments (Table 7). Tillage intensity influenced the number of active tillers hill^{-1} of BRRI dhan97. Application of poultry manure had a substantial influence on the number of active tillers hill^{-1} of BRRI dhan97. The maximum number of active tillers hill^{-1} (16.84) was observed in the T_3+C (3 passing of power tiller + chemical fertilizer application) treatment which was significantly higher than T_1+C and T_2+C treatments ($p<0.05$) where T_1+C and T_2+C treatments were statistically different (Table 7).

Non-active tillers hill^{-1}

The number of non-active tillers hill^{-1} was identical in BRRI dhan97. Though they were statistically the same, some numerical variation was found among the treatments. The maximum number of non-active tillers hill^{-1} (1.56) were recorded in T_1+C (One passing of power tiller+ chemical fertilizer application) treatment. The lowest number of non-active tillers hill^{-1} (1.35) were measured in T_3+C (3 passing of power tiller + chemical fertilizer application) treatment (Table 7).

Table 6. Impact of tillage intensity and poultry manure on soil bulk density, soil moisture and air-filled porosity

Treatments	Bulk density (g cm^{-3})	Soil moisture (%)	Air-filled porosity (%)
	Before harvest	Before harvest	Before harvest
T_1+C	1.08a	43.14d	7.85e
T_2+C	1.05a	47.65c	8.41d
T_3+C	0.96ab	49.78bc	11.95c
LSD	0.033	0.840	0.304
Level of sig.	**	**	**

LSD =Least substantial variation, ** = Significant at 1% level of probability

The figures in a column having common letter do not differ suggestively at 1% level of significance.

Table 7. Impact of tillage intensity and poultry manure on yield promoting attribute

Treatments	Plant length (cm)	Number of active tillers $hill^{-1}$	Number ofnon-active tillers $hill^{-1}$	Panicle length (cm)	1000-grain weight (g)
T_1+C	79.67	14.95a	1.56	19.12a	22.35c
T_2+C	80.01	15.78b	1.41	19.61b	22.51bc
T_3+C	80.40	16.84c	1.35	19.92c	22.58abc
LSD	1.65	0.64	0.19	0.39	0.23
Level of sig.	NS	*	NS	**	*

LSD = Least significant variance, ** = Significant at 1% level of probability, * = Significant at 5% level of probability, and NS =Not Significant. The figures in a column having common letter do not differ suggestively at 5% level of significance.

Table 8. Effect of tillage intensity and poultry manure on grain and straw yields of Boro rice (cv. BRRI dhan97)

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
T_1+C	6.33d	9.33ab	16.00bc	39.34c
T_2+C	6.67cd	9.53bc	16.16c	41.82ab
T_3+C	7.33bc	9.83bc	16.67abc	44.03b
LSD	0.69	0.86	1.22	2.73
Level of sig.	**	**	*	**

LSD = Least significant variance, ** = Significant at 1% level of probability, and * = Significant at 5% level of probability. The figures in a column having common letter do not differ suggestively at 1% level of significance.

Table 9. Correlation and regression analysis among some soil physical characteristics, yield promoting attributes and grain yield

Dependent variable	Independent variable	Regression equation	Correlation co-efficient
Grain yield (GY)	Bulk density (g cm^{-3})	GY= - 8.1026x+15.122	r=0.9904
Grain yield (GY)	Soil moisture (%)	GY= 0.1389x+0.2685	r = 0.8577
Grain yield (GY)	Air-filled porosity (%)	GY= 0.2235x+4.6754	r = 0.9546
Grain yield (GY)	1000 grain weight (gm)	GY= 3.964x-82.335	r = 0.8448

Panicle length

Tillage operation in a mixture with poultry manure application showed a substantial impact on the panicle length of BRRI dhan97. From the table it was observed that the highest panicle length (19.92 cm) was documented under the treatment mixture of T_3+C (Three passing of power tiller + chemical fertilizer application) treatment which was suggestively higher than all other treatments (p<0.01) and T_1,+C and T_2+C treatments were statistically different (Table 7).

1000 grain weight

Tillage operation in combination with poultry manure application showed a substantial impact on the 1000-grain weight of BRRI dhan97. From the table, it was detected that the maximum 1000-grain weight (22.58 g) was measured in T_3+C (3 passing of power tiller + chemical fertilizer application) treatment that was suggestively higher than all other treatments (p<0.05) and T_1+C and T_2+C treatments were statistically similar but numerically different (Table 7).

