Impact of Manures, Fertilizers, and Rice Straw Allelopathy on *T. Aman* Rice Yield

ABSTRACT

Nowadays, adopting agricultural practices that are sustainable and eco-friendly for crop production is a major concern. The present experiment was conducted at the AFLAB of BAU from June 2022 to November 2022 to estimate the combined effect of manures and fertilizers with rice straw allelopathy on the yield performance of transplant *aman* rice. The experiment consisted of two cultivars i.e.: BRRI dhan71 (V_1) and BRRI dhan49 (V_2) and eight treatments of the combination of rice straw, manures, and fertilizers such as Control (T_1), Recommended doses of NPKS (T_2), Rice straw @ 1.5 t ha^{-1} + Cow dung @ 5 t ha^{-1} (T_3), Rice straw @ 1.5 t ha^{-1} + Cow dung @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS (T_4), Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 5 t ha^{-1} (T_5), Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS (T_6), Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 10 t ha^{-1} (T_7), Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 5 t ha^{-1} + 50% less of recommended doses of NPKS (T_8). The grain yield as well as the yield contributing characters such as the number of effective tillers hill^{-1}, number of grains panicle^{-1}, 1000-grain weight was highest at BRRI dhan71 with Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS (T_6) treatment, followed by Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 10 t ha^{-1} (T_7) treatment. BRRI dhan71 expressed superiority at yield and all the yield contributing characters than BRRI dhan49. This current study's results indicate that combining rice straw with manures and fertilizer could enhance the yield of transplant *aman* rice. As a result, mixing rice straws with manures and fertilizers could be a viable bundle of sustainable and eco-friendly ways for increasing crop productivity in the future.

Keywords: *Allelopathy; fertilizer; manures; rice; yield.*

1. INTRODUCTION

"One of the most important challenges facing humanity today is to conserve or sustain natural resources, including soil and water, for increasing food production while protecting the environment. As the world population grows, stress on natural resources increases, making it difficult to maintain food security. Long term food security requires a balance between increasing crop production, maintaining soil health and environmental sustainability. However, application of imbalanced or excessive nutrients led to declining nutrient-use efficiency making fertilizer consumption uneconomical and producing adverse effects on atmosphere" (Salam et al., 2022) and groundwater quality (Aulakh et al., 2009) causing health hazards and climate change. "On other hand, nutrient mining has occurred in many soils due to lack of affordable fertilizer sources and where fewer or no organic residues are returned to the soils" (Halim et al., 2023).

"A strategy of integrated plant nutrient management is crucial to maintain soil fertility as well as to increase crop productivity. The role of integrated nutrient management is harnessing economically-viable sustainable production of prominent cropping systems, enhancing nutritive quality of the produce, improving soil health and minimizing environmental pollution" (Mia et al., 2023). "The application of chemical fertilizers is costly and gradually lead to the environmental problems. Organic residue recycling is becoming an increasingly important aspect of environmentally sound sustainable agriculture. Now-a-days, agriculture production based on organic applications is growing in interest and the demands for the resulting products are increasing" (Islam et al., 2024). Therefore, "the effective use of organic materials in rice farming is also likely to be promoted. Applying organic materials is essential because they improve the physical and chemical properties of soil, which increases its capacity to hold and buffer nutrients. They also provide a variety of plant nutrients, including micronutrients, and they boost microbial activity" (Halder et al., 2024). "Inorganic fertilizers can harm the soil, water, biodiversity, environment and etc. The frequent use of inorganic fertilizers can lead to weakened plant structure and a decrease in beneficial microorganisms. Inorganic fertilizer run-off in waterways can lead to damage and destruction of plant and animal life" (Doley et al., 2021).

"In addition to use of inorganic sources of plant nutrients, organic sources need to be considered to prevent nutrient mining, maintaining soil fertility and increasing crop production. Cow dung, poultry manure and their bio-slurries, vermicompost, trichocompost are the good sources of organic matter in soils" (Islam et al., 2024). "Integrated use of inorganic fertilizers with organic manures not only sustains the crop production but also is effective in improving soil health and enhancing nutrient use efficiency" (Zaman et al., 2018; Ali et al., 2009).

"Cow manure is not only an agricultural waste, but also an organic fertilizer resource. The application of organic fertilizer is a feasible practice to mitigate the soil degradation caused by over use of chemical fertilizers, which can affect the bacterial diversity and community composition in soils" (Siddika et al., 2024; Mou et al., 2017). "The Trichocompost significantly increases soil fertility and fetches higher crop yield. It also acts as biopesticides. It is well documented that the interaction of Trichoderma strains of Trichocompost with the plant may promote increase of growth nutrient availability and enhances power of disease resistance" (Latif et al., 2020; Matin et al., 2009). "Trichoderma also helps in plant growth and crop production. Its use saves production costs in agriculture. There is no harmful effect on land. Trichoderma increases soil fertility and reduces use of chemical fertilizers by 40%-60%. Vermicompost acts as an excellent nutrient rich organic fertilizer and soil conditioner. It greatly improves soil health by providing and improving nutrients stock and availability" (Mia et al., 2009; Dhok, 2013). Furthermore, "microbes and humic compounds in vermicomposts improve soil fertility and structure. They enhance soil aeration, water retention, and plant nutrition. This results in robust plant growth, increased yields, and reduced reliance on harmful synthetic fertilizers" (Yangchan et al., 2019; Mia et al., 2024; Islam et al., 2024). "Rice has been thoroughly studied with respect to its allelopathy and many rice varieties were observed to inhibit the growth of several weed species" Chung et al. (2001) identified "p-hydroxy benzoic acid, p-coumeic acid, ferulic acid, syringic acid and vanillic acid from rice cultivars". Kato-Noguchi et al. (2002) identified momilactone β from Japanese rice cultivar. Salam and Kato-Noguchi (2011) and Kato-Noguchi et al. (2011) identified "9-hydroxy-β-ionone and 3-oxo-α-ionol from Bangladeshi rice cultivar BR17 and Kartikshail. These compounds inhibited the growth of the barnyard grass at lower concentrations. Therefore, rice plants exhibited growth-inhibitory effects on other plant species". The present study was, therefore, undertaken to develop an integrated nutrient management to evaluate the varietal effect on yield performance of T. *aman* rice as well as to investigate the combined effect of manures and fertilizers with the rice straws on yield performance of T. *aman* rice.

2. MATERIAL AND METHODS

2.1 Experimental Site

The experiment was carried out at the Agronomy Field Laboratory (AFLAB) of Bangladesh Agricultural University (BAU), Mymensingh from June to November 2022 to estimate the combined effect of manures and fertilizers with the rice straw allelopathy on the weeding regime and yield performance of transplant *aman* rice. Under the old Brahmaputra floodplain (AEZ-9), the experimental territory is dominated by non-calcareous dark gray floodplain soil.

It is positioned at 24° 75'N latitude and 90° 50' E longitude. The plot was medium-high, silty loam textured soil was predominant with a pH of 6.5, where organic matter content (1.30%) and general fertility level were low. Tropical climate existed in the area.

