EFFICACY OF DIFFERENT COMBINATIONS OF NITROGENOUS FERTILIZER AND VERMICOMPOST ON YIELD AND QUALITY OF AROMATIC RICE

MD. ABU HENA MOSTAFA KAMAL

DEPARTMENT OF AGRONOMY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA-1207

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BY

MD. ABU HENA MOSTAFA KAMAL

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Approved by:

Professor Dr. Tuhin Suvra Roy
Supervisor

Dr. Bimal Chandra Kundu
Principal Scientific Officer
TCRC, BARI, Joydebpur, Gazipur
Co-supervisor

Professor Dr. Md. Shahidul Islam
Chairman
Examination Committee

DEPARTMENT OF AGRONOMY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

*This is to certify that the thesis entitled '**EFFICACY OF DIFFERENT COMBINATIONS OF NITROGENOUS FERTILIZER AND VERMICOMPOST ON YIELD AND QUALITY OF AROMATIC RICE'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) IN AGRONOMY**, embodies the results of a piece of bona fide research work carried out by **MD. ABU HENA MOSTAFA KAMAL**, Registration No. **18-09225** 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 this investigation has been duly acknowledged.

Dated: June 2020
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Prof. Dr. Tuhin Suvra Roy
Supervisor

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EFFICACY OF DIFFERENT COMBINATIONS OF NITROGENOUS FERTILIZER AND VERMICOMPOST ON YIELD AND QUALITY OF AROMATIC RICE

ABSTRACT

The study was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from June to December 2019 to assess the proper combination of vermicompost and nitrogenous fertilizer on yield and grain quality of aromatic rice. Aromatic rice cultivars BRRI dhan37, BRRI dhan38, and BRRI dhan80 were used as the test crops in this experiment. This experiment consisted of two factors: Factor A: T_1: 100% N through urea, T_2: 90% N through urea + 10% N through vermicompost, T_3: 80% N through urea + 20% N through vermicompost, T_4: 70% N through urea+30% N through vermicompost, T_5: 60% N through urea + 40% N through vermicompost and Factor B: Aromatic rice variety (3 varieties) as- V_1: BRRI dhan37, V_2: BRRI dhan38, and V_3: BRRI dhan80. The two factors experiment was laid out in split-plot design with three replications. The five combinations of nitrogenous fertilizer and vermicompost were assigned in the main plot and 3 aromatic rice varieties in the sub-plot. Results exposed that different combinations of vermicompost and nitrogenous fertilizer and/or different varieties had a significant effect on most of the yield and quality contributing parameters. Effective tillers, filled grains, grain yield, protein content, proline content, and grain 2-AP content increased with an increasing rate of vermicompost level. Among the three varieties, BRRI dhan80 produced a maximum number of filled grains panicle^{-1}, 1000 grain weight, and grain yield while BRRI dhan37 produced maximum protein, proline, and 2-AP content. Among the treatment combinations, the highest number of effective tillers hill^{-1} (14.81) was found from T_5V_3 and the lowest (9.56) from the T_1V_1. The highest grain yield (4.94 t ha^{-1}) was found from T_5V_3, whereas the lowest (3.09 t ha^{-1}) was recorded from the T_1V_2. The highest protein content (12.29%) was recorded from T_5V_1 and the lowest (8.58%) was observed from the T_1V_2. The highest amylose content (24.32%) was observed from T_1V_3, while the lowest (20.04%) was found from the T_5V_2. The highest proline content (25.09mg g^{-1}) was observed from T_5V_1, while the lowest (21.44 mg g^{-1}) was found from the T_1V_2. The maximum grain 2-AP content (0.99µg g^{-1}) was recorded from T_5V_1 and the lowest (0.89 µg g^{-1}) was observed from the T_1V_1. From the 15 treatment combinations, T_5V_3 and T_4V_3 produced maximum yield however 70% N through urea+30% N through vermicompost may be used for producing maximum yield. Although T_5V_1, T_5V_2, T_5V_3 and T_4V_1 showed excellent performance when considering proline, and 2-AP content but farmer may use 70% N through urea+30% N through vermicompost for the production of good quality aromatic rice.

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CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is a vital crop under the Gramineae family and a major food that is widely consumed throughout the world in a different race, religion, and political organization (Ohajianya and Onyenweaku, 2002). Aromatic rice has gained remarkable market shares in the international rice trade for the last 15 years (Calpe, 2004). Considerably, efforts have been undertaken in many countries of the world to rise or develop the production of such kind of rice. Primarily these efforts were focused mainly on breeding programs to improve or cope with existing scented rice varieties to native conditions (FAO, 2001). Aromatic fine rice cultivation has given priority throughout the world along with coarse rice to provide local and international food demands (Bhuiyan et al.,2004). Scented rice contains 15 times more 2-acetyl- 1-pyrroline content than normal rice as 0.14 and .009 ppm respectively (Singh *et al.,* 2000). The fragrant rice has a wider demand in the market due to its test and aroma content as well as its soothing taste. As a result, the price rate becomes 2-3 times more than normal rice (Biswas *et al*., 1992). Whatever, fine and slender rice could be grown under a large range of environmental conditions and ecology (Begum *et al*.,1999). Especially the traditional fine rice is more resistant under adverse environmental conditions than the modern rice varieties. For fine and slender rice cultivation, it took fewer amounts of input materials especially nitrogenous fertilizers and water than modern coarse rice (BRRI, 2003). In most cases, the outcomes of the plant breeding techniques have been limited by two main factors. First, the improvement of aromatic rice varieties has been faced challenges by the environmental and ecological issues by genotypical interactions for fragrant rice quality. Though genotypic factors have a pivotal role to differentiate the rice aromaticity (Lorieux *et al.,* 1996; Bradbury *et al.,* 2008; Fitzgerald *et al.,* 2008), environmental issues, as well as crop growing methods, have been depicted to substantially affect the fragrant rice quality (Champagne, 2008). Fewer experiments have focused on the variability of the aromatic quality of the grain when the rice has been grown in local areas (Rohilla *et al*., 2000; Itani *et al*., 2004; Yoshihashi et al., 2004; Gay *et al*., 2006). The environmental temperature during grain filling and ripening (Itani et al., 2004), soil type (Sagar and Ali, 1993), the timing of field drying and harvest (Arai and Itani, 2000; Champagne *et al*., 2005) are few factors together with cultivation practices that affect the aromaticity of scented rice (Gay *et al.*,2010).

Bangladesh is the 3rd largest rice producer in the world with an increased output of 36 million metric tonnes. Lately, the World Agricultural Production data of the US Department of Agriculture (USDA) assessed that Bangladesh will have 36 million metric tons of paddy while Indonesia (34.9 million m ton), India (118 million m ton), and China (149 million m ton) in 2020-21 period. Production of rice has been increased by 3 times since the independence of Bangladesh. Bangladesh was in fourth place for rice production while Indonesia was in 3rd position, India was in the second position, and China first was in the world for rice production. The global rice production region is forecast to rise in 2020-21. Production of rice is up by more than 8 million tons to a new record for rice cultivation. There is a large production of rice increasing in several countries including China, Thailand, and the United States of America.

Total area in Bangladesh under aman crop has been assessed 1,38,92,398 acres 56,21,949 hectares in 2018-19 as compared to 1,40,34,504 acres 56,79,456 hectares of last year in 2017-18. The harvested area has reduced by 1.01% by 2019. The average amount of yield of aman for the financial year 2018-19 has been estimated at 2.500 metric tons per hectare which are 1.46% more than that of the last year 2017-18. In Bangladesh, the total rice production area was 28456083 acres and the total production of rice grain was 36390896 m tons in 2019(BBS,2019). The productivity and rice quality of *(Oryza sativa* L.) depend on environmental conditions and the regional agronomic management practices(Singh *et al.* 2006). Chemical, organic, and biofertilizers are the basic sources for replenishing plant nutrients in agricultural soils (Masarirambi *et al*.,2012). Continuous use of chemical fertilizers provokes to deteriorate the soil chemical, physical, and biological properties, and soil health (Mahajan *et al*., 2008). The adverse effects of chemical fertilizers, coupled with escalating prices, have led to growing interests in the use of organic fertilizers as a pivotal source of nutrients (Satyanarayana *et al*., 2002; Mahajan *et al*., 2008).

Vermicompost has been considered as a soil additive to condense the use of chemical fertilizers because it provides required nutrient in proper amounts, increases cation exchange capacity, increase the nutrient availability and improves water holding capacity (Tejada and Gonzaler,2009). Vermicompost not only increases the yield of rice but also acts as a precise substitute for chemical fertilizer to some extent (Sharma *et al*., 2008; Guera, 2010). Several research outcomes have revealed that neither inorganic fertilizers nor organic sources alone can result in sustainable crop production (Satyanarayana *et al*.,2002; Jobe, 2003). However, organic manures or any biofertilizer alone might not meet the plant requirement due to the presence of relatively low nutrients content. Organic manure application with chemical fertilizer boosts the microbial activity, upsurges nutrient use efficiency (Narwal and Chaudhary, 2006), and by enhancing the availability of the native nutrients to the plants resulting in higher nutrient uptake. Therefore, to make the soil well supplied with all the essential nutrients that are required to plant in the available form and to preserve good soil health, it is obligatory to use organic manures in combination with inorganic fertilizers to gain the best yields (Ramalakshmi *et al*., 2012). Some workers have highlighted that vermicompost may be an effectual source of plant nutrition correspondingly good to the nutrient practice efficacy of fertilizers in many crops including rice besides the enhancement in soil condition (Rani and Shrivastava, 1997).

Vermicompost can ensure organic soil modifications that are formed by a non-thermophilic procedure, where organic matter is broken down through exchanges between earthworms and microorganisms, through the aerobic conditions. During vermicomposting the nutrients are caused and turned into solvable and obtainable forms (Ndegwa and Thompson, 2001) that’s providing nutrients such as presented N, soluble K, transferrable Ca, Mg, P, and microelements such as Fe, Mo, Zn, and Cu (Amir and Fouzia, 2011) which can simply yield up by plants. Sugar factory leftover byproduct (Lakshmi and Vijayalakshmi, 2000), horticultural scums (Edwards 1988), agricultural residues (Bansal and Kapoor 2000), livestock’s dung (Gunadi *et al*. 2002), and weeds (Gajalakshmi *et al.* 2001) could all be transformed into good worth vermicompost with a reasonable value of NPK. Vermicompost has much greater microbial biodiversity and action than conformist thermophilic composts (Edwards *et al.*, 1998; Edwards 2004). Microbes present in the gut wall of earthworm accountable for the biochemical dilapidation of organic substances and altered it into vermicompost. Vermicompost encompasses plant growth controllers and other plant growth manipulating materials formed by microbes (Grappelli *et al*., 1987) including humates (Atiyeh *et al*., 2000), cytokinins, and auxins (Krishnamoorthy and Vajrabhiah, 1986). In agriculture soil treated with vermicompost exhibited better plant growth than treated with mineral fertilizers or cattle dung (Subler *et al*.1998). Adding vermicompost to soil expands the chemical and biological assets (Purakeyastha and Bhatnagar, 1997), expand the soil structure, increasing the water holding volume, and penetrability (Parthasarathi et al., 2008). Vermicompost contains 2.1-2.6% nitrogen, 1.5-1.7% phosphorus and 1.4-1.6% potassium respectively (Rana and Surinder,2018).

Lately, organic farming has kept the mind of organizers, gardeners, researchers, dealers, and administrators in relevance to sustainable agriculture including altering situations of agriculture on looking at the trend of world business organizations. In rice-based zones, organically produced aromatic rice has a better opportunity to make higher pecuniary values through the native market as well as export. But the productivity of organically grown rice envisions to be less than that of the rice grown with the use of improved production technologies including agrochemicals viz, fertilizers, herbicides, and pesticides. Though our ancient agriculture was nature-based farming which was almost closer to modern organic farming, systematic information was not well documented in these aspects in the past. A large number of natural sources of plant nourishments were used for improving the soil fertility to harvest the good quality outputs of crops in the past. Green manuring and decomposed animal waste application and crop wastes as organic manures were normally utilized for plant-nutrition since a very initial time. Later on, the exercise of oilcake and different biofertilizers has been also considering for agriculture. These natural properties of plant nutrition can provide almost all essential elements in very inadequate quantity and the obtainability of nutrient elements is also very sluggish. They are needed to apply in enormous amounts to encounter the need for crops.

Hence, the practice of fertilizers has been extensively acknowledged for plant nutrition by the farmers which are now looking hard to continue in the future. Vermicomposting of numerous biodegradable organic sources has been presented which is supportive of the swift production of organic manures with greater quality. Vermicompost is sanitary without unpleasant odor and they are rich in nutrient elements with rigorous concentration microbes. Cultivation of scented rice under organic farming situations seems one of the lucrative cropping systems in rice-based zones because of its high market value in the resident markets and global market. Therefore, it is imperative to judge the ability of vermicompost to substitute certain amounts of chemical fertilizers to be applied in aromatic rice without foregoing the yields.

By considering these views, the present study entitled, "Efficacy of Different Combinations of Nitrogenous Fertilizer and Vermicompost on Yield and Quality of Aromatic Rice " has been conducted with the following objectives:

- To study the effects of different combinations of nitrogenous fertilizer and vermicompost on yield and grain quality of aromatic rice.
- To find out the suitable combination for producing good quality aromatic rice.

