RESPONSE OF VERMICOMPOST AND BIOCHAR ON YIELD AND QUALITY OF FRAGRANT RICE THROUGH MINIMIZATION OF NITROGEN

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CERTIFICATE

*This is to certify that the thesis entitled '**RESPONSE OF VERMICOMPOST AND BIOCHAR ON YIELD AND QUALITY OF FRAGRANT RICE THROUGH MINIMIZATION OF NITROGEN**' submitted to the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE in AGRONOMY**, embodies the results of a piece of bona fide research work carried out by **AHONA TANJI UPOMA,** Registration No. **14-06017** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

Dated: June, 2021
Dhaka, Bangladesh

Prof. Dr. Tuhin Suvra Roy
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DEDICATED

TO

MY BELOVED

PARENTS

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ABSTRACT

The pot experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from July to December 2019 to assess the response of vermicompost and biochar on yield and quality of fragrant rice through minimization of nitrogen. Fragrant rice cultivars BRRI dhan80 was used as planting material. The experiment consisted of three factors: Factor A: Three levels of vermicompost as- Vm_1: 2.5 t ha^{-1}, Vm_2: 5 t ha^{-1}, Vm_3: 7.5 t ha^{-1} ; Factor B: Three levels of biochar as- Bc_1: 2.5 t ha^{-1}, Bc_2: 5 t ha^{-1}, Bc_3: 7.5 t ha^{-1} ; and Factor C: Two levels of nitrogen as- N_1: 37 kg N ha^{-1} and N_2: 42 kg N ha^{-1} (recommended dose). The three factors experiment was laid out in Randomized Complete Block Design with three replications. The result revealed that amendment of vermicompost, biochar and nitrogen had significant effect on most of the yield and quality contributing parameters. Plant height, tillers number, effective tillers, panicle length, filled grains, total grain yield, 1000-grain weight and protein content increased with increasing vermicompost, biochar and nitrogen. But in case of nitrogen lower level 37 kg N ha^{-1} showed slightly higher grain 2-AP content in fragrant rice. The highest grain yield $plant^{-1}$ (65.21 g) was recorded from $Vm_3Bc_3N_2$ treatment combination and the lowest grain yield $plant^{-1}$ (41.49 g) was observed from $Vm_1Bc_1N_1$ treatment combination. The highest protein content in grain (11.03%) was recorded from $Vm_3Bc_3N_2$ treatment combination whereas the lowest protein content in grain (7.06%) was observed from $Vm_1Bc_1N_1$ treatment combination. The highest grain 2-AP (1.53 µg g^{-1}) was recorded from $Vm_3Bc_3N_1$ treatment combination and the lowest grain 2-AP (0.34 µg g^{-1}) was observed from $Vm_1Bc_1N_1$ treatment combination. So it may be concluded that applications of vermicompost at 7.5 t ha^{-1} exhibited the best performance on most of the traits studied under present study which was at par with 5.0 t ha^{-1}. Application of biochar at 7.5 t ha^{-1} also exhibited the best performance studied under present experiment. Soil application of nitrogen with 42 kg ha^{-1} exhibited the best performance on most the yield and quality traits studied under present experiment except, in case of grain 2-AP content the application of nitrogen with 37 kg ha^{-1} performed the best one.

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CHAPTER I

INTRODUCTION

Globally, rice is a major food crop preferred by nearly half of the world's population (Patunru and Ilman, 2020). More than 90% of the world's rice is produced and consumed in Asia (Anonymous, 2000). Rice provides 75% of the calories and 55% of the protein in the average daily diet of the people (Bhuiyan *et al*., 2002). Rice contains protein (8.1%), Vitamins, minerals, fibers (2.2%) and carbohydrates (77.1%) with a total of 349 calories (Bisen *et al*., 2019). Rice contains the "Oryzinin", a protein which is responsible for softness of rice after cooking. The world countries have to increase more than 25% of rice production by 2025 to meet out the food requirements of the increasing population (Fahad *et al*., 2018).

Rice is the main staple food of Bangladesh. In Bangladesh, rice occupies more than 96% of the land area under "Cereal Agriculture". Bangladesh is the third-largest rice producer in the world after China and India. The average production of rice is approximately 3.05 t ha^{-1} which is nearly 50% less than the world average yield (BBS, 2017).

Fragrant rice is the best quality rice type, and is known worldwide for its distinctive aroma and flavor (Bryant and McClung, 2011). Aromatic rice (*Oryza sativa* L.), also known as "flavored", "fragrant", "scented", "popcorn" or "pecan" rice, is warmly welcomed world-wide (Itani *et al*., 2004). It is a medium to long grained rice. Globally, there is an increase in demand in the consumption of aromatic and superior grain quality rice (Calingacion *et al*., 2014).

The demand for aroma rice is increasing day by day. Unfortunately, the aromatic rice often has undesirable agronomic characters, such as low yield, susceptibility to pests and diseases, and strong shedding (Doan *et al*., 2015). Nature of sensitivity of aroma is a genetic factor, which is highly affected by environmental conditions (Singh *et al*., 1998).However, environmental factors, such as- light, temperature, water, and soil conditions, also have significant effects on the grain quality (Cheng *et al*., 2003; Shi *et al*., 2016; Li *et al*., 2018). Rice grain yield is determined by several agronomic characters such as- heading days, days to maturity, grain filling period, number of fertile tiller, number of fertile grain $panicle^{-1}$, panicle length, 1000 grain weight and plant height (Guereña *et al*., 2013). On the other hand rice grain quality is judged based on three sets of features: raw-grain properties (including appearance and milling quality), eating and cooking quality (ECQ), and nutritional levels (Kaul, 1970).

Vermicompost is composted organic waste substrates in the presence of earthworms with a good physical structure, abundant labile resources, and high microbial activities (Doan *et al*., 2015). In recent years, numerous studies have shown that vermicompost amendments can promote soil quality and productivity by improving the structure and chemical properties of the soil, increasing the amount of plant-available nutrients, promoting soil biological activities, and enhancing crop yield and/or quality (Doan *et al.*, 2015). BADH2 is the key gene influenced the biosynthesis of 2-AP in fragrant rice (Chen *et al*., 2008). Vermicompost includes multiple nutrient elements and many of them have been reported to have roles in enhancing biosynthesis of 2-AP in fragrant rice (Ruan *et al*., 2021).

Biochar is the solid product of thermal decomposition of organic matter under a limited supply of oxygen (Lehmann *et al*., 2003). Moreover, biochar application has the potential to stimulate crop growth by enhancing water storage, improving nutrient supply, increasing beneficial microbial activity, and disease suppression. It has been considered that biochar could be a beneficial soil amendment for crop production (Xie *et al*., 2013). Recent research has identified several environmental and agricultural benefits of applying biochar, including carbon sequestration for reducing carbon emission into the atmosphere (Mašek *et al*., 2013; Mukherjee and Lal, 2013; Jiang *et al*., 2016; Wang *et al*., 2016); phytoremediation of soil contaminants (Mohan *et al*., 2014; Wiszniewska *et al*., 2016) and improving crop growth and yield (Vaccari *et al*., 2015; Agegnehu *et al*., 2016). Results showed that biochar application resulted in 23–27 % increase in fertilizer N uptake by rice plants and consequently 8–10 % increase in grain yield. Fertilizer N loss rate was reduced by 9–10 % by applying biochar (Huang *et al*., 2014). Recent studies also showed that biochar could be used with vermicompost to increase its stability and reduce OM solubility (Ngo *et al*., 2014; Doan *et al*., 2014).In case of quality it was found that the addition of biochar to soil can improve the viscosity and taste quality of rice starch (Gong *et al*., 2020).

The most important and essential plant nutrient is nitrogen (N) and will increase the crop yield positively (Salman *et al*., 2012). Nitrogen fertilizer application was also considered to be effective to increase free proline content in rice kernels during ripening (Bates *et al*., 1973). The 2AP accumulation is affected by nitrogen application and high total nitrogen content led to a high flavor content of cereals (Yang *et al*., 2012). It was found that 2AP content in grains was increased with increasing nitrogen application (Mo *et al*., 2018). The optimization of N application for rice production is justified through high grain yield and profitable farming, whereas excessive N application is not only costly but could detrimentally affects our environment (Rice Production, BMP) (Anonymous, 2000). High nitrogen can lead to lodging in rice (Mahajan *et al*., 2010). Increasing nitrogen can help improve the nutritional quality and processing quality of rice, but the cooking and eating quality of rice becomes worse (Li *et al*., 2019). Nitrogen is one of the most yield-limiting nutrients in lowland rice production, and proper N management is essential for optimizing rice grain yields (Fageria *et al*., 2010). The judicious application of nitrogen fertilizer may also improve grain yield and grain protein content in rice (Ray *et al*., 2015).

From the above content the experiment was conducted with the following objectives

1) To study the effect of vermicompost, biochar and nitrogen on yield and quality of aromatic rice.

2) To find out the optimum combination of vermicompost, biochar and nitrogen on yield and quality of aromatic rice.

CHAPTER II

REVIEW OF LITERATURE

2.1 Effect of vermicompost on growth and yield attributes of rice

2.1.1 Plant height

A study was explored by Mahmud *et al*. (2016) to assess the effect of vermicompost and chemical fertilizers on the growth and yield components in rice. Among all treatments results showed that application of medium level of chemical fertilizer with 4 t ha^{-1} vermicompost gave the maximum yield and highest plant height.

A field experiment was performed by Yadav *et al*. (2021) to find out the effect of integrated nutrient management (INM) on yield, and economics of aromatic rice (*Oryza sativa* L.) *var*. Basmati. The results revealed that among all the treatments, application of 100% NPK+25% vermicompost (T_9) registered taller plant.

Ibrahim *et al*. (2008) set up a study to understand the response of wheat growth and yield to various levels of compost and organic manure. Results showed that the application of organic manures increased the wheat yield by 11.13 (105 %) to 13.53 (128 %) g pot^{-1}, relative to the control. The wheat plant height was statistically different from that of control. This study suggested that instead of using inorganic chemical fertilizer alone, the integrated use could be more effective and sustainable for environment and agriculture.

2.1.2 Tillering pattern

Gandhi and Shivakumar (2010) conducted an experiment to find out the impact of vermicompost carrier based bioinoculants on the growth, yield and quality of rice. The result showed that the combined form of vermicompost carrier based inoculants application significantly influenced the number of tillers.

Jayakumar *et al*. (2011) conducted an experiment to find out the effect of turkey litter (*Meleagris gallopavo* L.) vermicompost on growth and yield characteristics of paddy. It was found that the growth and yield of paddy with the amendment of vermicompost showed notable increase in 40 kg $plot^{-1}$ vermicompost amendment with regular farmers practice.

Thirunavukkarasu and Vinoth (2013) conducted an experiment to know the influence of vermicompost application along with nitrogen on growth, nutrients uptake, yield attributes and economics of rice. It was reported that vermicompost 2.5 t ha^{-1} along with nitrogen enhance the total tiller number.

Kumar *et al.* (2017) explored a study to know the effect of timing of vermicompost application and different level of NPK on growth, yield attributing characters and yield of rice in rice-wheat cropping system. Results showed that the maximum and significantly higher numbers of tillers per meter row length were recorded in T_2 (100% NPK) followed by vermicompost with 75% N.

2.1.3 Effective tillers plant^{-1}

Taheri Rahimabadi *et al*. (2018) conducted a field experiment to assess the impact of cow manure and its vermicompost on the improvement of rice grain yield and quality. The result revealed that the application of cow manure and vermicompost increased leaf chlorophyll and grain yield components such as the number of fertile tillers.

A field research work was conducted by Kumar *et al.* (2017) to explore the impact of different organic sources of nitrogen on growth yield attributes and yield of scented rice. The results explored that the growth, yield attributing characters such as effective tillers and yield of scented rice was significantly highest noted under treatment 100% N through 1/3 Vermicompost+1/3 FYM (farm yard manure) +1/3 Poultry manure at basal (T_1), which was at par to treatment 100% N through 1/2 poultry manure as basal + 100% vermicompost at 30 DAT (T_4).

In order to study the effect of vermicompost and chemical fertilizers on the growth and yield components in rice, an experiment was carried out by Mahmud *et al*. (2016). Results indicated that the highest effective tillers $hill^{-1}$ obtained from the combination of 4 t ha^{-1} vermicompost with 100 kg ha^{-1} N.

A field experiment was performed by Yadav *et al.* (2021) to assess the effect of integrated nutrient management (INM) on yield, and economics of aromatic rice. The results revealed that among all the treatments, application of 100% NPK+25% vermicompost (T_9) registered the highest no. tillers m^{-2} and number of panicle m^{-2} .

2.1.4 Panicle length and 1000-grain weight

Gandhi and Sivakumar (2010) conducted a study to find out the impact of vermicompost carrier based bioinoculants on the growth, yield and quality of rice. The result revealed that the combined form of vermicompost carrier based inoculants application significantly influenced the panicle length and 1000 grain weight.

Duary and Pramanik (2019) conducted an experiment to find out the response of aerobic rice to irrigation and nitrogen management in red and lateritic soil of West Bengal. The highest panicle length was recorded at N_1 (100% N through inorganic fertilizer) which was at par with N_2 (75 % N through fertilizer + 2.5 t ha^{-1} of vermicompost). Panicle length increased with the increase of nitrogen fertilization along with vermicompost because of nitrogen takes part in panicle formation as well as panicle elongation.

Ibrahim *et al*. (2008) set up a study to understand the response of wheat growth and yield to various levels of compost and organic manure. The results stated that the organic manures application increased the wheat yield by 11.13 (105 %) to 13.53 (128 %) g pot^{-1}, relative to the control. The wheat spike length was statistically different from that of control. This study suggested that instead of using inorganic chemical fertilizer alone, the integrated use could be more effective and sustainable for environment and agriculture.