2.2 Experimental Treatments and Design

The experiment consisted of two cultivars i.e.: BRRI dhan71 (V_1) and BRRI dhan49 (V_2) and eight treatments of the combination of rice straw, manures, and fertilizers such as Control (T_1), Recommended doses of NPKS (T_2), Rice straw @ 1.5 t ha^{-1} + Cow dung @ 5 t ha^{-1} (T_3), Rice straw @ 1.5 t ha^{-1} + Cow dung @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS (T_4), Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 5 t ha^{-1} (T_5) , Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS (T_6), Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 10 t ha^{-1} (T_7), Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 5 t ha^{-1} + 50% less of recommended doses of NPKS (T_8).The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Each block was divided into 16-unit plots of 2 m × 2.5 m size. Thus, the total number of plots was 48.

2.3 Crop Husbandry

The rice straws were collected from the AFLAB of BAU, Mymensingh. After collection, the rice straws were dried and cut into small pieces using a sickle. Cowdung was collected from the AFLAB. Vermicompost and Trichocompost were collected from Horticulture Farm, BAU, and Agroholic Farm, Rajshahi respectively. One of the main requirements for a good harvest is good quality seed. Seeds of the test cultivars (BRRI dhan49 and BRRI dhan71) were collected from AFLAB of BAU. Test cultivar seeds were selected using a specific gravity method, soaked in water for 24 hours, and then stored in gunny bags for sprouting. Most seeds were suitable for sowing after 72 hours. High land was selected, watered, and leveled; weeds were removed before sowing in a nursery bed on 22 June 2022.

The experimental land was opened on 15 July 2022, puddled, and leveled using a tractor and laddering. Weeds, stubbles, and crop residues were collected and removed. Field layout was done on 20 July, and cowdung, Vermicompost, and Trichocompost were applied as basal doses. Fertilizers were applied as per the experimental specification (Urea 250 kg ha^{-1}, TSP 125 kg ha^{-1}, MoP 125 kg ha^{-1} and Gypsum 100 kg ha^{-1}). The entire amounts of triple super phosphate, muriate of potash and gypsum were applied at the time of final land preparation. Urea was applied as top dressing in three installments at 15, 30 and 45 days after transplanting (DAT), and rice straw residues were applied 7 days before transplanting *aman* rice on 25 July. Rice straws were mixed with the plots.

2.4 Harvesting and Processing

Maturity of crops was determined when 90% of the grains became golden yellow in color. BRRI dhan71 (V_1) was harvested on 1 November 2022 while BRRI dhan49 (V_2) was harvested on 20 November 2022. Three hills (excluding border hill and central (1m x 1m) were selected randomly from each plot to record data on crop characters and yield contributing characters. An area of central $1m^2$ was selected and harvested of each plot to record the yields of grain and straw. The harvested crop of each $1m^2$ plot was separately bundled, properly tagged and brought to threshing floor. Then the crop was threshed and the fresh weights of grain and straw were recorded from central $1m^2$ area of each plot. The grains were cleaned and sun dried to a moisture content of 14%. Straws also sun dried properly. Finally grain and straw yields $plot^{-1}$ were recorded and converted into t ha^{-1}.

2.5 Statistical analysis

Data were compiled and tabulated in proper form with different parameters for statistical analysis. Data were analyzed using the Analysis of Variance (ANOVA) technique following two factor Randomized Complete Block Design (RCBD) with the help of computer package program MSTAT-C and mean comparisons of the treatments were evaluated by Duncan's Multiple Range Test (Gomez and Gomez, (1984).

3. RESULTS AND DISCUSSION

3.1 Yield and Yield Contributing Characters at Harvest

3.1.1 Plant Height

3.1.1.1 Effect of Variety

The plant height was significantly different between the varieties. The tallest plant (102.45 cm) was observed in V_1 (BRRI dhan71) and the shortest plant (100.60 cm) was observed in V_2 (BRRI dhan49) (Table 1). Plant height is a varietal character and it is the genetic constituent of the cultivar. Therefore, plant height was different between the two varieties. The results are consistent with the findings of Mia et al. (2024) who observed plant height differed significantly among the varieties.

3.1.1.2 Effect of Manures and Fertilizers with Rice Straw

Plant height was significantly affected by the combination of manures and fertilizers with rice straw. The tallest plant (103.68 cm) was found in T_6 (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS) treatment followed by T_8 (Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 5 t ha^{-1} + 50% less of recommended doses of NPKS) treatment and the shortest plant (96.84 cm) was found in T_1 (Control) treatment (Table 2). This might be due to the availability of more nutrients in a weed-free environment. Saito et al. (2010) reported that the grain yield, plant height at maturity and visual growth vigor at 42–63 DAS increased significantly with different crop residues due to weed free conditions.

3.1.1.3 Combined Effect of Interaction among Variety, Manures and Fertilizers with Rice Straw

The combined effect of interaction among variety, manures and fertilizers with residues of rice straw was significant for plant height. Numerically, the tallest (105.60 cm) plant was obtained from V_1T_6 [BRRI dhan71 × (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS)] combination and V_2T_1 [BRRI dhan49 × Control] combination produced the shortest plant (96 cm) in combination (Table 3).

3.1.2 Number of Total Tillers Hill^{-1}

3.1.2.1 Effect of Variety

The effect of cultivar on the number of total tillers hill^{-1} was non-significant. Numerically, the highest number of total tillers hill^{-1} (9.17) was found in V_1 (BRRI dhan71) and the lowest number of total tillers hill^{-1} (9.06) was in V_2 (BRRI dhan49) (Table 1).

3.1.2.2 Effect of Manures and Fertilizers with Rice Straw

The number of total tillers in hill^{-1} was significantly influenced by the combination of manures and fertilizers with rice straw. The highest number of total tillers hill^{-1} (10.49) was produced by T_6 (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS) treatment followed by T_5 (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 5 t ha^{-1}) treatment and the lowest number of total tillers hill^{-1} (7.99) was produced by T_1 (Control) treatment (Table 2). This might due to the combined effect of rice straw with manures and fertilizers which enrich the soil with more available nutrient and suppress weed infestation. Mia et al. (2023) observed that the number of total tillers hill^{-1} differed significantly among the residues.

3.1.2.3 Combined Effect of Interaction among Variety, Manures and Fertilizers with Rice Straw

Significant variation was found in the number of total tillers hill^{-1} due to interaction between variety and manures and fertilizers with rice straw. The highest number of total tillers hill^{-1} (9.68) was produced by V_1T_6 [BRRI dhan71 × (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS)] combination followed by 9.47 number of total tillers hill^{-1} obtained from V_2T_6 [BRRI dhan49 × (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS)] combination while the lowest number of total tillers hill^{-1} (8.13) was found in V_2T_1 (BRRI dhan29 × Control) combination (Table 3). The result might due to the combined effect of rice straw, varieties and integrated nutrient. These results are in conformity with the findings of Ashraf et al. (2021) who reported the variation of tiller production due to the interaction of cultivars and residues.