CHAPTER II

Review of Literature

Rice has outstanding flexibility to diverse environmental conditions as is obvious from its universal dispersal. Several scientists at home and overseas studied various aspects of fruitful rice production. Nitrogenous fertilizer is one of the key elements which significantly influences the vegetative growth and development as well as the yield of rice. The judicious application of nitrogenous fertilizer along with vermicompost is a key factor in a rice-based production system which can increase yield and quality of rice. Different rice varieties are developed by BRRI, BINA, and IRRI both aromatic and non-aromatic. Several scientists reported the effects of nitrogenous fertilizer along with vermicompost on yield attributes and yield of both aromatic and non-aromatic rice but these findings are not adequate and conclusive for the agro-climatic condition of Bangladesh. An effort was taken to review the available vital and useful research conclusions that are related to nitrogenous fertilizer on yield and yield attributes of both aromatic and non-aromatic rice have been reviewed under the following headings:

2.1.1 Effect of different amounts of vermicompost and inorganic fertilizers on growth, yield, and yield quality of crops.

These experiments were conducted in three replicates, with two local rice cultivars in North Iran, in 2016. Esfahani *et al.* (2018) concluded that by the integrated consumption of mineral and biological fertilizers, farmers can significantly reduce the impacts of chemical fertilizers on the environment, and improve the qualitative and the quantitative parameters of rice cultivars with biological fertilizers.

Guosheng *et al*. (2015) revealed that applying vermicompost leach liquor after the blooming stage is an effective method to improve varietal characteristics, grain weight, yield, and quality. According to the results, vermicompost leach liquor reduced average grain number by 2.1%, significantly increased 1000-grain weight by 15.2%, enhanced grain weight and grain yield by 6.4% and 4.3%, improved grain starch content, protein content, and wet gluten content by 1.5%, 1.4%, and 2.3%, respectively and declined moisture content by 12.3%.

An experiment at Varanasi revealed that the ability of vermicompost for replacing a particular proportion of the urea fertilizer provided to rice, Rani and Srivastava (1997) stressed that application of one-third or one-quarter of N as vermicompost and remaining N with fertilizer urea improved the plant height, grain yield and yield components of rice when compared with N fertilizer alone.

Dry matter production and uptake of most-major nutrient elements (N, P, K, and Mg) were highest in rice cv. RTN-1 with 75 kg N/ha as urea plus 25 kg N as vermicompost among all nutrient management mentioned at Dapoli in Maharashtra(Jadhav *et al.*,1997).

An experiment was conducted by Vasanthi and Kumaraswamy (1999) where they revealed that the application of 5 and 10 t vermicompost/ha along with N, P, and K at the recommended rate gave significantly higher grain yields of rice in the treatments that received vermicompost plus N, P and K at a recommended rate than in the treatment that received N, P, and K alone at Madurai (T.N).

A study that was related to the response of scented rice cv Pusa Basmati-1 to different levels of NPK fertilizers (100:50:50, 125:62.5:62.5 and 150:75:75 kg/ha), vermicompost (0 and 5 t/ha), and growth regulator (triacontanol, at 0, 250 and 500 mI/ha) at Siruguppa, (Karnataka), Murali and Setty (2000) revealed that fragrant rice significantly responded to rates of vermicompost. Application of 5 t vermicompost/ha gives rise to potentially higher yield (4889 kg/ha) compared to no vermicompost application.

Based on the direct and residual effect of different sources of organic N with fertilizer N and biofertilizers in rice-legume crop sequence at Anamalai Nagar (T.N), Jeyabal and Kuppuswamy (2001) stressed that application of 50% N through vermicompost + 50% via fertilizer N and _biofertilizers led to higher grain yield for rice and legume and these yields were higher than those obtained with the application of N through the other combinations.

A field experiment was conducted by Nehra *et al.* (2001) on wheat at Hisar; Haryana, which consisted of 6 organic manure treatments. (no organic manure, farmyard manure at 15 tonnes, vermicompost at 10 and 15 tonnes, press mud at 2.5 and 5 tonnes/ha) and 5 chemical fertilizer treatments (no fertilizer, N at 60 and 120 kg/ha, N at 90 kg/ha + Azotobacter and recommended dose of 120 kg N + 60 kg P205 + 60 kg K2/ha). They reported from the results that the application of organic manures irrespective of source and rate amplified the dry matter accumulation, leaf area index, effective tillers m2, grains/panicle, grain and straw yields, photosynthesis of wheat significantly over no organic manure during two years of experimentation. The values of all these attributes were maximum with 15 t vermicompost /ha, which was significantly superior to the rest of the organic manure treatments.

A field experiment was done on rice at Bhuvaneshwar, Orissa, consisting of the treatment as full (100%) dose of vermicompost, farmyard manure (5 t/ha), and N: P: K (60:30:30 kg/ha); and combinations of 25, 50 and 75% of vermicompost and FYM with chemical fertilizers. From the results, Das *et al.* (2002) revealed that yield components increased more by the combined application of vermicompost and chemical fertilizers compared to the other treatments. The best results in terms of grain and straw yields were obtained with 50% vermicompost+50% chemical fertilizers.

Sudha and Chandini (2002) experimented and revealed that application of 105 kg N + 52.5 kg P205 + 52.5 kg K20 + 25 kg S-/ha, along with organic manures either as 10 t farmyard manure or 5 t vermicompost/ha were quite effective in the improvement of the grain yield of rice at Karamana (Kerala).

Based on the study about the effect of different integrated nutrient management systems- of green manure (sun hemp), farmyard manure (FYM), and vermicompost supplied with NPK fertilizers at 4 levels (0, 33, 66, and 100% of the recommended dose of fertilizers, RDF) on the yield of aromatic rice cv. Pusa Basmati-1 under upland direct-sown conditions in Karnataka, Kumar *et al. (2002)* exposed comparable yields with the application of either 10 t FYM /ha, 2.5 t vermicompost /ha, and 100% RDF (100:50:50 kg NPK/ ha).

Agrawal *et al, (*2003) experimented with the effects of NPK provided through various combinations of vermicompost, FYM and, chemical fertilizers (100% vermicompost or

FYM, or chemical fertilizers; 25% vermicompost+75% chemical fertilizer; 25% vermicompost+75% FYM; 50% vermicompost+50% FYM; and 75% vermicompost+25% FYM) were, studied on the growth and yield of wheat at Allahabad (U.P.). The results discovered that the application of vermicompost significantly increased biomass production and yields. Application of 75%. vermicompost*+25%* FYM resulted in the greatest plant height at 105 days after sowing (DAS), leaf number at 90 DAS, fresh weight at 90 DAS, dry weight at 105 DAS, and -number of spikelets/plant, number of seeds/spikes, test weight, grain yield/pot, and harvest index at 105 DAS.

Parthsarthi *et al.* (2003) revealed that higher grain yield with superior quality of grain (protein and sugar content in seeds) due to the application of vermicompost than with chemical fertilizers while studying the nutrient use efficiency of vermicompost on the black gram at Shivpuri (T.N.).

Prakash and Bhadoria (2003) reported that organic manure treatments on balancing with chemical fertilizers to the recommended dosage of N, P, and K favored increasing the higher dry matter production and grain yields as compared to the application of only chemical fertilizers from the results of the field experiments carried out on rice at Kharagpur (W.B.).

Singh et al. (2003) discovered that the application of FYM, vermicompost, or green manuring (GM) assisted to decrease the NPK rate by 1/3 without dropping rice and wheat yields.

The application of vermicompost alone or in -mixture with chemical fertilizers in tomato led to record better seed germination, growth parameters, and quality of products than any other treatments in Argentina. They further emphasized that vermicompost may be effectively used as a valid alternative for the traditional substitute with or without fertilizers (Rotondo *et al.*,2003).

Maximum grain yield of rice cv. Pankaj with the use of 60 kg N + 17.5 kg P + 33.3 kg K / ha at Giridih (Jharkhand) that replaced 15 kg N/ha by the substitution of vermicompost produced almost similar grain yields as obtained by the application of full N through fertilizer (Banik and Bejbaruah, 2004).

By Applying 2.8 t vermicompost + 50:50:50 kg NPK /ha; 10 t FYM + 50:50 kg NP /ha and 10 t green leaf (gliricidia) + 50:100:100 kg NPK /ha produced almost comparable grain and straw yields of rice, which were higher than the application of full NPK through fertilizers as per recommended dose (Powar, 2004).

By using 33% of recommended N through vermicompost plus 67% NPK gave almost the same grain yield of rainfed lowland rice as to those obtained with the application of 100% NPK at Imphal (Manipur), that was revealed by Singh *et al.* (2005).

According to Kathuria *et al.* (2005), the grain yield of wheat was meaningfully higher with the application of several organic manures (FYM, GM, press mud, and vermicompost) than no organic manure at Hisar (Haryana). They further added that the application of 100% NPK on a soil test basis, being at par with 120 and 160 kg N /ha, produced a significantly- higher grain yield of wheat than the control. (no fertilizer), 60 kg N/ ha and90 kg N/ha + Azatobactor.

In a field experiment on INM in rice in red and lateritic soil of Sriniketan (West Bengal), Barik et *al* (2006) seen that application of 50% recommended dose of fertilizer along with 10 t vermicompost /ha significantly enhanced the growth and yield attributes of *Kharif* rice as compared to the application of 100% RDF and thus, the INM produced significantly higher grain and straw yields than latter.

From a pearl millet-mustard cropping sequence experiment at Bawal (Haryana), Satyajeet *et al. (2006)* discovered that the grain yield was maximum with 100% recommended dose of fertilizers in conjunction with vermicompost and biofertilizers. They further added that the application of 100% recommended dose only and 75% recommended dose + vermicompost + biofertilizers provided comparable yields.

According to Alam *et al.* (2007), 10 t vermicompost/ha with NPKS (100% RDF) produced the highest growth parameters, yield attributing characters, and yields of potato in Bangladesh.

From an experiment by Singh *et -al.* (2007), the grain yield of rice cv. Pusa Basmati-1 significantly improved with the application of different organic amendments viz; 15 kg BGA or 1 t Azolla or 5 t vermicompost or 5 t FYM / ha alone or in combinations at IARI, New Delhi. They further added four organic amendments viz: BGA, Azolla, FYM, and vermicompost that could be able to give the optimum grain yield of organic basmati rice with superior grain quality. By taking their findings, Singh and Rai (2007) also stated higher grain yield of rice with 50% NPK + vermicompost or FYM or neem cake equivalent to 50% of N than those obtained with 100% NPK alone at Kanpur (U.P.). They further stressed that former treatment was more remunerative than later.

The integrated use of chemical fertilizers and vermicompost (1:1 on N basis) significantly increased the biomass and N uptake in sunflower compared to control, nitrogen alone, and vermicompost alone at Hyderabad (Sharma *et al.* (2007).

According to Das *et al.* (2008), using a 50% recommended dose of fertilizers + 2.5 t vermicompost + 5 t FYM /ha produced significantly higher fruit yield of tomato over 100% recommended dose of fertilizers only while assessing the most appropriate integrated management system.

According to Gopinath *et al.* (2008), the efficacy of organic amendments on the yield and quality of wheat and then changes in soil properties after the harvest of the crop at Almora (Uttrakhand). From the results, they revealed that the grain yield in all the treatments involving organic amendments was markedly lower for the first two years of application than with the mineral 'fertilizer treatments. They further added that the grain yield was higher with FYM treatment closely followed by vermicompost, when these were provided in the quantities equivalent to the recommended N rate.

According to Mahmud *et al.* (2016), the highest plant height, effective tillers hill^{-1}, flag leaf length, panicle length, filled grains panicle^{-1}, 1000-grain weight, grain yield, straw yield, and biological yield were 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. It was observed that yield of rice can be increased substantially with the judicious application of organic fertilizer with chemical fertilizer.

According to Kale *et al.* (1992) the results of the soil analysis after harvesting rice at that the vermicompost application enhanced the activity of selected microbes in the soil system and there was a high level of total N in the experimental plot which received more proportion of N through vermicompost.

organic carbon content and fertility status as reflected by the available status and cation exchange capacity were higher and bulk density was lower in the treatments that received vermicompost plus. N, P, and K than in the treatment with N, P and K alone in rice(Vasanthi and Kumaraswamy, 1999)

While studying the effect of enriched vermicompost on the yield and uptake of nutrient on cowpea at Vellayani (Kerala), Sailaja Kumari and Usha Kumari (2002) observed that enriched vermicompost showed its superiority over other treatments for the uptake of major nutrients like N, P, K, Ca and Mg.

According to Parthasarthi et al. (2003), the efficacy of vermicompost on the physicochemical and biological properties of the soil and yield and nutrient content of black-gram in comparison to inorganic fertilizers at Sivapuri (T.N). They stressed from the results that the application of vermicompost had a marked influence on the physicochemical and biological properties of soil. It helped to increase the pore space, WHO, OC content, available N, P, K, and microbial population in the soil, besides reduction in particle and bulk masses. On the contrary, the application of inorganic fertilizers had led to a reduction of porosity, compaction of soil, OC content, and microbial population of the soil.

Waclawowicz and Parylak (2004) revealed that the application of organic manures caused a non-significant rise in water reserves of the soil and an insignificant decline of soil density, while after using mineral nitrogen fertilization the insignificant increase of capillary capacity of the soil and water reserves of the soil. They further added that both organic manures and nitrogen fertilization improved soil chemical properties by a slight increase of N and P contents in the soil. The application of nitrogen fertilizers exaggerated the decreasing content of potassium in the soil.

Singh *et al.* (2005), highlighted that combined usage of vermicompost and inorganic fertilizers had a better build-up of soil OC and available N, P, and K after crop harvest, in rainfed rice at IARI New Delhi.

