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POTENTIALS OF ORGANIC AMENDMENTS ON YIELD ATTRIBUTES AND PROTEIN CONTENT OF RICE

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Keywords: BR 22 rice, organic amendments, protein content, yield attributes

Abstract

A field experiment was carried out in Habiganj, Bangladesh, to evaluate the effects of various organic amendments, including rice straw plus cow dung composts (1:2 and 1:4 ratios), sawdust compost, rice husk compost, vermicompost, and tricho-compost on the yield attributes and protein content of BR 22 rice grown under natural field conditions. The experiment was structured with a completely randomized block design and included three replications. In subplots, organic amendments were applied at varying rates of 0, 5, and 10 tons per hectare. The application of these organic amendments significantly ($p \leq 0.05$) improved various agronomic attributes of rice compared to the control plot. Tricho-compost (TC) at 5 and 10 t ha^{-1} ranked 1st and 2nd, respectively, in terms of tillers per hill (45 and 40 at the maximum tillering stage; 42 and 38 at harvest), productive tiller ratio (0.89 and 0.72), straw dry matter production (10.72 and 10.29 t ha^{-1}), and grain yield (8.00 and 7.57 t ha^{-1}). However, the highest protein content in grains (14.0%) was achieved with vermicompost at its higher dose (T_3), followed by TC (T_8) and rice husk compost (T_{13}). The study concludes that locally available organic amendments of tricho-compost and vermicompost found to be significantly ($p \leq 0.05$) improve rice yield and protein content, making them a viable option for sustainable rice production.

Introduction

Rice (*Oryza sativa* L.), in terms of economics, is the main crop grown in Asia, and following maize it holds the second highest importance as a staple food, satiating the hunger of around 60% of the population worldwide(1). It is the principal staple food for the people of Bangladesh, an agricultural country with most of its lands suitable and used for rice cultivation due to the favorable agroecological setting. As a result, Bangladesh gained self-sufficiency in rice production(2,3), with a per capita-annum consumption of 179.9 kg. While the world's average consumption is 53.5 kg, rice supplies 76% of calories and 66% of the total protein needs(4). Thus, Bangladesh has gone from a so-called bottomless bucket to a food of full buckets with an astonishing 25.19 million tons more production gain in 45 years from 1977, despite a concomitant 2.29-time increasing population. Though these are accompanied by the application of heavy irrigation, fertilizer, pesticide, and intelligent crop

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management[2], the average rice grain production (3.25 t ha^{-1}) in Bangladesh is still much lower than in Japan and China[5].

Again, the increasing use of high-yielding rice cultivars with low organic matter content in Bangladesh's soil as well as imbalance, sole use, and overuse of different agrochemicals without any organic amendments to confirm and sustain this production threaten the soil health and degrade it over the years. However, inappropriate tillage operation and irrigation water deteriorate soil health through declining soil carbon stocks[6]. Previously most of the stakeholders related to farming centered predominantly on the chemical properties of soil for crop cultivation, but, recent studies show that biological and physical properties of soil are equally important for crop production. In this line, keeping SDGs 1, 2, 13, 14, and 15 and national priority targets in mind, climate resilience and smart technology are required for the above-mentioned issues. Organic amendments can help much regarding the above matters considering the socio-economic conditions of Bangladesh which increase nutrient status and availability for crop growth. By improving soil health i.e., physical viz. reducing sodicity and bulk density, increasing water infiltration rate, porosity, and aeration, saline soil leaching; chemical viz. improving essentials macro-micro nutrients[7], humus contents, decreasing acidity; biological viz. flourishing beneficial macro- and microorganisms, reducing crop disease[8], eco-friendly and cost-effective organic amendments have the potentiality of enhancing soil fertility and ultimately rice productivity through the improvement of various physical attributes i.e. height[9], number of tillers[10], grain yield[11-13] of rice. On the other hand, limited use of organic matter impacts crop yield negatively[14]. Against the background, the present research had the following objectives: (a) to evaluate the potentials of different doses of some selected locally available organic amendments on different yield attributes of rice; and (b) to find out the best use order of applied organic amendments concerning grain quality, particularly the protein content.