3.1.3 Number of effective tillers hill^{-1}

3.1.3.1 Effect of Variety

Number of effective tillers hill^{-1} was non-significant. Numerically, the highest number of effective tillers hill^{-1} (8.05) was found in V_1 (BRRI dhan71) and the lowest number of effective tillers hill^{-1} (8.01) was found in V_2 (BRRI dhan49) (Fig. 1). Number of effective tillers hill^{-1} was not significantly different between the two varieties due to genetic similarity and environmental effect.

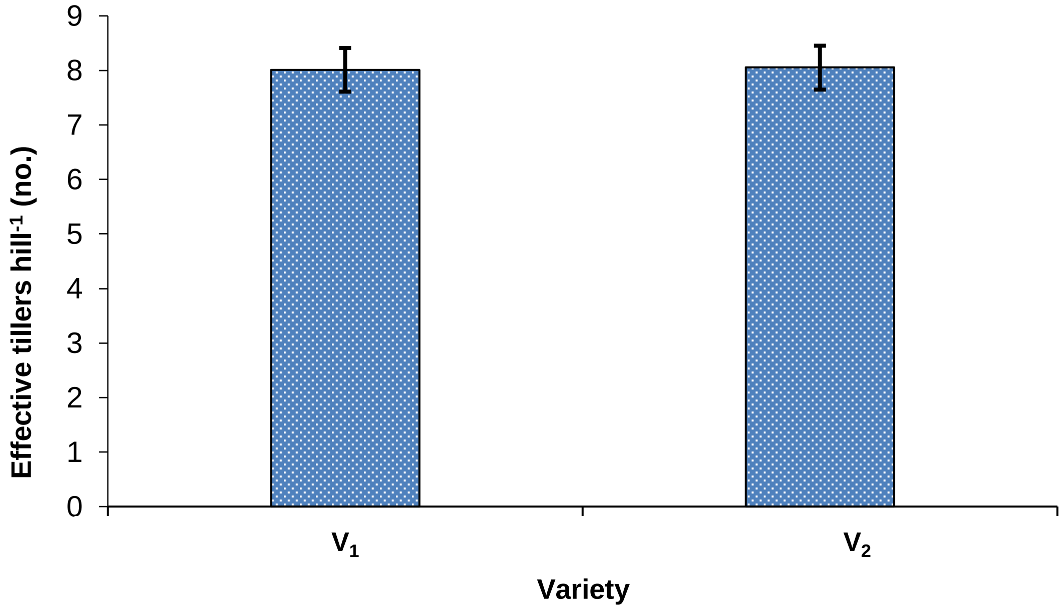

Fig. 1. Effect of variety on no. of effective tillers hill^{-1}

Here, Vertical bars indicate the standard error of the mean. V_1 =BRRI dhan71, V_2 = BRRI dhan49

3.1.3.2 Effect of Manures and Fertilizers with Rice Straw

The number of effective tillers hill^{-1} was significantly influenced by the combination of manures and fertilizers with rice straw. The highest number of effective tillers hill^{-1} (9.30) was produced by T_6 (Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 5 t ha^{-1} + 50% less of recommended doses of NPKS) treatment and the lowest number of effective tillers hill^{-1} (6.68) was produced by T_1 (Control) treatment (Fig. 2). Farhat et al. (2023) reported that weed-free conditions encouraged a higher number of effective tillers.

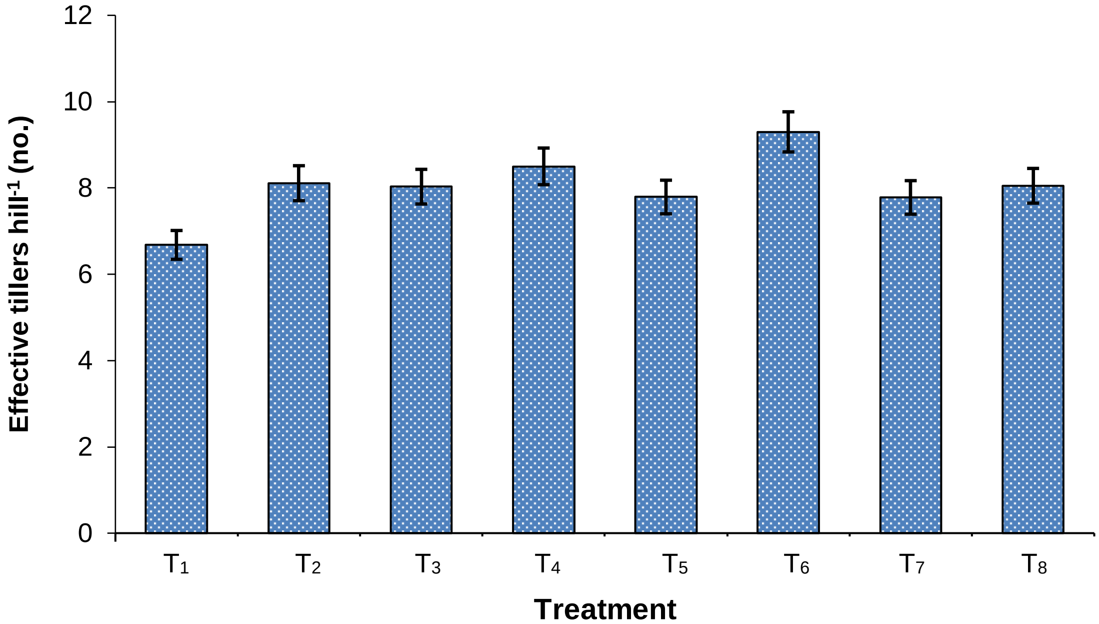

Fig. 2. Effect of combination of manures and fertilizers with rice straw on no. of effective tillers hill^{-1}

Here, Vertical bars indicate the standard error of the mean. T_1 = Control, T_2 = Recommended doses of NPKS (N = 115 kg ha^{-1}, P = 26.40 kg ha^{-1}, K = 62.25 kg ha^{-1}, S =18 kg ha^{-1}), T_3 = Rice straw @ 1.5 t ha^{-1} + Cow dung @ 5 t ha^{-1}, T_4 = Rice straw @ 1.5 t ha^{-1} + Cow dung @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS, T_5 = Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 5 t ha^{-1}, T_6 = Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS, T_7 = Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 10 t ha^{-1}, T_8 = Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 5 t ha^{-1} + 50% less of recommended doses of NPKS.

3.1.3.3 Combined Effect of Interaction Among Variety, Manures and Fertilizers with Rice Straw

Significant variation was found in number of effective tillers hill^{-1} due to combined effect of interaction among variety, manures and fertilizers with rice straw. The highest number of effective tillers hill^{-1} (9.49) was produced by V_1T_6 [BRRI dhan71 × (Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 5 t ha^{-1} + 50% less of recommended doses of NPKS)] combination, followed by V_2T_6 [BRRI dhan49 × (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS)] combination that produced 9.11 no. of effective tillers hill^{-1} while the lowest number of effective tillers hill^{-1} (6.47) was found from $V_2 T_1$ (BRRI dhan49 × Control) combination (Table 3).