From a study to assess the relative contribution of organic fertilizers (paddy straw, microbial inoculants, and vermicompost) and inorganic fertilizers (urea and superphosphate) in improving pH, C, N, humus, microbial biomass, activities of soil under wheat crop, Gaind and Nain (2006) stressed that vermicompost fertilization resulted into maximum microbial biomass, available P and N contents in soil. They further mentioned that the application of vermicompost was quite effective in minimizing the alkalinity of soil compared to other treatments as indicated by pH change.

From the results of the experiment conducted at Almora (Uttaranchal) to find out the effect of different sources and rates of organic manures (farmyard manure, vermicompost, and poultry manure) on the yield of organically grownup garden pea along with the possible changes in the physicochemical properties of soil, Pandey *et al.* (2006) stressed that application of organic manures, irrespective of sources and rates led to record significant improvement in Physico-chemical properties of soil.

While studying the impact of organic farming on yield and quality of Basmati rice and soil properties., Singh *et al.* (2007) noted an increase in soil microbial population (Actinomycetes, Bacteria, Fungi, and BGA) due to the application of organic amendments in comparison to absolute control as well as recommended fertilizer application They again observed a significant increase in soil OC and available P contents due to organic farming practice over control as well as chemical fertilizer application.

Results of field experiment at Bhopal (M.P.) to study the effect of different manure viz; vermicompost, phosphocompost, poultry manure and cattle-dung manure vis-a-vis chemical fertilizers on the soil fertility of maize-linseed cropping system, Ramesh *et a1.*.2008 discovered that the treatment receiving vermicompost led to record the highest soil OC and available N that at the end of the cropping cycle.

2.1.2 Yield of different rice varieties

Roy (2006) observed and assessed several indica/japonica (I/J) lines was by for advanced grain yield within the Boro season. the finest grain yield of 9.2 t ha-1 was attained from hand-picked I/J line IR58565-2B-12-2-2, which was accomplished that of indica hybrid CNHR3 and considerably over that of contemporary selection IR36. A trial was administered by Alam et al. (2012) at the science Field Laboratory, Department of agronomy and Agricultural Extension, University of Rajshahi to review the impact of selection, spacing, and range of seedlings hill^{-1} on the yield potentials of transplant Aman rice. The experiment consisted of 3 high yielding varieties viz. BRRI dhan32, BRRI dhan33 and BR11, four levels of spacing, and 4 levels of a range of seedlings hill^{-1}. variety had vital effects on yield and BR11 created the best grain yield (5.92 t ha-1).

Haque and Biswash (2014) had experimented with 5 kinds of hybrid rice that was collected from totally different personal seed firms and one hybrid and 2 checks from East Pakistan Rice analysis Institute (BRRI). Varieties were Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid dhan1 and 2 checks were BRRI dhan28 and BRRI dhan29. just in case of biological yield (g), BRRI dhan29 showed the highest yield (49.6 g) and Hira solely 18 g. Bhuiyan et al. (2014) conducted an associate experiment with aimed to see the ability and performance of various hybrid rice varieties and to spot the most effective hybrid rice selection in terms of yield and suggest it to rice farmers. Findings disclosed that different hybrid rice varieties had vital effects on yield. RGBU010A × SL8R is thus counseled as planting material among hybrid rice varieties as a result of it created favorable yield.

Jisan *et al.* (2014) directed an experiment at, Bangladesh Agricultural University, Mymensingh to look at the yield performance of some transplant Aman rice varieties as influenced by totally different levels of N. The experiment consisted of 4 varieties viz. BRRI dhan49, BRRI dhan52, BRRI dhan56, BRRI dhan57, and 4 levels of N. data disclosed that the highest grain yield (5.69 t ha-1) was obtained from BRRI dhan52 followed by BRRI dhan49 (5.15 t ha-1) and also the lowest one (4.25 t ha-1) was obtained from BRRI dhan57.

Hosain *et al.* (2014) analyzed a trial in the farm of Shere-Bangla Agricultural University (SAU), capital of Bangladesh throughout Aus season (March to Gregorian calendar month 2010) to look at the impact of transplantation dates on the yield and yield attributes of exotic hybrid rice varieties. The experiment included 3 rice varieties (two hybrids-Heera2, Aloron, and one inbred- BRRI dhan48). BRRI dhan48 created the best grain yield (3.51 t ha-1). Kanfany et al. (2014) led an associate experiment at the continent Rice Sahel Regional Station throughout 2 rainy seasons to measure the performances of presented hybrid varieties alongside associate inbred check cultivar below low input plant food levels. there have been a vital variety of effects for all traits. The grain yield of rice hybrids (bred by the International Rice Research Institute) wasn't considerably over that of the check variety widely grown in the Republic of Senegal.

According to Sarkar *et al*. (2016), the performance of five hybrid rice varieties namely Shakti 2, Suborna 8, Tia, Aloron, and BRRI hybrid dhan2 in *Aman* season with an inbred BRRI dhan33 as checked. The maximum grain yield was attained from Tia (7.82 t ha^{-1}), which was closely followed by Shakti 2 (7.65 t ha^{-1}). These two hybrid varieties produced a 24.0% higher yield over the inbred BRRI dhan33.

Huang and Yan (2016) have made a research work based on 41 entries, 32 new hybrids, 8 male parents restore lines, and 1 inbred variety, at the farm of the University of Arkansas at Pine Bluff (UAPB). Outcomes showed that the yields of 7 hybrids were 25.7%-30.7% higher than check Francis. Hybrid 28s/BP23R had the highest yield, 10846.6 kg ha^{-1} and over check by 30.7%. The yield of hybrid 28s/PB-24 was 10628.9 kg ha^{-1} and over check by 28.1%. The yields of hybrid 28s/PB-22 and 33A/PB24 were 10549.8 and 10539.8 kg ha^{-1} and over check by 27.1% and 27.0%, respectively.

Chowdhury *et al*. (2016) experimented with a trial at Bangladesh Agricultural University, Mymensingh to find out the outcome of variety and level of nitrogen on the yield performance of fine aromatic rice. The experiment consisted of three varieties viz. Kalizira, Binadhan-13 and BRRI dhan34, and six levels of nitrogen. The maximum grain yield (3.33 t ha^{-1}) was found from Binadhan-13 followed by BRRI dhan34 (3.16 t ha^{-1}) and the minimum grain yield was gained by Kalizira (2.11 t ha^{-1}).

From a study carried by Sumon *et al*. (2018), the growth, yield, and proximate composition of aromatic rice varieties in Aman season at the research farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh with 3 aromatic rice varieties and 6 fertilizer levels. From the results, they suggested that 'Raniselute' variety produced the highest straw yield (7.81 t ha^{-1}), biological yield (9.05 t ha^{-1}), and 'BRRI dhan34' gave the maximum grain yield (2.26 t ha^{-1}).

According to Hossain *et al*. (2018), the outcome stated that the maximum grain yield of 3.38 t ha^{-1}, the maximum biological yield (7.87 t ha^{-1}), and harvest index (42.89%) was attained from BRRI dhan38 this experiment was conducted at Patuakhali Science and Technology University, Dumki, Patuakhali under AEZ-13 to optimize the nitrogen rate for three aromatic rice varieties in Aman season. The experiment consisted of three

According to (Kader *et al.*,2020), a newly released jasmine type, aromatic, high yielding, long slender grain, and exportable rice variety viz., BRRI dhan80, suitable for the rain-fed low land ecosystem of Bangladesh is an advancement over existing premium quality rice varieties. The variety has reasonably conceded the Proposed Variety Trial (PVT) conducted at the farmer's field. As a result, the National Seed Board (NSB) of Bangladesh has sanctioned this variety for its commercial cultivation in the wet season (Transplanted Aman season) in 2017. It has a modern plant type with 120 cm plant height and matures by 130-135 days. The salient feature of this variety is like jasmine as having good quality grain, aroma, ten days earlier maturing than check variety. The proposed variety exposed around 1.0 t/ha higher yield than check variety namely BRRI dhan37. Isolating characters of this variety are deep blackish green leaf, erect to semi-erect flag leaf, long slender aromatic grain with colored tip, and presence of anthocyanin pigmentation/coloration on stem nodes. Its grain yield producing range is 4.5-5.0 t/ha grain yield. It has a long and erect flag leaf with deep green color, brownish root, and strong stem. Thousand-grain weight of the variety is 26.2 gm and it has a colored grain tip and pointed awn. This variety has 23.6% amylose content and 8.5% protein content. The jasmine type, exportable, aromatic rice variety (BRRI dhan80) is a superb variety for cultivating in the wet season and therefore, farmers can be economically more benefited if they will prefer BRRI dhan80 for its cultivation at a large scale.

According to Assaduzzaman *et al*., 2013 various aromatic rice varieties such as Kalizira, Begun Bichi, BRRI dhan-34, BRRI dhan-37, BRRI dhan50, Philippine Katari were analyzed for physicochemical, total phenol, flavonoid contents, and functional properties. All aromatic rice varieties had moisture contents (11.25 to 15.13%), protein (3.23 to 6.21%), fat (0.68 to 1.45%) and ash (0.88 to 1.46%). The maximum amount of amylose and starch content was obtained in BRRI dhan-37 and BRRI dhan-50 (23.01 and 72.606%, respectively). Total phenolic content was higher in BRRI-37 (474 mg/100 g), whereas a lower value was observed in BRRI dhan-34 (268.67 mg/100 g) variety. Both Philippine Katari and kalizira variety possessed the highest level of flavonoid content among all rice varieties. The highest water absorption index value was found in BRRI dhan-37 and lowest in Begun Bichi variety. On the other hand, the water-soluble index value was varied by 1.32 to 2.12% in all aromatic rice varieties. Therefore, the study indicates that aromatic rice could be used as functional food ingredients as well as sources of natural phytochemicals.

CHAPTER III

MATERIALS AND METHODS

The experiment was done at the Agronomy field laboratory of Sher-e-Bangla Agricultural University. Dhaka. Bangladesh, from June to December 2019 to study the effect of Vermicompost and chemical fertilizers on growth, yield, and quality of Three aromatic rice varieties viz. BRRI dhan37, BRRI dhan38, BRRI dhan80. This chapter includes materials and methods that were applied during the experiment. The descriptions are given below under the following heading and sub-headings:

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted during the period from June to December 2019.

3.1.2 Experimental location

The experiment was done within the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. the placement of the location is 23.740N latitude and 90.350E line of longitude with an elevation of 8.2 meters from ocean level. An experimental location is given in Appendix I.

3.1.3 Climatic condition

The geographical location of the experimental site belonged to the subtropic climate and its weather conditions are characterized by 3 distinct seasons, particularly in the winter season from November to February, the pre-monsoon amount or hot season from March to April, and the monsoon period from the month of could to October (Edris *et al*., 1979). throughout the experimental period the most temperature (36.8 ^{0}C), highest ratio (87%), and highest downfall (573 mm) were recorded for July 2019, whereas the minimum temperature (22.6 ^{0}C), minimum relative humidity (74%), and no rainfall were recorded for December 2019. Details of the earth science information of air temperature, relative humidity, downfall, and sunshine hour throughout the study amount have been given in Appendix II.

3.1.4 Soil characteristics

The soil of the experimental field belonged to “The Modhupur Tract”, AEZ-28 (FAO, 1988). high soil was loose Clay in texture, olive-grey with common fine to medium distinct dark caramel mottles. The experimental space having obtainable irrigation and drainage system and is located on top of the flood level. The soil has a texture of sandy loam organic matter 1.15% and is composed of 26% sand, 43% silt, and 31% clay. Details morphological, physical, and chemical properties of the experimental field soil are given in Appendix III.

3.2 Experimental details

3.2.1 Planting material

Scented rice cultivars, BRRI dhan37, BRRI dhan38, BRRI dhan80 were taken in this experiment.

3.2.2 Treatment of the experiment

The experiment consisted of two factors:

Factor A: Combination of nitrogenous fertilizer and vermicompost as

T_1: 100% N through nitrogenous fertilizer (Urea).

T_2: 90% N through nitrogenous fertilizer (Urea) + 10% N through vermicompost.

T_3: 80% N through nitrogenous fertilizer (Urea) + 20% N through Vermicompost.

T_4: 70% N through nitrogenous fertilizer (Urea) + 30% N through Vermicompost.

T_5: 60% N through nitrogenous fertilizer (Urea) + 40% N through Vermicompost.

Urea (46% N) was used as a nitrogen source.

Factor B: Aromatic rice variety (three varieties) as

i V_1: BRRI dhan37

ii. V_2: BRRI dhan38

iii. V_3: BRRI dhan80

There were total of 15 (5×3) treatment combinations as a whole and they are T_1V_1

T_1V_2, T_1V_3, T_2V_1, T_2V_2, T_2V_3, T_3V_1, T_3V_2, T_3V_3, T_4V_1, T_4V_2, T_4V_3, T_5V_1, T_5V_2, and T_5V_3.

3.2.3 Experimental design and layout

The two factors experiment was done by split-plot design with three replications. An area of 300 m^2 was divided into 3 blocks. The five combinations of nitrogenous fertilizer and vermicompost were applied in the main plot and three fragrant rice varieties depicted in the sub-plot. The size of each unit plot was 3.0 m × 1.0 m. The space between two blocks, main and two plots and subplots were 1.0 m, 1 m, and 0.6 m respectively. Each plot and sub-plot were separated by a raised border. The layout of the experiment is presented in Figure 1.

3.3 Growing of crops

3.3.1 Seed collection and sprouting

Seeds of different fragrant rice varieties were collected from BRRI (Bangladesh Rice Research Institute), Gazipur. For seed germination, clean seeds were immersed in water in a bucket for 24 hours. The soaked seeds were then taken out of the water and put in gunny bags. The seeds started sprouting after 48 hours then suitable for sowing in the seedbed within 72 hours.