Materials and Methods

The field trial took place during Aman season at Mithapukur (GPS: 24° 03′ 27″ N, 91° 18′ 32″E), Madhabpur, Habiganj, Bangladesh. The site is a part of the Agroecological Zone (AEZ 19) named Old Meghna Estuarine Floodplain (FAO, 1988). As per drainage, the field is seasonally shallow to moderately flooded, and poorly drained, with subsoil of clay loam texture. The properties of the soil are listed in Table 1. At first, the experimental field was prepared by crisscross plowing method with the help of a tractor two weeks before planting. It helped to mix the organic amendments that were added to the soil previously. A total of 13 treatments viz., T_1 (Control, without any organic amendments), T_2 (V_5, Vermicompost at 5 tha^{-1}), T_3 (V_{10}, Vermicompost at 10 tha^{-1}), T_4 (1RS:4CD_5, Rice Straw and Cow Dung of 1:4 compost at 5 tha^{-1}), T_5 (1RS:4CD_{10}, Rice Straw and Cow Dung of 1:4 compost at 10 tha^{-1}), T_6 (1RS:2CD_5, Rice Straw plus Cow Dung of 1:2 compost at 5 tha^{-1}), T_7 (1RS:2CD_{10}, Rice Straw plus Cow Dung of 1:2 compost at 10 tha^{-1}), T_8 (TC_5, Tricho-compost at 5 tha^{-1}), T_9 (TC_{10}, Tricho-compost at 10 tha^{-1}), T_{10} (SD_5, Saw Dust compost at 5 tha^{-1}), T_{11} (SD_{10}, Saw Dust compost at 10 tha^{-1}), T_{12} (RH_5, Rice husk compost at 5 tha^{-1}), T_{13} (RH_{10}, Rice husk compost at 10 tha^{-1}) were applied. As per the fertilizer recommendation of the Bangladesh Agricultural

Research Council (BARC, 2018), urea was applied to supplement nitrogen at the rate of 120 kg ha^{-1} having two splits of 2/3 as basal dose plus 1/3 as top-dressed at the active tillering stage. Phosphate (P_2O_5) from Triple Super Phosphate (TSP) at 60 kg ha^{-1} and K_2O from Muriate of Potash (MoP) at 80 kg ha^{-1} were also applied as basal doses.

The chosen experimental design was completely randomized with three replications under field conditions as local farmers. In each of the main plots, the treatments comprising composts were added. Each block consists of 13 sub-blocks (2m × 2m) as per design. A 25 cm drain was curved among the three main blocks to control the irrigation water supply. Again, a standard spacing of 15 cm among the subblocks and an earthen border of 10 cm were established around each subblock to rule out contamination from adjacent subplots. Each subplot received 6 rows of seedlings for BR 22 collected from the farmers. Some 3 seedlings were transplanted per hill, with respective 15 cm and 20 cm gaps between the hill-to-hill and row-to-row. Except the first and last rows, plants were considered for sampling. Intercultural operations such as weeding and thinning were practiced when required. The land was irrigated twice.

Harvesting occurred at 1.0 cm above the ground surface at the maturity stage of the plants (120 days). Two-row strips of rice from each subplot were randomly selected for plant sampling. At the maximum tillering (75 days after transplantation) and harvesting stages, the harvested vegetative part of the plants was collected for laboratory analyses. During harvesting, the rice grains were also collected to determine the protein content of the rice. Then the collected samples were cleaned and washed, sun-dried, cut into smaller pieces, oven-dried, crushed in an electric grinder, and stored in plastic bottles for analyses. Minitab 20 and Microsoft Excel 2016 were used for statistical analysis and graph making.

