Supplemental Organic Manures and Foliar Application of Magic Growth Improve the Productivity of Transplanted Rice with Reduced Application of Chemical Fertilizers

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Summary

Chemical fertilizers integrated with organic manures have proven as a better fertilizer management option for continuous crop productivity and improved soil fertility. An experiment was conducted to observe the growth and yield performances of transplanted aman rice as influenced by different organic manures under reduced chemical fertilizers conditions. The experiment consisted of eight treatments *viz*. ½ NPK (recommended dose of NPK for rice), full NPK, green manure (GM) + ½ NPK, poultry manure (PM) + ½ NPK, cowdung (CD) + ½ NPK, quick compost (QC) + ½ NPK, vermicompost (VC) + ½ NPK, magic growth (MG) + ½ NPK. This study was carried out in a randomized complete block design (RCBD) with three replications. Plant morphological characters, yield and different yield contributing traits were significantly influenced in different treatments. It was observed that, except for the total dry matter production and effective tiller hill^{-1}, plant height, number of filled grain panicle^{-1}, grain and straw yield were the highest with the treatment VC + ½ NPK. In our study, panicle length and 1000-grain weight of rice were also found to be the highest in VC + ½ NPK treatment, which was statistically similar with other ½ NPK + manure treatments. In overall observation, manure integrated treatments performed well compared to ½ NPK fertilization. Better performances were documented when VC was used in combination followed by QC and GM compared to ½ NPK fertilization.

Key words

organic manure, agronomic management, soil productivity, plant nutrition, green manure

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Introduction

Increasing world's population and rapid industrialization rate are aggravating the future research concern on land scarcity and sustainable crop productivity. Unfortunately, current agriculture has to address a set of tremendous environmental concerns, compounding this challenge (Zhou et al., 2020). More than one-third of the world's population lives on consuming rice as a staple food which accounts for almost one fourth of the calories consumed by the entire world population (Sharada and Sujathamma, 2018; Foysal et al., 2020). In Bangladesh, rice covers almost 80% of cropped area and is the source of major food grain. However, rice production in Bangladesh is still below half of the world average yield. In a rice-based cropping system, different factors are responsible for the declining productivity along with increasing intensification. Therefore, farmers are forced to use higher amounts of inorganic fertilizers to maintain the regular market demand which in terms is highly detrimental for the long-time land fertility and productivity (Hasanuzzaman et al., 2010). Although the application of inorganic fertilizer is considered to be the most effective measure for improving rice production, a sustainable cropping system with high yield target is still impossible unless a balanced nutrient inputs are supplied to soil against nutrient removal by crops. Excessive application of inorganic fertilizers and improper management cause degradation of soil health and it is hazardous for the environment. Consequently, it adversely affects the productivity of the crop (Iqbal et al., 2020).

On the other hand, organic manure is an eco-friendly source of plant nutrients that accelerates crop productivity and replenishes soil health for long time. Additionally, it is well-reported that along with improving the physical properties of the soil, organic manure also enhances the biological and physiochemical properties of the soil. It improves soil water holding capacity, nutrient availability, enzymatic activity, pH, bulk density, soil organic carbon, microbial activity etc. (Zhang et al., 2018; Khan et al., 2019; Ibrahim et al., 2020). Despite this, the use of organic manures alone is not the alternative to inorganic fertilizer that can maintain the present levels of crop productivity. As manures are low in nutrients and also slow-releasing, hence the application of manure along with synthetic fertilizer is a judicial approach to enhance productivity and soil fertility (Ali et al., 2020; Zhang et al., 2020). Therefore, integrated nutrient management in which both organic manures and inorganic fertilizers are used simultaneously is probably the most effective method to maintain healthy sustainable soil system while increasing crop productivity (Hasanuzzaman et al., 2010).

Several studies have confirmed that green manure (GM) and rice straw decomposition prior to the crop cultivation can potentially increase crop yield by reducing use of inorganic fertilizers (Nawaz et al., 2017). Legume crops used as green manure (GM) substantially add nitrogen (N) to soil through biological N fixation hence increasing the soil N supply to subsequent crops. However, leguminous GM with high N concentrations and a low C/N ratio often decomposes quickly, and peak net N mineral accumulation in soil occurs at approximately 2–4 weeks after incorporation (Zhou et al., 2020). Zhou et al. (2020) also reported that GM increased the rice yield as well as the fertility of the soil, after conducting a 3-year field experiment.

It revealed that organic sources of nutrients applied to preceding crop could benefit the succeeding crop and give higher yield of crop by reducing fertilizer cost (Foysal et al., 2020). Mythili et al. (2003) reported that zinc and sulphur deficient soil with N, P (phosphorus), K (potassium), and S (sulfur) as gypsum coupled with poultry manure (PM) produced the highest grain yield. Poultry manure contains sufficient amount of nutrients, it especially has enough phosphorus that is very beneficial for rice crop. Fresh chicken manure is rich with 0.8% K, 0.4% to 0.7% P, and 0.9% to 1.5% N (Yang et al., 2019). Hoque et al. (2018) observed the maximum straw and grain yield due to supplementation of PM coupled with 75% dose of recommended synthetic fertilizers. Similarly, Hasanuzzaman et al. (2010) observed the highest total tillers hill^{-1}, biological yield and grain yield in rice while 4 t ha^{-1} PM was coupled with 50% NPK. The addition of PM with the synthetic fertilizers has increased the yield contributing characters and yield in rice (Foysal et al., 2020). The supplementation of cowdung (CD) with 70% recommended dose of N, P, and K increased the grain yield in BRRI dhan41 (Farid et al., 2011). Similarly, Marzia et al. (2016) observed that 75% recommended chemical fertilizers along with CD (5 t ha^{-1}) significantly enhanced the physical, chemical and biological properties of soil, thus helping to increase and conserve the soil productivity.