3.3.2 Raising of seedlings

The nursery bed was made by puddling with repeated plowing followed by laddering. The germinated seeds were sown on beds as uniformly as possible on 14^{th} June 2019. Irrigation was provided to the bed whenever it was needed. The nursery bed was nurtured without fertilizers.

3.3.3 Land preparation

The plot selected for experimenting was opened on the 4th of July, 2019 with a power tiller, and left exposed to the sun for a week. After one week the land was harrowed, plowed, and cross-plowed several times followed by laddering to obtain good puddle condition. Weeds and stubbles were removed. The experimental plot was partitioned into unit plots by the experimental design on 22nd June 2019. Organic and inorganic manures as indicated 3.3.4 were mixed with the soil of each unit plot.

3.3.4 Fertilizers and manure application

The fertilizers N, P, K, S, Zn, and B in the form of urea, TSP, MoP, Gypsum, zinc sulphate, and borax, respectively. TSP, MoP, Gypsum and zinc were applied @ 90, 53,60, 30 and 10 kg ha-1 (BRRI, 2016). Vermicompost was applied @5.0 t/ha. N and vermicompost were applied as per treatment. The entire amount of Vermicompost, TSP, MoP, gypsum, and zinc sulphate was applied during final land preparation. Urea was applied in three equal installments as a top dressing at early and maximum tillering and panicle initiation stages.

3.3.5 Transplanting of seedling

Seedlings were carefully uprooted from the nursery bed and transplanted on 31^{st} July 2019 in a well-puddled plot with a spacing of 20 × 25 cm. Three seedlings were transplanted in each hill. After 7 days of transplanting all the plots were checked for any single missing hill that was filled up with extra seedlings of the same source whenever needed.

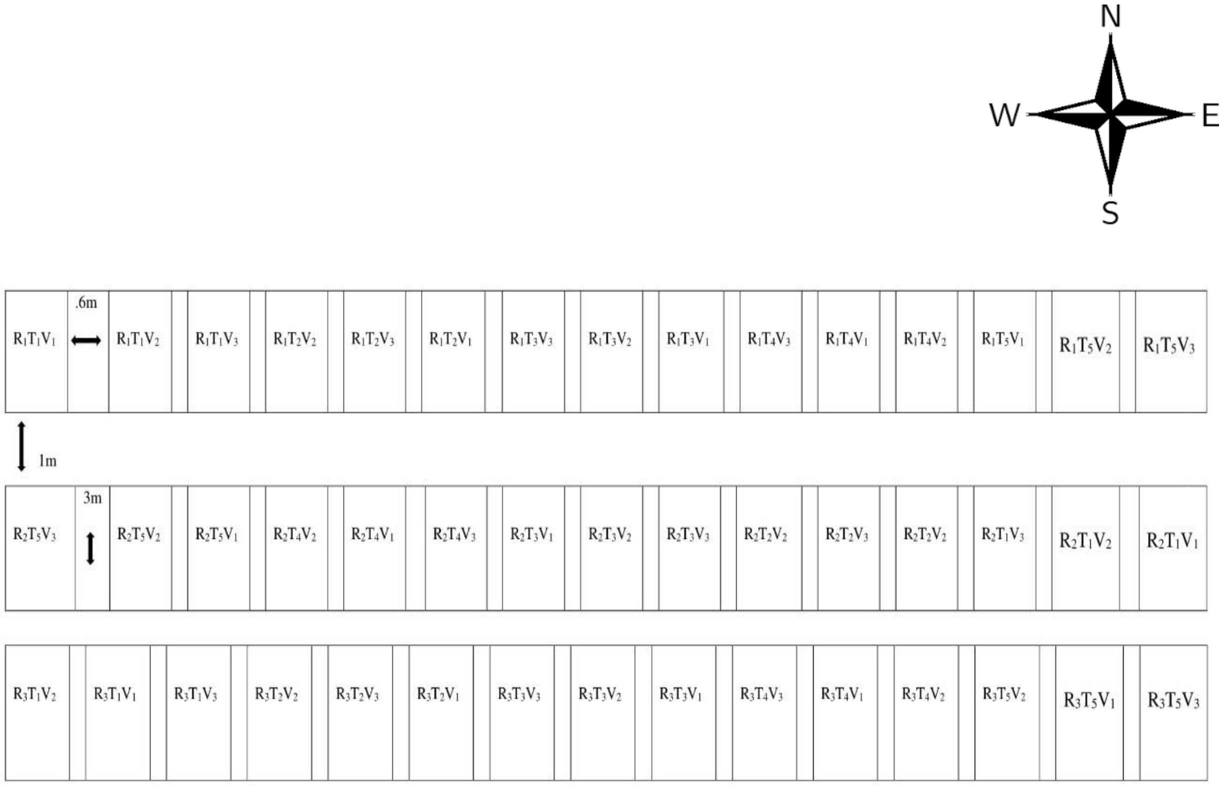

Figure 1: Layout of the experimental plot.

T_1: 100% N Through Nitrogenous Chemical Fertiliser.	V_1: BRRI dhan37
T_2: 90% N Through Nitrogenous Chemical Fertiliser + 10% N Through Vermicompost.	V_1: BRRI dhan38
T_3: 80% N Through Nitrogenous Chemical Fertiliser + 20% N Through Vermicompost.	V_1: BRRI dhan80
T_4: 70% N Through Nitrogenous Chemical Fertiliser + 30% N Through Vermicompost.	
T_5: 60% N Through Nitrogenous Chemical Fertiliser + 40% N Through Vermicompost.	

3.3.6 Intercultural operations Intercultural practices were made to confirm the normal growth of the crop. Plant shield measures were surveyed when it was needed. The following intercultural operations were done timely

3.3.6.1 Irrigation and drainage

At the beginning stages for the establishment of seedlings irrigation was provided to maintain a constant level of standing water upon 6 cm and then controlled the amount by drying and wetting system throughout the entire vegetative period. No water deficiencies were encountered in the reproductive and ripening stage. The plot was exactly dried out at 15 days before harvesting.

3.3.6.2 Weeding

Weeding was got to keep the plots free from weed infestation, that was ultimately ensured the better growth and development of the seedlings. The weeds were uprooted precisely at 20 DAT (days after transplanting) and 40 DAT in mechanical ways.

3.3.6.3 Insect and pest control

Furadan was used at 15 DAT in the field. Leaf roller (*Chaphalocrosis medinalis*) was noticed and applied Malathion @ 1.12 L ha-1 at 25 DAT by sprayer but disease infections were not observed in the experiment plot.

3.4 Harvesting, threshing, and cleaning

The crop was harvested at complete maturity based on variety when 80-90% of the grains were turned into straw color. The harvested crop was stacked separately, tagged perfectly, and brought to the threshing room. Grains were dried, cleaned, and weighed for the individual plot. The weight was accustomed to 12% moisture level. Yields of grain and straw were recorded properly from each plot.

3.5 Data recording

3.5.1 Plant height

The height of the plant was measured in centimeter (cm) from the ground level to the tip of the plant at 20, 40, 60 DAT, and at harvest. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot.

3.5.2 Number of tillers hill^{-1}

The number of tillers hill1 was recorded at 20, 40, 60 DAT and at harvest as the average of randomly selected 5 plants from the inner rows of each plot.

3.5.3 Chlorophyll content in flag leaf

Flag leaves were sampled from 3 plants at flowering stage and a segment of 20 mg from the middle portion of flag leaf was used for chlorophyll content estimation on fresh weight basis extracting with 80% acetone and for that double beam spectrophotometer (Model: U-2001, Hitachi, Japan) were used according to Witham et al. (1986).

3.5.4 Effective tillers hill^{-1}

The total number of effective tillers hill^{-1} was counted as the number of panicles bearing tillers during harvesting. Data on effective tillers hill^{-1} were counted from 5 selected hills and the average value was recorded.

3.5.5 Non-effective tillers hill^{-1}

The total quantity of non-effective tillers hill^{-1} was measured as the number of non-panicles bearing tillers in harvesting. Data on non-effective tillers hill^{-1} were calculated from 3 selected hills and the average value was noted.

3.5.6 Panicle length

The length of the panicle was measured with a meter scale from 3 selected panicles and the average length was noted as panicle^{-1} in cm.

3.5.7 Filled grains panicle^{-1}

The total numbers of filled grains were collected randomly from selected 3 hill's panicles of a plot based on grain in the spikelet and then average numbers of filled grains panicle^{-1} were noted.

3.5.8 Unfilled grains panicle^{-1}

The total numbers of unfilled grains were collected arbitrarily from selected 3 hills of a plot based on the absence of grain in the spikelet after that average number of unfilled grains panicle^{-1} was noted.

3.5.9 Total grains panicle^{-1}

The total numbers of grains were estimated by adding filled and unfilled grain selected three selected hills of a plot and average numbers of grains panicle^{-1} were noted.

3.5.10 Weight of 1000-grains

Thousand-grain weight was counted randomly from the total cleaned harvested grains and then weighed in grams and noted.

3.5.11 Grain yield

Grains obtained from each unit plot were sun-dried and weighed carefully. A dry weight of grains of each plot was taken and converted to ton hectare^{-1} (t ha^{-1}).

3.5.12 Straw yield

Straw obtained from each unit plot were sun-dried and weighed carefully. The dry weight of straw of each plot was taken and converted to ton hectare^{-1} (t ha^{-1}).

3.5.13 Biological yield

Grain yield and straw yield together were regarded as biological yield. The biological yield was calculated with the following formula:

Biological yield = Grain yield + Straw yield.

3.5.14 Harvest index

The harvest index was calculated from the grain and straw yield of rice for each plot and expressed in percentage.

$$HI = \frac{\text{Economic yield (grain weight)}}{\text{Biological yield (total dry weight)}} \times 100$$

3.5.15 Protein content

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

3.5.16 Amylose content

The amylose content of the rice samples was found using methodology by Juliano (1971) with some modifications. 100 milligrams of the powdered rice sample was taken in a volumetric flask. Where 1 ml of 95% ethanol and 9 ml of 1 NaOH were added. It was then heated in a boiling water bath to gelatinize the starch. 5 ml of the starch extract was taken in a 100 ml volumetric flask. Then 1 ml of 1N acetic acid and 2 ml iodide solution was added to the starch extract and the volume was made up to 100 ml. The solution was shaken and allowed to stand for 20 min. Then the absorbance was measured at 620 nm using Agilent Technologies Cary 60 UV-VIS spectrophotometer. Then the amylose content of the sample was determined concerning the standard curve of potato amylose and expressed on a percentage basis.

3.5.17 Proline content

The proline content of rice grains was measured according to the strategy established by Bates *et al*. (1973). Grains during which the weight was nearly 0.3 g, were homogenized in a very four milliliters solution of 3% sulfosalicylic acid and cooled after bringing to a boil for ten min. Samples were filtered and a couple of ml of the filtrate was mixed with 3 ml ninhydrin chemical agent (2.5 g ninhydrin in 60 ml glacial ethanoic acid and 40 milliliters 6 M phosphoric acid) and 2 ml glacial acetic acid. For the extraction of proline, the mixture was boiled for 30 min and 4 ml toluene was added to the cooled liquid. The extract was centrifuged at 4000 rpm for five min, and proline absorbance was detected at 520 nm and concentration expressed as μg g^{-1}.

3.5.18 Grain 2-AP content

The 2-AP content in grain was estimated using the strategy represented by Huang *et al*. (2012), before analysis, grains were ground by mortar and pestle. around 10 g grains were mixed homogeneously with 150 milliliters purified water into a 500 ml round-bottom flask connected to a continual steam distillation extraction head. The mixture was cooked at 1500C 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 to the opposite head of the continual steam distillation apparatus, and this flask was boiled in a water pot at 530C. the continual steam distillation extraction was joined with a cold water circulation machine to keep the temperature at 100C. once around 35 min, the extraction was complete. anhydrous sodium sulphite was added to the extract to soak up the water. The dried extract was filtered by organic needle filter and analyzed for 2-AP content by gc MS-QP 2010 Plus. High purity helium gas was used because of the carrier gas at the rate of flow of 2 ml/min. The temperature gradient of the GC oven was as follows: 400C (1 min), redoubled at 20C min^{-1} to 650C, and held at 650C for 1 min, then redoubled to 2200C at 100C min^{-1}, and held at 2200C for 10 min. The retention time of 2-AP was confirmed at 7.5 min. every sample had 3 replicates, and 2-AP was expressed as μg g^{-1}. Protein, amylose, proline, and 2-AP content were measured at the Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka.

3.6 Statistical Analysis

The data obtained 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 Statistix-10 software. The difference of the means value was differentiated by LSD at a 5% level of probability.

CHAPTER IV
RESULTS AND DISCUSSION

The experiment was conducted to minimize the use of chemical sources as a nutrient source on the growth, yield, and quality of aromatic rice. The analyses of variance (ANOVA) of the data on yield contributing characters, yield, and quality of fragrant rice are presented in Appendix IV-X. The outputs have been depicted and deliberated with the help of different tables and graphical representation additionally possible interpretations are provided under the following headings and sub-headings:

4.1. Yield contributing characters and yield of fragrant rice

4.1.1 Plant height

Plant height of fragrant rice at 20, 40, 60 DAT (days after transplant) and at harvest showed statistically significant variations due to different fertilizer combinations (Table 1). At 20, 40, 60 DAT and at harvest, the tallest plant (55.16, 93.08, 123.02 and 123.42 cm respectively) was observed fromT_5 while the shortest plant (48.65, 89.13, 119.08 and 117.18 cm respectively) was found from T_1. Cultivars are the key component for producing plant height based on their genotypic characters and off course the prevailing environmental conditions of the growing season. Vermicompost promotes the growth and development of various crops such as vegetables, fruits, cereals as well as it has been found to have positive effects on different aromatic and medicinal plants (Domínguez *et al.*, 2010). Gopinath *et al.* (2008) and Khandwe *et al.* (2006) stated that combined doses of urea and vermicompost increase the growth of crops.