2.1.5 Filled grains $panicle^{-1}$

A field experiment was conducted by Tripathi and Verma (2008) to compare the performance of basmati rice under organic and inorganic source of nutrition. The result stated vermicompost treated plots had comparatively high number of filled grains $panicle^{-1}$ (80.3) and low percentage of floret sterility (20.7).

Taheri Rahimabadi *et al.* (2018) studied the impact of cow manure and its vermicompost on the improvement of rice grain yield and quality. It was found that the application of cow manure and vermicompost increased leaf chlorophyll and grain yield components such as the number of fertile tillers and the number of filled grains.

Bejbaruah *et al*. (2013) performed an experiment to test whether nitrogen use efficiency (NUE) and crop yield can be enhanced by split applicationof vermicompost. Split application of vermicompost enhances the sustainability of rice cropping system and resulted higher yield contributing parameters such as filled grains panicle^{-1} (138).

Dhanuja *et al.* (2019) carried out an effort to assess the effect of application of vermicompost on methane emission and grain yield of paddy crop. The average grain yield (2300 kg ha^{-1}) of the vermicompost-fertilized rice were all marginally higher than the corresponding values: 2060 kg ha^{-1}.

2.1.6 Protein% and grain 2-AP content

An experiment was carried out by Ruan *et al*. (2021) to examined the effect of vermicompost rates on growth, 2-Acetyl-1-Pyrroline, photosynthesis and antioxidant responses of fragrant rice (*Oryza sativa* L.) seedling. The results stated that application of vermicompost significantly increased 2-acetyl-1-pyrroline (2-AP, the key compound of fragrant rice aroma) content of fragrant rice seedling.

Tejada and Gonzalez (2009) found tangible effects of vermicompost application on soil biological properties and rice quality and yield. Two vermicompost of different chemical nature cowdung (CD) (3 t ha^{-1}) and green forages (GF) (6 t ha^{-1}) were applied. The result revealed that CD treated soil increased the grain protein concentration (5.6%), the grain starch concentration (7.8%), the percentage of full grains (3.1%), and the rice yield (7.9%) compared with the GF-treated soils.

Bora *et al.* (2014) conducted a field experiment to assess the effect of organic inputs on production and quality of scented rice (*Oryza sativa*) variety Keteki joha and its economic aspect. Results found out that among different treatment 2.5 ton ha^{-1} enriched compost provide highest yield and 2AP in rice grain.

Ghadimi *et al.* (2021) performed an effort to know the response of organic soil amendments using vermicomposts under inoculation of N_2-fixing bacteria for sustainable rice production. The interaction effect of organic amendments (vermicompost, manure etc) × bacteria × year on protein yield was significant ($P < 0.01$). In both years, organic amendments had significant superiority compared to the control.

2.1.7 Total grain yield

A field experiment was designed by Chandrasoorian *et al.* (2020) to explore the effect of different sources of organic manures and inorganic nutrients on growth and yield seeragasamba rice. The different combinations of organic sources of nitrogen have played dynamic effects on growth and yield parameter. The result revealed that the application of 50% N through vermi composted pressmud + 50% N through RDF (recommended dose of fertilizer) provide higher grain yield of 4436 kg ha^{-1} and recorded significantly higher B: C ratio than other treatments.

A field research work was conducted by Kumar *et al.* (2017) to explore the impact of different organic sources of nitrogen on growth yield attributes and yield of scented rice. The results revealed that the growth, yield attributing characters and yield of scented rice was significantly highest noted under treatment 100% N through 1/3 vermicompost+1/3 FYM(farm yard manure)+1/3 poultry manure at basal (T_1), which was at par to treatment 100% N through 1/2 poultry manure as basal + 100% vermicompost at 30 DAT (T_4).

Jayakumar *et al*. (2011) carried out a study to identify the effect of turkey litter (*Meleagris gallopavo* L.) vermicompost on growth and yield characteristics of paddy. The growth and yield of paddy with the amendment of vermicompost showed notable increase in 40 kg $plot^{-1}$ vermicompost amendment with regular farmers practice.

Vasanthi and Kumaraswamy (1999) carried out a study to know the efficacy of vermicompost to improve soil fertility and rice yield. The result revealed that vermicompost 5 t ha^{-1} is enough for rice production and grain yield increased significantly with the addition of vermicompost compared to control.

2.2 Effect of biochar on growth and yield attributes of rice

2.2.1 Plant height

Kamara *et al.* (2015) carried out a pot experiment to investigate the effect of rice straw biochar on soil quality and the early growth and biomass yield of two rice varieties**.** There were two biochar levels (0 and 15 g kg^{-1} soil). The result appeared that application of biochar improved available phosphorus, exchangeable cations and cation exchange capacity in biochar treated soils compared to the control soil without biochar.

Plant height of rice varieties grown in soils amended with rice straw biochar was significantly higher than those on untreated soils.

A pot experiment was conducted by Weiming and Wenfu (2011) to find out the effect of biochar on rice. The result showed that biochar amendments in rice soil could boost height of rice plant and reported that the rice yield of C_2 (20g·kg $^{-1}$ biochar amendment) was the highest which significant difference compared with other treatments.

Hamzah and Shuhaimi (2018) conducted a field trial to compare effectiveness on rice growth of variety MR 263 using rice husk and paddy straw biochar was determined by applying four different rates of biochar 300 g, 600 g, 900 g and control (without biochar). Plant growth analysis based on average plant height was optimum with addition of 900 g rice husk biochar.

Rizwan *et al.* (2018) performed an experiment to assess the residual effects of biochar on growth, photosynthesis and cadmium uptake in rice under Cd stress with different water conditions. Rice was grown after wheat on Cd-contaminated soil amended with different levels of biochar (0, 3.0, and 5.0%, w/w). Result revealed that biochar increase in plant growth such as plant height and reduce oxidative stress.

Pratiwi and Shinogi (2016) conducted an experiment to investigate the effects of the application of rice husk biochar on selected soil physical properties, rice growth, including root extension, and methane (CH_4) emissions from paddy field soil. The experiments showed that the application of rice husk biochar improved the physical properties of paddy soils. The shoot height of rice plants was significantly higher in soil amended with 4% biochar than in the control soil.

2.2.2 Tillering pattern

Lakitan *et al.* (2018) performed an investigation to evaluate the benefits of biochar on rice growth and yield. Results indicated that applying biochar at rates up to 1.2 Mg.ha^{-1} increased rice yield, but restrained shoot elongation rate and plant height. But during the vegetative growth phase, applying biochar significantly increased the number of tillers, leaves, shoot dry weight, and root dry weight.

Masulili *et al*. (2010) conducted an experiment to investigate the effect of rice husk biochar for rice based cropping system in acid soil. The characteristics of rice husk biochar and its influence on the properties of acid sulfate soils and rice growth. The experimental results of biochar made from rice husk grown in acid sulfate soil and other organic soil amendment applications significantly improve some properties of the acid sulfate soil. The improvement of soil properties with organic soil amendment applications resulted in an improvement of rice growth as shown by an increase in number of tillers.

Chen *et al*. (2021) explored an experiment to assess the effects of biochar addition on rice growth and yield under water-saving irrigation with different biochar application amounts (0, 20, 40 t ha^{-1}) and irrigation management (flooding irrigation and water-saving irrigation). Results showed that the average rice tiller number of the C_{20} treatment was the highest.

2.2.3 Effective tillers $plant^{-1}$

Kamara *et al.* (2015) conducted an effort to find out the effect of rice straw biochar on soil quality and the early growth and biomass yield of two rice varieties. The results of this study showed that application of rice-straw biochar to soil can improve soil properties and rice growth. Specifically, application of rice-straw biochar at 15 g kg^{-1} soil was found to significantly tiller numbers as well as effective tiller relative to the control without biochar.

Rong *et al.* (2020) carried out a study to know the combined effect of ferrous ion and biochar on cadmium and arsenic accumulation in rice. The effective tiller number was increased with increasing Fe (II) ratio in BC+ Fe (II) treatments.

2.2.4 Panicle length and 1000-grain weight

Singh *et al.* (2018) explored a study to investigate the effect of rice husk biochar (RHB) on soil nutrient status, microbial biomass and paddy productivity of nutrient poor agriculture soils. The paddy plant growth variables such as panicle length was found higher in RHB treated plots compared to untreated (control) plots, and varied significantly ($P \leq 0.001$) due to treatments.

A greenhouse experiment was conducted by Jatav *et al.* (2018) to find out the effect of biochar and sewage sludge (SS) on growth, yield, and micronutrient uptake in rice crop. Nine treatments were employed using six different doses of biochar 2.5, 5.0, 7.5 10, 15, and 20 t ha^{-1}. Experimental results showed application of biochar at 20 t ha^{-1} along with 30 t ha^{-1}SS increased grain yield to the extent of 2.5 times over absolute control (no fertilizers) and 8.5% over control (100% RDF).

Hossain (2019) conducted an experiment to know the effect of biochar and fertilizer application on the growth and nutrient accumulation of rice and vegetable in two contrast soils. Fertilized biochar treatments were significantly ($p < 0.01$) better in panicle enlargement than non-fertilized ones in kalma soil.

2.2.5 Filled grains panicle^{-1}

Chen *et al.* (2021) conducted a field experiment to know the effects of biochar addition on rice growth and yield under water-saving irrigation. Three biochar level were added (0, 20 and 40 t ha^{-1}). Results showed that with the increasing biochar rate the filled grains panicle^{-1} increased compared with control.

Lakitan *et al.* (2018) performed an investigation to evaluate the benefits of biochar on rice growth and yield. Results indicated that applying biochar at rates up to 1.2 Mg.ha^{-1} increased rice yield, but restrained shoot elongation rate and plant height. Biochar significantly affected the filled grain panicle^{-1}.

Kartika *et* al. (2018) carried out a study to determine the potential use of biochar in improving soil chemical properties, rice growth and yields. The results explored that R_3 treatment (3 t ha^{-1}) significantly increased grain weight panicle^{-1}, number of filled spikelet.

2.2.6 Protein% and grain 2-AP content

Mannan *et al*. (2009) carried out an experiment to evaluate the influence of nitrogen on grain qualities of fine rice. The study was conducted with 0, 25, 50, 75, and 100 kg N ha^{-1} in Aman and 0, 35, 70, 105, and 140 kg N ha^{-1} in Boro season. The result revealed that the protein% increased with the increase of nitrogen levels and higher level of protein was observed in Basniati PNR. The amylose and aroma content of the test varieties did not sharply vary due to the application of nitrogen although aroma was slightly higher at the lower level of N (below 50 kg N ha^{-1}).

A field experiment was conducted by Mo *et al.* (2019) to assure that nitrogen levels and different water regimes at booting stage improve yield and 2 -Acetyle -1 pyroline formation in fragrant rice. The results showed that, N_2 (30 kg N ha^{-1}) and N_3 (60 kg N ha^{-1}) treatment significantly increased the 2AP contents in brown rice by 9.54% and 11.95%, and 8.88% and 32.54% in the early and the late season, respectively.W_3 N_3 treatment showed the strongest interaction regarding improvement of 2AP contents in brown rice.

Li *et al*. (2021) conducted an experiment to enhance yield and 2AP content in aromatic rice through using additional nitrogen and irrigation water. There were three rice cultivars and applied with three N levels, i.e., 0, 30, and 60 kg N ha^{-1}. Nitrogen (30 kg ha^{-1}) found effective regarding grain yield and aroma improvements than other levels of nitrogen. In fact, additional N application at tillering stage with intermittent irrigation could improve rice yield and aroma of fragrant rice.

2.2.7 Total grain yield

A pot experiment was conducted by Weiming and Wenfu (2011) to find out the effect of biochar on rice. The results showed that biochar amendments in rice soil could boost height of rice, and also increased the dry matter accumulation of leaf, stem and root at various growth stage. Also stated that the rice grain yield of C_2 (20g biochar kg^{-1} soil) was the highest which significant difference compared with other treatments.

Yin *et al*. (2021) conducted an experiment to examine the effects of nitrogen enriched biochar on rice growth and yield, iron dynamics, and soil carbon storage and emission. The result revealed that field application of N-enriched biochar at 4 and 8 t ha^{-1} increased C emissions in early and late rice, whereas application at 4 t ha^{-1} significantly increased rice grain yields.

A fixed field experiment was conducted by Huang *et al.* (2018) to know the effect of continuous application of biochar on nitrogen uptake and utilization in rice field. The results showed that the effect of biochar application on fertilizer N uptake was not significant in three of the first four seasons, but in fifth and sixth season biochar application led to 7–11% increases in internal N use efficiency and 6% increase in grain yield in sixth season. The study suggested that longer continuous application of biochar increase grain yield and internal N use efficiency.

2.3 Effect of different nitrogen levels on growth and yield attributes of rice

2.3.1 Plant height

Zhilin *et al.* (1997) performed a study on physiological effect of nitrogen application on aromatic rice. In case of plant height non aromatic rice showed better performance due to nitrogen application because nitrogen application increased photosynthesis and respiration rates and nitrogen content of rice plant.

Hossain *et al.* (2005) carried out an experiment to assess the effects of nitrogen (30, 60, 90 and 120 kg ha^{-1} N) and phosphorus on the growth and yield of rice and reported that application of nitrogen up to 90 kg ha^{-1} enhanced the growth contributing character such as plant height.

Manzoor *et al.* (2006) carried out a study to find out the response of rice crop (super basmati) to different nitrogen levels. There were nine different nitrogen levels i.e., 0, 50, 75, 100, 125, 150, 175, 200 and 225 kg ha^{-1} for observing the field performance of rice. Plant height showed increasing trend from 0 kg ha^{-1} N up to 175 kg ha^{-1} N.

Mannan *et al.* (2010) explored an experiment to optimize the nitrogen rate for aromatic basmati rice. The result indicated that plant height was increased with the increase of nitrogen levels up to 75 kg ha^{-1} N. Maximum plant growth at the highest level of N caused lodging of plant which increased spikelet sterility and lower grains $panicle^{-1}$ and ultimately decreased grain yield.