Vermicompost (VC) is the end-product of the breakdown of organic matter by earthworms. It improves soil aeration, enriches soil with microorganisms (adding plant hormones such as auxins and gibberellic acid). The application of vermicompost VC along with 75% recommended fertilizer dose decreases the sterile spikelet panicle^{-1} (Foysal et al., 2020). Vermicompost applied with different levels of NPK has increased the plant height of rice in different studies (Kumar et al., 2017). Quick compost (QC) contains N, P, K, calcium, magnesium and also some micronutrients. It is a mixture of oilcake, sawdust and CD at 1:2:4 ratio. Supplementation of QC increases water holding capacity, microbial activity and aeration of the soil along with providing nutrients, which ultimately enhanced productivity (AIS, 2013). Application of magic growth (MG) increased the yield and yield contributing parameters in rice. Furthermore, MG with 75% of recommended nitrogen dose enhanced the grain yield by 10.5% in rice (Alam et al., 2015).

Chemical and organic fertilizers need to be applied simultaneously to improve the soil physical properties and thus continuous supply of essential plant nutrients will be prevailed. In this way, added pressure on chemical fertilizer could be relieved significantly. In this study, we used 6 different organic sources to determine the imperative effect of organic manures and foliar applied MG on the growth and yield of transplanted rice while reducing the use of chemical fertilizers. The aim was also to find out the most effective combination of organic manure and chemical fertilizer for transplanted rice cultivation.

Materials and Methods

Experimental Site

The experiment was accomplished in the agronomy research field of Sher-e-Bangla Agricultural University, Dhaka which belongs to Madhupur tract of agro-ecological zone (AEZ-28). The size of the individual plot was 4 m × 4 m and a total number of plots was 24, which covered a total area of 656 m^2. There were 8 treatment combinations. Each block was divided into 8 unit plots. The layout of the experiment was done keeping 1 m and 1 m inter block and inter plot spacing, respectively. The regular elevation of the land is above 18 m from sea level (medium high land). The soil physical and chemical values were tested prior to commencing the initial field preparation (Table 1).

Table 1. Physiological and chemical properties of initial soil (0 to 15 cm depth)

No	Value
% Sand	27
% Silt	43
% Clay	30
Textural class	**Silty-clay**
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me 100 g^{-1} soil)	0.10
Available S (ppm)	45

Source: SRDI (Soil Resource Development Institute), Farmgate, Dhaka

Experimental Materials and Treatments and Design

A total number of 8 treatments were considered for the experiment *viz.*, ½ NPK (half amount of NPK as recommended for rice), full NPK, GM + ½ NPK, PM + ½ NPK, CD + ½ NPK, QC + ½ NPK, VC + ½ NPK, MG + ½ NPK. BRRI dhan54 was used as an experimental crop and a randomized complete block design was followed with three replications.

Crop Husbandry

Seeds were collected from the Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur. Seeds were then soaked for 48h and sprouted seeds were sown in a pre-prepared seedbed following the standard agronomic practices in seedbed. Seedlings were allowed to grow in seedbed for 27 days. Organic manures such as GM, PM, CD, QC, VC and MG contain mineral nutrients at different composition (Table 2).

Table 2. Chemical compositions of the organic manures used for the experiment. Here, green manure (GM), poultry manure (PM), cowdung (CD), quick compost (QC), vermicompost (VC) and magic growth (MG)

Sources of organic manures	Nutrient content				
	C (%)	N (%)	P (%)	K (%)	C:N
GM	46	2.95	0.26	1.56	15
PM	29	2.19	1.98	0.81	8
CD	36	1.48	0.29	0. 75	24
QC	-	2.56	0.98	0.75	-
VC	11.54	1.66	1.25	0.25	9.60
MG	-	0.35	3.18	1.50	-

Source: Hasanuzzaman et al. (2010)

Mineral nutrients from organic sources were added, 15 t ha^{-1} Daincha as GM were incorporated 10 days before transplanting and allowed to rot. In addition, QC (0.7 t ha^{-1}), VC (4 t ha^{-1}), CD (10 t ha^{-1}), PM (5 t ha^{-1}) were applied 5 days before transplanting. A week before the transplantation, final land preparation had been completed and 149 kg urea, 52 kg triple super phosphate (TSP), 82 kg muriate of potash (MoP), 59 kg gypsum ha^{-1} were incorporated in the soil. Urea was applied in three installments at final land preparation, 28 days after transplanting (DAT) and 7 days before panicle initiation. Seedlings were transplanted in prepared land maintaining 15 cm x 25 cm spacing. Intercultural operations and other management practices were conducted as required for proper growth and development of the crop. Magic growth was applied 400 L ha^{-1} in the evening, three times at 15 day- intervals.

Harvesting, Processing and Data Collection

To observe the growth data, 5 plants were selected and tagged randomly from each treatment. For collecting the yield contributing data, 5 hills were sampled from each plot prior to harvesting. The crops were harvested on 80% maturity of panicle in each plot. An area of 1 m^2 was harvested for measuring the grain and straw yield. After conducting harvesting procedures like threshing, cleaning, winnowing and drying, necessary data were collected on various crop yield characters.

Statistical Analysis

For statistical analysis, field data were tabulated and analysis of variance was done by computer package program CoStat v.6 (CoHort 2008). The differences among the treatments means were attuned by Least Significance Difference (LSD) test at 5% level of significance.