Different rice varieties varied significantly in terms of plant height of scented rice at 20, 40, 60 DAT, and at harvest (Table 2). At 20, 40, 60 DAT and harvest, the tallest plant (54.06, 93.42, 122.90, and 121.84cm respectively) was recorded from V_1 (BRRI dhan37), whereas the shortest plant (49.66, 89.66, 118.31 and 118.52 cm respectively) was found from V_3 (BRRI dhan80).

Table 1. Effects of different combinations of fertilizers and fragrant rice varieties on plant height at different days after transplanting (DAT) and harvest.

Plant height (cm) at				
Treatments	20 DAT	40 DAT	60 DAT	Harvest
T_1	48.65 c	89.13 b	119.08 d	117.18 d
T_2	49.58 bc	90.82 ab	119.92 cd	118.19 d
T_3	50.91 b	91.29 ab	120.61 bc	119.80 c
T_4	54.43 a	92.00 a	121.53 b	121.65 b
T_5	55.16 a	93.08 a	123.02 a	123.42 a
$LSD_{(0.05)}$	1.50	2.64	1.08	1.67
Level of Significant	*	*	*	**
CV (%)	5.67	4.67	6.83	6.90
Varieties	20 DAT	40 DAT	60 DAT	Harvest
V_1	54.06 a	93.42 a	122.90 a	121.84 a
V_2	51.51 b	90.71 b	121.29 b	119.78 b
V_3	49.66 c	89.66 b	118.31 c	118.52 c
$LSD_{(0.05)}$	1.37	1.06	0.85	0.79
Level of Significant	*	*	*	**
CV (%)	4.49	5.53	5.92	5.87

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

** : Significant at 0.01 level of significance   * : Significant at 0.05 level of significance

T_1: 100% N through urea.

T_2: 90% N through urea + 10% N through vermicompost.

T_3: 80% N through urea + 20% N through vermicompost.

T_4: 70% N through urea + 30% N through vermicompost.

T_5: 60% N through urea + 40% N through vermicompost.

V_1: BRRI dhan37

V_2: BRRI dhan38

V_3: BRRI dhan80

Table 2. The combined effect of different combinations of fertilizers and fragrant rice varieties on plant height at different days after transplanting (DAT) and harvest.

Interactions	Plant height (cm) at			
	20 DAT	40 DAT	60 DAT	Harvest
T_1V_1	51.46 cde	90.56	120.90 def	119.52 ef
T_1V_2	47.98 f	89.57	119.50 f-i	116.79 gh
T_1V_3	46.52 f	87.25	116.83 j	115.23 h
T_2V_1	52.54 bcd	92.95	121.37 c-f	120.06 def
T_2V_2	48.72 ef	89.87	120.70 d-g	117.55 g
T_2V_3	47.47 f	89.63	117.70 ij	116.95 gh
T_3V_1	52.77 bcd	93.78	122.27 bcd	121.35 cde
T_3V_2	51.35 de	90.31	121.43 cde	119.59 ef
T_3V_3	48.60 ef	89.80	118.13 hij	118.46 fg
T_4V_1	56.49 a	94.30	124.03 b	123.68 ab
T_4V_2	54.35 abc	91.20	121.63 cde	121.54 cd
T_4V_3	52.45 bcd	90.51	118.93 ghi	119.72 ef
T_5V_1	57.06 a	95.53	125.93 a	124.58 a
T_5V_2	55.13 ab	92.61	123.17 bc	123.45 ab
T_5V_3	53.28 bcd	91.10	119.97 e-h	122.22 bc
$LSD_{(0.05)}$	3.07	2.06	1.90	1.79
Level of Significant	*	NS	*	**
CV (%)	4.49	5.53	5.92	5.87

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

** : Significant at 0.01 level of significance   * : Significant at 0.05 level of significance   NS: Non significant

T_1: 100% N through urea.

T_2: 90% N through urea + 10% N through vermicompost.

T_3: 80% N through urea + 20% N through vermicompost.

T_4: 70% N through urea + 30% N through vermicompost.

T_5: 60% N through urea + 40% N through vermicompost.

V_1: BRRI dhan37

V_2: BRRI dhan38

V_3: BRRI dhan80

Similarly, different researchers stated different sizes of the plant for different rice cultivars (Sumon *et al.*, 2018; Haque and Biswash, 2014; Khalifa, 2009). Statistically significant variation was recorded on plant height of fragrant rice at 20, 60 DAT, and at harvest due to the combined effect of different combinations of fertilizers and rice varieties but at 40 DAT, non-significant variation was observed (Table 3). At 20, 40, 60 DAT and harvest, the tallest plant (57.06, 95.53, 125.93, and 124.58 cm, respectively) was found from T_5V_1 while the shortest plant (46.52, 87.25,116.83 and 115.23 cm, respectively) was recorded from T_1V_3 treatment combination.

4.1.2 Number of tillers hill^{-1}

Different combinations of fertilizers showed statistically significant variations in terms of the number of tillers hill^{-1} of fragrant rice at 20, 40, 60 DAT, and at harvest (Table 3). At 20, 40, 60 DAT and harvest, the maximum number of tillers hill^{-1} (10.29, 14.18,16.38 and 16.83, respectively) was recorded from T_5 while the minimum number (7.09, 10.08, 11.57 and 10.74, respectively) was observed from T_1. Razdi *et al.* (2017) reported that increasing the rate of vermicompost along with chemical nutrient sources can raise the tiller number.

The number of tillers hill^{-1} of fragrant rice at 20, 40, 60 DAT, and at harvest showed statistically significant differences due to different rice varieties (Table 3). At 20, 40, 60 DAT and at harvest, the maximum number of tillers hill^{-1} (8.81, 12.71, 14.41 and 14.33 respectively) was found from V_3 which was followed (8.52, 12.37, 14.16 and 13.70 respectively) by V_2 , whereas the minimum number (8.21, 12.04, 13.84 and 13.30 respectively) was recorded from V_1. Khalifa (2009) reported that modern rice variety surpassed other varieties in the case of tillers hill^{-1}. Kader *et al.* (2020) reported that BRRI dhan80 gave the maximum number of effective tillers hill^{-1} than other aromatic rice varieties. The combined effects of different combinations of fertilizers and rice varieties showed statistically significant differences in terms of number of tillers hill^{-1} of fragrant rice at 20, 40, 60 DAT but at harvest, non-significant variations of combined treatment combinations were observed (Table 4). At 20, 40, 60 DAT and harvest, the maximum number of tillers hill^{-1} (10.94, 14.56, 16.72, and 17.31, respectively) was observed from T_5V_3 and the minimum number (6.82, 9.54, 11.17, and 10.09, respectively) was recorded from T_1V_1.

4.1.3 Dry Matter Weight

Different combinations of fertilizers showed statistically significant variations in terms of dry matter weight fragrant rice at 20, 40, 60 DAT (Table 5). At 20, 40, 60 DAT, the maximum dry matter weight (5.43, 46.80, and 91.22g respectively) was recorded from T_5 while the minimum number (4.26, 32.53 and 73.49 g respectively) was observed from T_2.

Dry matter weight of fragrant rice at 20, 40, 60 DAT showed statistically significant differences due to different rice varieties (Table 5). At 20, 40, 60 DAT, and the maximum dry weight (5.28, 43.63, and 85.30g respectively) was found from V_1, whereas the minimum weight (4.49, 38.09 and 71.21g respectively) was recorded from V_3. Khalifa (2009) reported that modern rice variety surpassed other varieties in case of dry weight.

Combined effects of different combinations of fertilizers and rice varieties showed statistically significant differences in dry matter weight of fragrant rice at 20, and 60 DAT but at 40 DAT, combined treatment combinations were showed non-significant variations. (Table 6). At 20, 40, 60 DAT where the maximum dry weight (10.94, 14.56, 16.72, and 17.31g, respectively) was observed from T_5V_3 and the minimum number (6.82, 9.54, 11.17, and 10.09 g, respectively) was recorded from the T_1V_1 treatment combination.

4.1.4 Chlorophyll content in flag leaf

Statistically significant variations were recorded in terms of chlorophyll content in the flag leaf of fragrant rice for different combinations (Table 7). Data discovered that the highest chlorophyll content in flag leaf (41.14 mg g^{-1}) was found fromT_4 which was statistically similar to T_3 , whereas the lowest (36.24 mg g^{-1}) was recorded from T_1. Shivaputra *et al* (2004) found higher P levels in tissues as a result of root colonization by the VAM fungi can be expected to increase the chlorophyll content with a certain level of vermicompost application, as P is one of the important components of chlorophyll. Different rice varieties are varied non-significantly in terms of chlorophyll content in the flag leaf of fragrant rice (Table 7).

Table 3. Effects of different combinations of fertilizers and fragrant rice varieties on the number of tillers hill^{-1} at different days after transplanting (DAT) and harvest.

Tiller Number hill^{-1} at				
Treatments	20 DAT	40 DAT	60 DAT	Harvest
T_1	7.09 d	10.08 e	11.57 e	10.74 d
T_2	7.98 c	11.82 d	13.06 d	12.17 c
T_3	8.34 bc	12.62 c	14.12 c	13.84 b
T_4	8.87 b	13.17 b	15.56 b	15.32 a
T_5	10.29 a	14.18 a	16.38 a	16.83 a
$LSD_{(0.05)}$	0.55	0.25	0.18	1.11
Level of Significant	*	**	*	*
CV (%)	5.79	6.85	7.16	7.39
Varieties	20 DAT	40 DAT	60 DAT	Harvest
V_1	8.21 c	12.04 c	13.84 c	13.30 c
V_2	8.52 b	12.37 b	14.16 b	13.70 b
V_3	8.81 a	12.71 a	14.41 a	14.33 a
$LSD_{(0.05)}$	0.25	0.11	0.05	0.26
Level of Significant	*	**	**	*
CV (%)	3.91	4.12	5.91	5.57

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

** : Significant at 0.01 level of significance * : Significant at 0.05 level of significance

T_1: 100% N through urea. V_1: BRRI dhan37

T_2: 90% N through urea + 10% N through vermicompost. V_2: BRRI dhan38

T_3: 80% N through urea + 20% N through vermicompost. V_3: BRRI dhan80

T_4: 70% N through urea + 30% N through vermicompost.

T_5: 60% N through urea + 40% N through vermicompost.

Table 4. The combined effect of different combinations of fertilizers and fragrant rice varieties on tiller number at different days after transplanting (DAT) and harvest.

Interactions	Tiller Number hill^{-1} at			
	20 DAT	40 DAT	60 DAT	Harvest
T_1V_1	6.82 i	9.54 k	11.17 k	10.09
T_1V_2	7.02 hi	10.02 j	11.65 j	10.72
T_1V_3	7.43 gh	10.68 i	11.91 i	11.42
T_2V_1	7.81 fg	11.50 h	12.85 h	11.93
T_2V_2	8.00 efg	11.87 g	13.03 h	12.14
T_2V_3	8.12 efg	12.10 g	13.30 g	12.43
T_3V_1	8.24 def	12.52 f	13.93 f	13.06
T_3V_2	8.31 def	12.63 ef	14.04 f	13.75
T_3V_3	8.48 c-f	12.71 ef	14.39 e	14.71
T_4V_1	8.67 cde	12.85 e	15.41 d	15.03
T_4V_2	8.85 bcd	13.16 d	15.54 cd	15.13
T_4V_3	9.08 bc	13.52 c	15.74 bc	16.76
T_5V_1	9.51 b	13.82 c	15.87 b	15.81
T_5V_2	10.42 a	14.17 b	16.54 a	16.41
T_5V_3	10.94 a	14.56 a	16.72 a	17.31
$LSD_{(0.05)}$	0.57	0.24	0.22	0.60
Level of Significant	*	**	*	NS
CV (%)	3.91	4.12	5.91	5.57

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

** : Significant at 0.01 level of significance * : Significant at 0.05 level of significance NS: Non significant

T_1: 100% N through urea. V_1: BRRI dhan37

T_2: 90% N through urea + 10% N through vermicompost. V_2: BRRI dhan38

T_3: 80% N through urea + 20% N through vermicompost. V_3: BRRI dhan80

T_4: 70% N through urea + 30% N through vermicompost.

T_5: 60% N through urea + 40% N through vermicompost.

Table 5. Effects of different combinations of fertilizers and fragrant rice varieties on dry matter weight at different days after transplanting (DAT).

Dry Matter Weight (g) at			
Treatments	20 DAT	40 DAT	60 DAT
T_1	4.94 b	42.83 b	75.66 c
T_2	4.26 c	32.53 d	73.49 c
T_3	4.49 c	38.05 c	68.08 d
T_4	5.30 a	44.33 ab	83.30 b
T_5	5.43 a	46.80 a	91.22 a
$LSD_{(0.05)}$	0.23	3.86	2.61
Level of Significant	**	*	*
CV (%)	4.37	8.69	6.06
Varieties	20 DAT	40 DAT	60 DAT
V_1	5.28 a	43.63 a	85.30 a
V_2	4.89 b	41.00 b	78.53 b
V_3	4.49 c	38.09 c	71.21 c
$LSD_{(0.05)}$	0.09	1.55	2.08
Level of Significant	**	*	*
CV (%)	4.53	6.98	5.48

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

** : Significant at 0.01 level of significance   * : Significant at 0.05 level of significance

T_1: 100% N through urea.

T_2: 90% N through urea + 10% N through vermicompost.