3.1.4 Number of Non-Effective Tillers Hill^{-1}

4.4.4.1 Effect of Variety

The number of non-effective tillers hill^{-1} was not significantly influenced by variety. Numerically, the highest number of non-effective tillers hill^{-1} (1.16) was found in V_2 (BRRI dhan49) and the lowest number of non-effective tillers hill^{-1} (1.01) was found in V_1 (BRRI dhan71) (Table 1). Mia et al. (2023), found that number of non-effective tillers hill^{-1} was statistically similar among cultivars.

3.1.4.2 Effect of Manures and Fertilizers with Rice Straw

The number of non-effective tillers hill^{-1} was significantly influenced by combined effect of manures and fertilizers with rice residues. The highest number of non-effective tillers hill^{-1} (1.31) was obtained from T_1 (Control) treatment. The lowest (0.98) number of non-effective tillers hill^{-1} was produced by the T_6 (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS) treatment (Table 2).

3.1.4.3 Combined Effect of Interaction Among Variety, Manures and Fertilizers with Rice Straw

Significant variation was found in number of non-effective tillers hill^{-1} due to combined effect of interaction among variety, manures and fertilizers with rice straw. The highest number of non-effective tillers hill^{-1} (1.66) was produced by V_2T_1 [BRRI dhan49 × Control] combination, followed by 1.46 number of non-effective tillers hill^{-1} was found in V_1T_1 [BRRI dhan71 × Control] combination while the lowest number of non-effective tillers hill^{-1} (0.19) was found in V_1T_6 [BRRI dhan71 × (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS))] combination (Table 3).

3.1.5 Panicle Length

3.1.5.1 Effect of Variety

The effect of cultivar on panicle length was non-significant. Numerically, the longest panicle (23.40 cm) was recorded in V_1 (BRRI dhan71) and the shortest panicle (22.72 cm) was recorded in V_2 (BRRI dhan49) (Table 1). No varietal difference observed regarding the panicle length might be due to similarity in genetic make-up and environmental effect. This result was similar to that reported by Islam et al. (2024), who reported that panicle length has a non-significant relationship with cultivar.

3.1.5.2 Effect of Manures and Fertilizers with Rice Straw

Panicle length was not significantly influenced by the combination of manures and fertilizers with rice straw. Numerically, the longest panicle (23.80 cm) was observed in T_5 (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 5 t ha^{-1}) treatment followed by T_7 (Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 10 t ha^{-1}) treatment produced 23.55 cm and the shortest one (22.50 cm) was observed in T_1 (Control) treatment (Table 2). Hossain et al. (2024) reported that panicle length was statistically similar by different residue treatments.

3.1.5.3 Combined Effect of Interaction among Variety, Manures and Fertilizers with Rice Straw

Panicle length was not significantly influenced by the combined effect of interaction of variety and manures and fertilizers with rice straw. The longest panicle (23.72 cm) was obtained from V_1T_7 [BRRI dhan71 × Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 10 t ha^{-1}] combination and V_2T_1 (BRRI dhan49 × Control) combination produced the shortest (22.20 cm) one (Table 3). Islam et al. (2024) reported that the interaction between cultivars and crop residues was statistically similar.

3.1.6 Number of Grains Panicle^{-1}

3.1.6.1 Effect of Variety

Number of grains panicle^{-1} was non-significant which is not influenced by different varieties. Numerically, the highest number of grains panicle^{-1} (108.04) was observed in V_1 (BRRI dhan71) and the lowest one (103.00) was found in V_2 (BRRI dhan49) (Table 1). No varietal difference observed regarding the panicle length might be due to similarity in genetic make-up and environmental effect.

3.1.6.2 Effect of Manures and Fertilizers with Rice Straw

Number of grains panicle^{-1} was non-significant. It indicates that no. of grains panlce^{-1} is not influenced by the combination of manures and fertilizers with rice straw. Numerically, the highest number of grains panicle^{-1} (110.80) was produced by T_7 (Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 10 t ha^{-1}) treatment followed by T_6 (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS) treatment produced 109.13 while the lowest number of grains panicle^{-1} (96.79) was produced by T_1 (Control) treatment (Table 2).

3.1.6.3 Combined Effect of Interaction among Variety, Manures and Fertilizers with Rice

Number of grains panicle^{-1} was not significantly influenced by the combined effect of interaction of variety and manures and fertilizers with rice straw. Numerically, the highest number of grains panicle^{-1} (119.83) was produced by V_1T_6 [BRRI dhan71 × (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS)] combination, followed by 115 .66 number of grains panicle^{-1} was obtained from V_1T_7 [BRRI dhan71 × Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 10 t ha^{-1}] combination and the lowest number of grains panicle^{-1} (94.97) was produced by V_2T_1 (BRRI dhan49 × Control) combination (Table 3). This might have caused due to the combined effect of rice straw with manures and fertilizers which enrich the soil with more available nutrient and suppress weed infestation. As a result, rice plants got enough food materials then produced maximum no. of grains panicle^{-1}.

3.1.7 Number of Sterile Spikelet Panicle^{-1}

3.1.7.1 Effect of Variety

The effect of cultivar on the number of sterile spikelet panicle^{-1} was non-significant. Numerically, the highest number of sterile spikelet panicle^{-1} (10.97) was observed in V_2 (BRRI dhan49) and the lowest one (10.54) was found in V_1 (BRRI dhan71) (Table 1). Similar results were also obtained by Ullah *et al.* (2016) [25], who found that due to varietal characteristics, the number of sterile spikelets panicle^{-1} was statistically similar.

3.1.7.2 Effect of Manures and Fertilizers with Rice Straw

Number of sterile spikelets panicle^{-1} was significantly influenced by manures and fertilizers with rice straw. The highest number of sterile spikelets panicle^{-1} (14.89) was found in T_1 (Control) treatment followed by T_3 (Rice straw @ 1.5 t ha^{-1} + Cow dung @ 5 t ha^{-1}) treatment produced 14.33 number of sterile spikelets panicle^{-1}, while the lowest number of sterile spikelets panicle^{-1} (8.18) was found in T_6 (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS) treatment (Table 2).

3.1.7.3 Combined Effect of Interaction among Variety, Manures and Fertilizers with Rice Straw

The number of sterile spikelets panicle^{-1} was significantly affected by the combined effect of interaction among variety, manures and fertilizers with rice straw. The highest number of sterile spikelets panicle^{-1} (15.08) was produced by V_2T_1 (BRRI dhan49 × Control) combination and the lowest number of sterile spikelets panicle^{-1} (7.29) was produced by V_1T_6 [BRRI dhan71 × (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS)] combination (Table 3).

3.1.8 1000-Grain Weight

3.1.8.1 Effect of Variety

The effect of cultivar on weight of 1000-grain was significant. The highest (23.23 g) 1000-grain weight was found in V_1 (BRRI dhan71) and the lowest one (20.67 g) was found in V_2 (BRRI dhan49) (Table 1). The variation in weight of 1000-grain might be due to different size of grains that were partly controlled by genetic makeup of the studied varieties. Islam *et al.* (2010) [26] also expressed similar view.