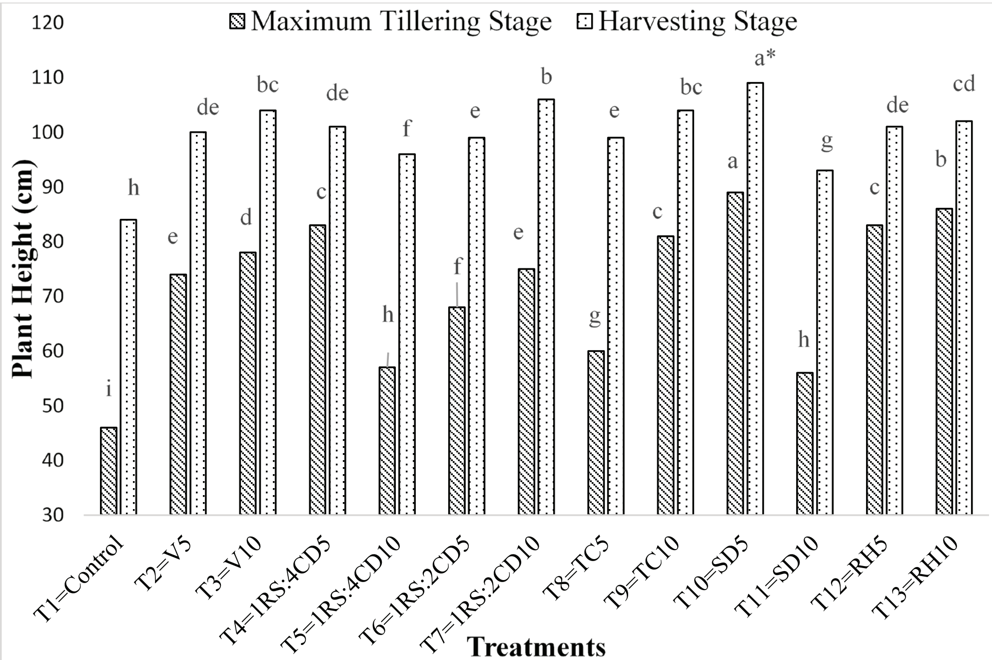
Table 1. Properties of the initial soil (1-15 cm depth) used under natural field conditions

Properties	Values
Series	Balua soil series
General soil type	Noncalcareous Grey Floodplain Soils
Textural class[15]	Clay loam
pH (soil:water = 1:2.5)[16]	5.59
Organic carbon (%)[17]	1.27
Cation Exchange Capacity (CEC: $cmol_c$ kg^{-1})[18]	24.98
Total N (%)[16]	0.16
C/N ratio	7.94
Available N (mg kg^{-1})[16]	39.38
Available P (mg kg^{-1})[19]	20.38
Exchangeable K ($cmol_c$ kg^{-1})[16]	0.18
Available S (mg kg^{-1})[20]	34.68

Results and Discussion

Plant height

The height of plants was measured and recorded at the maximum rice tillering and harvesting stages. The ANOVA and Tukey's range test demonstrated that the application of organic amendments had significant ($p \leq 0.05$) positive effects on plant height (Fig. 1).



*Means that don't share a letter are significantly different at 5% level by Tukey's Range Test performed seperately for two dfifferent sampling stages

Fig. 1. Influence of organic amendments on plant height (cm) of BR 22.

At the stage of maximum tillering, the applied treatment of T_{10} i.e., sawdust compost at 5 t ha^{-1} had the tallest plant height of 89 cm. The satisfactory heights of 86, 83, and 81 cm were also obtained from rice husk compost at 10 and 5 t ha^{-1} (T_{13} and T_{12}) and TC at 10 t ha^{-1} (T_9), respectively. At the harvesting stage, the maximum height (109 cm) of the rice plant was observed in sawdust compost at 5 t ha^{-1} (T_{10}), and rice straw plus cow dung of 1:2 compost at 10 t ha^{-1} (T_7: 107 cm) which showed that the T_7 treatment had additive effects though it was statistically ($p \leq 0.05$) identical to the T_{10}. In both the sampling stages, the shortest plant was marked out in the control plot (T_1: 46 and 84 cm). These positive effects might be due to the potentiality of organic amendments which acted as a house of nutrients i.e., to supply essential nutrients throughout the life cycle of the rice plant of BR 22. These enhanced nutrients might help increase leaf area which ultimately enhances photo-accumulation along with higher dry matter accumulation as evidenced by organic manure and compost application in rice[21].