2.3.2 Tillering pattern

Haque *et al.* (2015) conducted an experiment to investigate the effect of plant spacing and nitrogen on yield of transplant aman rice. Five nitrogen levels viz., 0, 40, 80, 100 and 140 kg ha^{-1} N were used and result revealed that the highest number of total tiller and effective tillers was observed with 100 kg ha^{-1} N followed by 140 kg ha^{-1} N.

Rajesh *et al*. (2017) carried out an experiment to find out the effect of different nitrogen levels on morpho-physiological and yield parameters in rice under two nitrogen levels 120 kg N ha^{-1} [N_{120}], 60 kg N ha^{-1} [N_{60}] as main treatments and twenty six rice genotypes as sub treatments. The result stated that 120 kg N ha^{-1} recorded significantly higher values for morpho-physiological parameters such as number of tillers $hill^{-1}$.

2.3.3 Effective tillers plant^{-1}

A field experiment was conducted by Devi and Sumathi (2011) to find out the effect of nitrogen fertilizer management on growth, yield and quality of scented rice under aerobic conditions. In this experiment different levels of nitrogen fertilizer were applied at different stage of rice plant. Plant height was greatest at 175 kg N ha^{-1}. However the number of effective tillers increased with the increase in the rate N rate only up to 150 kg ha^{-1}.

An experiment was conducted by Chowdhury *et al*. (2016) with a view to find out the effect of variety and level of nitrogen on the yield performance of fine aromatic rice. There were six levels of nitrogen viz., 0, 30, 60, 90 kg N ha^{-1}, USG 1.8 g 4 hills$^{\mathbf{-1}}$ (55 kg N ha^{-1}) and USG 2.7 g 4 hills$^{\mathbf{-1}}$ (80 kg N ha^{-1}) for this experiment. In case of N, the highest number of effective tillers hill^{-1} (11.40) was obtained when fertilized with USG 1.8 g 4 hills^{-1} and the lowest values were found in 0 kg N ha^{-1}.

A Research was examined by Islam *et al.* (2021) to find out the effect of fertilizer management on growth and yield performance of aromatic fine rice varieties. The result revealed that the highest effective tillers number hill^{-1} (18.36) was found with BRRI Dhan34 combined with 50% of recommended dose of fertilizers + 50% cowdung.

2.3.4 Panicle length and 1000-grain weight

Mannan *et al.* (2010) performed an experiment with four rice genotypes (Basmati PNR, Basmati 370, Basmati 375 and Basmati-D) and tested with 0, 25, 50, 75 and 100 kg N ha^{-1} to explore the optimum N level as well as to assess the genotype having high yield potential. The number of panicles, panicle length and 1000 grain weight increased with the increase of nitrogen levels up to 75 kg N ha^{-1}.

Yoseftabar (2013) conducted a study to identify the effect of nitrogen management on panicle structure and yield in rice. The combined effect of treatments revealed that the panicle length at harvesting stage and total grain increased significantly with an application of 300 kg ha^{-1} N-fertilizer at four stages.

Manzoor *et al.* (2006) conducted a study to know the response of rice crop (super basmati) to different nitrogen levels. The response of nine different nitrogen levels i.e., 0, 50, 75, 100, 125, 150, 175, 200 and 225 kg ha^{-1} on paddy yield and yield components were studied in this experiment .The Panicle length, 1000 grain weight showed increasing trend from 0 kg N ha^{-1} up to 175 kg N ha^{-1}.

2.3.5 Filled grains panicle^{-1}

Kandil *et al.* (2010) conducted an effort to assess the effect of hill spacing, nitrogen levels and harvest date on rice productivity and grain quality. In case of nitrogen fertilizer rates, the results showed that nitrogen fertilizer levels had significant effects on number of filled grains panicle^{-1}, 1000-grain weight. Increasing nitrogen fertilizer levels up to 80 kg N ha^{-1} resulted in marked increases in filled grains panicle^{-1}.

A field experiment was performed by Shukla *et al.* (2015) to find out the performance of rice varieties in relation to nitrogen levels under irrigated condition. Three nitrogen levels (40, 80 and 120 kg ha^{-1}) were used for this study. From 120 kg N ha^{-1}, the yield attributes recorded number of fertile grains (106.51 seeds panicle^{-1}) and 1000-grains weight (25.89 g) than lower fertilities.

2.3.6 Protein% and grain 2-AP content

Mannan *et al.* (2009) carried out an experiment to evaluate the influence of nitrogen on grain qualities of fine rice. The study was conducted with 0, 25, 50, 75, and 100 kg N ha^{-1} in Aman and 0, 35, 70, 105, and 140 kg N ha^{-1} in Boro season. The result revealed that the protein increased with the increase of nitrogen levels. The amylose and aroma content of the test varieties did not sharply vary due to the application of nitrogen although aroma was slightly higher at the lower level of N (below 50 kg N ha^{-1}).

A Field experiment was conducted by Mo *et al.* (2019) to assure that nitrogen levels and different water regimes at booting stage improve yield and 2 -Acetyle -1 pyroline formation in fragrant rice. The result showed that, N_2 (30 kg N ha^{-1}) and N_3 (60 kg N ha^{-1}) treatment significantly increased the 2AP contents in brown rice by 9.54% and 11.95%, and 8.88% and 32.54% in the early and the late season, respectively.

Li *et al.* (2021) conducted an experiment to enhance yield and 2-AP content in aromatic rice through using additional nitrogen and irrigation water. There were three rice cultivars and applied with three N levels, i.e., 0, 30, and 60 kg N ha^{-1}. Higher aroma found from 30 kg N ha^{-1}. In fact, additional N application at tillering stage with intermittent irrigation could improve rice yield and aroma of fragrant rice.

2.3.7 Total grain yield

Mahajan *et al.* (2010) conducted a study to optimize N levels for higher yield and NUE (nitrogen use efficiency) of modern aromatic rice cultivars. Across all genotypes, the mean nitrogen-fertilizer response was highest at 40 kg N ha^{-1} as compared to other N levels (0, 20 and 60 kg N ha^{-1}), indicating that further increase in N level had no effect on crop response to fertilizer..

A field experiment was performed Sharma *et al.* (2017) in order to find out the effect of integrated nutrient management on growth and yield of scented rice. The yield contributing parameter like grain yield were found highest under the 50% recommended NPK+50% N as FYM +5kg zinc ha^{-1}.

CHAPTERIII

MATERIALS AND METHODS

The experiment was conducted to find out the effect of vermicompost and biochar on the yield and quality of aromatic rice (BRRI dhan80) through minimization of nitrogen. The details of the materials and methods has been presented below under the following headings:

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted during the period from July to November 2019 in aman season.

3.1.2 Experimental site description

The present experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site is $23^{0}74^{/}$N latitude and $90^{0}35^{0}$E longitude with an elevation of 8.2 meter from sea level. Experimental location presented in Appendix I.

3.1.3 Climatic condition

The geographical location of the experimental site was under the subtropical climate and its climatic conditions is characterized by three distinct seasons, namely winter season from the month of November to February, the pre-monsoon period or hot season from the month of March to April and monsoon period from the month of May to October (Edris *et al.*, 1979). During the experimental period the maximum temperature (32.5^{0}C) recorded for the month of August, 2019. The highest relative humidity (84%) and highest rainfall (742 mm) was recorded for the month of July, 2019, whereas the minimum temperature (19.9^{0}C), minimum relative humidity (78%) and lowest rainfall (122 mm) was recorded for the month of November, 2019. Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during study period has been presented in Appendix II.

3.1.4 Soil characteristics of the experimental pot

There were 54 earthen pots altogether and 15 kg soil was taken in each earthen pot. The soil of the experimental pot belonged to "The Modhupur Tract", AEZ-28 (FAO, 1988). Top soil was Silty Clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. The experimental area having available irrigation and drainage system and situated above the flood level. The soil having a texture of sandy loam organic matter 0.78% and composed of 26% sand, 45% silt and 29% clay. Details morphological, physical and chemical properties of the experimental field soil are presented in Appendix III.

3.2 Experimental details

3.2.1 Planting material

BRRI dhan80 was used as the test crop in this experiment. This variety was developed at the Bangladesh Rice Research Institute (BRRI). It is recommended for Aman season and average plant height of the variety is 120 cm. It requires about 120 days completing its life cycle with an average yield is 4.5-5 t ha^{-1}.

3.2.2 Treatments of the experiment

The experiment consisted of three factors

Factor A: Levels of vermicompost (3 levels)
i. Vm_1: 2.5 t ha^{-1}
ii. Vm_2: 5 t ha^{-1}
iii. Vm_3: 7.5 t ha^{-1}
Factor B: Levels of biochar (3 levels)
i. Bc_1: 2.5 t ha^{-1}
ii. Bc_2: 5 t ha^{-1}
iii. Bc_3: 7.5 t ha^{-1}

Factor C: Levels of nitrogen (2 levels)
i. N_1: 37 kg nitrogen ha^{-1}
ii. N_2: 42 kg nitrogen ha^{-1} (recommended dose)

There were total 18 (3×3×2) treatment combination as a whole viz., $Vm_1Bc_1N_1$, $Vm_1Bc_1N_2$, $Vm_1Bc_2N_1$, $Vm_1Bc_2N_2$, $Vm_1Bc_3N_1$, $Vm_1Bc_3N_2$, $Vm_2Bc_1N_1$, $Vm_2Bc_1N_2$, $Vm_2Bc_2N_1$, $Vm_2Bc_2N_2$, $Vm_2Bc_3N_1$, $Vm_2Bc_3N_2$, $Vm_3Bc_1N_1$, $Vm_3Bc_1N_2$, $Vm_3Bc_2N_1$, $Vm_3Bc_2N_2$, $Vm_3Bc_3N_1$, $Vm_3Bc_3N_2$.

3.2.3 Experimental design and layout

The experiment was laid out in a randomized complete block design (RCBD) with three replications. Each block was divided into 18 unit pots as treatments. Thus the total numbers of pots were 54.

3.3 Growing of crops

3.3.1 Seed collection and sprouting

Seeds were collected from BRRI, Gazipur just 20 days ahead of the sowing of seeds in seed bed. For seedlings, seeds were immersed in water in a bucket for 24 hours. These were then taken out of water and kept in gunny bags. The seeds started sprouting after 48 hours which were suitable for sowing in the seedbed 72 hours.

3.3.2 Raising of seedlings

The nursery bed was prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown as uniformly as possible at 7th July, 2019. Irrigation was gently provided to the bed when needed. No fertilizer was used in the nursery bed.

3.3.3 Pot preparation

The pot selected for conducting the experiment was filled up with 15 kg soil at 3rd August, 2019. Weeds and stubbles were removed. The experimental pot was partitioned in accordance with the experimental design. Organic and inorganic fertilizers as indicated below were mixed with the soil of each pot. The pots were properly tagged.

3.3.4 Fertilizers and manure application

The fertilizers N, P, K, S and Zn in the form of urea, TSP, MoP, Gypsum and zinc sulphate, respectively were applied as per treatment. Vermicompost and biochar were also applied as treatment. The one third amounts of nitrogen and entire amount of TSP, MOP, gypsum and zinc sulphate were applied during the final preparation of pot. Rest nitrogen was applied in two equal installments at tillering and before panicle initiation stages.

3.3.5 Transplanting of seedling

Thirty days old seedlings of BRRI dhan80 were carefully uprooted from the seedling nursery and transplanted on 7th August in well prepared pots. Two seedling pot^{-1} were used. After one week of transplanting all pots were checked for any missing, which was filled up with extra seedlings whenever required.

3.3.6 Intercultural operations

Intercultural operations were done to ensure normal growth of the crop. Plant protection measures were followed as and when necessary. The following intercultural operations were done.

3.3.6.1 Irrigation

Necessary irrigations were provided to the pots and when required during the growing period of rice crop. Drying and wetting system conducted throughout the entire vegetative phase. No water stress was encountered in reproductive and ripening phase. The pot was finally dried out at 15 days before harvesting.

3.3.6.2 Weeding

The plots were infested with some common weeds, which were removed by uprooting from the pots at several times during the cropping season.

3.3.6.3 Insect and pest control

There was no infection of diseases in the pot but leaf roller (*Chaphalocrosis medinalis*) was observed in the pot and used Malathion @ 1.12 L ha^{-1}.

3.4 Harvesting, threshing and cleaning

The crop was harvested at full maturity when 80-90% of the grains were turned into straw colored at 25th November, 2019. The harvested crop was bundled separately, properly tagged and brought to threshing floor. Enough care was taken during threshing and cleaning period of rice grain. Fresh weight of rice grain and straw were recorded pot wise. The grains were dried, cleaned and weighed for individual pot. The weight was adjusted to a moisture content of 12%.

3.5 Data recording

3.5.1 Plant height

The height of plant was measured in centimeter (cm) from the ground level to the tip of the plant at 20, 40, 60, 80 DAT and at harvest from each pot.

3.5.2 No of tillers pot^{-1}

Number of tillers pot^{-1} were recorded at 20, 40, 60, 80 DAT and at harvest.

3.5.3 Effective tillers pot^{-1}

The total number of effective tillers pot^{-1} was counted as the number of panicle bearing tillers during harvesting. Data of effective tillers pot^{-1} were counted from plant^{-1}.

3.5.4 Length of panicle plant^{-1}

The length of panicle was measured with a meter scale from plant^{-1}.

3.5.5 Filled grains panicle$^{-`1}$

The total numbers of filled grains panicle^{-1} were collected randomly from selected 3 panicle of a pot on the basis of grain in the spikelet and then average numbers of filled grains panicle^{-1} were recorded.

3.5.6 Total grains panicle^{-1}

The total numbers of grains panicle^{-1} was calculated by adding filled and unfilled grain selected 3 panicle of a pot and average numbers of grains panicle^{-1} were recorded.