3.1.8.2 Effect of Manures and Fertilizers with Rice Straw

Effect of 1000-grain weight was significantly affected by the combination of manures and fertilizers with rice straw. Numerically, the highest weight of 1000-grain (23.11 g) was recorded in T_6 (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS) treatment and the lowest one (20.13 g) was produced by T_1 (Control) treatment (Table 3).

3.1.8.3 Combined Effect of Interaction among Variety, Manures and Fertilizers with Rice Straw

Weight of 1000-grain was significantly affected by the combined effect of interaction among variety, manures and fertilizers with rice straw. The highest weight (25.75 g) of 1000-grain was recorded in V_1T_6 [BRRI dhan71 × (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS)] combination, followed by 24.01 g weight of 1000-grain in V_1T_7 [BRRI dhan71 × (Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 10 t ha^{-1})]

combination and the lowest weight (19.98 g) of 1000-grain was produced by V_2T_1 (BRRI dhan49 × Control) combination (Table 3).

3.1.9 Grain Yield

3.1.9.1 Effect of Variety

The studied varieties significantly affected the grain yield. The highest grain yield (4.87 t ha^{-1}) was obtained from V_1 (BRRI dhan71) and the lowest grain yield (4.57 t ha^{-1}) was obtained from V_2 (BRRI dhan49) (Fig. 3). Grain yield differences might be genetic characteristics of the varieties. Sohel et al. (2009) reported variable grain yields among the varieties. The difference was observed due to different varietal characteristics of the rice plant like effective tillers $hill^{-1}$, panicle length, number of grains $panicle^{-1}$, 1000-grain weight.

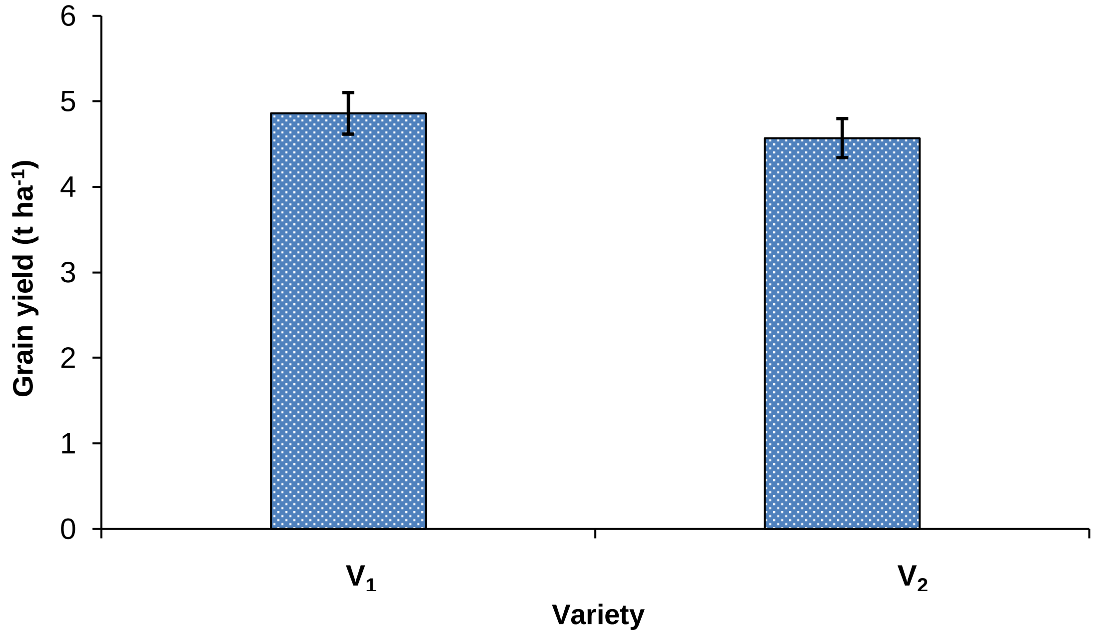

Fig. 3. Effect of variety on grain yield

Here, Vertical bars indicate the standard error of the mean. V_1 = BRRI dhan71, V_2 = BRRI dhan49

3.1.9.2 Effect of Manures and Fertilizers with Rice Straw

Grain yield was significantly influenced by the combination of manures and fertilizers with rice straw. The highest grain yield (5.60 t ha^{-1}) was produced by T_6 (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS) treatment, followed by 5.42 t ha^{-1} grain obtained from T_7 (Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 10 t ha^{-1}) treatment and lowest one (3.53 t ha^{-1}) was produced by T_1 (Control) treatment (Fig. 4). It might be due to application of chemical fertilizers along with vermicompost and trichocompost enhanced microbial activity, added organic matter to the soil also inhibited any pathogenic attack and thus, enhanced grain yield. Incorporation of rice straw decreased weed emergence in the rice field and produced maximum grain yield also. On the other hand, plots where control treatment was applied showed maximum weed population and highest dry weight of weed. The weeds compete with the crop for nutrient, water, air, sunlight and space and so grain yield decreased. Fiza et al. (2024) also reported the similar results, where crop residues influenced in crop performance.