Results

Plant Height

In this experiment, a gradual increase in plant height was observed with increasing crop duration. However, the application of manures significantly increased plant height compared to ½ NPK (Table 3). The highest plant height (32%) was observed at full NPK treatment, followed by VC + ½ NPK and MG + ½ NPK, each 31% higher than ½ NPK. In contrast, the lowest plant height (26%) was observed at GM + ½ NPK treatment followed by PM + ½ NPK (29%). Although plant height was increased due to the application of CD and QC combined with ½ NPK, they showed statistically similar result (30%).

Tillers Hill^{-1}

It was evident from this study that tillers hill^{-1} increased up to a certain crop duration (75 DAT) and gradually reduced till harvesting (Table 4). At an early stage, tiller numbers were not significantly increased by the application of different manures. However, after 30 DAT, tillers were sharply increased up to 75 DAT. The highest tillers hill^{-1} (44%) at 75 DAT was observed with full NPK treatment whereas 30, 25, 28, 25, 33 and 20% were increased with GM + ½ NPK, PM + ½ NPK, CD + ½ NPK, QC + ½ NPK, VC + ½ NPK and MG + ½ NPK treatments, respectively, compared to ½ NPK. Furthermore, due to application of organic manures at harvesting, the highest (44%) and lowest (14%) tillers hill^{-1} resulted from GM + ½ NPK and PM + ½ NPK, respectively, compared to ½ NPK.

Table 3. Effect of treatments on plant height (cm) of rice. Mean (±SD) was calculated from three replications for each treatment. GM, PM, CD, QC, VM and MG indicate green manure, poultry manure, cowdung, quick compost, vermicompost and magic growth, respectively. Values in the column with different letters are significantly different at $P \leq 0.05$ applying LSD test

Treatment	Plant height (cm)					
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	Harvest
½ NPK	53.00 ± 2.65 b	62.50 ± 0.50d	80.00 ± 1.00c	83.67 ± 1.53d	85.00 ± 1.00d	91.00 ± 1.00c
Full NPK	58.77 ± 1.63a	89.67 ± 0.58a	106.00 ± 4.00a	109.50 ± 1.32c	116.33 ± 1.53c	119.67 ± 0.58b
GM + ½ NPK	57.00 ± 2.00a	81.83 ± 1.76c	101.00 ± 1.32b	106.17 ± 0.29c	110.67 ± 2.52e	116.50 ± 0.50cde
PM+ ½ NPK	56.13 ± 1.80ab	90.67 ± 2.08a	101.83 ± 1.26b	108.33 ± 1.53abc	113.67 ± 1.53b	118.17 ± 1.04ab
CD + ½ NPK	58.00 ± 2.65a	89.67 ± 1.53a	101.17 ± 2.02b	108.00 ± 1.73abc	116.00 ± 1.00ab	117.17 ± 3.01ab
QC + ½ NPK	57.67 ± 3.51a	90.33 ± 1.53a	101.67 ± 2.08b	107.00 ± 1.73bc	115.00 ± 2.00ab	118.67 ± 1.15ab
VC + ½ NPK	58.17 ± 1.76a	89.00 ± 1.04ab	102.67 ± 3.06ab	109.17 ± 1.26ab	116.33 ± 1.26ab	119.33 ± 2.08a
MG + ½ NPK	59.20 ± 0.72a	87.17 ± 1.04b	105.67 ± 0.58a	108.67 ± 1.53ab	117.33 ± 1.53a	119.17 ± 1.04a
CV (%)	3.85	1.93	2.13	1.54	1.43	1.28

Table 4. Effect of treatments on tillers hill^{-1} of rice. Mean (±SD) was calculated from three replicates for each treatment. GM, PM, CD, QC, VC and MG indicate green manure, poultry manure, cowdung, quick compost, vermicompost and magic growth, respectively. Values in the column with different letters are significantly different at $P \leq 0.05$ applying LSD test

Treatment	Tillers hill^{-1}					
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	Harvest
½ NPK	5.07 ± 0.12d	7.27 ± 0.25e	9.27 ± 0.25e	10.17 ± 0.28e	8.33 ± 0.35c	6.83 ± 0.28d
Full NPK	7.40 ± 0.10a	9.40 ± 0.10a	11.40 ± 0.10a	14.20 ± 0.20a	12.30 ± 0.107a	9.83 ± 0.28a
GM + ½ NPK	6.67 ± 0.29b	8.73 ± 0.25bc	10.73 ± 0.25bc	13.07 ± 0.11bc	11.00 ± 0.11b	8.80 ± 0.20b
PM+ ½ NPK	6.83 ± 0.29b	8.03 ± 0.06d	10.03 ± 0.57d	12.33 ± 0.28d	10.43 ± 0.23b	7.77 ± 0.25c
CD + ½ NPK	6.57 ± 0.12bc	8.43 ± 0.12c	10.43 ± 0.15c	13.00 ± 0.20c	10.77 ± 0.14b	8.23 ± 0.25bc
QC + ½ NPK	6.47 ± 0.64bc	8.03 ± 0.06d	10.03 ± 0.11d	12.40 ± 0.36d	10.73 ± 0.14b	8.60 ± 0.65b
VC + ½ NPK	6.83 ± 0.29b	8.93 ± 0.12b	10.93 ± 0.11b	13.43 ± 0.11b	10.93 ± 0.12b	8.53 ± 0.50b
MG + ½ NPK	6.13 ± 0.12c	7.83 ± 0.29d	9.83 ± 0.28d	12.27 ± 0.25d	10.27 ± 0.14b	8.17e ± 0.28bc
CV (%)	5.65	6.80	7.5	6.5	6.00	7.3

Dry Matter Production Hill^{-1}

Higher dry matter production is a significant indicator of higher yield. In this study, dry matter production gradually increased with crop duration. However, the highest dry matter produced at the harvesting stage due to the application of manure and fertilizers (Table 5). Considering the total dry matter production, the application of VC+ ½ NPK showed the highest (34%) result while GM + ½ NPK (19%) showed the lowest compared to ½ NPK treatment. In addition, application of other manures *viz*., PM + ½ NPK, CD + ½ NPK, QC + ½ NPK and MG + ½ NPK showed 27, 26, 24 and 23% increased dry matter accumulation, respectively, which was significantly higher than the ½ NPK treatment.