T_3: 80% N through urea + 20% N through vermicompost.

T_4: 70% N through urea + 30% N through vermicompost.

T_5: 60% N through urea + 40% N through vermicompost.

V_1: BRRI dhan37

V_2: BRRI dhan38

V_3: BRRI dhan80

Table 6. The combined effect of different combinations of fertilizers and fragrant rice varieties on dry weight at different days after transplanting (DAT).

Interactions	Dry Matter Weight (g) at		
	20 DAT	40 DAT	60 DAT
T_1V_1	5.17 bc	46.06	82.55 b
T_1V_2	4.87 de	42.94	75.00 c
T_1V_3	4.79 ef	39.49	69.43 de
T_2V_1	4.66 ef	36.56	81.66 b
T_2V_2	4.43 g	32.59	76.40 c
T_2V_3	3.71 i	28.44	62.40 g
T_3V_1	4.87 de	38.78	73.22 cd
T_3V_2	4.53 fg	38.34	67.44 ef
T_3V_3	4.08 h	37.02	63.57 fg
T_4V_1	5.82 a	47.22	92.91 a
T_4V_2	5.31 bc	43.29	81.49 b
T_4V_3	4.77 ef	42.50	75.51 c
T_5V_1	5.90 a	49.55	96.17 a
T_5V_2	5.31 b	47.84	92.33 a
T_5V_3	5.09 cd	43.02	85.17 b
$LSD_{(0.05)}$	0.21	3.47	4.65
Level of Significant	**	NS	*
CV (%)	4.53	6.98	5.48

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

** : Significant at 0.01 level of significance * : Significant at 0.05 level of significance NS: Non significant

T_1: 100% N through urea.

T_2: 90% N through urea + 10% N through vermicompost.

T_3: 80% N through urea + 20% N through vermicompost.

T_4: 70% N through urea + 30% N through vermicompost.

T_5: 60% N through urea + 40% N through vermicompost.

V_1: BRRI dhan37

V_2: BRRI dhan38

V_3: BRRI dhan80

The highest chlorophyll content in flag leaf (41.31 mg g^{-1}) was recorded from V_2 while the lowest (37.78 mg g^{-1}) was observed from V_3. This may be caused due to the varietal effect or genetic makeup of modern varieties.

Chlorophyll content in the flag leaf of fragrant rice showed statistically significant differences due to the combined effect of different combinations of fertilizers and rice varieties (Table 8). The highest chlorophyll content in flag leaf (40.56 mg g^{-1}) was observed from T_4V_2, while the lowest (36.20 mg g^{-1}) was recorded from the T_1V_3 treatment combination.

4.1.5 Effective tillers hill^{-1}

Different doses varied significantly in terms of effective tillers/hill of fragrant rice (Table 7). The highest number of effective tillers hill^{-1} (14.39) was recorded from T_5 which was statistically similar to T_4 while the lowest effective tiller number (9.84) was obtained from T_1. Radzi *et al*. (2017) found 50% vermicompost and 50% NPK shows higher means number of tillers. Vermicompost with the increasing rate can increase the effective tiller number (Kumar *et al.*,2014 and Esfahani *et al*. 2018).

The number of effective tillers hill^{-1} of fragrant rice varied significantly due to the different rice varieties varied (Table7). The highest number of effective tillers hill^{-1} (12.51) was found from V_3 while the lowest number (11.7) was observed from V_1. Khalifa (2009) reported that the H_1 hybrid rice variety surpassed other varieties in consideration of effective tillers hill^{-1}.

Non-significant variation was recorded on the number of effective tillers hill^{-1} of fragrant rice due to the combined effect of different doses of fertilizers and rice varieties (Table 8). The highest number of effective tillers hill^{-1} (14.81) was recorded from T_5V_3 and the lowest number (9.56) was found from the T_1V_1 treatment combination.

4.1.6 Non-effective tillers hill^{-1}

Non-effective tillers hill^{-1} of fragrant rice showed statistically significant variations due to different fertilizer combinations (Table 7). The highest number of non-effective tillers hill^{-1} (2.43) was observed from T_5, whereas the lowest number (0.9) was recorded from T_1.

Statistically, significant variation was recorded due to different rice varieties in terms of the number of non-effective tillers hill^{-1} of fragrant rice (Table 7). The highest number of non-effective tillers hill^{-1} (1.82) was observed from V_3 and the lowest number of no effective tillers (2.53) was observed by V_1.

The combined effect of different levels of combinations of fertilizers and rice varieties showed non-significant variation in terms of the number of non-effective tillers hill^{-1} of fragrant rice (Table 8). The highest number of non-effective tillers hill^{-1} (2.50) was found from T_5V_3, whereas the lowest number (0.53) was recorded from the T_1V_1 treatment combination.

Table 7. Effects of different combinations of fertilizers and fragrant rice varieties on chlorophyll content in flag leaf, effective, non-effective tillers hill^{-1}, panicle length flag leaf length and flag leaf breadth.

Treatments	Chlorophyll content in flag leaf (mg g^{-1})	Number of effective tillers hill^{-1}	Number of non-effective tillers hill^{-1}	Panicle length (cm)	Flag leaf length (cm)	Flag leaf breadth (cm)
T_1	36.26 d	9.84 d	0.90 d	22.97 c	44.93 a	1.06 ab
T_2	38.24 c	10.80 c	1.36 cd	25.48 b	41.56 ab	0.97 b
T_3	40.11 a	12.19 b	1.64 bc	26.04 b	37.68 b	1.18 a
T_4	40.41 a	13.28 a	2.04 ab	27.68 a	37.70 b	1.17 a
T_5	39.24 b	14.39 a	2.43 a	28.27 a	40.04 ab	1.08 ab
LSD $_{(0.05)}$	0.77	0.98	0.51	2.15	5.31	0.19
Level of Significant	**	*	*	**	*	*
CV (%)	6.81	7.44	12.18	7.64	12.10	10.74
Varieties	Chlorophyll content in flag leaf (mg g^{-1})	Number of effective tillers hill^{-1}	Number of non-effective tillers hill^{-1}	Panicle length (cm)	Flag leaf length (cm)	Flag leaf breadth (cm)
V_1	38.66	11.77 c	1.53 b	25.06 b	37.29 b	0.90 b
V_2	38.92	12.02 b	1.68 ab	25.93 ab	38.36 b	1.02 b
V_3	38.98	12.51 a	1.82 a	26.67 a	45.49 a	1.37 a
LSD $_{(0.05)}$	0.64	0.20	0.15	0.97	3.33	0.13
Level of Significant	NS	*	*	**	*	*
CV (%)	8.16	5.18	10.48	4.91	10.85	12.64

In a column means having a similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

** : Significant at 0.01 level of significance   * : Significant at 0.05 level of significance   NS: Non significant

T_1: 100% N through urea.
T_2: 90% N through urea + 10% N through vermicompost.
T_3: 80% N through urea + 20% N through vermicompost.
T_4: 70% N through urea + 30% N through vermicompost.
T_5: 60% N through urea + 40% N through vermicompost.

V_1: BRRI dhan37
V_2: BRRI dhan38
V_3: BRRI dhan80

Table 8. The combined effect of different combinations of fertilizers and fragrant rice varieties on chlorophyll content in flag leaf, effective, non-effective tillers hill^{-1}, panicle length, flag leaf length and flag leaf breadth.

Interaction	Chlorophyll content in flag leaf (mg g^{-1})	Number of effective tillers hill^{-1}	Number of non-effective tillers hill^{-1}	Panicle length (cm)	Flag leaf length (cm)	Flag leaf breadth (cm)
T_1V_1	36.83 de	9.56	0.53	20.75 e	35.56 def	0.93
T_1V_2	35.76 e	9.75	0.96	23.52 d	48.63 ab	1.03
T_1V_3	36.20 e	10.22	1.20	24.63 cd	50.60 a	1.23
T_2V_1	37.90 cd	10.63	1.30	25.30 bcd	41.90 b-e	0.93
T_2V_2	38.40 bc	10.74	1.40	25.48 bcd	38.66 cde	0.70
T_2V_3	38.43 bc	11.03	1.40	25.66 bcd	44.13 abc	1.30
T_3V_1	39.50 ab	11.56	1.50	25.87 bcd	37.06 cde	0.90
T_3V_2	40.46 a	12.11	1.63	26.07 bcd	28.56 f	1.06
T_3V_3	40.36 a	12.91	1.80	26.18 bcd	47.42 ab	1.60
T_4V_1	40.30 a	13.06	1.96	26.23 bcd	35.26 ef	0.90
T_4V_2	40.56 a	13.16	1.96	26.83 bc	34.73 ef	1.30
T_4V_3	40.36 a	14.33	2.43	29.74 a	43.10 a-d	1.33
T_5V_1	38.76 bc	13.61	2.20	26.98 bc	36.66 cde	0.86
T_5V_2	39.40 ab	14.05	2.36	27.14 b	41.23 b-e	1.00
T_5V_3	39.56 ab	14.81	2.50	29.93 a	42.23 b-e	1.40
$LSD_{(0.05)}$	1.43	0.45	0.33	2.17	7.46	0.29
Level of Significant	*	NS	NS	**	*	NS
CV (%)	8.16	5.18	10.48	4.91	10.85	12.64

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

** : Significant at 0.01 level of significance   * : Significant at 0.05 level of significance   NS: Non significant

T_1: 100% N through urea.
T_2: 90% N through urea + 10% N through vermicompost.
T_3: 80% N through urea + 20% N through vermicompost.
T_4: 70% N through urea + 30% N through vermicompost.
T_5: 60% N through urea + 40% N through vermicompost.

V_1: BRRI dhan37
V_2: BRRI dhan38
V_3: BRRI dhan80

4.1.7 Panicle length

Different combinations of fertilizers showed statistically significant differences in terms of the panicle length of fragrant rice (Table 7). The longest panicle (28.27 cm) was observed from T_5 which was statistically similar to T_4 (27.68 cm) while the shortest panicle (22.97 cm) was found from T_1. Vermicompost provides nutrient elements as endure mineralization and consistent supply of nutrient elements thus provoke the growth of crops' reproductive parts (Havlin *et al.*,1999). Panicle length of fragrant rice varied significantly due to different rice varieties (Table 7). The longest panicle (26.67 cm) was recorded from V_3 , whereas the shortest panicle (25.06 cm) was found from V_1. Kader *et al*. (2020) reported that the aromatic BRRI dhan80 gave the longest panicle. Statistically significant variation was recorded on the panicle length of fragrant rice due to the combined effect of different combinations of fertilizers and rice varieties (Table 8). The longest panicle (29.93 cm) was observed from T_5V_3 which was statistically similar to T_4V_3, while the shortest panicle (20.75 cm) was found from the T_1V_1 treatment combination.

4.1.8 Flag leaf length and breadth

Length

Flag leaf length of fragrant rice showed variations due to different fertilizer combinations (Table 7). The highest flag leaf length (44.93) was observed from T_1, whereas the lowest flag leaf length (37.68) was recorded from T_3.

Statistically, significant variation was recorded due to different rice varieties in terms of flag leaf length of fragrant rice (Table 7). The highest flag leaf length (45.49 cm) was observed from V_3 and the lowest flag leaf length was recorded from V_1 (37.29 cm) which is statistically similar to V_2. Different varieties might be varied due to genetic traits.

The combined effect of different combinations of fertilizers and rice varieties showed statistically significant variation in terms of flag leaf length of fragrant rice (Table 8). The highest flag leaf length (43.10 cm) was found from T_4V_3, whereas the lowest flag leaf length (28.56) was recorded from the T_3V_2 treatment combination.

Breadth

Flag leaf breadth of fragrant rice showed statistically significant variations due to different fertilizer combinations (Table 7). The highest flag leaf breadth (1.18) was observed from T_3 whereas, the minimum Flag leaf breadth (1.06) was recorded from T_2.

Statistically significant variation was recorded due to different rice varieties in terms of flag leaf breadth of fragrant rice (Table 7). The highest flag leaf breadth (1.37) was observed from V_3 while the lowest (0.90 cm) was V_1 which was statistically similar to V_2. The differences between the three varieties might be varied due to genetic traits. The combined effect of different combinations of fertilizers and rice varieties showed statistically non-significant variation in terms of flag leaf breadth of fragrant rice (Table 8). The highest flag leaf breadth of fragrant rice (1.60) was found from T_3V_3, whereas the lowest flag leaf breadth of fragrant rice (0.90) was recorded from the T_3V_1 treatment combination.

4.1.9 Filled grains panicle^{-1}

Statistically significant variations were recorded in terms of filled grains panicle^{-1} of fragrant rice due to different combinations of fertilizers (Table 9). The highest number of filled grains panicle^{-1} (134.32) was found from T_5 while the lowest number (91.31) was recorded from T_1. Razdi *et al*. (2017) found the highest grains panicle^{-1} with the increasing pattern of vermicompost application.

Different rice varieties varied significantly in terms of filled grains panicle^{-1} of fragrant rice (Table 9). The highest number of filled grains panicle^{-1} (117.37) was observed from V_3, whereas the lowest number (110.10) was recorded from V_1. Kader *et al*. (2020) revealed that the number of grains panicle^{-1} more in BRRI dhan80 than other released aromatic varieties.

Filled grains panicle^{-1} of fragrant rice showed statistically significant differences due to the combined effect of different combinations of fertilizers and rice varieties (Table10). The highest number of filled grains panicle^{-1} (138.56) was recorded from T_5V_3, and the lowest number (85.94) was observed from the T_1V_1 treatment combination. This might be caused due to the increasing rate of vermicompost.