3.5.7 Weight of 1000-grain

One thousand grains were counted randomly from the total cleaned harvested grains and then weighed in grams and recorded.

3.5.8 Grain yield plant^{-1}

Grains obtained from each plant were sun-dried and weighed carefully and recorded.

3.5.9 Protein content

The protein content of rice grain was determined by the Micro-Kjeldahl method using automated nitrogen determination system (AOAC, 1990).

3.5.10 Grain-2AP content

The 2-AP content in grain was estimated using the method described by Huang *et al*. (2012), prior to analysis, grains were ground by mortar and pestle. Approximately 10 g grains were mixed homogeneously with 150 ml purified water into a 500 ml round-bottom flask attached to a continuous steam distillation extraction head. The mixture was boiled at 150^0C in an oil pot. A 30 ml aliquot of dichloromethane was used as the extraction solvent and was added to a 500 ml round-bottom flask attached the other head of the continuous steam distillation apparatus, and this flask was boiled in a water pot at 53^0C. The continuous steam distillation extraction was linked with a cold water circulation machine in order to keep temperature at 10^0C. After approximately 35 min, the extraction was complete. Anhydrous sodium sulfite was added to the extract to absorb the water. The dried extract was filtered by organic needle filter and analyzed for 2-AP content by GCMS-QP 2010 Plus. High purity helium gas was used as the carrier gas at flow rate of 2 ml min^{-1}. The temperature gradient of the GC oven was as follows: 40^0C (1 min), increased at 2^0C min^{-1} to 65^0C and held at 65^0C for 1 min, and then increased to 220^0C at 10^0C min^{-1}, and held at 220^0C for 10 min. The retention time of 2-AP was confirmed at 7.5 min. Each sample had three replicates, and 2-AP was expressed as µg g^{-1}.

Protein and grain 2-AP content were measured at Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka.

3.6 Statistical Analysis

The recorded data for different characters were statistically analyzed to observe the significant difference among different treatments. The analysis of variance of all the recorded parameters performed using MSTAT-C software. The difference of the means value was separated by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984)

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the response of vermicompost and biochar on yield and quality of fragrant rice through minimization of nitrogen. The analysis of variance (ANOVA) of the data on yield attributes, yield and quality of aromatic rice are presented in Appendix IV-X. The results of this experiment have been presented and discusses with the help of different table and graphs with possible interpretations under the following headings and sub-headings:

4.1 Growth and yield attributes of aromatic rice

4.1.1 Plant height

Plant height of aromatic rice at 20, 40, 60 and 80 DAT (days after transplanting) and at harvest showed statistically significant differences due to different levels of vermicompost (Table 1). At 20, 40, 60, 80 DAT and at harvest, the tallest plant (61.033, 76.017, 102.67, 119.97 and 126.48 cm, respectively) was found from Vm_2 which was followed by (58.80, 74.94, 100.88, 117.82 and 123.87 cm, respectively) Vm_3 while the shortest plant (56.26, 71.21, 97.7, 115.85 and 121.12 cm, respectively) was recorded from Vm_1. By applying vermicompost into the soil, nutrients are changed to assimilable forms in the gut, that are more rapidly taken up by the plants (Lee, 1985) which can be the reason for increasing plant height.

Statistically significant variation was recorded in terms of plant height of aromatic rice at 20, 40, 60 and 80 DAT and at harvest for different levels of biochar (Table 1). At 20, 40, 60, 80 DAT and harvest, the tallest plant (61.53, 77.25, 103.78, 121.23 and 127.88 cm, respectively) was found from Bc_3 which was followed by (57.76, 73.08, 99.17, 116.59 and 122.35 cm, respectively) Bc_2 while the shortest plant (56.80, 71.83, 98.35, 115.82 and 121.23 cm, respectively) was recorded from Bc_1. Biochar improves the soil physical and chemical properties were reflected in the improved growth of rice varieties sown on the biochar treated soil. Plant height of rice grown in soils amended with biochar was significantly higher than those of control soils (Kamara *et al*., 2015). Fertile soil with biochar may be responsible for promoting plant height.

Plant height of aromatic rice showed statistically significant differences due to different levels of nitrogen (Table 1). At 20, 40, 60, 80 DAT and at harvest, the tallest plant

(59.91, 75.46, 102.17, 119.43 and 125.68 cm, respectively) was found from N_2 while the shortest plant (57.489, 72.644, 98.70, 116.33 and 121.97 cm, respectively) was recorded from N_1.

Table 1. Effect of vermicompost, biochar and nitrogen on plant height at different days after transplanting (DAT) and at harvest

Treatment	Plant height (cm) pot^{-1} at				
	20 DAT	40 DAT	60 DAT	80 DAT	Harvest
Levels of vermicompost					
Vm_1	56.26 c	71.21 c	97.75 c	115.85 c	121.12 c
Vm_2	61.03 a	76.01 a	102.67 a	119.97 a	126.48 a
Vm_3	58.80 b	74.93 b	100.88 b	117.82 b	123.87 b
CV (%)	1.75	1.65	2.06	1.54	2.06
Level of significance	**	**	**	**	**
LSD (.05)	0.6968	0.8271	1.4015	1.2333	1.7276
Levels of biochar					
Bc_1	56.80 c	71.83 c	98.35 b	115.82 b	121.23 b
Bc_2	57.76 b	73.08 b	99.17 b	116.59 b	122.35 b
Bc_3	61.53 a	77.25 a	103.78 a	121.23 a	127.88 a
CV (%)	1.75	1.65	2.06	1.54	2.06
Level of significance	**	**	**	**	**
LSD (.05)	0.6968	0.8271	1.4015	1.2333	1.7276
Levels of nitrogen					
N_1	57.48 b	72.64 b	98.70 b	116.33 b	121.97 b
N_2	59.91 a	75.46 a	102.17 a	119.43 a	125.68 a
CV (%)	1.75	1.65	2.06	1.54	2.06
Level of significance	**	**	**	**	**
LSD (.05)	0.5689	0.6753	1.1443	1.0070	1.4106

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per DMRT at .05 level of probability

Vm_1: 2.5 t ha^{-1} (18.75 g for 15 kg soil pot^{-1}) Bc_1: 2.5 t ha^{-1} (18.75 g for 15 kg soil pot^{-1}) N_1: 37 kg N ha^{-1}

Vm_2: 5 t ha^{-1} (37.5 g for 15 kg soil pot^{-1}) Bc_2: 5 t ha^{-1} (37.5 g for 15 kg soil pot^{-1}) N_2: 42kg N ha^{-1}

Vm_3: 7.5 t ha^{-1} (52.5 g for 15 kg soil pot^{-1}) Bc_3: 7.5 t ha^{-1} (52.5 g for 15 kg soil pot^{-1})

*=Significant at 5% level and **= Significant at 1% level

Table 2. Combined effect of vermicompost, biochar and nitrogen on plant height at different days after transplanting (DAT) and at harvest.

Treatment combination	Plant height (cm) pot^{-1} at				
	20 DAT	40 DAT	60 DAT	80 DAT	Harvest
$Vm_1Bc_1N_1$	55.00 i	70.00 g	97.00 d	115.00 d	120.00 d
$Vm_1Bc_1N_2$	55.40 hi	70.30 fg	97.20 d	115.30 d	120.30 d
$Vm_1Bc_2N_1$	55.80 g-i	70.80 e-g	97.40 d	115.70 cd	120.70 d
$Vm_1Bc_2N_2$	56.50 f-i	71.70 d-g	98.00 d	116.00 b-d	121.50 b-d
$Vm_1Bc_3N_1$	56.90 e-h	71.90 d-g	98.10 d	116.20 b-d	121.80 b-d
$Vm_1Bc_3N_2$	58.00 c-f	72.60 c-e	98.80 b-d	116.90 b-d	122.40 b-d
$Vm_2Bc_1N_1$	58.30 c-e	72.90 cd	98.90 b-d	117.00 b-d	122.80 b-d
$Vm_2Bc_1N_2$	59.20 b-d	73.70 b-d	100.00 b-d	117.40 b-d	123.50 b-d
$Vm_2Bc_2N_1$	59.60 bc	74.20 bc	100.20 b-d	117.90 b-d	123.90 b-d
$Vm_2Bc_2N_2$	60.40 b	75.00 b	101.93 bc	118.70 bc	125.10 bc
$Vm_2Bc_3N_1$	60.70 b	75.30 b	102.00 b	118.80 b	125.60 b
$Vm_2Bc_3N_2$	68.00 a	85.00 a	113.00 a	130.00 a	138.00 a
$Vm_3Bc_1N_1$	56.20 g-i	71.80 d-g	98.20 d	115.00 d	120.10 d
$Vm_3Bc_1N_2$	56.70 e-i	72.30 c-f	98.80 b-d	115.20 d	120.70 d
$Vm_3Bc_2N_1$	57.40 e-g	73.50 b-d	99.00 b-d	116.00 b-d	121.50 b-d
$Vm_3Bc_2N_2$	56.90 e-h	73.30 b-d	98.50 cd	115.23 d	121.40 b-d
$Vm_3Bc_3N_1$	57.50 d-g	73.40 b-d	97.50 d	115.40 d	121.30 cd
$Vm_3Bc_3N_2$	68.10 a	85.30 a	113.30 a	130.10 a	138.20 a
CV (%)	1.75	1.65	2.06	1.54	2.06
Level of significance	**	**	**	**	*
LSD (.05)	1.7068	2.0260	3.4330	3.0210	4.2317
Vm×Bc	**	**	*	**	*
Vm×N	**	**	*	*	*
Bc×N	**	**	**	**	**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per DMRT at .05 level of probability

Vm_1: 2.5 t ha^{-1} (18.75 g for 15 kg soil pot^{-1}) Bc_1: 2.5 t ha^{-1} (18.75 g for 15 kg soil pot^{-1}) N_1: 37 kg N ha^{-1}

Vm_2: 5 t ha^{-1} (37.5 g for 15 kg soil pot^{-1}) Bc_2: 5 t ha^{-1} (37.5 g for 15 kg soil pot^{-1}) N_2: 42kg N ha^{-1}

Vm_3: 7.5 t ha^{-1} (52.5 g for 15 kg soil pot^{-1}) Bc_3: 7.5 t ha^{-1} (52.5 g for 15 kg soil pot^{-1})

*=Significant at 5% level and **= Significant at 1% level

Mannan *et al.* (2010) reported that plant height was increased significantly with the increase of nitrogen levels up to 75 kg ha^{-1} N. The increase in plant height with increased N application may be due to enhanced vegetative growth with more nitrogen supply to plant.

Combined effect of different levels of vermicompost, biochar and nitrogen showed significant differences on plant height of aromatic rice at 20, 40, 60 and 80 DAT and at harvest (Table 2). At 20, 40, 60, 80 DAT and at harvest, the tallest plant (68.10, 85.30, 113.30, 130.10 and 138.20 cm, respectively) was observed from $Vm_3Bc_3N_2$ treatment combination, which was followed by (68.00, 85.00, 113.00, 130.00 and 138.00 cm, respectively) $Vm_2Bc_3N_2$ and they were statistically similar and the shortest plant (55.00, 72.00, 97.00, 115.00 and 120.00 cm, respectively) was observed from $Vm_1Bc_1N_1$ treatment combination. Organic and inorganic fertilizers may be the reason for boosting the plant height.

4.1.2 Tillering pattern

Tillering pattern of aromatic rice at 20, 40, 60 and 80 DAT and at harvest showed statistically significant differences due to different levels of vermicompost (Table 3). At 20, 40, 60, 80 DAT and at harvest, the highest tiller number $plant^{-1}$(17.60, 32.95, 36.36, 36.73 and 27.12, respectively) were found from Vm_2 which was followed (17.19, 32.93, 34.97, 35.93 and 26.60, respectively) by Vm_3 while the lowest tiller number $plant^{-1}$ (15.07, 28.81, 33.18, 33.23 and 23.70, respectively) were recorded from Vm_1.This higher tiller no with increasing level of vermicompost not only because of the presence of greater amounts most of the plant nutrients but also due to the presence of microbial metabolites, the plant-growth promoting hormone-like substances (Tomati *et al*., 1988).

Statistically significant variation was recorded in terms of tillering pattern of aromatic rice at 20, 40, 60 and 80 DAT and at harvest for different levels of biochar (Table 3). At 20, 40, 60, 80 DAT and at harvest, the highest tiller number $plant^{-1}$ (17.72, 32.98, 36.32, 36.42 and 27.23, respectively) was found from Bc_3 which was followed by (16.42, 31.48, 34.48, 34.89 and 25.50, respectively) Bc_2 while the lowest tiller number $plant^{-1}$ (15.72, 30.28, 33.71, 34.58 and 24.68, respectively) was recorded from Bc_1. Application of biochar will increase total porosity, and at the same time will increase soil water retention (Sharma and Uehara, 1968). Optimum water and aearation during vegetative growth may be the reason for better tillering in rice with biochar.