Effective Tillers Hill^{-1}

The application of manure and fertilizers also influences the effective tillers hill^{-1}. In this study, the highest tillers hill^{-1} (20%) was observed with full NPK and VC + ½ NPK treatment which were statistically similar with PM + ½ NPK and QC + ½ NPK compared to ½ NPK fertilization. On the contrary, the lowest effective tillers hill^{-1} was produced by MG integrated with ½ NPK. In addition, no significant difference was observed due to the application of GM and CD along with ½ NPK fertilizer (Fig. 1).

Non-Effective Tillers Hill^{-1}

The result showed that organic manures played a significant role in reducing the non-effective tillers hill^{-1} (Fig. 2), although the lowest non-effective tillers hill^{-1} was resulted from full NPK fertilization. Compared to ½ NPK, 58, 32, 39, 18, 48, 48 and 18% reduced non-effective tillers were observed from full NPK, GM + ½ NPK, PM + ½ NPK, CD + ½ NPK, QC + ½ NPK, VC + ½ NPK and MG + ½ NPK treatment respectively. However, CD and MG, QC and VC showed similar reduction of non-effective tillers hill^{-1}.

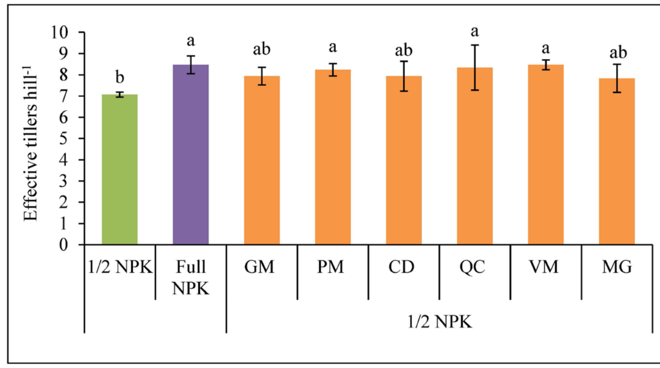

Figure 1. Effect of treatment on effective tiller hill^{-1} of rice. GM, PM, CD, QC, VM and MG indicate green manure, poultry manure, cow-dung, quick compost, vermicompost and magic growth, respectively.
Note: Mean (±SD) was calculated from three replications for each treatment. Bars with different letters are significantly different at $P \leq 0.05$ applying LSD test

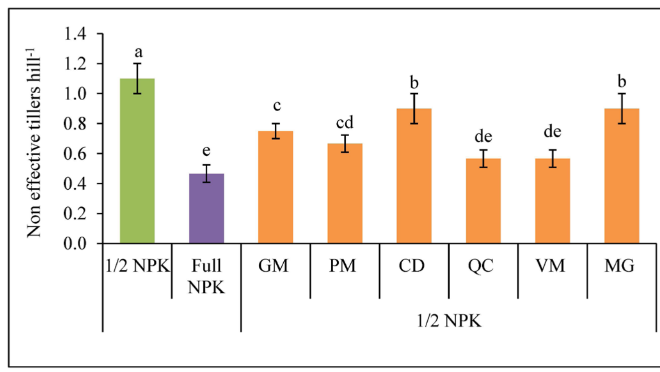

Figure 2. Effect of treatment on non-effective tiller hill^{-1} of rice. GM, PM, CD, QC, VM and MG indicate green manure, poultry manure, cowdung, quick compost, vermicompost and magic growth, respectively.
Note: Mean (±SD) was calculated from three replications for each treatment. Bars with different letters are significantly different at $P \leq 0.05$ applying LSD test

Table 5. Effect of treatments on dry matter production of rice. GM, PM, CD, QC, VC and MG indicate green manure, poultry manure, cowdung, quick compost, vermicompost and magic growth, respectively. Mean (±SD) was calculated from three replications for each treatment. Values in the column with different letters are significantly different at $P \leq 0.05$ applying LSD test

Treatment	Dry matter production hill^{-1} (g)				
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
½ NPK	3.78 ± 0.25e	11.52 ±1.17d	18.50 ± 0.50d	28.92 ± 1.12c	35.60 ± 0.65c
Full NPK	6.13 ± 0.22ab	18.99 ± 0.64a	26.30 ± 0.26a	36.17 ± 1.04ab	42.50 ± 0.50ab
GM + ½ NPK	5.14 ± 0.24cd	13.77 ± 0.81c	23.57 ± 0.51bc	34.48 ± 0.67b	37.89 ± 1.02ab
PM+ ½ NPK	5.32 ± 0.30bc	18.63 ± 0.55a	22.67 ± 0.57c	35.64 ± 1.42ab	42.33 ± 1.52ab
CD + ½ NPK	4.39 ± 0.24de	19.10 ± 0.53a	25.30 ± 1.17ab	35.57 ± 0.51ab	39.30 ± 2.13bc
QC + ½ NPK	6.24 ± 0.38a	15.77 ± 0.68b	23.13 ± 0.32bc	35.33 ± 0.76ab	41.67 ± 0.57ab
VC + ½ NPK	6.19 ± 0.25ab	18.70 ± 0.70a	26.50 ± 0.50a	36.83 ± 1.60a	43.83 ± 2.46a
MG + ½ NPK	4.73 ± 0.24cd	16.72 ± 1.12b	24.17 ± 0.76abc	36.83 ± 0.76a	38.67 ± 0.57bc
CV (%)	7.39	4.94	4.54	3.24	4.24

Panicle Length

Panicle length is one of the vital yield contributing parameters that determine the number of grain panicle^{-1}. In this study, a significant variation in panicle length was observed due to the application of organic and inorganic fertilizers (Fig. 3). Although 10% increased panicle length was observed from full NPK and QC + ½ NPK treatment, there were no significant difference among other manure integrated treatments compared to ½ NPK.