Number of tillers per hill

Rice tiller is an important property of rice that affects rice production though it varies with soil, varieties, and surrounding environments. The number of tillers was counted and recorded during the maximum tillering and harvesting stages of rice grown under field experiment. It was observed that organic amendments had significant ($p \leq 0.05$) positive effects on tiller production for BR 22 (Fig. 2).

At the maximum tillering stage, TC at 5 t ha^{-1} (T_8) significantly produced the maximum number of tillers (45) per hill followed by TC at 10 t ha^{-1} (T_9: 40) whereas the lowest number of tillers per hill (25) was obtained from the control plot (T_1) that had no organic amendments. The other treatments also had an increased number of tillers than the control at this stage. The range of increase over the control (IOC) of the number of tillers per hill at this stage of rice was 20-80%.

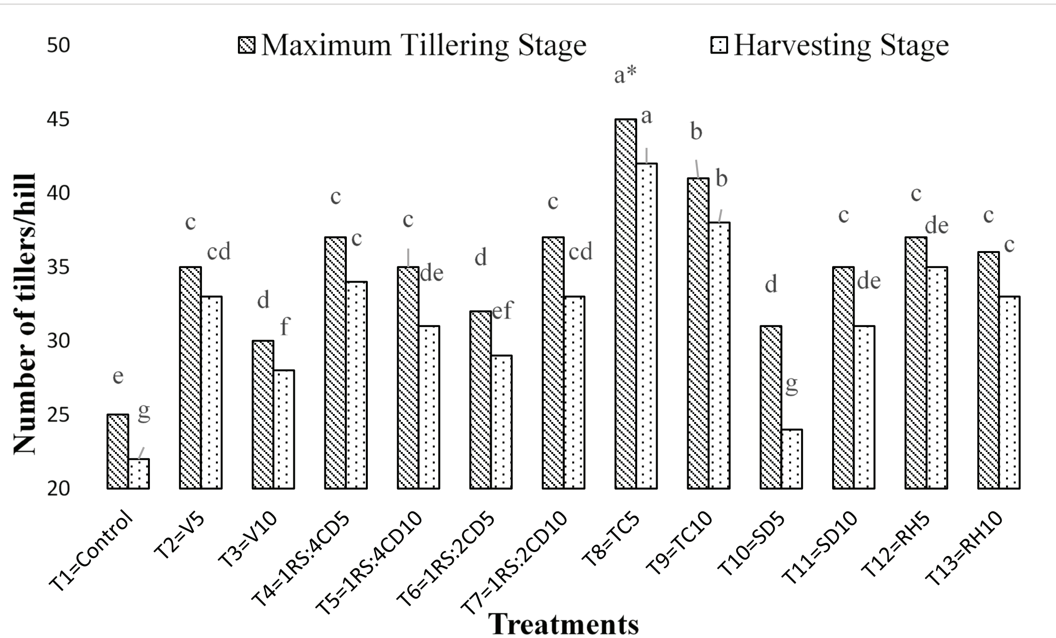


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Fig. 2. Potentials of organic amendments on the tillers per hill of BR 22.

In the case of the harvesting period, the treatment T_8 (TC at 5 t ha^{-1}: 42) and T_9 (TC at 10 t ha^{-1}: 38) also ranked 1st and 2nd regarding the number of tillers per hill with the highest IOC of 91 and 73%, respectively. Whereas, the minimum number of tillers per hill (22) was also observed in the control plot. All the treatments have shown a higher number of tillers than that of control which might be due to the supply of nutrients, especially nitrogen which is important for cell division. In the present study, these fertilizer practices i.e., organic sources along with inorganic influences the area of leaves and active basal vegetative buds finally increase the number of tillers through absorption of sunlight during photosynthesis. The higher number of tillers per square meter is also reported by scientists[22].