4.1.10 Unfilled grains panicle^{-1}

Unfilled grains panicle^{-1} of fragrant rice showed statistically significant variations due to different combinations of fertilizers (Table 9). The highest number of unfilled grains panicle^{-1} (39.91) was observed from T_5 while the lowest number (28.18) was found from T_1. Grain filling and grain maturation depend on environmental factors (Rao, 2005).

Different rice varieties varied significantly in terms of unfilled grains panicle^{-1} of fragrant rice (Table 9). The highest number of unfilled grains panicle^{-1} (38.70) was recorded from V_2 while the lowest number (27.58) was found from V_3. This might be caused due to environmental conditions as well as genetic traits (Rao,2005).

Statistically, significant variation was recorded on unfilled grains panicle^{-1} of fragrant rice due to the combined effect of different combinations of fertilizers and rice varieties (Table 10). The highest number of unfilled grains panicle^{-1} (49.50) was observed from T_5V_1, whereas the lowest number (16.73) was found from the T_4V_3 treatment combination.

4.1.11 Weight of 1000-grains

The weight of 1000-grains of fragrant rice showed statistically significant variations due to different combinations of fertilizers (Table 9). The highest weight of 1000-grains (20.99 g) was observed from T_5, and the lowest weight (20.82 g) was recorded from $T_{1.}$ Kumar *et al.* (2014) reported that 1000 grain weight may be increased by up to 12.90% with the increasing rate of vermicompost.

Different rice varieties varied significantly in terms of weight of 1000-grains (Table 9). The highest weight of 1000-grains of fragrant rice (26.27 g) was recorded from V_3, whereas the lowest weight (17.26 g) from V_1. Kader *et al.* (2020) stated that ‘BRRI dhan80’ is a high yielding modern aromatic rice variety.

Statistically, significant variation was recorded on the weight of 1000-grains of fragrant rice due to the combined effect of different combinations of fertilizers and rice varieties (Table 10). The highest weight of 1000-grains (26.37 g) was observed from T_5V_3 and the lowest weight (17.18 g) was found from the T_2V_1 treatment combination.

4.1.12 Grain yield

Statistically significant variation was recorded in terms of grain yield of fragrant rice due to different combinations of fertilizers (Table 9). The highest grain yield (4.01 t ha^{-1}) was found from T_5 which was statistically similar (3.95 t ha^{-1}) to T_4, while the lowest grain yield (3.46 t ha^{-1}) was observed from T_1. Esfahani *et al*. (2018) reported that grain yield increases with the increasing rate of vermicompost and Singh *et al*. (2007) reported that the rice grain yield increased by 114 to 116.8% over absolute control when organic amendments were applied. Das *et al.* (2002) revealed that the best results in terms of grain and straw yields were obtained with 50% vermicompost+50% chemical fertilizers. Different rice varieties varied significantly in terms of grain yield of fragrant rice (Table 9). The highest grain yield (4.56 t ha^{-1}) was observed from V_3 while the lowest (3.33 t ha^{-1}) was obtained by V_2 which was statistically similar to V_1. Kader *et al*. (2020) obtained the highest grain yield from BRRI dhan80 compared to other aromatic rice varieties. The grain yield of fragrant rice showed statistically significant differences due to the combined effect of different combinations of fertilizers and rice varieties (Table 10). The highest grain yield (4.94 t ha^{-1}) was found from T_5V_3, whereas the lowest grain yield (3.09 t ha^{-1}) was recorded from the T_1V_2 treatment combination.

4.1.13 Straw yield

The straw yield of fragrant rice showed statistically significant variations due to different combinations of fertilizers (Table 9). The highest straw yield (7.84 t ha^{-1}) was observed from T_5 which was statistically similar to T_4, whereas the lowest straw yield (5.29 t ha^{-1}) was recorded from T_1. Razdi *et al.* (2017) found the highest straw yields with the increasing rate of vermicompost. Kumar *et al.* (2014) and Das *et al.* (2002) reported that the increasing rate of vermicompost can promote the straw yield up to 37.12% under an increasing rate of vermicompost.Different rice varieties varied significantly in terms of straw yield of fragrant rice (Table 9). The highest straw yield (7.90 t ha^{-1}) was recorded from V_1 which was while the lowest straw yield (5.18 t ha^{-1}) was observed from V_3. Statistically, significant variation was recorded on the straw yield of fragrant rice due to the combined effect of different combinations of fertilizers and rice varieties (Table 10). The highest straw yield (8.64t ha^{-1}) was recorded from T_5V_1, whereas the lowest straw yield (3.96 t ha^{-1}) was observed from the T_1V_3.

Table 9. Effects of different combinations of fertilizers and fragrant rice varieties on the number of filled grain, unfilled grain, the weight of 1000-grains, grain yield, straw yield, biological yield, and harvest index.

Treatments	Number of filled grains $panicle^{-1}$	Number of unfilled grains $panicle^{-1}$	1000-grain weight (g)	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
T_1	91.31 e	28.18 b	20.82 c	3.46 d	5.29 d	8.75 e	40.08 a
T_2	100.98 d	34.01 ab	20.82 c	3.60 c	6.17 c	9.78 d	37.60 b
T_3	116.83 c	29.11 b	20.87 bc	3.73 b	6.91 b	10.64 c	35.88 c
T_4	125.33 b	31.81 ab	20.93 ab	3.95 a	7.67 a	11.63 b	34.14 d
T_5	134.32 a	39.91 a	20.99 a	4.01 a	7.84 a	11.85 a	34.02 d
$LSD_{(0.05)}$	1.96	9.85	0.08	0.07	0.07	0.13	0.44
Level of Significant	**	*	**	*	*	*	**
CV (%)	8.59	13.54	5.72	5.37	6.21	7.30	8.56
Varieties	Number of filled grains $panicle^{-1}$	Number of unfilled grains $panicle^{-1}$	1000-grain weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ ha)	Harvest index (%)
V_1	110.10 c	31.53 ab	17.26 c	3.35 b	7.90 a	11.26 a	29.90 c
V_2	113.79 b	38.70 a	19.13 b	3.33 b	7.25 b	10.59 b	31.83 b
V_3	117.37 a	27.58 b	26.27 a	4.56 a	5.18 c	9.75 c	47.29 a
$LSD_{(0.05)}$	0.99	7.52	0.07	0.06	0.08	0.11	0.45
Level of Significant	**	*	**	*	*	**	*
CV (%)	5.15	15.28	6.51	5.20	6.83	6.45	8.70

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

** : Significant at 0.01 level of significance   * : Significant at 0.05 level of significance

T_1: 100% N through urea.
T_2: 90% N through urea + 10% N through vermicompost.
T_3: 80% N through urea + 20% N through vermicompost.
T_4: 70% N through urea + 30% N through vermicompost.
T_5: 60% N through urea + 40% N through vermicompost.

V_1: BRRI dhan37
V_2: BRRI dhan38
V_3: BRRI dhan80

Table 10. Combined effect of different combinations of fertilizers and fragrant rice varieties on the number of filled grain, unfilled grain, weight of 1000-grains, grain yield, straw yield, biological yield, and harvest index.

Interaction	Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}	1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
T_1V_1	85.94 m	21.73 cde	17.19 f	3.13 hi	6.55 ef	9.68 f	32.35 f
T_1V_2	92.49 l	40.00 ab	19.07 d	3.09 i	5.36 g	8.45 h	36.61 e
T_1V_3	95.50 k	22.83 cde	26.19 b	4.17 d	3.96 j	8.13 i	51.27 a
T_2V_1	96.58 k	34.20 a-d	17.18 f	3.22 ghi	7.62 d	10.84 e	29.74 g
T_2V_2	101.20 j	37.96 abc	19.10 cd	3.25 gh	6.57 e	9.83 f	33.09 f
T_2V_3	105.15 i	29.86 b-e	26.19 b	4.33 c	4.33 i	8.66 h	49.98 b
T_3V_1	113.56 h	19.06 de	17.23 ef	3.35 fg	8.19 c	11.54 b	29.02 g
T_3V_2	117.32 g	38.23 abc	19.11 cd	3.33 g	7.77 d	11.10 d	29.97 g
T_3V_3	119.62 f	30.03 b-e	26.26 ab	4.52 b	4.77 h	9.29 g	48.65 c
T_4V_1	123.44 e	33.16 a-e	17.32 ef	3.52 e	8.51 a	12.04 a	29.26 g
T_4V_2	124.50 e	45.53 ab	19.12 cd	3.47 ef	8.12 c	11.59 b	29.95 g
T_4V_3	133.44 b	16.73 e	26.34 a	4.86 a	6.39 f	11.26 cd	43.21 d
T_5V_1	128.04 d	49.50 a	17.36 e	3.55 e	8.64 a	12.20 a	29.15 g
T_5V_2	130.98 c	31.80 b-e	19.24 c	3.53 e	8.43 b	11.97 a	29.55 g
T_5V_3	138.56 a	38.43 abc	26.37 a	4.94 a	6.45 ef	11.40 bc	43.38 d
$LSD_{(0.05)}$	2.23	16.81	0.17	0.15	0.19	0.25	1.01
Level of Significant	**	*	**	*	*	*	*
CV (%)	5.15	15.28	6.51	5.20	6.83	6.45	8.70

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

** : Significant at 0.01 level of significance   * : Significant at 0.05 level of significance

T_1: 100% N through urea.

T_2: 90% N through urea + 10% N through vermicompost.

T_3: 80% N through urea + 20% N through vermicompost.

T_4: 70% N through urea + 30% N through vermicompost.

T_5: 60% N through urea + 40% N through vermicompost.

V_1: BRRI dhan37

V_2: BRRI dhan38

V_3: BRRI dhan80

4.1.14 Biological yield

Different combinations of fertilizers showed statistically significant variations in terms of the biological yield of fragrant rice (Table 8). The highest biological yield (11.85 t ha^{-1}) was found from T_5 while the lowest biological yield (8.75 t ha^{-1}) was observed from T_1. Kumar *et al.* (2014) reported that the increasing rate of vermicompost can promote the biological yield.

The biological yield of fragrant rice showed statistically significant differences due to different rice varieties (Table 8). The highest biological yield (9.75 t ha^{-1}) was recorded from V_1 while the lowest biological yield (9.75 t ha^{-1}) was found from V_3. Biological yield significantly increased with the increasing rate of organic matter and varietal character of rice is responsible for biological yield (Esfahani *et al*. 2018).

Statistically, significant variation was recorded in the biological yield of fragrant rice due to the combined effect of different combinations of fertilizers and rice varieties (Table 10). The highest biological yield (12.20 t ha^{-1}) was found from T_5V_1 and the lowest biological yield (8.13 t ha^{-1}) was found from the T_1V_3 treatment combination.

4.1.15 Harvest index

The harvest index of fragrant rice showed statistically significant variations due to different combinations of fertilizers (Table 9). The highest harvest index (40.08 %) was found from T_1 and the lowest harvest index (34.02 %) was recorded from T_5.

Different rice varieties varied significantly in terms of harvest index of fragrant rice (Table 9). The highest harvest index (47.29%) was recorded from V_3, whereas the lowest harvest index (29.90%) was found from V_1. This might be caused due to genetic makeup (Esfahani *et al*. 2018).

Statistically, significant variation was recorded on the harvest index of fragrant rice due to the combined effect of different combinations of fertilizers and rice varieties (Table 10). The highest harvest index (51.27%) was observed from T_1V_3 and the lowest harvest index (29.02%) was found from the T_3V_1 treatment combination.

4.2 Grain quality of fragrant rice varieties

4.2.1 Protein content

Different combinations of fertilizers varied significantly in terms of the protein content of fragrant rice (Table 12). The highest protein content (11.61%) was found from T_5 while the lowest (9.43%) was observed from T_1. Guosheng *et al*. (2015) reported that the application of vermicompost can raise the protein percentage significantly. Kumar *et al.* (2014) reported that the increasing rate of vermicompost can promote the protein percentage.

Statistically significant variation was recorded due to different rice varieties in terms of the protein content of fragrant rice (Table 12). The highest protein content (11.34%) was found from V_1, whereas the lowest (9.81%) was observed from V_2.

The combined effect of different combinations of fertilizers and rice varieties showed statistically significant variation was recorded in terms of the protein content of fragrant rice (Table 13). The highest protein content (12.29%) was recorded from T_5V_1 which was statistically similar to T_5V_3, T_4V_1 and T_3V_1 while the lowest protein content (8.58%) was observed from the T_1V_2.

4.2.2 Amylose content

Amylose content of fragrant rice showed statistically significant variations due to different combinations of fertilizers (Table 12). The highest amylose content (23.84 %) was found from T_1, whereas the lowest (20.23%) was recorded from T_5. The application of cow manure and vermicompost increased the grain's N, P, and K content by 8–20%, 22–23%, and 20–33%, but decreased the starch content by 3–7% (Taheri *et al.,* 2017).

Different rice varieties varied significantly in terms of the amylose content of fragrant rice (Table 12). The highest amylose content (22.29%) was observed from V_1 which was statistically similar (22.10%) to V_3 while the lowest (21.62%) was recorded from V_2.

Statistically, significant variation was recorded on the amylose content of fragrant rice due to the combined effect of different combinations of fertilizers and rice varieties (Table 13). The highest amylose content (24.32%) was recorded from T_1V_3 which was statistically similar to T_1V_1 whereas, the lowest amylose (20.04%) was observed from the T_5V_2 treatment combination.

4.2.3 Proline content

Different combinations of fertilizers varied significantly for the proline content of fragrant rice (Table 12). The highest proline content (24.92 mg g^{-1}) was observed from T_5 while the lowest (22.03 mg g^{-1}) from T_1. Guosheng *et al.* (2015) reported that the application of vermicompost liquors can raise proline concentration as it increases the protein percentage. Vermicompost may promote the vegetative growth of plants as well as boost the nutritional value of some crops (Lazcano *et al.,* 2011).

