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ANALYSIS OF CO-COMPOST QUALITY FOR RICE PRODUCTIVITY, PROFITABILITY, AND SOIL HEALTH IMPROVEMENT

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ABSTRACT

Mymensingh city with 83,682 inhabitants mostly comprises onsite systems i.e septic tanks and pits. When the pit or septic tank is full, the usual practice is to engage professional sweepers are employed to manually empty them and deposit the wastes in mostly the nearby water bodies and open environment which creates environmental degradation. A co-compost (CC) plant was established, and it's been in operation since December 2018 to tackle FS generated from pit toilets and septic tanks, and solid waste from households exploring FSM value chain. The treated FS and solid waste collected from households are mixed to produce co-compost. This CC is being manufactured with the objective that it will be put to further use of different agricultural field. To ensure the proper use, it is needed to assess the quality of the CC and is to be carried out its potential on crop productivity, profitability, and soil health. This research was carried out in collaboration with Bangladesh Agriculture University. The experiment was done in a randomized complete block design with three replications consisting of 2 Boro rice varieties and 10 chemical fertilizer and CC combinations and the result was that highest grain yield was obtained by application of 100% RDF (Recommended Dose of Fertilizers) + high dose of CC in both varieties. Thus, reaching a conclusion that CC could be a potential soil conditioner and an alternative source of plant nutrients to reduce chemical fertilizer dependence in rice cultivation. This could lead to a decrease in environmental pollution, improve soil health and ensure sustainable rice production.

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EXECUTIVE SUMMARY

Insufficient waste management has led to growing interests in approaches to safe emptying, transport, and disposal of faecal sludge (FS). Numerous technical developments have attempted to address the problems of emptying, transporting, and disposal of FS from urban centers. Currently, the focus of research is shifting from FS disposal to reuse, with fertilizer and soil conditioner being among the most common reuse options. The FS, like animal manure, is a good soil conditioner and a renewable source of plant nutrients, such as nitrogen (N), phosphorus (P) and potassium (K), and organic matter. There is, therefore, need to transform this valuable waste into useful soil amendments for crop production. This will represent an important option for both sustainable waste management and sustainable agriculture. Judicious use chemical fertilizers along with organic manure may not only help to maintain soil fertility but may also increase crop productivity.

Recently, NGO Forum for Public Health has been implementing a project titled “Resilient, Inclusive and Innovative Cities in Bangladesh Project” in Mymensingh City Corporation. The one of the major objectives of the project is to establish a functional FS management (FSM) system ensuring livelihood opportunity while ensuring safe disposal and treatment of FS for targeted city dwellers of Mymensingh City Corporation. Mymensingh. A co-compost (CC) plant was established, and it’s been in operation since December 2018 to tackle FS generated from pit toilets and septic tanks, and solid waste from households exploring FSM value chain. The treated FS and solid waste collected from households are mixed to produce co-compost. This CC is being manufactured with the objective that it will be put to further use of different agricultural field. To ensure the proper use, it is needed to assess the quality of the CC and is to be carried out its potential on crop productivity, profitability, and soil health.

The experiment was carried out at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, Bangladesh. It was laid out in a randomized complete block design with three replications consisting of two Boro rice varieties. To ensure no detrimental effects, soil samples were collected randomly from the whole experimental field before land preparation and were bulked together to a composite sample as initial soil sample. After harvesting the Boro rice, soil samples were again collected randomly and then were bulked together into a composite sample for each field separately, as final soil sample for further analysis; moreover co-compost was tested for further assurance.

In general, any compost including CC is quite low in nutrients and its nutrient releasing ability is also slow to meet crop plant requirements in a short period of time. Therefore, CC coupled with synthetic fertilizer has been proved to be a better approach to improve and sustain soil fertility and crop production than sole application of compost or chemical fertilizer but there is hope in long term usage of CC for improvement of soil health.

MATERIALS AND METHOD

Experimental location and soil

The experiment was carried out at the Agronomy Field Laboratory (90°25'35.2"E and 24°43'07.3"N), Bangladesh Agricultural University, Mymensingh, Bangladesh during December 2021 to May 2022 jointly with NGO Forum for Public Health. The experimental site belongs to the Old Brahmaputra Floodplain Agro-ecological zone (AEZ-9). The land was medium high and the soil was non-calcareous dark-grey. 3.1.2 Experimental treatments and design The experiment was laid out in a randomized complete block design with three replications consisting of two Boro rice varieties; (i) BRRI dhan89-an inbred and (ii) Heera-1-a hybrid; and ten chemical fertilizer and CC combinations; (i) BRRI recommended dose of fertilizer (RDF), (ii) CC @ 5 t ha-1 , (iii) RDF + CC @ 2 t ha-1 , (iv) RDF + CC @ 1.5 t ha-1 , (v) RDF + CC @ 1 t ha-1 , (vi) RDF + 0.5 t ha-1 , (vii) 75% RDF + CC @ 2 tha-1 , (viii)

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75% RDF + CC @ 1.5 t ha-1 , ix) 75% RDF + CC @ 1 t ha-1 and 75% RDF + 0.5 t ha-1 . The size of the unit plot was 5 m2 (2.5 m × 2 m) and the spaces between blocks and plots were 1 m and 0.5 m, respectively.