Ratio of Productive Tillers

The ratio of productive tillers (PTR) is recognized as an important rice growth parameter. The effects of the studied treatments on the PTR of the BR 22 rice variety were found significant ($p \leq 0.05$) by the application of locally available organic amendments for these soils (Figure 3). The highest value of PTR of 0.89 was obtained from the T_8 (TC at 5 t ha^{-1}) at the harvesting stage of rice. On the other hand, the least value (0.72) of PTR was determined for the control plot (T_1). Other treatments compared to the control also exerted higher values of PTR of the tested variety. So, it was evident that the applied locally available organic amendments had significant ($p \leq 0.05$) competence to increase PTR and ultimately rice yield. Productive tillers, tillers containing panicles, are more important for the final production of grain from rice plants than the total tiller count. In the present experiment, the organic amendments treated plots produced higher productive tillers than that control might be due to the capability of these amendments to act as a supplement of essential macro-micro nutrients other than the selectively supplied inorganic nutrients.

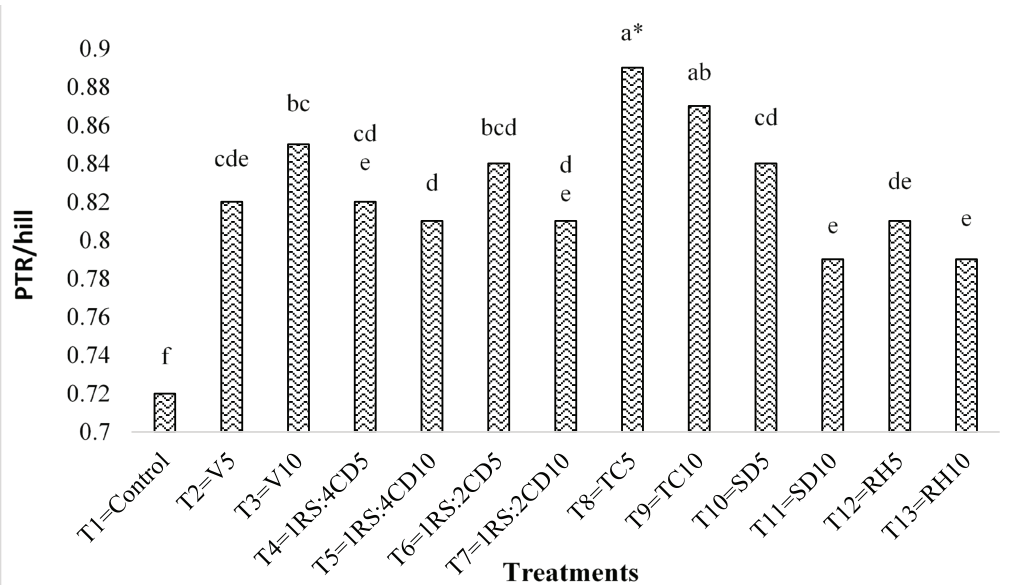

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Fig. 3. The changes in the PTR values of BR 22 with the organic amendments.

Straw dry matter production

The straw yield of the Aman rice of the BR 22 cultivar was observed to be increased to a great extent by the application of all the organic treatments. The ANOVA and Tukey's range test analyses showed that the straw yield response of rice positively ($p \leq 0.05$) increased with the different doses of organic amendments and produced significantly ($p \leq 0.05$) more straw than that of the control plot (Table 2).