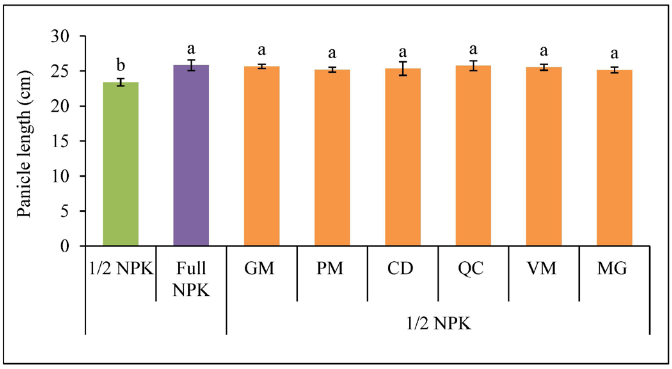

Figure 3. Effect of treatment on panicle length (cm) of rice. GM, PM, CD, QC, VM and MG indicate green manure, poultry manure, cowdung, quick compost, vermicompost and magic growth, respectively.

Note: Mean (±SD) was calculated from three replications for each treatment. Bars with different letters are significantly different at $P \leq 0.05$ applying LSD test

Filled Grain Panicle^{-1}

A good number of filled grain panicle^{-1} indicates a higher grain yield of crop. We observed that manure application with NPK fertilizers markedly increased the filled grain panicle^{-1} (Fig. 4). Vermicompost integrated with ½ NPK produced 35% higher filled grain compared to ½ NPK, which was 7% higher than the full NPK treated plant. On the contrary, the lowest filled grain panicle^{-1} (9%) was produced from ½ NPK fertilization.

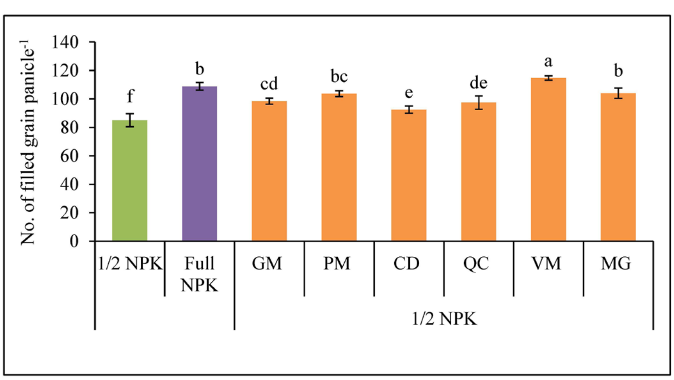

Figure 4. Effect of treatment on number of filled grain panicle^{-1} of rice. GM, PM, CD, QC, VM and MG indicate green manure, poultry manure, cowdung, quick compost, vermicompost and magic growth, respectively.

Note: Mean (±SD) was calculated from three replications for each treatment. Bars with different letters are significantly different at $P \leq 0.05$ applying LSD test

Unfilled Grain Panicle^{-1}

Organic manure conclusively reduces the unfilled grain number in panicle. Therefore, we observed the highest 54% reduction of unfilled grain while VC was applied with half NPK fertilizers (Fig. 5). However, if plants were treated with no organic manures and only ½ NPK was applied, it resulted in the maximum unfilled grain number panicle^{-1}. Comparing other manures ½ NPK treatment, 39, 46, 41, 40, 48, and 27% reduction of unfilled grain number in panicle was obtained from full NPK, GM + ½ NPK, PM + ½ NPK, CD + ½ NPK, QC + ½ NPK and MG + ½ NPK treatment, respectively (Fig 5).

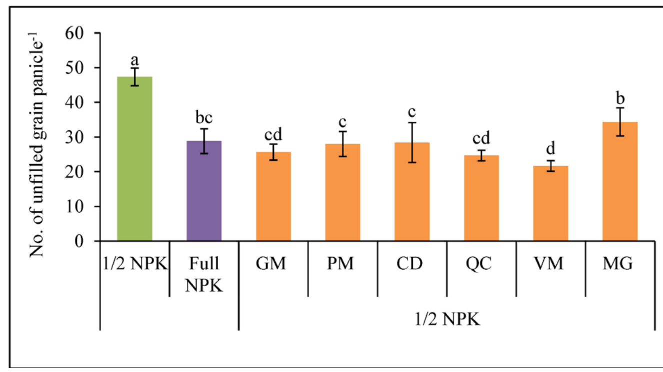

Figure 5. Effect of treatment on number of unfilled grain panicle^{-1} of rice. GM, PM, CD, QC, VM and MG indicate green manure, poultry manure, cowdung, quick compost, vermicompost and magic growth, respectively.

Note: Mean (±SD) was calculated from three replications for each treatment. Bars with different letters are significantly different at $P \leq 0.05$ applying LSD test

1000-Grain Weight

It was speculated that higher dry matter partitioning resulted in higher grain weight. In this experiment, 1000-grain weight significantly varied with manure and fertilizers treatment (Fig. 6).