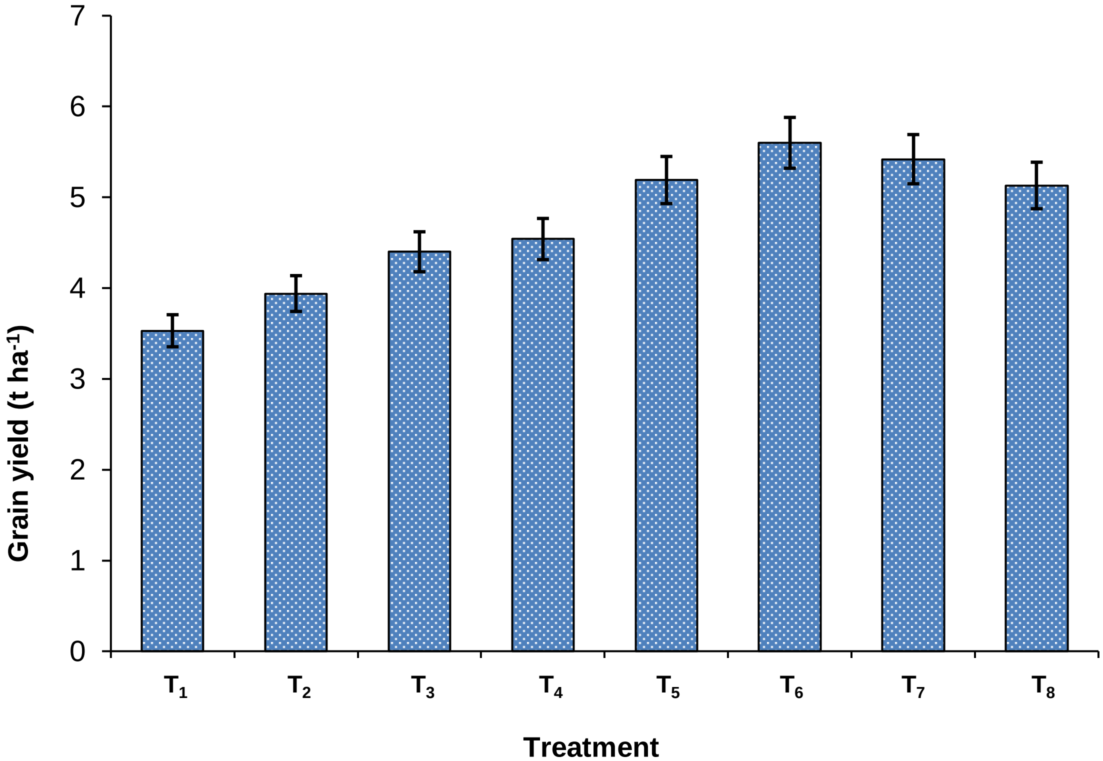

Fig. 4. Effect of combination of manures and fertilizers with rice straw on grain yield
Here, Vertical bars indicate the standard error of the mean. T_1 = Control, T_2 = Recommended doses of NPKS (N = 115 kg ha^{-1}, P = 26.40 kg ha^{-1}, K = 62.25 kg ha^{-1}, S =18 kg ha^{-1}), T_3 = Rice straw @ 1.5 t ha^{-1} + Cow dung @ 5 t ha^{-1}, T_4 = Rice straw @ 1.5 t ha^{-1} + Cow dung @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS, T_5 = Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 5 t ha^{-1}, T_6 = Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS , T_7 = Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 10 t ha^{-1}, T_8 = Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 5 t ha^{-1} + 50% less of recommended doses of NPKS.

3.1.9.3 Combined Effect of Interaction among Variety, Manures and Fertilizers with Rice Straw

Grain yield was significantly influenced by the combined effect of interaction among variety and manures and fertilizers with rice straw. The highest grain yield (5.66 t ha^{-1}) was produced by V_1T_6 [BRRI dhan71 × (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS)] combination which is statistically similar to 5.54 t ha^{-1} and 5.52 t ha^{-1} grain yield that was found in V_2T_6 [BRRI dhan49 × (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS)] combination and V_1T_7 [BRRI dhan71 × (Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 10 t ha^{-1})] combination respectively. The lowest number of grain yield (3.38 t ha^{-1}) was produced by V_2T_1 (BRRI dhan49 × Control) combination (Table 3). The lowest grain yield ha^{-1} in the plot might be due to not application of any nutrient elements and weed inhibiting material, the poor performance of yield contributing characters like number of tillers hill^{-1} and grains panicle^{-1}, genetic makeup of variety, severe weed infestation occurred in the plots due to competition for moisture, nutrients between weed and rice plants.

3.1.10 Straw Yield

3.1.10.1 Effect of Variety

The effect of cultivar on the straw yield was non-significant. Numerically, the highest straw yield (6.22 t ha^{-1}) was found in V_1 (BRRI dhan71) and the lowest straw yield (6.19 t ha^{-1}) was found in V_2 (BRRI dhan49) (Fig. 5).

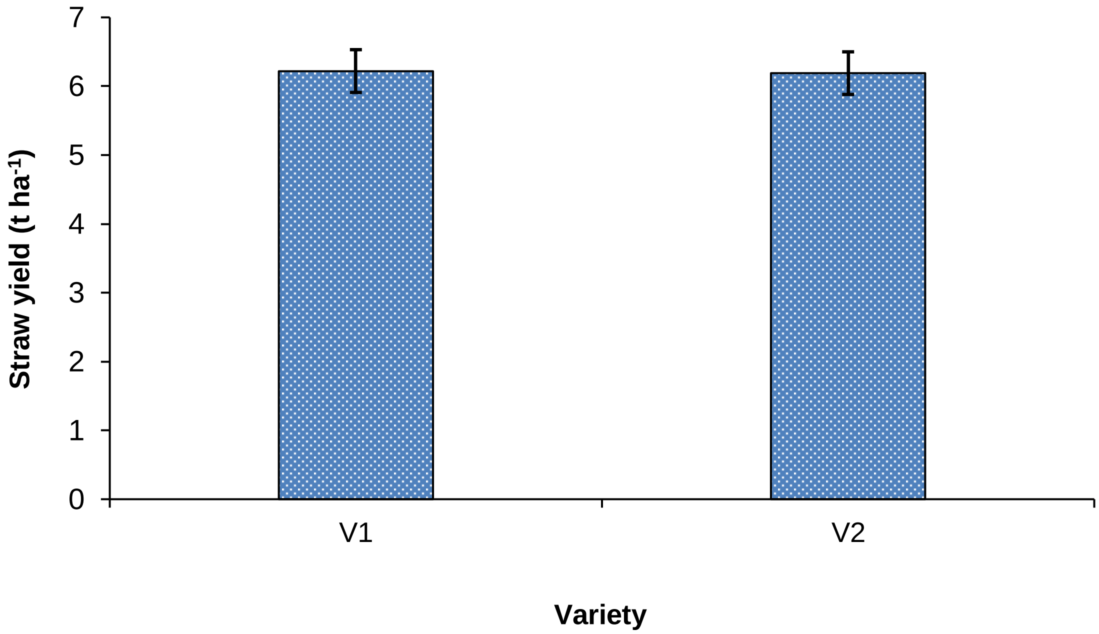

Fig. 5. Effect of variety on straw yield

Here, Vertical bars indicate the standard error of the mean. V_1 = BRRI dhan71, V_2 = BRRI dhan49

3.1.10.2 Effect of Manures and Fertilizers with Rice Straw

Straw yield was significantly influenced by the combination of manures and fertilizers with rice straw. The highest straw yield (7.52 t ha^{-1}) was observed in T_6 (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS) treatment, followed by 6.95 t ha^{-1} straw was found in T_5 (Rice straw @ 1.5 tha^{-1} + Vermicompost @ 5 t ha^{-1}) treatment while the lowest straw yield (4.49 t ha^{-1}) was observed in T_1 (Control) treatment (Fig. 6).