Grain yield

Tillage operation in combination with chemical fertilizer application showed a substantial impact on the grain yield of BRRI dhan97. The maximum grain (7.33 t ha^{-1}) yields were measured in the T_3+C (Three passing of power tiller + chemical fertilizer application) treatment that was suggestively higher (p<0.01) than all other treatments and the lowest grain yields (6.33 t ha^{-1}) were measured in T_1+C (1 passing of power tiller+ chemical fertilizer application) (Table 8).

Straw yield

Tillage operation in combination with chemical fertilizer application presented a substantial effect on the straw yield of BRRI dhan97. The maximum straw (9.83 t ha^{-1}) yields were measured in T_3+C (Three passing of power tiller + chemical fertilizer application) which was suggestively higher (p<0.01) than all other treatments and the lowest straw yields (9.33 t ha^{-1}) were measured in T_1+C (1 passing of power tiller + chemical fertilizer application) treatment (Table 8).

Biological yield

Tillage operation in combination with chemical fertilizer application showed a significant effect on the biological yield of BRRI dhan97. The maximum biological 3.2(16.67 t ha^{-1}) yields were measured in T_3+C (Three passing of power tiller + chemical fertilizer application) which was substantially higher *(p<0.05)* than T_1+C and T_2+C treatments and the lowest biological yields (16.0 t ha^{-1}) were measured in T_1+C (1 passing of power tiller+ chemical fertilizer application) treatment (Table 8).

Correlation and regression analyses

The correlation and regression analyses (Table 9) revealed strong relationships between grain yield and soil physical properties. Grain yield was negatively correlated with bulk density (r = 0.9904) but positively associated with soil moisture (r = 0.8577), air-filled porosity (r = 0.9546), and 1000 grain weight (r = 0.8448). These results indicate that maintaining lower soil compaction, higher moisture, and improved aeration significantly enhances grain yield.

DISCUSSION

Tillage and chemical fertilizer applications have a considerable impact on soil bulk density. It may be owing to the enhancement of tillage number which developed granulation of soil, augmented aeration and porosity of soil. This finding was also assisted by Ahmadi *et al.* (2024). da Silva *et al.* (2023) found that the aeration effects and tillage number were significant. Greater bulk density denotes the poor physical situation of soil e.g. low aeration, low moisture content, low water circulation, etc. The same findings were also monitored through Panagos *et al.* (2024).

The findings showed that the looser soil (T_3+C treatment) absorbed more soil moisture related to compressed soil (T_1+C treatment). The existing results are supported by Ma *et al.* (2023).

The term "air-filled porosity" refers to the amount of area filled with air in soil. According to the research, T_3+C treatment produces more loose soil, which can let more air into the soil. The current findings were bestowed with the results of Fatoyinbo *et al.* (2024). Sufficient aeration in soil can boost the action of microbe existent in soil that may hasten the growth and development of a crop through delivering nutrient elements accessible to roots.

Tillage intensity and application of chemical fertilizer influenced the number of effective tiller hill^{-1}, non-effective tiller hill^{-1}, plant height, panicle length, 1000-grain weight, grain yield, and straw yield due to the uptake of more water and nutrients from deeper soil. The current finding is allowed with Akter *et al.* (2022) and Gong *et al.* (2023).

Tillers hill^{-1}, grains panicle^{-1}, soil moisture, air-filled porosity, and bulk density all have a significant impact on rice yield. Air-filled porosity, soil moisture, and 1000-grain weight all positively correlated with grain yield. Positive correlation shows the enhancement of grain yield was reliant on the enhancement of 1000 grain weight, soil moisture, and air-filled porosity.

However, there is a negative correlation between bulk density and grain yield. A negative correlation shows that grain yield will reduce with the enhancement of bulk density. Since high bulk density indicates limited root development that influences the yield-attributing characteristics of rice.

CONCLUSION

Tillage intensity and chemical fertilizer incorporation developed the physical characteristics of soil i.e. decreased the bulk density of soil, enhanced the air-filled porosity and soil moisture content. Grain yield has a significant positive relationship with soil moisture, air-filled porosity, and 1000 grain weight (p<0.01) and also has a substantial negative relationship with bulk density (p<0.01). Treatment combination T_3+C (Three passing of power tiller + chemical fertilizer) showed the highest grain and straw yields.

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