Table 3. Effect of vermicompost, biochar and nitrogen on tiller number at different days after transplanting (DAT) and harvest

Treatment	Tiller number pot^{-1} at				
	20 DAT	40 DAT	60 DAT	80 DAT	Harvest
Levels of vermicompost					
Vm1	15.07 c	28.81 b	33.18 c	33.23 c	23.70 c
Vm2	17.60 a	32.95 a	36.36 a	36.73 a	27.12 a
Vm3	17.19 b	32.93 a	34.97 b	35.93 b	26.60 b
CV (%)	1.96	2.06	2.58	2.37	2.09
Level of significance	**	**	**	**	**
LSD (.05)	0.2211	0.4413	0.6082	0.5667	0.3663
Levels of biochar					
Bc1	15.72 c	30.22 c	33.71 c	34.58 b	24.68 c
Bc2	16.42 b	31.48 b	34.48 b	34.89 b	25.50 b
Bc3	17.72 a	32.98 a	36.32 a	36.42 a	27.23 a
CV (%)	1.96	2.06	2.58	2.37	2.09
Level of significance	**	**	**	**	**
LSD (.05)	0.2211	0.4413	0.6082	0.5667	0.3663
Levels of nitrogen					
N1	16.19 b	31.02 b	34.19 b	34.90 b	25.22 b
N2	17.05 a	32.10 a	35.48 a	35.69 a	26.39 a
CV (%)	1.96	2.06	2.58	2.37	2.09
Level of significance	**	**	**	*	**
LSD (.05)	0.1805	0.3603	0.4966	0.4627	0.2991

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per DMRT at .05 level of probability

Vm_1: 2.5 t ha^{-1} (18.75 g for 15 kg soil pot^{-1}) Bc_1: 2.5 t ha^{-1} (18.75 g for 15 kg soil pot^{-1}) N_1: 37 kg N ha^{-1}

Vm_2: 5 t ha^{-1} (37.5 g for 15 kg soil pot^{-1}) Bc_2: 5 t ha^{-1} (37.5 g for 15 kg soil pot^{-1}) N_2: 42kg N ha^{-1}

Vm_3: 7.5 t ha^{-1} (52.5 g for 15 kg soil pot^{-1}) Bc_3: 7.5 t ha^{-1} (52.5 g for 15 kg soil pot^{-1})

*=Significant at 5% level and **= Significant at 1% level

Table 4. Combined effect of vermicompost, biochar and nitrogen on tiller number at different days after transplanting (DAT) and harvest

Treatment combination	Tiller number pot^{-1} at				
	20 DAT	40 DAT	60 DAT	80 DAT	Harvest
$Vm_1Bc_1N_1$	14.00 h	28.00 h	32.00 f	32.00 j	22.00 i
$Vm_1Bc_1N_2$	14.30 gh	28.20 h	32.80 ef	32.70 ij	23.33 h
$Vm_1Bc_2N_1$	14.80 g	28.70 gh	33.00 ef	33.00 ij	23.50 h
$Vm_1Bc_2N_2$	15.40 f	29.00 f-h	33.40 d-f	33.23 h-j	23.80 gh
$Vm_1Bc_3N_1$	15.60 f	29.30 fg	33.80 de	33.70 g-i	24.40 fg
$Vm_1Bc_3N_2$	16.33 de	29.70 fg	34.10 de	34.80 e-g	25.20 ef
$Vm_2Bc_1N_1$	16.66 cd	30.00 f	34.20 de	35.70 b-f	25.70 c-e
$Vm_2Bc_1N_2$	16.90 c	31.66 e	35.70 bc	35.90 b-e	26.00 c-e
$Vm_2Bc_2N_1$	16.66 cd	32.50 de	35.90 bc	36.30 b-d	26.20 c
$Vm_2Bc_2N_2$	17.66 b	33.60 bc	36.10 bc	36.70 bc	27.33 b
$Vm_2Bc_3N_1$	17.80 b	33.93 b	36.50 b	37.00 b	27.50 b
$Vm_2Bc_3N_2$	19.90 a	36.00 a	39.80 a	38.80 a	30.00 a
$Vm_3Bc_1N_1$	15.80 ef	31.50 e	33.70 de	35.50 c-f	25.30 de
$Vm_3Bc_1N_2$	16.66 cd	32.00 de	33.90 de	35.70 b-f	25.80 c-e
$Vm_3Bc_2N_1$	17.66 b	32.80 cd	34.80 cd	35.70 b-f	26.34 c
$Vm_3Bc_2N_2$	16.33 de	32.30 de	33.70 de	34.45 f-h	25.87 c-e
$Vm_3Bc_3N_1$	16.71 cd	32.50 de	33.87 de	35.23 d-f	26.12 cd
$Vm_3Bc_3N_2$	20.00 a	36.50 a	39.90 a	39.00 a	30.20 a
CV (%)	1.96	2.06	2.58	2.37	2.09
Level of significance	**	*	**	*	**
LSD (.05)	0.5415	1.0810	1.4898	1.3882	0.8972
Vm×Bc	NS	**	NS	NS	NS
Vm×N	*	*	NS	NS	NS
Bc×N	**	**	**	**	**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per DMRT at .05 level of probability

Vm_1: 2.5 t ha^{-1} (18.75 g for 15 kg soil pot^{-1}) Bc_1: 2.5 t ha^{-1} (18.75 g for 15 kg soil pot^{-1}) N_1: 37 kg N ha^{-1}

Vm_2: 5 t ha^{-1} (37.5 g for 15 kg soil pot^{-1}) Bc_2: 5 t ha^{-1} (37.5 g for 15 kg soil pot^{-1}) N_2: 42kg N ha^{-1}

Vm_3: 7.5 t ha^{-1} (52.5 g for 15 kg soil pot^{-1}) Bc_3: 7.5 t ha^{-1} (52.5 g for 15 kg soil pot^{-1})

*=Significant at 5% level and **= Significant at 1% level

Tillering pattern of aromatic rice showed statistically significant differences due to different levels of nitrogen (Table 3). At 20, 40, 60, 80 DAT and at harvest, the highest tiller number plant^{-1} (17.05, 32.10, 35.48, 35.69 and 26.39, respectively) was found from N_2 while the lowest tiller number plant^{-1} (16.19, 31.02, 34.19, 34.90 and 25.22, respectively) was recorded from N_1. Under field conditions, the application of nitrogen (N) fertilizer is the most common and effective way to enhance the tiller population, as it increases the cytokinin content within tiller nodes and further enhances the germination of the tiller primordium (Liu *et al*., 2011). With the increasing levels of nitrogen, cytokinin increased which results increase number of tiller.

Combined effect of different levels of vermicompost, biochar and nitrogen showed significant differences on tiller number of aromatic rice at 20, 40, 60 and 80 DAT and at harvest (Table 4). At 20, 40, 60, 80 DAT and harvest, the highest tiller number plant^{-1} (20.00, 36.50, 39.90, 39.00 and 30.20, respectively) was observed from $Vm_3Bc_3N_2$ treatment combination, which was followed by (19.90, 36.00, 39.80, 38.80 and 30.00 respectively) $Vm_2Bc_3N_2$ and they were statistically similar and the lowest tiller number plant^{-1} (14.00, 28.00, 32.00, 32.00 and 22.00 respectively) was observed from $Vm_1Bc_1N_1$ treatment combination.

4.1.3 Effective tillers pot^{-1}

Effective tillers pot^{-1}of aromatic rice showed statistically significant differences due to different levels of vermicompost (Table 5). The highest number of effective tillers pot^{-1} (19.32) was found from Vm_2 and the lowest number (15.99) was recorded from Vm_1. Taheri Rahimabadi *et al.* (2018) reported that that the application of cow manure and vermicompost increased leaf chlorophyll and grain yield components such as the number of fertile tillers. Some of the secretions of worms and associated microbes act as growth promoter along with other nutrients. Much interest in vermicomposting has been noticed due to the fact that earthworms play an important role in soil improvement, organic matter decomposition and enhancing plant growth (Gupta and Bhagat, 2004). So increasing of tillering as well as effective tiller may be due to for some growth promoting earthworms and microbs as vermicompost was used in this study.

Statistically significant variation was recorded in terms of effective tillers pot^{-1} for different levels of biochar (Table 5). The highest number of effective tillers pot^{1} (19.43) was recorded from Bc_3 whereas the lowest number (15.73) was found from Bc_1. Lakitan *et al.* (2018) reported that biochar significantly affected the percentage of productive tiller. From the previous experiments it was revealed that biochar applications can improve soil properties by increasing soil organic carbon, soil pH, and CEC (Shafie *et al.,* 2012; Lehman *et al.,* 2003). So the biochar amendments made the soil fertile which may be promotes the tillering as well as effective tillers in aromatic rice.

Effective tillers of aromatic rice pot^{-1} showed statistically significant differences due to different levels of nitrogen (Table 5). The highest number of effective tillers pot^{-1} (18.08) recorded from N_2 and lowest number (16.54) from N_1. Chowdhury *et al.* (2016) found that highest number of effective tillers hill^{-1} (11.40) was obtained when fertilized with USG 1.8 g hills^{-1} and the lowest values were found in 0 kg N ha^{-1}. The most common and effective way to enhance the tiller population is to apply nitrogen fertilizer because it increases the cytokinin content within tiller nodes and further enhances the germination of the tiller primordium (Liu *et al*., 2011). So as N has effect in increasing cytokinin it may be increase effective tiller.

Combined effect of different levels of vermicompost, biochar and nitrogen showed significant differences on effective tillers pot^{-1} (Table 6). The highest number of effective tillers pot^{-1} (24.12) was recorded from $Vm_3Bc_3N_2$ treatment combination, which was followed by (23.11) $Vm_2Bc_3N_2$ and they were statistically similar, whereas the lowest number (14.22) was observed from $Vm_1Bc_1N_1$ treatment combination.

4.1.4 Panicle length

Panicle length of aromatic rice showed statistically significant differences due to different levels of vermicompost (Table 5). The longest panicle (25.06 cm) was found from Vm_2 and the shortest panicle (21.86 cm) was recorded from Vm_1. This might be due to the balanced supply of nutrients from vermicompost which enhanced panicle length. Kumar *et al.* (2017) reported that 100% NPK followed by vermicompost with 75% N provide the maximum panicle length 28.67 cm.

Statistically significant variation was recorded in terms of longest panicle for different levels of biochar (Table 5). The longest panicle pot^{-1} (25.85 cm) was recorded from Bc_3 the shortest panicle (21.92 cm) was found from Bc_1. Biochar decreases nutrient leaching (Laird *et al*., 2010) which may be leads to increase in panicle length. Ali *et al*. (2020) found that 60 t biochar with 27 kg N ha^{-1} provide longest panicle.

Panicle length of aromatic rice showed statistically significant differences due to different levels of nitrogen (Table 5). The longest panicle (24.53 cm) recorded from N_2 and shortest panicle length (22.51 cm) from N_1. The better nitrogen status of plant during panicle growth period might be increase in panicle length. Mannan *et al*. (2010) reported that panicle length increased with the increase of nitrogen levels upto 75 kg N ha^{-1} among different levels of nitrogen. Hasanuzzaman *et al.* (2010) also reported the enhancing of panicle length with the application of NPKS fertilizer.

Combined effect of different levels of vermicompost, biochar and nitrogen showed significant differences on panicle length (Table 6). The longest panicle (31.00 cm) was recorded from $Vm_3Bc_3N_2$ treatment combination, which was followed by $Vm_2Bc_3N_2$ (30.00 cm) and they were statistically similar, whereas the shortest panicle (18.00 cm) was observed from $Vm_1Bc_1N_1$ treatment combination. The combined use of organic and inorganic fertilizers promote panicle length because of more availability of macro as well as micro nutrients (Awan *et al*., 2011). It may be responsible in increasing in panicle length under treatment combination.

4.1.5 Filled grains panicle^{-1}

Number of filled grain per panicle of aromatic rice showed statistically significant differences due to different levels of vermicompost (Table 5). The highest number (163.39) of filled grain panicle^{-1} (163.39) was found from Vm_2 and the lowest number (141.89) was recorded from Vm_1. Higher number of filled grain may be supposed due to better flowering with adequate nutrition at maximum tillering and panicle initiation stage. Tripathi and Verma (2008) reported that vermicompost treated plots had comparatively high number of filled grains panicle^{-1} (80.3) and low percentage of floret sterility (20.7).

Table 5. Effect of vermicompost, biochar and nitrogen on yield contributing traits of aromatic rice

Treatment	Effective tillers plant^{-1} (No.)	Panicle length(cm)	Filled grains panicle^{-1} (No.)	Total grains panicle^{-1}(No)
Levels of vermicompost				
Vm_1	15.99 c	21.86 c	141.89 c	170.72 c
Vm_2	19.32 a	25.06 a	163.39 a	187.64 a
Vm_3	16.62 b	23.65 b	149.67 b	180.65 b
CV (%)	5.20	5.18	5.16	4.87
Level of significance	**	**	**	**
LSD (.05)	0.6104	0.8253	5.3055	5.9333
Levels of biochar				
Bc_1	15.733 c	21.929 c	142.69 c	172.56 b
Bc_2	16.783 b	22.800 b	150.15 b	175.61 b
Bc_3	19.433 a	25.852 a	162.11 a	190.85 a
CV (%)	5.20	5.18	5.16	4.87
Level of significance	**	**	**	**
LSD (.05)	0.6104	0.8253	5.3055	5.9333
Levels of nitrogen				
N_1	16.547 b	22.517 b	147.47 b	175.07 b
N_2	18.087 a	24.537 a	155.84 a	184.27 a
CV (%)	5.20	5.18	5.16	4.87
Level of significance	**	**	**	**
LSD (.05)	0.4984	0.6739	4.3319	4.8445

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per DMRT at .05 level of probability

Vm_1: 2.5 t ha^{-1} (18.75 g for 15 kg soil pot^{-1}) Bc_1: 2.5 t ha^{-1} (18.75 g for 15 kg soil pot^{-1}) N_1: 37 kg N ha^{-1}

Vm_2: 5 t ha^{-1} (37.5 g for 15 kg soil pot^{-1}) Bc_2: 5 t ha^{-1} (37.5 g for 15 kg soil pot^{-1}) N_2: 42kg N ha^{-1}

Vm_3: 7.5 t ha^{-1} (52.5 g for 15 kg soil pot^{-1}) Bc_3: 7.5 t ha^{-1} (52.5 g for 15 kg soil pot^{-1})

*=Significant at 5% level and **= Significant at 1% level

Table 6. Combined Effect of vermicompost, biochar and nitrogen on yield contributing traits of aromatic rice