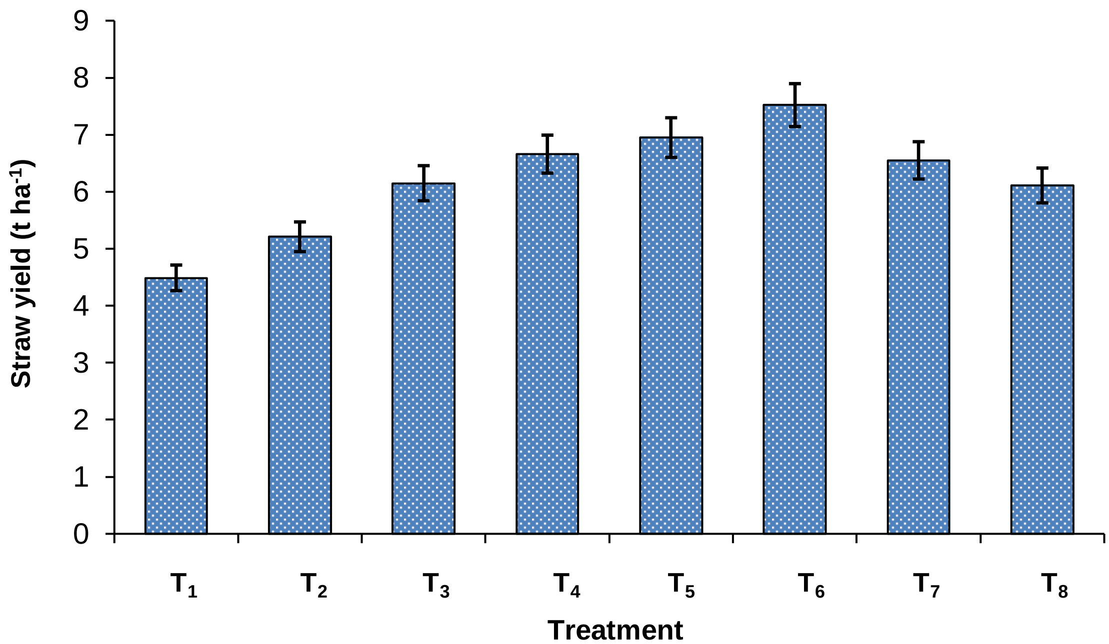

Fig. 6. Effect of combination of manures and fertilizers with rice straw on straw yield
Here, Vertical bars indicate the standard error of the mean. T_1 = Control, T_2 = Recommended doses of NPKS (N = 115 kg ha^{-1}, P = 26.40 kg ha^{-1}, K = 62.25 kg ha^{-1}, S =18 kg ha^{-1}), T_3 = Rice straw @ 1.5 t ha^{-1} + Cow dung @ 5 t ha^{-1}, T_4 = Rice straw @ 1.5 t ha^{-1} + Cow dung @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS, T_5 = Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 5 t ha^{-1}, T_6 = Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS , T_7 = Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 10 t ha^{-1}, T_8 = Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 5 t ha^{-1} + 50% less of recommended doses of NPKS.

3.1.10.3 Combined Effect of Interaction among Variety, Manures and Fertilizers with Rice Straw

Straw yield was significantly influenced by the combined effect of interaction among variety, manures and fertilizers with rice straw. The highest straw yield (7.78 t ha^{-1}) was produced by V_1T_6 [BRRI dhan71 × (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS)] combination, followed by 7.26 t ha^{-1} straw yield was found in V_2T_6 [BRRI dhan49 × (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS)] combination. The lowest straw yield (4.19 t ha^{-1}) was produced by V_2T_1 (BRRI dhan49 × Control) combination (Table 3).

3.1.11 Biological Yield

3.1.11.1 Effect of Variety

Biological yield was significantly affected by variety. The highest biological yield (11.09 t ha^{-1}) was found in V_1 (BRRI dhan71) and the lowest biological yield (10.76 t ha^{-1}) was found in V_2 (BRRI dhan49) (Table 1).

3.1.11.2 Effect of Manures and Fertilizers with Rice Straw

The combination of manures and fertilizers with rice straw had significant influence on biological yield. The highest biological yield (13.12 t ha^{-1}) was obtained in T_6 (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS) treatment, followed by 12.14 t ha^{-1} straw was observed in T_5 (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 5 t ha^{-1}) treatment that is statistically similar to 11.97 t ha $^{-1}$ founded in T_7 (Rice straw @ 1.5

t ha^{-1} + Trichocompost @ 10 t ha^{-1}) treatment while the lowest biological yield (8.20 t ha^{-1}) was obtained in T_1 (Control) treatment (Table 2). Higher weed infestation not only reduced grain yield but also influenced straw yield as well as biological yield finally.

3.1.11.3 Combined Effect of Interaction among Variety, Manures and Fertilizers with Rice Straw

Biological yield was significantly influenced by the combined effect of interaction among variety, manures and fertilizers with rice straw. The highest biological yield (13.44 t ha^{-1}) was produced by V_1T_6 [BRRI dhan71 × (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS)] combination, followed by 12.80 t ha^{-1} biological yield was found in V_2T_6 [BRRI dhan49 × (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS)] combination and the lowest biological yield (7.57 t ha^{-1}) was produced by V_2T_1 (BRRI dhan49 × Control) combination (Table 3).

3.1.12 Harvest Index (%)

3.1.12.1 Effect of Variety

The effect of cultivar on harvest index is non-significant. Numerically, the highest harvest index (43.91%) was found in V_1 (BRRI dhan71) and the lowest harvest index (42.47%) was found in V_2 (BRRI dhan49) (Table 1).

3.1.12.2 Effect of Manures and Fertilizers with Rice Straw

Harvest index was significantly influenced by combination of manures and fertilizers with rice straw. The highest harvest index (45.64%) was observed in T_8 (Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 5 t ha^{-1} + 50% less of recommended doses of NPKS) treatment which is statistically similar to 45.28% was found in T_7 (Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 10 t ha^{-1}) while the lowest harvest index (40.54%) was observed in T_4 (Rice straw @ 1.5 t ha^{-1} + Cow dung @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS) treatment (Table 2).

3.1.12.3 Combined Effect of Interaction among Variety, Manures and Fertilizers with Rice Straw

The Harvest index was significantly influenced by the combined effect of the interaction of variety and manures and fertilizers with rice straw. The highest harvest index (47.17%) was observed in V_1T_8 [BRRI dhan71 × (Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 5 t ha^{-1} + 50% less of recommended doses of NPKS)] combination, followed by 46.12% harvest index was found in V_1T_7 [BRRI dhan71 × (Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 10 t ha^{-1})] combination and the lowest harvest index (38.88%) was observed in V_2T_3 [BRRI dhan49 × (Rice straw @ 1.5 t ha^{-1} + Cow dung @ 5 t ha^{-1})] combination (Table 3).

Table 1: Effect of variety on yield and yield contributing characters of rice at harvest

Variety	Plant height (cm)	Total tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)	Panicle length (cm)	Grains panicle^{-1} (no.)	Sterile spikelets (no.)	1000-grain weight (g)	Biological yield (t ha^{-1})	Harvest index (%)
V_1	102.45a	9.17	1.01	23.40	108.04	10.54	23.23a	11.09a	43.91a
V_2	100.60b	9.06	1.16	22.72	103.00	10.97	20.67b	10.76b	42.47b
LSD $_{(0.05)}$	0.92	2.24	0.33	1.06	7.38	0.95	1.11	0.15	0.80
Level of Significance	**	NS	NS	NS	NS	NS	**	**	**
CV%	3.55	4.64	5.64	7.84	11.88	15.00	8.64	2.45	3.16

In a column, figures with same letter(s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT. ** = Significant at 1% level of probability, NS = Not significant, V_1 =BRRI dhan71, V_2 = BRRI dhan49

Table 2: Effect of combination of manures and fertilizers with rice straw on yield and yield contributing characters of rice at harvest