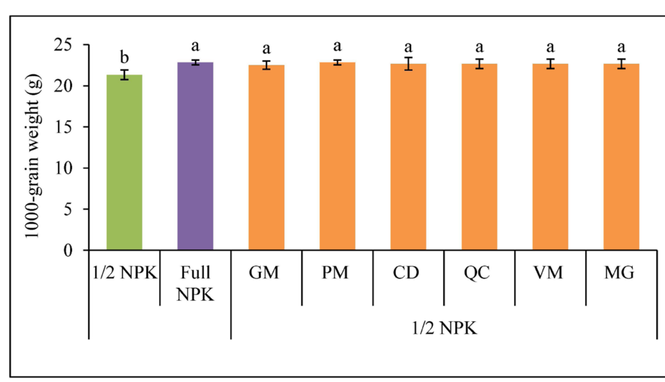

Figure 6. Effect of treatment on 1000-grain weight (g) of rice. GM, PM, CD, QC, VM and MG indicate green manure, poultry manure, cowdung, quick compost, vermicompost and magic growth, respectively.

Note: Mean (±SD) was calculated from three replications for each treatment. Bars with different letters are significantly different at $P \leq 0.05$ applying LSD test

Although no significant effect on increasing the 1000-grain weight was observed due to manures application, 7% increase was recorded from full NPK and PM + ½ NPK treatment compared to ½ NPK fertilization. On the contrary, the lowest 1000-grain weight was obtained by ½ NPK because of reduced panicle length and increased number of unfilled grain panicle^{-1}.

Grain Yield

Organic and inorganic fertilizers significantly improved the grain yield in rice crop. In this study, the highest grain yield (71%) was observed from the full NPK treatment followed by VC + ½ NPK (Fig. 7) whereas deficiency of primary nutrients in ½ NPK treatment resulted in reduced panicle length; filled grain panicle^{-1} and 1000-grain weight thus ultimately lowered the grain yield. However, from other manures (GM, PM, CD, QC and MG) integrated with ½ NPK, an increase of 41, 50, 44, 39 and 37% grain yield was obtained, respectively.

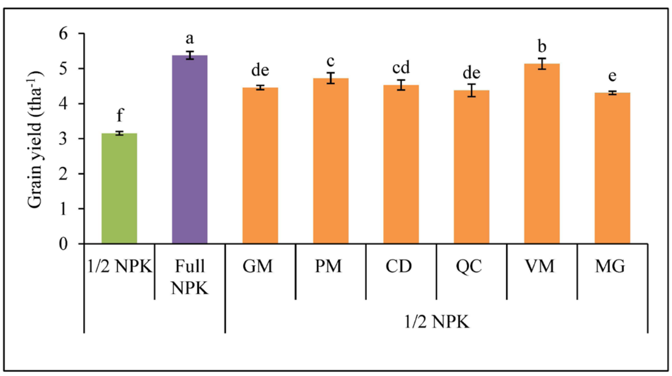

Figure 7. Effect of treatment on grain yield (t ha^{-1}) of rice. GM, PM, CD, QC, VM and MG indicate green manure, poultry manure, cow-dung, quick compost, vermicompost and magic growth, respectively.

Note: Mean (±SD) was calculated from three replications for each treatment. Bars with different letters are significantly different at $P \leq 0.05$ applying LSD test

Straw Yield

Increased dry matter production has an imperative role in increasing the straw yield of rice due to the application of organic and inorganic fertilizers. In Fig. 8, straw yield enhanced due to fertilizers and manures combination treatment over ½ NPK. However, the highest straw yield (77%) was obtained at full NPK fertilization, which is just 2% higher than the VC applied with ½ NPK compared to ½ NPK treatment. Conversely, the lowest straw yield was obtained from ½ NPK fertilization. Moreover, GM, PM, QC and MG with ½ NPK showed statistically similar result compared to ½ NPK treatment.

Harvest Index

Harvest index is the ratio of seed yield to total above ground. In this experiment, no significant differences were observed due to the application of manure and fertilizers except CD applied with ½ NPK. Compared to ½ NPK, CD application showed maximum harvest index (7%) while the rest of other manures and

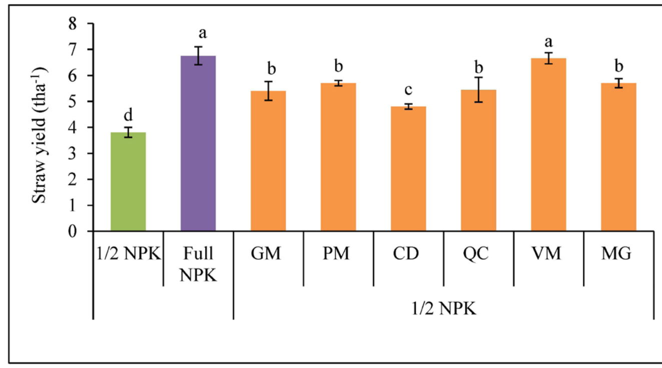

Figure 8. Effect of treatment on straw yield (t ha^{-1}) of rice. GM, PM, CD, QC, VC and MG indicate green manure, poultry manure, cow-dung, quick compost, vermicompost and magic growth, respectively.

Note: Mean (±SD) was calculated from three replications for each treatment. Bars with different letters are significantly different at $P \leq 0.05$ applying LSD test

NPK fertilizations exerted with statistical similar result (Fig. 9). In addition, harvest index reduced by 5% in MG + ½ NPK which was the lowest among the treatments.