The highest straw dry matter production (10.72 t ha^{-1}) was measured from the treatment T_8 (TC at 5 t ha^{-1}) followed by T_9 (10.72 t ha^{-1}). Whereas, the least straw yield (8.32 t ha^{-1}) was obtained from the control. The maximum increase over control (27.16%) of straw dry matter production was determined from the treatment plot that was amended with TC at 5 t ha^{-1} (T_8) followed by TC at 10 t ha^{-1} (T_9: 22.06%). As expected, the 1st (18.72 t ha^{-1}) and 2nd (17.86 t ha^{-1}) highest biological yields were obtained from T_8 (TC at 5 t ha^{-1}) and T_9 (TC at 10 t ha^{-1}) followed by sawdust compost at 5 t ha^{-1} (T_{10}: 17.86 t ha^{-1}). Whereas, the least biological yield (17.86 t ha^{-1}) was observed in the control plot.

In the present study, the increasing leaf number as well as leaf size as a result of the presence of sufficient nutrients possibly increases nutrient absorption due to good root development that ultimately resulted in higher translocation of carbohydrates through xylem and phloem tissue from soil solution to rice plant which might be the causes of higher straw dry matter production compared to control. These findings of the enhanced straw dry matter production of rice from the experiment are quite consistent with the previous study(23) where authors demonstrated that compost and sugarcane filter cake consequently improve above-ground biomass production.

Grain yield

The ANOVA and Tukey's range test showed that the treatments T_8 and T_9 ranked 1st (8.00 t ha^{-1}) and 2nd (7.57 t ha^{-1}) regarding grain yield production of rice. The rest of the treatments also demonstrated a significantly higher yield than that of the control (5.71 t ha^{-1}). Sawdust compost at 5 t ha^{-1} (T_{10}), rice straw plus cow dung of 1:2 compost at 10 and 5 t ha^{-1} (T_7 and T_6), and rice husk compost at 5 t ha^{-1} (T_{12}) produced notable grain yields of BR 22 rice of 7.10, 7.12, 7.06, and 6.99 t ha-1, respectively.

The 1st and 2nd highest grain yield increment over control (IOC %) were determined for TC at 5 t ha^{-1} (T_8: 40.11%) and TC at 10 t ha^{-1} (T9: 32.57%), respectively. Among other treatments, sawdust compost at 5 t ha^{-1} (24.34%), rice straw and cow dung of 1:2 compost at 10 and 5 t ha^{-1} (24.69 and 23.64%), and rice husk compost at 5 t ha^{-1} (22.42%) were found as an outstanding yield raised over control of BR 22 rice variety.

The application of locally available organic amendments increased grain yields of rice by facilitating better uptake and efficient use of macro- and micronutrients. The present findings of increasing grain yield from the experiment by applying locally available organic amendments are almost in similar conformity with the previous study(24) where authors suggested the grain yield increment of rice by applying vermicompost. The overall statements of the present findings revealed that the improved grain yield acquired using organic amendments might be due to the improvement of the soil properties as usually expected from the organic amendments which made a suitable medium for essential nutrient availability and ultimately grain yield production of rice.

Harvest index of rice

The harvest index of the BR 22 rice variety showed that the treatment T_7 (rice straw plus cow dung of 1:2 compost at 10 t ha^{-1}) and T_8 (TC at 5 t ha^{-1}) were ranked 1st (0.4395) and 2nd (0.4273: Table 2). The other treatments also found a statistically higher harvest index than the control, which didn't receive any amendment. Moreover, harvest indexes of 0.4238 and 0.4196 were ascertained from the soils amended with TC at 10 t ha^{-1} (T_9) and sawdust compost at 5 t ha^{-1} (T_{10}), respectively. The maximum increased in harvest index over control of 8.84% was found from the treatment T_7 followed by T_8 (5.83%) and T_9 (4.97%). In the present experiment, according to expectation, harvest indices for plots containing organic treatments also got positively influenced, due to their beneficial effects on grain and straw yield (Table 2).