Crop husbandry

Forty days old seedlings were transplanted in the puddled field using two seedlings hill-1 following 25 cm row and 15cm hill spacing on 23 January 2022. Co-compost was applied at the time of final land preparation (week before transplanting) as per treatment and mixed thoroughly with the soil. For recommended dose of chemical fertilizers, urea, triple super phosphate, muriate of potash, gypsum and zinc sulphate were applied at the rate of 296, 161, 210, 124 and 12 kg ha-1 as the source of nitrogen (N), phosphorus (P), potassium (K), Sulphur (S) and zinc (Zn) for both varieties. All the fertilizers except urea were applied as basal one day before transplanting. Urea was applied in three equal splits at 10, 30 and 50 days after transplanting (DAT). Intercultural operations were done as and when necessary. Flood irrigation was applied to maintain a constant level of standing water up to 6 cm in early stage to enhance tillering and 10-12 cm in later stage to discourage late tillering. The field was finally drained out 15 days before harvest to enhance maturity. Three times manual weeding was done at 15, 30 and 45 DAT. No remarkable infestation of insect or infection due to any disease organism was noticed in the field. So, no plant protection measure was taken.

Soil and co-compost sampling

Soil samples (0–15 cm) were collected randomly from 12 points of the whole experimental field before land preparation and were bulked together to a composite sample as initial soil sample. After harvesting the Boro rice, soil samples (0-15 cm) were again collected randomly from 3 points of each plot and then were bulked together to a composite sample for each field separately, as final soil sample. The samples were air dried, ground, passed through 2 mm sieve and then stored in airtight containers for further analysis.

Soil and co-compost analyses

a. Soil sample analyses: Routine soil analysis, such as pH and texture were done on initial soils. Total carbon (C; wet oxidation method), total N (micro kjeldahl method), P, K and S contents (spectrophotometric method) of soils were also measured.

b. Co-compost analyses: Co-compost was also analyzed for C (dry ashing method), N, P, K, S (spectrophotometric method) and heavy metals (Zn, cadmium (Cd), lead (Pb), nickel (Ni), chromium (Cr) and copper (Cu) by atomic absorption spectrophotometric method).

Crop and economic data collection

Five rice hills (excluding border hills) were randomly selected from each unit plot prior to harvest for recording data on different growth parameters (plant height and total tillers hill-1 at 30 and 60 days after transplanting-DAT), yield components and yield of rice. The date of harvesting was determined when 90% of the grains became golden yellow in color. Each plot was harvested separately to record the yields of grain and straw. The harvested crop was then threshed, cleaned and dried to a moisture content of 14%. Weight of grain and straw were recorded and converted into t ha-1.

Economic Analysis

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Economic analysis was performed to determine the cost effectiveness of using CC as a component of INM in rice cultivation. Price of rice was collected from different local rice markets and averaged for calculating gross income. The net benefit per hectare for chemical fertilizer + CC combinations was calculated by deducting the fertilizer + CC purchase and application related cost from the gross return.

Gross Income (Tk ha-1) = Rice Yield (kg ha-1) × Price (Tk kg-1) (1)

Net Benefit (Tk ha-1) = Gross Income (Tk ha-1) – Fertilizer + CC Related Cost (Tk ha-1) (2)

Statistical Analysis

The collected data were analyzed statistically with the help of a computer package MSTAT. The mean differences among the treatments were adjudged with Duncan 's Multiple Range Test (Gomez and Gomez, 1984).