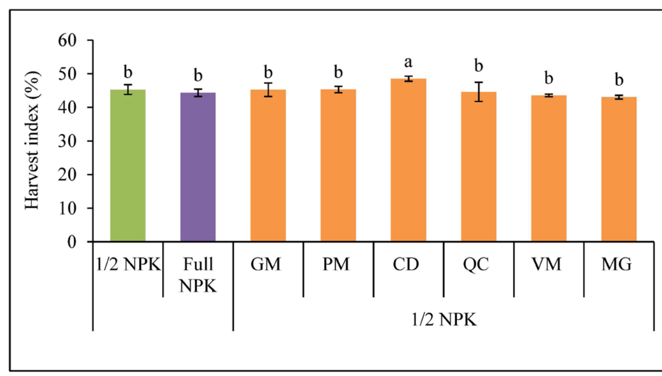

Figure 9. Effect of treatment on harvest index (%) of rice. GM, PM, CD, QC, VM and MG indicate green manure, poultry manure, cow-dung, quick compost, vermicompost and magic growth, respectively.

Note: Mean (±SD) was calculated from three replications for each treatment. Bars with different letters are significantly different at $P \leq 0.05$ applying LSD test

Discussion

Sustainabe crop production in terms of higher crop yield while respecting the environment is impossible without a balance between the use of organic and inorganic fertilizers (Moe et al., 2019). Organic and inorganic fertilizers accelerate plant growth and development by improving soil properties (Sumon et al., 2018; Iqbal et al., 2020). Nutrients released by chemical fertilizers are quickly soluble in water thus instantly up taken by plants from soil solution. Easily available nutrients enhance the leaf area of the plant, thereby enhancing higher photo-assimilates and higher dry matter accumulation (Siavoshi et al., 2011). On the contrary, organic manures release nutrients in the soil through microbial action, which also plays a vital role in imparting good soil physical condition (Sarker et al., 2004). In this study, plant height was increased due to the application of different organic manures associated with NPK fertilizers, especially the VC and MG application observed with the highest plant height, which might happen due to increased fresh weight and dry weight (Sarwar et al., 2008). Vermicompost application resulted in increased plant diameter, which provided physical strength to the plant and accelerated plant height in sunflower (Gül et al., 2021). A similar increase of plant height in BRRI dhan28 and BRRI dhan49 was observed by Islam et al. (2013) and Islam et al. (2018) respectively, while treated with different organic manures. Organic and inorganic fertilizers stimulate different physiological processes in plant *viz*., cell division and cell enlargement, which might also increase the plant height (Moe et al., 2017).

Tiller number is a vital morphological trait for rice grain production that determines the panicle number and thereby rice yield. An increase in N, P, K content in leaves and sheaths triggers the development of tiller primordium which results in higher tillers in rice (Bassi et al., 2018). Increased availability of nutrient with balanced fertilization of both organic and inorganic nutrients ensures better tillering in rice (Miller, 2007). In this experiment, increased tillers hill^{-1} was observed with different organic manure combinations, which might happen due to the positive role of organic manures in availing more essential nutrients through microbial activities. In the rice plant, Hasanuzzaman et al. (2010) also observed the higher tillering. They reported that the higher the nitrogen ability, the greater the cell division occurred, which might be responsible for the higher tillers in rice plant. Significantly higher tillers hill^{-1} with VC application is well understood with the fact that owing to mineralization N, the availability will be higher at maximum tillering and at panicle initiation stages in treatments fertilized with VC earlier. This finding corroborates the earlier results of Siavoshi et al. (2011). Hermawan and Sulistyani (2021) also report that the application of inorganic fertilizers to the soil can increase the availability of nutrients immediately available to plants. In rice field, when adequate inorganic fertilizers are added, it produces significant number of tillers. This happens due to nutrients N, P and K which can increase plant height and tillers number of paddy crops (Yadav and Gupta 2017).

The basic benefit of using organic manure is to provide plants with long-time nutrition which is released very slowly throughout the entire plant life cycle (Myint et al., 2011). Higher dry matter accumulation is a positive indicator of better plant growth with higher translocation of assimilates from source to sink. Increased dry matter results in terms of plant height and tiller number while manure and fertilizers are applied in an integrated way compared to sole application (Biswas et al., 2016). On the contrary, Islam et al. (2015) reported both parallel and increased amount of dry matter production due to integrated use of organic and inorganic fertilizers. In the present investigation, at initial crop growth stages we did not observe any significant differences in dry matter production. However, at later growth stages significant differences were observed due to combined application of organic manure with NPK fertilizers. This might happen due to higher nutrient demand for grain development at later stages which facilitates higher photosynthesis and dry matter production (Moe et al., 2019). In the earlier study, they found that the highest SPAD value at different growth stages resulted in the highest total dry matter (TDM) (Moe et al., 2017), which might be another reason for increased dry matter production of plant at later stage of plant cycle in our experiment. Furthermore, slow-release nature of organic manures enhanced greater availability of major nutrient like N, P, K at later growth stages, as reported in earlier results (Myint et al., 2011; Moe et al., 2019).

Effective tillers are prerequisites for the greater productivity of rice. Increased tiller number is useless unless it is productive (Siavoshi et al., 2011). Sumon et al. (2018) reported the significant responses of different fertilization on the number of effective tillers hill^{-1}. In this study, organic manure such as VC, QC and PM with half amount of NPK gives the best results compared to sole application of half NPK. This might happen due to the increase of assimilation rate enhanced by organic manure through releasing the nutrients responsible for panicle initiation (Ko et al., 2017). Organic and inorganic sources of nutrient varied with nutrient availability, thus effective tillers also varied in number. Panicle formation and development are greatly accelerated by the available sufficiency of the nutrient, which ultimately increases the effective tillers hill^{-1} (Kandil et al., 2010). Consequently, in this study non-effective tillers were reduced with organic manures application which signifies the compensating role of organic manure in increasing effective tiller. However, the non-effective tillers significantly varied with different sources and amounts of N supplementation (Alim, 2012). Furthermore, a higher tiller number due to more availability of micro nutrients in soil because of PM and VC was reported by Rakshit et al. (2008).