Table 2. Influence of applied organic amendments on yield components of BR 22

Treatments	Grain Yield (t ha^{-1})	IOC[a] %	Straw Yield (t ha^{-1})	IOC %	HI[b]	IOC %
T_1=Control	5.71h*	0	8.32g	0	0.4038l	0
T_2=V_5	6.66d	16.64	9.37d	11.27	0.4152g	2.83
T_3=V_{10}	6.37e	11.56	9.08ef	7.83	0.4120h	2.04
T_4=1RS:4CD_5	5.93g	3.85	8.65f	2.61	0.4067k	0.72
T_5=1RS:4CD_{10}	6.32ef	10.68	9.14e	7.24	0.4115i	1.90
T_6=1RS:2CD_5	7.06c	23.64	9.77c	16.01	0.4192e	3.82
T_7=1RS:2CD_{10}	7.12c	24.69	9.80c	7.71	0.4395a	8.84
T_8=TC_5	8.00a	40.11	10.72a	27.16	0.4273b	5.83
T_9=TC_{10}	7.57b	32.57	10.29b	22.06	0.4238c	4.97
T_{10}=SD_5	7.10c	24.34	9.84c	16.49	0.4196d	3.92
T_{11}=SD_{10}	6.19f	8.41	8.91ef	5.69	0.4099j	1.52
T_{12}=RH_5	6.35e	11.21	9.07ef	7.59	0.4117hi	1.98
T_{13}=RH_{10}	6.99c	22.42	9.73c	15.18	0.4185f	3.66

*Means that don't share a letter are significantly different at 5% level by Tukey's Range Test performed seperately for two dfifferent sampling stages

[a]IOC= Increased Over Control, [b]HI= (Grain Yield)/(Biological Yield)

Grains per panicle and thousand-grain weight

Organic amendments were found significantly ($p \leq 0.05$) effective in increasing the number of grains per panicle (Table 3). The maximum number of grains per panicle (241) was recorded for the TC at 5 t ha^{-1} (T_8) followed by rice straw plus cow dung of 1:4 compost at 5 t ha^{-1} (T_4: 223) and rice husk compost at 10 t ha^{-1} (T_{13}: 217). The other doses of treatments also had more grains per panicle than that of the control. As expected, the maximum increase over control of 37.76% was found in the treatment, which had the highest grains per panicle. Other treatments of different doses of locally available organic amendments also had 2.60 to 32.74% IOC.

The vermicompost at 5 t ha^{-1} was attributed with a maximum weight of 1000 grain (T_2: 24 g) among the other treatments in the studied experimental field. But Tukey's range test showed that 1000 grain weight of vermicompost at 5 (T_2: 24 g), TC at 10 (T_9: 23.8 g), and rice husk compost at 5 t ha^{-1} (T_{12}: 23.6 g) were almost identical. Whereas, the lowest weight of 1000 grain (T_1: 20 g) was detected in the treatment with basal doses. The IOC of 1000 grain weight ranged from 4.76 to 16.67% which might be due to the variation in rates and types of locally available organic amendments. The number of grains per panicle and thousand grains weight were also increased by the application of FYM with nitrogen fertilizers reported by several researchers(25).

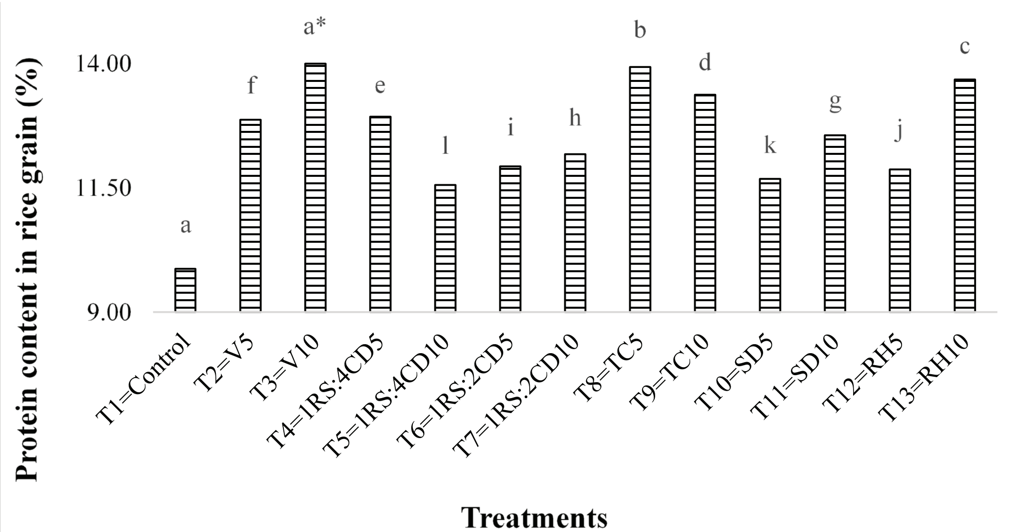
Table 3. Number of grains per panicle and 1000 grain weight of BR 22