RESULTS

General Soil and Co-compost Characteristics

Soil of the experimental field was slightly acidic in reaction (pH 6.82) and silt loam textured (Table 1). Total carbon (C) represents the organic carbon (OC) in the soil since there were very negligible amount of inorganic C from the carbonate analysis. The OC and total N content were 1.77 % and 0.16 %, respectively; and C:N ratio was 11.06 (Table 1). Phosphorus (P), potassium (K), sulphur (S) and zinc (Z) contents were 15.67 ppm, 0.087 meq 100 g-1, 23.08 and 92.5 ppm, respectively. Based on the analysis report, experimental soil may be considered as moderately fertile. The OC and total N contents of CC was 14.38 % and 0.16%, respectively, and C: N ratio was 7.04 (Table 1). Phosphorus, K and S contents were 0.728 ppm, 1.336 meq 100 g-1 and 0.445 ppm, respectively. In general, the nutritional status of the CC was as per Soil Resource Development Institute (SRDI) standard range (according to government regulation). Looking at the common heavy metals, zinc (Zn), cadmium (Cd), lead (Pb), nickel (Ni), chromium (Cr) and copper (Cu) level were 0.062 %, 2.8, 10.51, 10.97, 7.38 ppm and 0.0077 %, respectively.

Impact of co-compost application on the growth and yield of *Boro* rice varieties

Results revealed that plant height of *Boro* rice was significantly influenced by the combined application of fertilizer and CC at 60 DAT and at harvest (Table 2). At harvesting, the tallest plant (110.6 cm) was obtained from the application of RDF + CC @ 2 t ha^{-1} in Heera-1 dhan which was statistically identical to the same treatment combination in BRRI dhan89 and to almost all the treatment combinations except few, and the shortest plant was obtained from sole application of CC in BRRI dhan89 (96.4 cm). Along with nutrient source and amount variation, plant height difference of course due to genetic makeup of the varieties.

Yield contributing characters and yield of rice

Among yield contributing characters, number of effective tillers $hill^{-1}$, number of grains $panicle^{-1}$ and 1000-grains weight were significantly influenced by the combined application of fertilizer and CC (Table 4). Number of grains $panicle^{-1}$ was in the range of 94.7-122 for BRRI dhan89 and 98.71-130.1 for Heera-1. The highest number of grains $panicle^{-1}$ (130.7) was obtained from RDF + CC @ 2 t ha^{-1} application in Heera-1 and the lowest (94.7) was found when BRRI dhan89 was applied with sole CC. Thousand grains weight was highest (27.3 g) in Heera-1 with RDF + CC @ 1 t ha^{-1} application and ranged between 26.96- 27.3 g in Heera-1 which was from 21.96 g to 22.3 g in BRRI dhan89 (Table 4).

Combined application of fertilizer and CC significantly affected the grain and straw yield (Table 4). Overall, grain yield of inbred BRRI dhan89 ranged between 4 and 6.9 t ha^{-1}, whereas the same for hybrid dhan Heera-1 ranged from 4.2 to 7.3 t ha^{-1} (Table 4). Thus, hybrid rice variety showed higher yield potential over inbred variety.

Application of RDF is the most common practice by farmers of Bangladesh. In both varieties, sole application of CC reduced the grain yield by ~38 % compared to the 100% application of RDF (Table 4). Application of the higher dose of CC (2 t ha-1) along with 100 % RDF notably increased the grain yield in comparison to the sole application of 100% RDF. However, application of 1.5 or 1 t ha-1 CC with 100% RDF also increased (or remain same) grain yield.

After decreasing the application of RDF by 25% along with application 2 t ha^{-1} CC, grain yield still remained same for BRRI dhan89 (6.5 t ha^{-1}) and slightly increased (0.1 t ha^{-1}) for Heera-1. With similar amount of RDF (75%) with 1.5 t ha^{-1} CC produced slightly less (0.3 t ha^{-1}) grain yield of BBRI dhan89 and similar yield of Heera-1 compared to 100% RDF of the respective variety. Later, the grain yield decreased with decreasing the CC amount in the integrated fertilizer combinations (RDF + CC).

Straw yield followed the similar trend of grain yield. Looking at the harvest index, overall, it decreased with sole application of CC and then slightly increased when combinedly applied with fertilizer compared to sole application of 100 % RDF. Impact of Co-compost Application on Soil Health