Treatment combination	Effective tillers plant^{-1} (No.)	Panicle length(cm)	Filled grains panicle (No.)	Total grains panicle^{-1} (No.)
$Vm_1Bc_1N_1$	14.22 h	18.00 g	125.00 g	166.00 e
$Vm_1Bc_1N_2$	14.39 h	22.46 d-f	137.11 fg	167.67 de
$Vm_1Bc_2N_1$	15.99 e-g	22.88 b-f	142.21 ef	170.00 c-e
$Vm_1Bc_2N_2$	16.61 d-f	22.17 d-f	145.02 d-f	171.67 c-e
$Vm_1Bc_3N_1$	17.22 de	22.71 c-f	150.77 b-e	174.00 b-e
$Vm_1Bc_3N_2$	17.54 cd	22.96 b-f	151.21 b-e	175.00 b-e
$Vm_2Bc_1N_1$	17.89 b-d	23.16 b-e	156.22 b-d	177.00 b-e
$Vm_2Bc_1N_2$	18.01 b-d	23.79 b-e	158.33 bc	180.67 b-d
$Vm_2Bc_2N_1$	19.24 b	24.01 b-d	160.13 b	182.33 bc
$Vm_2Bc_2N_2$	18.77 bc	24.59 bc	162.32 b	183.67 bc
$Vm_2Bc_3N_1$	18.95 bc	24.82 b	163.35 b	187.33 b
$Vm_2Bc_3N_2$	23.11 a	30.00 a	180.00 a	214.87 a
$Vm_3Bc_1N_1$	15.01 gh	22.38 d-f	137.50 fg	170.00 c-e
$Vm_3Bc_1N_2$	14.88 gh	21.78 ef	142.00 ef	174.00 b-e
$Vm_3Bc_2N_1$	14.74 gh	21.06 f	145.01 d-f	175.00 b-e
$Vm_3Bc_2N_2$	15.35 f-h	22.08 d-f	146.22 c-f	171.00 c-e
$Vm_3Bc_3N_1$	15.66 f-h	23.61 b-e	147.01 c-f	174.00 b-e
$Vm_3Bc_3N_2$	24.12 a	31.00 a	180.30 a	219.92 a
CV (%)	5.20	5.18	5.16	4.87
Level of significance	**	**	*	*
LSD (0.05)	1.4952	2.0216	12.996	14.534
Vm×Bc	**	**	NS	NS
Vm×N	**	NS	NS	NS
Bc×N	**	**	*	**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per DMRT at .05 level of probability

Vm_1: 2.5 t ha^{-1} (18.75 g for 15 kg soil pot^{-1}) Bc_1: 2.5 t ha^{-1} (18.75 g for 15 kg soil pot^{-1}) N_1: 37 kg N ha^{-1}

Vm_2: 5 t ha^{-1} (37.5 g for 15 kg soil pot^{-1}) Bc_2: 5 t ha^{-1} (37.5 g for 15 kg soil pot^{-1}) N_2: 42kg N ha^{-1}

Vm_3: 7.5 t ha^{-1} (52.5 g for 15 kg soil pot^{-1}) Bc_3: 7.5 t ha^{-1} (52.5 g for 15 kg soil pot^{-1})

*=Significant at 5% level and **= Significant at 1% level

Statistically significant variation was recorded in terms of number of filled grain panicle^{-1} for different levels of biochar (Table 5). The highest number of filled grain panicle^{-1} (162.11) was recorded from Bc_3 and the lowest number (142.69) was found from Bc_1. High temperatures significantly reduced spike fertility, pollen fertility, anther dehiscence and pollen germination rates in two rice cultivars (Fahad *et al.*, 2015) and biochar amendments is an effective way to reduce the heat stress which may be increase the filled grain panicle^{-1}. Kartika *et al*., (2018) reported that 3 t ha^{-1} biochar significantly increased number of filled spikelet.

Number of filled grain panicle^{-1} of aromatic rice showed statistically significant differences due to different levels of nitrogen (Table 5). The highest number of filled grain panicle^{-1} (155.84) recorded from N_2 and lowest number of filled grain panicle^{-1} (147.47) from N_1. The increase in filled grain panicle^{-1} with the increase of nitrogen level might be due to the role of nitrogen in increasing photosynthetic efficiency as well as translocated assimilates (Ebaid and Ghanem , 2001). Uday and Khan (2021) reported that nitrogen 110 kg ha^{-1} + basmati 1121 recorded highest number of filled grains panicle^{-1} (141.90).

Combined effect of different levels of vermicompost, biochar and nitrogen showed significant differences on filled grain panicle^{-1} (Table 6). The highest number of filled grain panicle^{-1} (180.30) was recorded from $Vm_3Bc_3N_2$ treatment combination, which was followed by $Vm_2Bc_3N_2$ (180.00) and they were statistically similar, whereas the lowest number of filled grain panicle^{-1} (125.00) was observed from $Vm_1Bc_1N_1$ treatment combination. Vermicompost along with urea application leads to fast release of nitrogen in comparison with other manure which may be responsible for this higher filled grain in combination.

4.1.6 Total number of grains panicle^{-1}

Total number of grains panicle^{-1} of aromatic rice showed statistically significant differences due to different levels of vermicompost (Table 5). The highest total number of grains panicle^{-1} (187.64) was found from Vm_2 and the lowest number (170.72) was recorded from Vm_1. Vermicompost enhances the availability of nutrient in soil which may be leads to higher total grain number in aromatic rice. Yadav *et al*. (2021) found that among all the treatments, application of 100% NPK+25% vermicompost (T_9) registered highest number of total grain panicle^{-1}.

Statistically significant variation was recorded in terms of total grains panicle^{-1} for different levels of biochar (Table 1). The highest number of total grains panicle^{-1} (190.85) was recorded from Bc_3 and the lowest number (172.56) was found from Bc_1 which was statistically similar with Bc_2 (175.61). High temperatures significantly reduced spike fertility, pollen fertility, anther dehiscence and pollen germination rates in two rice cultivars (Fahad *et al*., 2015) and biochar amendments is an effective way to reduce the heat stress which may be increase the total grain number panicle^{-1}. Huang *et al*. (2018) reported that continuous application of biochar increase total number of grain panicle^{-1} as well as grain yield.

Total grain panicle^{-1} of aromatic rice showed statistically significant differences due to different levels of nitrogen (Table 5). The highest number of total grain panicle^{-1} (184.27) recorded from N_2 and lowest number of total grain panicle^{-1} (175.07) from N_1. N acts as a signaling element in plant that affects expression of numerous genes, regulates process of nitrogen assimilation, rate of photosynthesis, carbohydrate metabolism, antioxidant systems, the cell cycle, etc., So the presence of higher N in plants increase the rate of photosynthesis and other cell cycle which may leads to higher total grain panicle^{-1}. Hirzel *et al*. (2011) reported that with higher N rates the total number of grain panicle^{-1} increased.

Combined effect of different levels of vermicompost, biochar and nitrogen showed significant differences on total number of grain panicle^{-1} (Table 6). The highest number of total grain panicle^{-1} (219.92) was recorded from $Vm_3Bc_3N_2$ treatment combination, which was followed by $Vm_2Bc_3N_2$ (214.87) and they were statistically similar, whereas the lowest number (166.00) was observed from $Vm_1Bc_1N_1$ treatment combination.

4.1.7 Grain yield pot^{-1}

Grain yield pot^{-1} of aromatic rice showed statistically significant differences due to different levels of vermicompost (Table 7). The highest grain yield (53.71 g) was found from Vm_2 which was statistically similar (52.67 g) to Vm_3 while the lowest number (43.10 g) was recorded from Vm_1. Mahmud *et al*. (2016) stated that, the highest grain yield was obtained from the combination of 4 t ha^{-1} vermicompost with 100 kg ha^{-1} N, 16 kg ha^{-1} P, 66 kg ha^{-1} K, 12 kg ha^{-1} S.

Statistically significant variation was recorded in terms of grain yield pot^{-1} for different levels of biochar (Table 7). The highest grain yield (54.42 g) was recorded from Bc_3. The lowest (46.67 g) was found from Bc_1 and which was statistically similar (48.39 g) with Bc_2. From the previous research it was reported that biochar has the ability to improve soil nutrient status, improve water retention, encourage carbon sequestration, increase cation exchange capacity, decrease nitrogen leaching and able to reduce toxicity in contaminated soils (Islami *et al*., 2011; Feng *et al*., 2012; Shaheen *et al*., 2015; Powlson *et al*., 2011). All of them are positively affect on rice yield. Chen *et al*. (2021) found that the rice yield with biochar addition (20 and 40 t ha^{-1}) was 15.53% and 24.43% higher than that of non-biochar addition.

Grain yield pot^{-1} of aromatic rice showed statistically significant differences due to different levels of nitrogen (Table 7). The highest grain yield plant^{-1} (51.329 g) was recorded from N_2 and the lowest grain yield plant^{-1} (48.330 g) recorded from N_1. Ullah *et al.* (2018) stated that biochar addition increases soil available phosphorus (P), extractable zinc (Zn), iron (Fe), copper (Cu), and manganese. The more availability of nutrient in soil leads to better growth and yield of rice. Devi and Sumathi (2011) conducted an experiment and found that plant height was greatest at 175 kg N ha^{-1} but yield increased with the increase in the rate N rate only up to 150 kg ha^{-1}.

Combined effect of different levels of vermicompost, biochar and nitrogen showed significant differences on grain yield (Table 8). The highest grain yield plant^{-1} (65.217 g) was recorded from $Vm_3Bc_3N_2$ treatment combination, which was followed by $Vm_2Bc_3N_2$ (64.607 g) and they were statistically similar, whereas the lowest grain yield plant^{-1} (41.497 g) was observed from $Vm_1Bc_1N_1$ treatment combination.

Table 7. Effect of vermicompost, biochar and nitrogen on grain yield and quality of aromatic rice

Treatment	Grain yield (g $plant^{-1}$)	Weight of 1000-grain(g)	Protein content (%)	Grain-2AP (µg g^{-1})
Levels of vermicompost				
Vm_1	43.10 b	20.26 b	7.801 c	0.633 c
Vm_2	53.71 a	23.03 a	8.865 a	1.164 a
Vm_3	52.67 a	21.00 b	8.293 b	0.918 b
CV (%)	5.95	5.17	4.14	5.44
Level of significance	**	**	**	**
LSD (.05)	2.0069	0.7502	0.2335	0.0334
Levels of biochar				
Bc_1	46.67 b	20.42 b	7.740 c	0.697 c
Bc_2	48.39 b	20.95 b	8.153 b	0.899 b
Bc_3	54.42 a	22.91 a	9.066 a	1.119 a
CV (%)	5.95	5.17	4.14	5.44
Level of significance	**	**	**	**
LSD (.05)	2.0069	0.7502	0.2335	0.0334
Levels of nitrogen				
N_1	48.33 b	20.93 b	7.933 b	0.978 a
N_2	51.32 a	21.93 a	8.706 a	0.832 b
CV (%)	5.95	5.17	4.14	5.44
Level of significance	**	**	**	**
LSD (.05)	1.6386	0.6125	0.1907	0.0273

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per DMRT at .05 level of probability

Vm_1: 2.5 t ha^{-1} (18.75 g for 15 kg soil pot^{-1}) Bc_1: 2.5 t ha^{-1} (18.75 g for 15 kg soil pot^{-1}) N_1: 37 kg N ha^{-1}

Vm_2: 5 t ha^{-1} (37.5 g for 15 kg soil pot^{-1}) Bc_2: 5 t ha^{-1} (37.5 g for 15 kg soil pot^{-1}) N_2: 42 kg N ha^{-1}

Vm_3: 7.5 t ha^{-1} (52.5 g for 15 kg soil pot^{-1}) Bc_3: 7.5 t ha^{-1} (52.5 g for 15 kg soil pot^{-1})

*=Significant at 5% level and **= Significant at 1% level

Table 8. Combined effect of vermicompost, biochar and nitrogen on grain yield and quality of aromatic rice

Treatment combination	Grain yield (g $plant^{-1}$)	Weight of 1000-grain (g)	Protein content (%)	Grain-2AP (µg g^{-1})
$Vm_1Bc_1N_1$	41.49 g	19.22 fg	7.06 i	0.392 i
$Vm_1Bc_1N_2$	42.21 fg	19.54 e-g	7.39 hi	0.341 i
$Vm_1Bc_2N_1$	42.97 fg	20.11 e-g	7.88 f-h	0.739 f-h
$Vm_1Bc_2N_2$	43.55 fg	20.52 d-g	8.25 c-f	0.753 f-h
$Vm_1Bc_3N_1$	43.80 fg	20.87 c-f	7.75 f-h	0.888 de
$Vm_1Bc_3N_2$	44.54 e-g	21.33 b-e	8.48 b-e	0.689 h
$Vm_2Bc_1N_1$	46.76 d-f	22.05 b-d	8.89 b	0.901 d
$Vm_2Bc_1N_2$	49.20 c-e	21.99 b-d	8.01 d-g	0.873 de
$Vm_2Bc_2N_1$	50.23 cd	22.54 bc	8.22 c-f	1.219 bc
$Vm_2Bc_2N_2$	52.22 c	22.78 b	8.57 b-d	1.205 c
$Vm_2Bc_3N_1$	59.26 b	23.01 b	8.61 bc	1.501 a
$Vm_2Bc_3N_2$	64.60 a	25.80 a	10.89 a	1.288 b
$Vm_3Bc_1N_1$	50.09 cd	20.75 c-g	7.34 hi	0.899 de
$Vm_3Bc_1N_2$	50.27 cd	19.01 g	7.75 f-h	0.778 fg
$Vm_3Bc_2N_1$	51.23 cd	19.77 e-g	8.01 d-g	0.731 gh
$Vm_3Bc_2N_2$	50.10 cd	20.01 e-g	7.99 e-g	0.750 f-h
$Vm_3Bc_3N_1$	49.08 c-e	20.11 e-g	7.64 gh	1.533 a
$Vm_3Bc_3N_2$	65.21 a	26.37 a	11.03 a	0.819 ef
CV (%)	5.95	5.17	4.14	5.44
Level of significance	**	**	**	**
LSD (.05)	4.9158	1.8376	0.5720	0.0818
Vm×Bc	**	NS	**	**
Vm×N	NS	NS	**	**
Bc×N	**	**	**	**

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per DMRT at .05 level of probability

Vm_1: 2.5 t ha^{-1} (18.75 g for 15 kg soil pot^{-1}) Bc_1: 2.5 t ha^{-1} (18.75 g for 15 kg soil pot^{-1}) N_1: 37 kg N ha^{-1}

Vm_2: 5 t ha^{-1} (37.5 g for 15 kg soil pot^{-1}) Bc_2: 5 t ha^{-1} (37.5 g for 15 kg soil pot^{-1}) N_2: 42 kg N ha^{-1}

Vm_3: 7.5 t ha^{-1} (52.5 g for 15 kg soil pot^{-1}) Bc_3: 7.5 t ha^{-1} (52.5 g for 15 kg soil pot^{-1})

*=Significant at 5% level and   **= Significant at 1% level

4.1.8 1000-grain weight

1000 grain weight of aromatic rice showed statistically significant differences due to different levels of vermicompost (Table 7). The highest weight (23.03 g) was found from Vm_2 which was statistically similar (21.00 g) to Vm_3 while the lowest number (20.26 g) was recorded from Vm_1. Vermicompost stimulates plant growth possibly through supplying nutrients and increasing chlorophyll which improves photosynthesis or through having such plant growth hormones as auxin and cytokinin (Ievinsh, 2011). As higher chlorophyll content enhances photosynthesis rate and carbohydrate production, which in turn increases 1000–grain weight (Xu *et al*., 2008; Tejada and González, 2009). Pontillas *et al*. (2009) stated that a slightly heavier grains or paddy was found in the application of the half inorganic and 1 t vermicompost in all cropping seasons with 29.9 and 30.3 g, respectively than other treatments.