Panicle length and numbers are generally related to the tiller number. So, to an extent, it can be estimated that increased tiller number ensures a higher number and length of panicles. The amount of primary nutrients (N, P, K) uptaken during the panicle initiation stage determines the panicle length and panicle branching in rice (Moe et al., 2019). In this study GM, PM and VC showed the increased length of panicle, although no significant difference among the organic manures combined with inorganic fertilizers was observed. This might have happened owing to the same ranges of N availability in the organic sources. N-fertilization considerably increases the panicle length as nitrogen assists in panicle formation as well as elongation according to Hasanuzzaman et al. (2010). Alim (2012) observed the significant differences in panicle length between two varieties of Boro rice which varied with different nitrogen sources and doses. Poultry manure stimulates the microbial activity in soil which consequently quickens the nutrient mineralization for proper plant nourishment (Biswas et al., 2016). Increased grain yield, protein content and fragrance in aromatic rice were also hastened while PM integrated with chemical fertilizers (Sarkar et al., 2014).

Filled and unfilled grain number panicle^{-1} determine the grain yield of rice which seems to be significantly varied in this study due to the change in photosynthetic assimilates under different combination of organic and inorganic fertilizers. Nitrogen has an essential role in grain formation, which might notably increase the number of grains in panicle. Chander and Pandey (1996) observed the higher grain panicle^{-1} with 120 kg N ha^{-1} and that explicitly supports our findings that the application of manures with fertilizers might increase the N availability in soil for proper grain development. Additionally, filled grain panicle^{-1} in treatments over control might have increased due to an adequate supply of essential nutrient elements by CD, GM, PM, QC, VC and MG that accelerated physiological activities. Kumar et al.

(2012) also reported the similar findings.

In this study, we perceived the reduction of unfilled grain panicle^{-1} in all the treatments except the 1/2 NPK. For grain development, primary nutrients play essential role; thus the lack of these nutrients results in a higher number of unfilled grains in ½ NPK treatment. However, the maximum number of filled grains panicle^{-1} were recorded while 75% of chemical fertilizers were applied with CD and compost manure (Hoque et al., 2018). Furthermore, Foysal et al. (2020) observed the highest reduction of sterile spikelet panicle^{-1} while VC was applied with 75% RDF.

Grain weight is a genetic characteristic of a variety which seems less affected due to fertilizer management (Foysal et al., 2020). In this study, no significant differences were observed in 1000-grain weight due to the application of different organic manures. However, other yield attributes like panicle number and length and grain panicle^{-1} are increased due to the positive role of organic component in making good soil structure and they enhance nutrient exchange capacity as well (Karmakar et al., 2014). However, the use of PM with prilled and urea super granule showed significant differences in 1000-grain weight of aromatic Boro rice (Biswas et al., 2016).

Balanced fertilization has an imperative role on the grain yield of rice and at the same time it efficiently minimizes the fertilizer cost (Hasan et al., 2004). In this study, the application of organic and inorganic fertilizers increased the grain yield, which might be due to the increased nutrient supply during vegetative and reproductive growth of the plant. Increased vegetative growth might have increased the photosynthesis which was another reason of increased grain yield under this circumstance. Higher grain yield in zinc and sulphur deficit land was observed while chemical fertilizer was integrated with PM (Mythili et al., 2003). Similarly, a higher amount of grain and yield of Aman rice was obtained with CD application (Mollah et al., 2011). Therefore, balanced fertilization may certainly increase soil fertility along with crop yield.

Increased plant height, dry matter accumulation and tiller number positively correlate with the increase of straw yield of rice (Das et al., 2011). In our study, a significant increase in straw yield due to the application of GM, PM, CD and VC integrated with NPK was observed, which might happen owing to the availability of essential nutrients during the vegetative growth stage of rice plant (Imrul et al., 2016). A similar consequence of integrated use of organic and inorganic fertilizers on increased straw yield of rice was observed by Joshi et al. (2017).

Harvest index determines the ratio between the grain yield and biological yield. The yield of rice mainly depends on the yield contributing characters (tiller number, panicle length, filled grain, 1000-grain weight, etc.). However, an increased amount in the yield contributing characters due to integrated use of organic and inorganic fertilizers was observed previously by many researchers (Sumon et al., 2018; Geng et al., 2019; Foysal et al., 2020). In this investigation, a higher harvest index was observed while CD was applied with ½ NPK, which might happen because of fruitful partitioning of photosynthates to economic yield (Kusalkar et al., 2003). Similarly, the highest harvest index in rice was also observed while CD and compost were applied with chemical fertilizers (Moe et al., 2019).

Conclusion

Indiscriminate use of chemical fertilizers is a curse to soil health and fertility. Therefore, the judicious application of inorganic fertilizers integrated with organic manures has proven as a better remedy to uphold the uninterrupted crop productivity. In this study, in combined treatments, higher number of effective tillers and biomass production were observed, which increased panicle length and ultimately enhanced the rice grain yield compared to half amount of NPK fertilization. In addition, better performances were documented when VC was used in combination followed by QC and GM. Thus, it can be concluded by saying that organic manure reduces the burden of inorganic fertilizers while promoting crop productivity and soil health simultaneously.

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