After adding different rates of CC to the soils during *boro* rice cultivation in combination with chemical fertilizers, soil OC, N, P, K and S contents changed substantially (Table 4). The content of OC in final soil (after rice harvest) ranged from 1.72-2.64% (Table 4), which showed about 13.9-49.5% OC increase in soils due to application of different RDF+ CC combination for both rice varieties, except slight decrease (2.5%) in case of 100 % RDF application for Heera-1 (Figure 1). Relatively higher OC increment (42-50%) occurred in 100 % RDF + CC @ 2 & 1.5 t ha^{-1} and 75 % RDF + CC @ 1.5 t ha^{-1} for BRRI dhan89 compared to the other combinations. For Heera-1, about 31-46% OC increment happened from 100 % RDF + CC (0.5-2 t ha^{-1}) which is higher than other treatment combinations. Total N in the final soils ranged between 0.14-0.18%, which presented 4.9-10.8 % increment of total N in soils from different fertilizer + CC combinations (Table 4 and Figure 1). There were decrease in N content in case of sole RDF (4.3-7.4%) and sole CC (9.9-11.4 %) application for both rice varieties (Figure 1). Phosphorus, K and S contents in final soils ranged between 13.09-15 ppm, 0.07-0.09 meq 100 g^{-1} and 20-23.2 ppm, respectively (Table 4). Among these three nutrients, K increment was more prominent than other two (Figure 1). There was overall decline in P, K, S nutrient content in soils without any noticeable pattern, which could be due to very slight changes among the treatment combinations. Although the changes were not very distinguishable, relatively higher increment in case of K and lower decline for P and S were visible in 100 % RDF + CC @ 2 & 1.5 t ha^{-1} and 75 % RDF + CC @ 1.5 t ha^{-1} considering both varieties.

In general, any compost including CC is quite low in nutrients and its nutrient releasing ability is also slow to meet crop plant requirements in a short period of time. Therefore, CC coupled with synthetic fertilizer has been proved to be a better approach to improve and sustain soil fertility and crop production than sole application of compost or chemical fertilizer (Akhtar *et al*., 2019; Ali *et al*., 2020; Zhang *et al*., 2020). Although there were no remarkable changes in the soil nutrient contents of this short-term experimental field, the nutrient content change in the soil showed indication of soil health improvement through long-term application of the combination of chemical fertilizers + CC (particularly 75 % RDF + CC 1.5 t ha^{-1}).

ECONOMIC ANALYSIS

In this experiment, for calculating fertilizer and CC related cost, their market price and labour wage for applying them to the field were considered. Since, CC is still not available in market for selling and price is yet to be fixed, a range of price from 10 to 25 Tk kg^{-1} was considered for this calculation. Looking at the fertilizer and CC application related cost, the highest cost (51000-140000 Tk ha^{-1} depending on the price of CC) was spent when only CC was applied to the field and the lowest one (19722 Tk ha^{-1}) was spent when only RDF was applied to the field. Although the only CC application resulted in the highest cost, it failed to produce the highest income. This is expected since application of CC only supplied a tiny portion of nutrients required by the crop and yielded lower rice grain. Gross

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income ranged between 1.4- 2.4 lac Tk. ha^{-1} for BRRI dhan89 and 1.1-1.9 lac Tk ha^{-1} for Heera-1. In both rice varieties, the lowest gross income was obtained from sole application of CC and the highest from the combined application of RDF + CC @ 2 t ha^{-1}. Although the Heera-1 variety produced higher grain yield than BRRI dhan89, the latter one gave higher gross income due to the lower price of course rice grain of Heera-1 variety. In both varieties, the highest benefit (207778 and 161403 Tk. ha^{-1} for BRRI dhan89 and Heera-1, respectively) was obtained from sole application of RDF since this treatment produced higher grain yield and needed lowest cost for application of fertilizer and CC. The second highest profit (200678 and 150803 Tk. ha^{-1} for BRRI dhan89 and Heera-1, respectively) was obtained when RDF + CC@ 2 t ha^{-1} was applied to either variety and selling price of CC is assumed as 10 Tk kg^{-1}. Overall, in both varieties, combination of 100% RDF with different CC rates gave profit close to the highest one, while combination of 75% RDF with similar CC rates provided reasonable profits; particularly 75% RDF+ CC @ 2 t ha^{-1} for BRRI dhan89 and 75% RDF + 1.5 t ha^{-1} for Heera-1, when the CC selling price is considered as 10 Tk kg^{-1}. Again, when the CC selling price was considered higher like 15, 20 and 25 Tk kg^{-1}, the second highest profit was obtained from the combination of 100% RDF + CC @ 1 t ha^{-1} for BRRI dhan89 and 75% RDF + CC @ 0.5 t ha^{-1} for Heera-1.

CONCLUSION

Although highest grain yield was obtained by application of 100% RDF + Co-compost @ 2 t ha^{-1} in both varieties, the yield was very close to this value when the RDF was reduced to 75%. Apart from productivity, considering both soil health improvement and profitability integration of 75 % RDF with Co-compost @ 1.5 t ha^{-1} combination would be economic for *boro* rice growers in Bangladesh. To conclude, co-compost could be a potential soil conditioner and a supplementary source of plant nutrients to reduce chemical fertilizer dependence in rice cultivation, which could ultimately decrease environmental pollution, improve soil health, and ensure sustainable rice production.

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