Treatments	Plant height (cm)	Total tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)	Panicle length (cm)	Grains panicle^{-1} (no.)	Sterile spikelets (no.)	1000-grain weight (g)	Biological yield (t ha^{-1})	Harvest index (%)
T_1	96.84e	7.99e	1.31c	22.50	96.79	14.89a	20.13c	8.02f	44.01ab
T_2	99.83d	8.98d	1.20bc	22.59	101.71	11.55bc	20.73bc	9.15e	43.06bc
T_3	100.42d	9.11cd	1.08b	22.93	106.24	13.13ab	21.47abc	10.55d	41.71cd
T_4	101.21cd	9.20bc	1.05b	22.82	105.51	9.06de	22.50ab	11.20c	40.54d
T_5	102.96bc	9.49ab	0.99a	23.80	106.66	9.31de	22.86ab	12.14b	42.75bc
T_6	103.68ab	10.28a	0.98b	23.17	109.13	8.18e	23.11a	13.12a	42.68bc
T_7	101.21cd	9.18d	1.07b	23.55	110.80	9.21de	22.89ab	11.97b	45.28a
T_8	103.14b	9.79cd	1.01b	23.12	107.31	10.72cd	21.92abc	11.24c	45.64a
LSD $_{(0.05)}$	1.85	0.49	0.67	2.13	14.77	1.90	2.23	0.31	1.60
Level of Significance	**	**	**	NS	NS	**	**	**	**
CV%	3.55	4.64	5.64	7.84	11.88	15.00	8.64	2.45	3.16

In a column, figures with the same letter do not differ significantly as per DMRT. ** = Significant at 1% level of probability, NS = Not significant, T1 = Control, T2 = Recommended doses of NPKS (N = 55 kg ha^{-1}, P = 26.40 kg ha^{-1}, K = 62.25 kg ha^{-1}, S =18 kg ha^{-1}), T3 = Rice straw @ 1.5 t ha^{-1} + Cow dung @ 5 t ha^{-1}, T4 = Rice straw @ 1.5 t ha^{-1} + Cow dung @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS, T5 = Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 5 t ha^{-1}, T6 = Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS , T7 = Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 10 t ha^{-1}, T8 = Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 5 t ha^{-1} + 50% less of recommended doses of NPKS.

Table 3: Combined effect of interaction among variety, manures and fertilizers with rice straw on yield and yield contributing characters of rice at harvest

Interaction	Plant height (cm)	Total tillers hill^{-1} (no.)	Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)	Panicle length (cm)	Grain panicle^{-1} (no.)	Sterile spikelet (no.)	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1T_1	97.28f	8.40e	6.94ef	1.46abcd	22.28	98.62	14.71ab	19.83d	3.67f	4.79j	8.46i	43.38cde
V_1T_2	101.55de	9.02d	7.77cde	1.25bcde	22.56	103.61	10.61def	21.91bcd	4.12e	5.17i	9.29h	44.35bc
V_1T_3	102.47bcde	9.00d	7.89cde	1.11bcdef	22.61	104.57	11.77cde	22.66abcd	4.70d	5.84h	10.54g	44.59bc
V_1T_4	103.08abcde	9.08c	8.01cd	1.07cdef	22.91	104.67	9.47efg	23.32abc	4.54d	6.69de	11.23de	40.43fg
V_1T_5	103.81abcd	9.20bc	8.15bcd	1.05cdef	23.00	108.87	8.72fg	23.86ab	5.28ab	7.00c	12.28c	43.00cde
V_1T_6	105.60a	9.68a	9.49a	0.19f	23.39	119.83	7.29g	25.75a	5.66a	7.78a	13.44a	42.11def
V_1T_7	104.68ab	8.85cd	8.33bcd	0.52def	23.72	115.66	8.80fg	24.01ab	5.52a	6.45f	11.97c	46.12ab
V_1T_8	104.27abc	9.10c	8.66abc	0.44ef	23.32	108.75	9.62efg	23.92ab	5.41ab	6.06gh	11.47d	47.17a
V_2T_1	96.00f	8.13de	6.47f	1.66a	22.20	94.97	15.08a	19.93d	3.38f	4.19k	7.57j	44.65bc
V_2T_2	97.34f	8.91d	7.56de	1.35bc	22.39	98.43	14.15abc	19.56d	3.76ef	5.25i	9.01h	41.73ef
V_2T_3	97.67f	8.96d	7.81cde	1.15def	22.48	100.17	12.50abcd	20.29cd	4.11e	6.46ef	10.57fg	38.88g
V_2T_4	100.75e	9.09c	7.96cde	1.13bcdef	22.70	103.25	9.06fg	20.48cd	4.54d	6.62ef	11.16de	40.68fg
V_2T_5	102.26bcde	9.19bc	8.11bcd	1.08cdef	23.20	105.94	9.89defg	21.67bcd	5.10bc	6.91cd	12.01c	42.46cdef
V_2T_6	103.66abcd	9.47ab	9.11ab	0.36ef	23.68	109.95	8.66fg	21.86bcd	5.54a	7.26b	12.80b	43.28cde
V_2T_7	101.67cde	9.11c	8.17bcd	0.94cdef	23.34	106.13	9.67efg	21.77bcd	5.32ab	6.66ef	11.98c	44.40bc
V_2T_8	102.32bcde	9.29b	8.56abcd	0.73cdef	23.16	104.88	12.11bcde	20.44cd	4.85cd	6.16g	11.01ef	44.05bcd
LSD $_{(0.05)}$	2.62	0.70	1.04	0.95	3.01	20.89	2.69	3.16	0.38	0.23	0.44	2.27
Level of Significance	**	**	**	**	NS	NS	**	**	**	**	**	**
CV%	3.55	4.64	7.80	5.64	7.84	11.88	15.00	8.64	4.93	2.28	2.45	3.16

In a column, figures with same letter(s) or without letter do not differ significantly whereas figures with dissimilar letter differ significantly as per DMRT. ** = Significant at 1% level of probability, NS = Not significant, V_1 =BRRI dhan71, V_2 = BRRI dhan49, T_1 = Control, T_2 = Recommended doses of NPKS (N = 115 kg ha^{-1}, P = 26.40 kg ha^{-1}, K = 62.25 kg ha^{-1}, S =18 kg ha^{-1}), T_3 = Rice straw @ 1.5 t ha^{-1} + Cow dung @ 5 t ha^{-1}, T_4 = Rice straw @ 1.5 t ha^{-1} + Cow dung @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS, T_5 = Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 5 t ha^{-1}, T_6 = Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS , T_7 = Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 10 t ha^{-1}, T_8 = Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 5 t ha^{-1} + 50% less of recommended doses of NPKS.

5. CONCLUSION

From the completed experiment it was found that the variety BRRI dhan71 and T6 (Rice straw @ 1.5 t ha^{-1} + Vermicompost @ 2.5 t ha^{-1} + 50% less of recommended doses of NPKS) treatment exhibited the superior effect followed by BRRI dhan49 and T7 (Rice straw @ 1.5 t ha^{-1} + Trichocompost @ 10 t ha^{-1}) treatment for most of the studied traits. The results of the present study revealed that the combined effect of rice straw with manures and fertilizers enhanced yield and yield-contributing characteristics. Therefore, rice straw combined with manures and fertilizers could be a potential source of eco-friendly yield enhancement tools for sustainable crop production.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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