Statistically significant variation was recorded in terms of 1000 grain weight for different levels of biochar (Table 7). The highest weight of 1000 grain weight (22.91 g) recorded from Bc_3 and the lowest weight (20.42 g) recorded from Bc_1 and which was statistically similar with Bc_2. Oladele *et al*. (2019) observed that biochar × N-fertilizer interaction significantly ($p < 0.05$) enhanced rain-fed rice yield and yield components such 1000 grain weight (g) by 16% when compared to the control.

Thousand grains weight of aromatic rice showed statistically significant differences due to different levels of nitrogen (Table 7). The highest weight of 1000 grain (21.93 g) was recorded from N_2 and the lowest weight (20.93 g) recorded from N_1. Pramanik and Bera (2013) reported that among different levels of nitrogen (N_0, N_{50}, N_{100}, N_{150} and N_{200} kg ha^{-1}), nitrogen levels N_{200} kg ha^{-1} gave significant higher plant height, panicle initiation, number of tillers $hill^{-1}$, total chlorophyll content, panicle length and straw yield but nitrogen levels N_{150} kg ha^{-1} gave significant higher 1000 grain weight.

Combined effect of different levels of vermicompost, biochar and nitrogen showed significant differences in 1000 grain weight (Table 8). The highest weight of 1000 grain (26.37 g) was recorded from $Vm_3Bc_3N_2$ treatment combination, which was followed by $Vm_2Bc_3N_2$ (25.80 g) and they were statistically similar, whereas the lowest weight (19.22 g) was observed from $Vm_1Bc_1N_1$ treatment combination.

4.1.9 Protein content in rice grain

Protein% of aromatic rice grain showed statistically significant differences due to different levels of vermicompost (Table 7). The highest protein content (8.865%) was found from Vm_2 and the lowest protein content (7.801%) was recorded from Vm_1. Ashrafi Esfahani *et al*. (2019) reported that the most grain nitrogen content, grain nitrogen uptake, protein content, and protein yield were observed with 100% recommended NPK applied with 10 t of rotted manure and eight t of vermicompost usage ha^{-1}. Organic manures acting as slow release source of N are expected to more closely match with N and also improved the nutrient use efficiency particularly of nitrogen (Becker *et al*., 1994). So the accumulation of protein in grain under adequate N supply might be accounted to continuous availability of nitrogen for protein synthesis.

Statistically significant variation was recorded in terms of protein percentage of aromatic rice grain for different levels of biochar (Table 7). The highest protein content (9.0667%) was recorded from Bc_3 and the lowest protein content (7.7400%) was found from Bc_1. The possible reason of increasing quality traits in noodle rice by biochar is due to slow release and consistent availability of essential plant nutrients during the entire growing period (Huang *et al*., 2013). Protein percentage in grain increased may be for slow realease and consistent availability of essential plant nutrient from biochar. Ali *et al*. (2020) demonstrated that the combination of biochar (60 t ha^{-1}) and N (360 kg N ha^{-1}) significantly improved soil physiochemical properties improved rice quality by enhancing protein content in rice grain.

Protein percentage of aromatic rice grain showed statistically significant differences due to different levels of nitrogen (Table 7). The highest protein content in grain (8.706%) was recorded from N_2 and the lowest protein content (7.933%) from N_1. N fertilization may enhance the nutritional quality of rice grain by increasing the glutenin content, which is rich in lysine. Anatomical sections showed that there was more storage protein accumulated in the lateral regions of polished grain of high N concentration than in grain of low N concentration. Chandel *et al*. (2010) reported that the brown rice grain protein content (GPC) increased significantly (1.1% to 7.0%) under higher nitrogen fertilizer application (120 kg hm^{-2})

Combined effect of different levels of vermicompost, biochar and nitrogen showed significant differences on protein content in rice grain (Table 8). The highest protein content in grain (11.03%) was recorded from $Vm_3Bc_3N_2$ treatment combination, which was followed by $Vm_2Bc_3N_2$ (10.89%) and they were statistically similar, whereas the lowest protein content (7.06%) was observed from $Vm_1Bc_1N_1$ treatment combination.

4.1.10 Grain 2-AP content

2-AP content of aromatic rice grain showed statistically significant differences due to different levels of vermicompost (Table 7). The highest grain 2-AP (1.164 µg g^{-1}) was found from Vm_2 and the lowest grain 2-AP (0.633 µg g^{-1}) was recorded from Vm_1.Ruan *et al*. (2021) reported that application of vermicompost significantly increased 2-acetyl-1-pyrroline (2-AP, the key compound of fragrant rice aroma) content of fragnant rice seedling.

Statistically significant variation was recorded in terms of 2-AP content of aromatic rice grain for different levels of biochar (Table 7). The highest grain 2-AP (1.119 µg g^{-1}) was recorded from Bc_3 and the lowest grain 2-AP (0.697 µg g^{-1}) was found from Bc_1.

2-AP content of aromatic rice grain showed statistically significant differences due to different levels of nitrogen (Table 7).The highest grain 2-AP of grain (0.9781 µg g^{-1}) recorded from N_1 and the lowest grain 2-AP (0.8329 µg g^{-1}) from N_2. Mannan *et al.* (2009) reported that aroma was slightly higher at the lower level of N (below 50 kg N ha^{-1}).

Combined effect of different levels of vermicompost, biochar and nitrogen showed significant differences on 2-AP content in rice grain (Table 8). The highest 2-AP (1.5330 µg g^{-1}) was recorded from $Vm_3Bc_3N_1$ treatment combination, which was followed by $Vm_2Bc_3N_1$ (1.5010 µg g^{-1}) and they were statistically similar, whereas the lowest 2-AP (0.3410 µg g^{-1}) was observed from $Vm_1Bc_1N_1$ treatment combination.

CHAPTER V

SUMMARY AND CONCLUSION

The study was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from July to December 2019 to assess the response of vermicompost and biochar on yield and quality of fragrant rice (BRRI dhan80) through minimization of nitrogen. The experiment consisted of three factors: Factor A: Levels of vermicompost (3 levels) as-Vm_1: 2.5 t ha^{-1},Vm_2: 5 t ha^{-1}, Vm_3: 7.5 ton ha^{-1} ; Factor B: Levels of biochar (3 levels) as- Bc_1: 2.5 t ha^{-1}, Bc_2: 5 t ha^{-1}, Bc_3: 7.5 t ha^{-1}; and Factor C: Levels of nitrogen (2 levels) as-N_1: 37 kg N ha^{-1} and N_2: 42 kg N ha^{-1} (recommended dose). The three factors experiment was laid out in randomized complete block design with three replications. Data were recorded on growth and yield contributing characters, yield and quality of scented rice and statistically significant variation was revealed for most of the studied characters for different treatments and their interaction effect.

In case of different levels of vermicompost, at 20, 40, 60, 80 DAT and at harvest, the tallest plant (61.033, 76.017, 102.67, 119.97 and 126.48 cm, respectively) was found from Vm_2 and the shortest plant (56.267, 71.217, 97.75, 115.85 and 121.12 cm, respectively) was recorded from Vm_1. At 20, 40, 60, 80 DAT and at harvest, the highest tiller number $plant^{-1}$ (17.600, 32.950, 36.367, 36.733 and 27.122, respectively) were found from Vm_2 while the lowest tiller number $plant^{-1}$ (15.072, 28.817, 33.183, 33.238 and 23.705, respectively) were recorded from Vm_1. The highest number of effective tillers pot^{-1} (19.328) was found from Vm_2 and the lowest number (15.995) was recorded from Vm_1. The longest panicle (25.065 cm) was found from Vm_2 and the shortest panicle (21.864 cm) was recorded from Vm_1. The highest number of filled grains $panicle^{-1}$ (163.39) was found from Vm_2 and the lowest number of filled grains $panicle^{-1}$ (141.89) was recorded from Vm_1. The highest total number of grains $panicle^{-1}$ (187.64) was found from Vm_2 and the lowest number (170.72) was recorded from Vm_1. The highest grain yield $plant^{-1}$ (53.718 g) was found from Vm_2 while the lowest grain yield $plant^{-1}$ (43.100 g) was recorded from Vm_1. The highest weight of 1000 grain (23.031 g) was found from Vm_2 which was while the lowest weight of 1000 grain (20.267 g) was recorded from Vm_1. The highest protein content (8.8650%) was found from Vm_2 and the lowest protein content (7.8017%) was recorded from Vm_1.The highest grain 2-AP

(1.1645 µg g $^{-1}$) was found from Vm_2 and the lowest grain 2-AP (0.6337 µg g $^{-1}$) was recorded from Vm_1.

For different levels of biochar, at 20, 40, 60, 80 DAT and harvest, the tallest plant (61.533, 77.250, 103.78, 121.23 and 127.88 cm, respectively) was found from Bc_3. and the shortest plant (56.800, 71.833, 98.35, 115.82 and 121.23 cm, respectively) was recorded from Bc_1. At 20, 40, 60, 80 DAT and at harvest, the highest tiller number plant^{-1} (17.724, 32.988, 36.328, 36.422 and 27.237, respectively) was found from Bc_3 while the lowest tiller number plant^{-1} (15.722, 30.288, 33.717, 34.583 and 24.689, respectively) was recorded from Bc_1. The highest number of effective tillers pot^{-1} (19.433) was recorded from Bc_3 and the lowest number (15.733) was found from Bc_1. The longest panicle pot^{-1} (25.852 cm) was recorded from Bc_3 while the shortest panicle (21.929 cm) was found from Bc_1. The highest number of filled grains panicle^{-1} (162.11) was recorded from Bc_3 and the lowest number (142.69) was found from Bc_1. The highest number of total number of grains panicle^{-1} (190.85) was recorded from Bc_3 and the lowest number (172.56) was found from Bc_1. The highest grain yield plant^{-1} (54.422 g) was recorded from Bc_3 and the lowest grain yield plant^{-1} (46.677 g) was found from Bc_1.The highest weight of 1000 grain weight (22.918 g) was recorded from Bc_3 and the lowest 1000 grain weight (20.429 g) recorded from Bc_1. The highest protein content of rice grain (9.0667%) was recorded from Bc_3 and the lowest protein content (7.7400%) was found from Bc_1. The highest grain 2-AP (1.1197 µg g $^{-1}$) was recorded from Bc_3 and the lowest grain 2-AP (0.6973 µg g $^{-1}$) was found from Bc_1.

In case of different levels of nitrogen, at 20, 40, 60, 80 DAT and at harvest, the tallest plant (59.911, 75.467, 102.17, 119.43 and 125.68 cm, respectively) was found from N_2 while the shortest plant (57.489, 72.644, 98.70, 116.33 and 121.97 cm, respectively) was recorded from N_1. At 20, 40, 60, 80 DAT and at harvest, the highest tiller number plant^{-1} (17.056, 32.107, 35.489, 35.698 and 26.393, respectively) was found from N_2 while the lowest tillers number plant^{-1} (16.190, 31.026, 34.197, 34.903 and 25.229, respectively) was recorded from N_1. The highest number of effective tillers pot^{-1} (18.087) recorded from N_2 and lowest number (16.547) from N_1. The longest panicle (24.537cm) recorded from N_2 and shortest (22.517 cm) from N_1. The highest number of filled grains panicle^{-1} (155.84) recorded from N_2 and lowest number of filled grains panicle^{-1} (147.47) from N_1. The highest number of total grains panicle^{-1} (184.27) of recorded from N_2 and lowest number of total grains panicle^{-1} (175.07) from N_1. The highest grain yield plant^{-1} (51.329 g) was recorded from N_2 and the lowest grain yield plant^{-1} (48.330 g) recorded from N_1. The highest weight of 1000 grain (21.931 g) was recorded from N_2 and the lowest weight (20.938 g) recorded from N_1. The highest protein content in grain (8.7067%) was recorded from N_2 and the lowest protein content (7.9333%) from N_1. The highest grain 2-AP of grain (0.9781 µg g -^{1}) recorded from N_1 and the lowest grain 2-AP (0.8329 µg g -^{1}) from N_2.