Treatments	No. of grains/ panicle	IOC (%)	1000 grain weight (g)	IOC (%)
T_1=Control	150k*	0	20i	0
T_2=V_5	182e	17.58	24a	16.67
T_3=V_{10}	175f	14.29	23bcd	13.04
T_4=1RS:4CD_5	223b	32.74	22.8cde	12.28
T_5=1RS:4CD_{10}	154j	2.60	22.2def	9.91
T_6=1RS:2CD_5	210d	28.57	21.8efg	8.26
T_7=1RS:2CD_{10}	167g	10.18	21h	4.76
T_8=TC_5	241a	37.76	21h	4.76
T_9=TC_{10}	192d	21.88	23.8ab	15.97
T_{10}=SD_5	160i	6.25	22.4de	10.71
T_{11}=SD_{10}	182e	17.58	22.8cde	12.28
T_{12}=RH_5	159i	5.66	23.6abc	15.25
T_{13}=RH_{10}	217c	30.88	21.2gh	5.66

*Means that don't share a letter are significantly different at 5% level by Tukey's Range Test performed seperately for two dfifferent sampling stages

Protein content of rice

In addition to calories, rice grain is a good source of protein. The protein contents of the BR 22 rice variety in the studied experiment were determined to vary significantly ($p \leq 0.05$) in a positive way as influenced by the application of some selected locally available organic amendments (Fig. 4). Vermicompost at 10 t ha^{-1} (T_3: 14%) and TC at 5 t ha^{-1} (T_3: 13.93%) ranked 1st and 2nd regarding protein contents in rice grain followed by rice husk at 10 t ha^{-1} (T_{13}: 13.68%) > TC at 10 t ha^{-1} (T_9: 13.37%). The other treatments were also found to have significantly ($p \leq 0.05$) higher protein contents compared to the control plot (T_1: 9.87%). So, the present study evinced that the application of the selected locally available organic amendments had a strong positive influence on rice grain protein and this improvement of protein might help to increase its nutritional value. The increased nitrogen availability could be attributed to the positive impacts of organic amendments on amino acid concentration which ultimately increases the protein contents in rice[26].



*Means that don't share a letter are significantly different at 5% level by Tukey's Range Test performed seperately for two dfifferent sampling stages

Fig. 4. Influence of locally available organic amendments on protein (%) contents of BR 22 rice grain.

Conclusion

Yield components of the field crops, among many other factors, are influenced by organic fertilizers. Tricho-compost was the most effective one regarding the number of tillers per hill, productive tiller ratio, straw dry matter production, and grain yield of rice among the applied amendments. Whereas, the protein content of rice grain was detected to enhance significantly by the applied organic amendments too. The highest protein content of rice grain was obtained by vermicompost at its higher dose followed by TC and rice husk. Tricho-compost was detected to assert the best response in the present study to produce the highest biological yield. The present findings of the study conclude that the application of the selected organic amendments was found to have significant potential to increase different agronomic attributes of rice. However, further research with these locally sourced composts is still essential under diverse field conditions for recommendations.

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