Due to the combined effect of vermicompost, biochar and nitrogen, at 20, 40, 60, 80 DAT and at harvest, the tallest plant (68.100, 85.300, 113.30, 130.10 and 138.20 cm, respectively) was observed from $Vm_3Bc_3N_2$ treatment combination and the shortest plant (55.000, 72.000, 97.00, 115.00 and 120.00 cm, respectively) was observed from $Vm_1Bc_1N_1$ treatment combination the tallest plant (67.430, 85.3, 113.3, 130.10 and 138.20 cm, respectively) was observed from $Vm_3Bc_3N_2$ treatment combination, which was followed by (67.333, 85.00, 113.00, 130.00 and 138.00 cm, respectively) $Vm_2Bc_3N_2$ and they were statistically similar, and the shortest plant (58.00, 72.00, 97.00, 115.00 and 122.00 cm, respectively) was observed from $Vm_1Bc_1N_1$ tratment combination. At 20, 40, 60, 80 DAT and at harvest, the highest tiller number plant^{-1} (20.00, 36.50, 39.90, 39.00 and 30.20, respectively) was observed from $Vm_3Bc_3N_2$ treatment combination, which was followed by (19.90, 36.00, 39.80, 38.80 and 30.00, respectively) $Vm_2Bc_3N_2$ and they were statistically similar and the lowest tiller number plant^{-1} (14.00, 28.00, 32.00, 32.00 and 22.00, respectively) was observed from $Vm_1Bc_1N_1$ treatment combination. The highest number of effective tillers pot^{-1} (24.120) was recorded from $Vm_3Bc_3N_2$ treatment combination whereas the lowest number of effective tillers pot^{-1} (14.220) was observed from $Vm_1Bc_1N_1$ treatment combination. The longest panicle (31.000 cm) was recorded from $Vm_3Bc_3N_2$ treatment combination whereas the shortest panicle (18.000 cm) was observed from $Vm_1Bc_1N_1$ treatment combination. The highest number of filled grains panicle^{-1} (180.30) was recorded from $Vm_3Bc_3N_2$ treatment combination while the lowest number of filled grains panicle^{-1} (125.00) was observed from $Vm_1Bc_1N_1$ treatment combination. The highest number of total grains panicle^{-1} (219.92) was recorded from $Vm_3Bc_3N_2$ treatment combination whereas the lowest number of total grains panicle^{-1} (166.00) was observed from $Vm_1Bc_1N_1$ treatment combination. The highest grain yield plant^{-1} (65.217 g) was recorded from $Vm_3Bc_3N_2$ treatment combination and the lowest grain yield plant^{-1} (41.497 g) was observed from $Vm_1Bc_1N_1$ treatment combination. The highest weight of

1000 grain (26.375 g) was recorded from $Vm_3Bc_3N_2$ treatment combination while the lowest weight of 1000 grain (19.221 g) was observed from $Vm_1Bc_1N_1$ treatment combination. The highest protein content in grain (11.030%) was recorded from $Vm_3Bc_3N_2$ treatment combination whereas the lowest protein content in grain (7.060%) was observed from $Vm_1Bc_1N_1$ treatment combination. The highest grain 2-AP (1.5330 $\mu g\ g^{-1}$) was recorded from $Vm_3Bc_3N_1$ treatment combination and the lowest grain 2-AP (0.3410 $\mu g\ g^{-1}$) was observed from $Vm_1Bc_1N_1$ treatment combination.

From the above discussion it may be concluded that,

1) The application of vermicompost, biochar along with nitrogen and shown significant responses on grain yield and aromatic quality of fragrant rice.

2) Vermicompost 7.5 t ha^{-1} exhibited the best performance on most of the traits' studied under present experiment which was at par with 5.0 t ha^{-1}.

3) Application of biochar 7.5 t ha^{-1} also exhibited the best performance on most the traits' studied under present experiment.

4) Soil application of nitrogen 42 Kg ha^{-1} exhibited the best performance on most the yield and quality traits studied under present experiment except, in case of grain 2-AP content the application of nitrogen 37 Kg ha^{-1} performed the best one.

Recommendations:

1.The rice growers may use vermicompsot and biochar to improve the quality of rice without imparting any yield losses.

2.In further research, the researcher should take the data on soil status before and after of biochar application.

3.In further research, the researcher should take the data on soil organic matter addition from vermicompost application.

4.Finally, to validate the present findings further research should be conducted on other organic sources along with other agronomic factors in different Agro-ecological Zones (AEZ) of Bangladesh.

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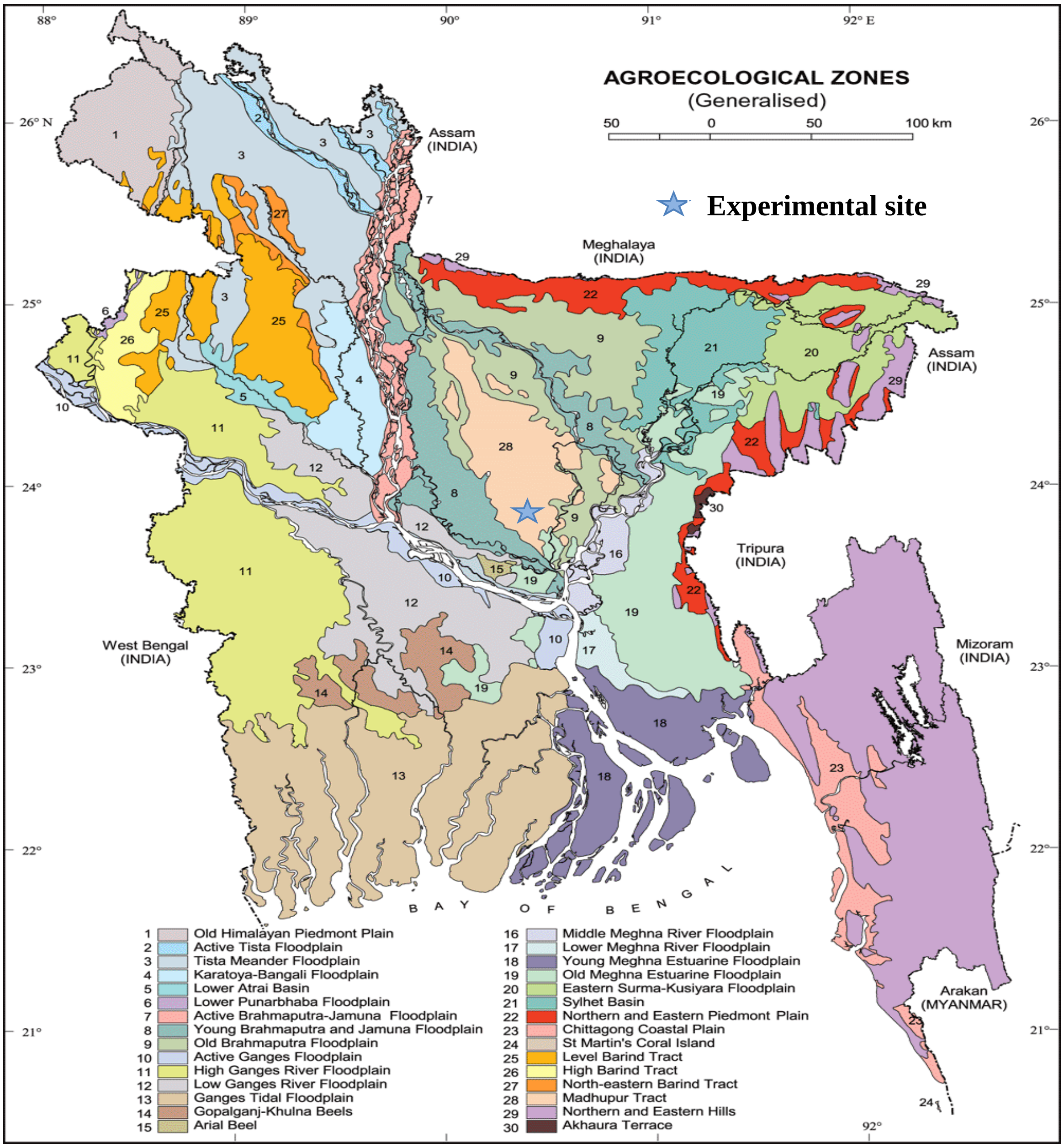
APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Weather data, 2019, Dhaka

Month	Average RH (%)	Average Temperature (ºC)		Total Rainfall (mm)	Average Sunshine hours
		Min.	Max.		
June	82	25.5	32.4	637	4.7
July	84	25.7	31.4	742	3.3
August	81	26.4	32.5	514	4.9
September	81	26.4	32.0	188	3.0
October	79	23.8	31.4	331	5.2
November	78	19.9	29.0	122	5.7
December	70	15.0	25.8	0	5.5

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1207.

Appendix III. Physiochemical properties of the initial soil

Characteristics	Value
Partical size analysis.	
% Sand	26
% Silt	45
% Clay	29
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 soil)	0.10
Available S (ppm)	45

Source: Soil Resources Development Institute (SRDI), Dhaka-1207

Appendix IV. Analysis of variance of the data on plant height at different days after transplanting (DAT) and at harvest as influenced by supplementation of vermicompost,biochar and nitrogen

Source of variation	Degrees of freedom	Mean square				
		Plant height pot^{-1} (cm) at				
		20 DAT	40 DAT	60 DAT	80 DAT	Harvest
Replication	2	0.008	0.009	0.022	0.010	0.025
Vm	2	102.380**	114.082**	111.716**	76.306**	129.632**
Bc	2	112.580**	144.792**	154.391**	154.535**	228.262**
N	1	79.207**	107.527**	162.552**	129.085**	185.927**
Vm×Bc	4	9.827**	15.879*	24.534**	24.180*	32.397*
Vm×N	2	9.947*	16.272NS	30.306**	24.234*	34.572NS
Bc×N	2	51.707**	71.762**	109.526*	112.577**	132.082**
Vm×Bc×N	4	12.919**	18.599*	30.574**	28.185*	36.227*
Error	34	1.058	1.491	4.280	3.315	6.504
Total	53					

**: Significant at 0.01 levelofsignificance; *: Significant at 0.05 level ofsignificance

Appendix V. Analysis of variance of the data on tillers number pot^{-1} at different days after transplanting (DAT) and at harvest as influenced by supplementation of vermicompost, biochar and nitrogen

Source of variation	Degrees of freedom	Mean square of				
		Number of tillers pot^{-1} at				
		20 DAT	40 DAT	60 DAT	80 DAT	Harvest
Replication	2	0.0012	0.002	0.0047	0.0015	0.0025
Vm	2	33.1961**	102.083**	45.8493**	60.3163**	61.0445**
Bc	2	18.5697**	34.385**	32.4378**	17.4098**	30.4569**
N	1	10.1114**	15.802**	22.5428**	8.5204**	18.2911**
Vm×Bc	4	0.2788**	3.107**	1.8976*	0.8330**	0.4561*
Vm×N	2	0.3805**	2.151**	2.1203*	0.0596*	0.4245*
Bc×N	2	4.8248**	4.168**	13.5378**	7.2606**	5.8398**
Vm×Bc×N	4	2.2971**	2.289**	5.9156**	2.0879**	2.5130*
Error	34	0.1065	0.424	0.8061	0.6999	0.2924
Total	53					

**: Significant at 0.01 levelofsignificance; *: Significant at 0.05 level ofsignificance

Appendix VI. Analysis of variance of the data on yield contributing traits of aromatic rice as influenced by supplementation of vermicompost, biochar and nitrogen

Sourceof variation	Degrees of freedom	Mean square of			
		Effective tillers plant^{-1} (No.)	Panicle length(cm)	Filled grains panicle^{-1} (No)	Total grains panicle^{-1}(No)
Replication	2	0.0267	0.0459	0.79	1.96
Vm	2	56.4274**	46.3251**	2133.76**	1301.40**
Bc	2	65.4450**	76.4016**	1726.00**	1729.00**
N	1	32.0166**	55.1218**	945.44**	1142.73**
Vm×Bc	4	5.8971**	11.0446**	73.37 ^{NS}	198.83^{NS}
Vm×N	2	7.9096**	1.8529^{NS}	76.28 ^{NS}	225.25^{NS}
Bc×N	2	26.0034**	18.6869**	259.28*	836.51**
Vm×Bc×N	4	8.7958**	14.9186**	185.10*	278.60*
Error	34	0.8119	1.4843	61.34	76.72
Total	53				

**: Significant at 0.01 levelofsignificance; *: Significant at 0.05 level ofsignificance

Appendix VII. Analysis of variance of the data on grain yield and quality of aromatic rice as influenced by supplementation of vermicompost, biochar and nitrogen

Sourceof variation	Degrees of freedom	Mean square of			
		Grain yield ($g\ plant^{-1}$)	Weight of 1000-grain (g)	Protein content (%)	Grain-2AP ($\mu g\ g^{-1}$)
Replication	2	0.585	0.0111	0.00431	0.00024
Vm	2	616.299**	36.8516**	5.09765**	1.27025**
Bc	2	297.905**	30.9524**	8.29520**	0.80313**
N	1	121.410**	13.2968*	8.07360**	0.28471**
Vm×Bc	4	60.380**	2.5791NS	0.96370**	0.11522**
Vm×N	2	21.807*	1.5913NS	0.81215*	0.05429**
Bc×N	2	65.923*	16.7420**	6.33060**	0.18471**
Vm×Bc×N	4	38.777*	6.5109*	1.36070**	0.03940**
Error	34	8.777	1.2264	0.11885	0.00243
Total	53				

**: Significant at 0.01 levelofsignificance; *: Significant at 0.05 level ofsignificance

List of plate

Plate 1: preparation of seed bed

Plate 2: plant growing on pot