Proline content of fragrant rice varied significantly in terms of different rice varieties (Table 12). The highest proline content (23.80 mg g^{-1}) was recorded from V_3 which is statistically similar to V_1, whereas the lowest (23.18 mg g^{-1}) was found from V_2.

The combined effect of different combinations of fertilizers and rice varieties showed statistically significant variation in terms of the proline content of fragrant rice (Table 13). The highest proline content (24.97 mg g^{-1}) was observed from T_5V_3 while the lowest (21.10 mg g^{-1}) was found from the T_1V_1 treatment combination.

4.2.4 Grain 2-AP content

Statistically, significant variation was recorded in terms of grain 2-AP content of fragrant rice due to different combinations of fertilizers (Table 11). The highest grain 2-AP content (0.98 µg g^{-1}) was recorded from T_5, whereas the lowest (0.90 µg g^{-1}) was observed from T_1. Vermicompost has positive effects on the aromaticity of crops as well as on the medicinal value of medicinal plants (Domínguez *et al.,* 2010).

Grain 2-AP content of fragrant rice showed statistically significant differences due to different rice varieties (Table 11). The highest grain 2-AP content (0.95 µg g^{-1}) was found from V_1 which was followed by V_2 (0.91 µg g^{-1}), while the lowest (0.93 µg g^{-1}) was recorded from V_3. Aromaticity depends on the genetic make of plants. The combined effect of different combinations of fertilizers and rice varieties showed statistically significant differences in terms of grain 2-AP content of fragrant rice (Table 12). The highest grain 2-AP content (0.99 µg g^{-1}) was recorded from T_5V_1 and the lowest (0.89 µg g^{-1}) was observed from T_1V_1.

Table 11. Effects of different combinations of fertilizers and fragrant rice varieties on protein, amylose, proline, and 2-AP content in grain.

Treatments	Protein (%)	Amylose (%)	Proline ($mg\ g^{-1}$) on dry weight basis	2-AP ($\mu g\ g^{-1}$) on dry weight basis
T_1	9.43 e	23.84 a	22.03 e	0.90 e
T_2	9.95 d	22.80 b	22.88 d	0.92 d
T_3	10.54 c	21.99 c	23.66 c	0.94 c
T_4	11.04 b	21.15 d	24.40 b	0.96 b
T_5	11.61 a	20.23 e	24.92 a	0.98 a
$LSD_{(0.05)}$	0.23	0.41	0.48	0.01
Level of Significant	**	**	**	**
CV (%)	6.04	7.73	6.90	5.88
Varieties	Protein (%)	Amylose (%)	Proline ($mg\ g^{-1}$)	2-AP ($\mu g\ g^{-1}$)
V_1	11.34 a	22.29 a	23.75 a	0.95 a
V_2	9.81 c	21.62 b	23.18 b	0.94 ab
V_3	10.38 b	22.10 a	23.80 a	0.93 b
$LSD_{(0.05)}$	0.27	0.25	0.54	0.01
Level of Significant	**	**	**	**
CV (%)	7.41	6.50	9.03	6.67

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

** : Significant at 0.01 level of significance

T_1: 100% N through urea.

T_2: 90% N through urea + 10% N through vermicompost.

T_3: 80% N through urea + 20% N through vermicompost.

T_4: 70% N through urea + 30% N through vermicompost.

T_5: 60% N through urea + 40% N through vermicompost.

V_1: BRRI dhan37

V_2: BRRI dhan38

V_3: BRRI dhan80

Table 12. The combined effect of different combinations of fertilizers and fragrant rice varieties on protein, amylose, proline and 2-AP content in grain.

Interaction	Protein (%)	Amylose (%)	Proline ($mg\ g^{-1}$) on dry weight basis	2-AP ($\mu g\ g^{-1}$) on dry weight basis
T_1V_1	10.38 cde	24.17 a	22.10 fg	0.89 f
T_1V_2	8.58 h	23.04 bc	21.44 g	0.92 de
T_1V_3	9.32 g	24.32 a	22.55 efg	0.89 ef
T_2V_1	10.78 c	23.10 b	22.89 def	0.92 d
T_2V_2	9.39 g	22.48 cde	22.56 ef	0.92 d
T_2V_3	9.69 fg	22.82 bcd	23.19 def	0.92 de
T_3V_1	11.43 b	22.26 de	23.96 bcd	0.97 ab
T_3V_2	9.96 ef	21.63 fg	23.25 de	0.94 cd
T_3V_3	10.22 def	22.08 ef	23.78 cd	0.93 cd
T_4V_1	11.85 ab	21.38 gh	24.72 abc	0.98 ab
T_4V_2	10.43 cde	20.90 hi	23.96 bcd	0.97 ab
T_4V_3	10.86 c	21.16 gh	24.51 abc	0.95 bc
T_5V_1	12.29 a	20.52 ij	25.09 a	0.99 a
T_5V_2	10.71 cd	20.04 j	24.72 abc	0.98 ab
T_5V_3	11.84 ab	20.12 j	24.97 ab	0.98 a
$LSD_{(0.05)}$	0.61	0.56	1.22	0.03
Level of Significant	**	**	**	**
CV (%)	7.41	6.50	9.03	6.67

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

** : Significant at 0.01 level of significance.

T_1: 100% N through urea.

T_2: 90% N through urea + 10% N through vermicompost.

T_3: 80% N through urea + 20% N through vermicompost.

T_4: 70% N through urea + 30% N through vermicompost.

T_5: 60% N through urea + 40% N through vermicompost.

V_1: BRRI dhan37

V_2: BRRI dhan38

V_3: BRRI dhan80

CHAPTER V

SUMMARY AND CONCLUSION

For plant height of fragrant rice at 20, 40, 60 DAT (days after transplanting) and at harvest showed significant variations due to different fertilizer combinations. At 20, 40, 60 DAT and harvest, the tallest plant (55.16, 93.08, 123.02, and 123.42 cm respectively) was observed from T_5 while the shortest plant (48.65, 89.13, 119.08, and 117.18 cm respectively) was found from T_1. Different combinations of fertilizers showed significant variations in terms of the number of tillers hill^{-1} of fragrant rice at 20, 40, 60 DAT and at harvest, the maximum number of tillers hill^{-1} (10.29, 14.18,16.38 and 16.83, respectively) was recorded from T_5 while the minimum number (7.09,10.08,11.57 and 10.74 respectively) was observed from T_1. Different combinations of fertilizers showed significant variations in terms of dry matter weight fragrant rice at 20, 40, 60 DAT, the maximum dry matter weight (5.43, 46.80, and 91.22g respectively) was recorded from T_5 while the minimum number (4.26, 32.53, and 73.49 g respectively) was observed from T_2. In terms of chlorophyll content in the flag leaf of fragrant rice for different combinations, data discovered that the highest chlorophyll content in flag leaf (41.14 mg g^{-1}) was found fromT_4 which was statistically similar to T_3, whereas the lowest (36.24 mg g^{-1}) was recorded from T_1.

In terms of effective tillers/hill of fragrant rice, the highest number of effective tillers hill^{-1} (14.39) was recorded from T_5 which was were statistically similar to T_4, while the lowest number (9.84) from $T_{1.}$ Non-effective tillers hill^{-1} of fragrant rice showed significant variations due to different fertilizer combinations. The highest number of non-effective tillers hill^{-1} (2.43) was observed from T_5, whereas the lowest number (0.9) was recorded from T_1. Different combinations of fertilizers showed significant differences in terms of the panicle length of fragrant rice. The longest panicle (28.27 cm) was observed from T_5 which was statistically similar to T_4 (27.68 cm) while the shortest panicle (22.97 cm) was found from T_1. The highest flag leaf length (44.93) was observed from T_1, whereas the lowest flag leaf length (37.68) was recorded from T_3.

Flag leaf breadth of fragrant rice showed statistically significant variations due to different fertilizer combinations. The highest flag leaf breadth (1.18 cm) was observed from T_3, whereas the minimum flag leaf breadth (1.06) was recorded from T_1.

Significant variations were recorded in terms of filled grains panicle^{-1} of fragrant rice due to different combinations of fertilizers. The highest number of filled grains panicle^{-1} (134.32) was found from T_5 while the lowest number (91.31) was recorded from T_1. Unfilled grains panicle^{-1} of fragrant rice showed statistically significant variations due to different combinations of fertilizers. The highest number of unfilled grains panicle^{-1} (39.91) was observed from T_5, while the lowest number (28.18) was found from T_1. The weight of 1000-grains of fragrant rice showed significant variations due to different combinations of fertilizers. The highest weight of 1000-grains (20.99 g) was observed from T_5 and the lowest weight (20.82 g) was recorded from T_1 which statistically similar to T_2 . A significant variation was recorded in terms of grain yield of fragrant rice due to different combinations of fertilizers. The highest grain yield (4.01 t ha^{-1}) was found from T_5 which was statistically similar to T_4, while the lowest grain yield (3.46 t ha^{-1}) was observed from T_1.

For a straw yield of fragrant rice, the highest straw yield (7.84 t ha^{-1}) was observed from T_5 which was statistically similar to T_4, whereas the lowest straw yield (5.29 t ha^{-1}) was recorded from T_1. Different combinations of fertilizers showed statistically significant variations in terms of the biological yield of fragrant rice. The highest biological yield (11.85 t ha^{-1}) was found from T_5 while the lowest biological yield (8.75 t ha^{-1}) was observed from T_1. The highest harvest index (40.08 %) was found from T_1 and the lowest harvest index (34.02 %) was recorded from T_5. The highest protein content (11.61%) was found from T_5 while the lowest (9.43%) was observed from T_1. Amylose content of fragrant rice showed statistically significant variations due to different combinations of fertilizers. The highest amylose content (23.84 %) was found from T_1, whereas the lowest (20.23%) was recorded from T_5. The highest proline content (24.92 mg g^{-1}), based on dry weight, was observed from T_5 while the lowest (22.03 mg g^{-1}) from T_1. Significant variation was recorded based on dry weight in terms of grain 2-AP content of fragrant rice due to different combinations of fertilizers. The highest grain 2-AP content of grain (0.98 µg g^{-1}) was recorded from T_5, whereas the lowest (0.90 µg g^{-1}) was observed from T_1.

In term of varieties, at 20, 40, 60 DAT and at harvest, the tallest plant height (54.06, 93.42, 122.90, and 121.84cm respectively) was recorded from V_1 (BRRI dhan37), whereas the shortest plant (49.66, 89.66, 118.31, and 118.52 cm respectively) was found from V_3 (BRRI dhan80). The number of tillers hill^{-1} of fragrant rice at 20, 40, 60 DAT, and harvest showed statistically significant differences due to different rice varieties. At 20, 40, 60 DAT and harvest, the maximum number of tillers hill^{-1} (8.81, 12.71, 14.41, and 14.33 respectively) was found from V_3, whereas the minimum number (8.21, 12.04, 13.84, and 13.30 respectively) was recorded from V_1. For rice varieties, the dry matter weight at 20, 40, 60 DAT, the maximum dry weight (5.28, 43.63, and 85.30g respectively) was found from V_1, whereas the minimum weight (4.49, 38.09, and 71.21g respectively) was recorded from V_3. In terms of rice varieties, they are varied non-significantly for chlorophyll content in the flag leaf of fragrant rice. The highest chlorophyll content in flag leaf (41.31 mg g^{-1}) was recorded from V_2 and the lowest chlorophyll content in flag leaf (37.78 mg g^{-1}) was observed from V_3. The highest number of effective tillers hill^{-1} (12.51) was found from V_3 where the lowest number was observed from V_1. Significant variation was recorded due to different rice varieties the highest number of non-effective tillers hill^{-1} (1.82) was observed from V_3 and the lowest was V_1 (2.53). Panicle length of fragrant rice varied significantly; the longest panicle (26.67 cm) was recorded from V_3, whereas the shortest panicle (25.06 cm) was found from V_1. A significant variation was recorded due to different rice varieties in terms of flag leaf length of fragrant rice. The highest flag leaf length (45.49 cm) was observed from V_3 and the minimum length V_1 (37.29 cm).

Statistically, significant variation was observed from different rice varieties, the highest flag leaf breadth (1.37) was observed from V_3 and the lowest was V_1 (0.90 cm). The highest number of filled grains panicle^{-1} (117.37) was observed from V_3, whereas the lowest number (110.10) was recorded from V_1. The highest number of unfilled grains panicle^{-1} (24.73) was recorded from V_3 which was statistically similar (31.53) to V_1 and followed (38.70) by V_2, while the lowest number (27.58) was found from V_3. The highest weight of 1000-grains of fragrant rice (26.27 g) was recorded from V_3 and followed (19.13 g) by V_2, whereas the lowest weight (17.26 g) from V_1. Different rice varieties varied significantly in terms of grain yield of fragrant rice. The highest grain yield (4.56 t ha^{-1}) was observed from V_3 and the lowest grain yield (3.33 t ha^{-1}) was obtained from V_2 while V_2 was statistically similar to V_1. The highest straw yield (7.90 t ha^{-1}) was recorded from V_1 while the lowest straw yield (5.18 t ha^{-1}) was observed from V_3. Significant differences due to different rice varieties were observed. The highest biological yield (9.75 t ha^{-1}) was recorded from V_1 while the lowest biological yield (9.75 t ha^{-1}) was found from V_3. The highest harvest index (47.29%) was recorded from V_3 whereas, the lowest harvest index (29.90%) was found from V_1.

A significant variation was recorded due to different rice varieties in terms of the protein content of grains. The highest protein content (11.34%) was found from V_1, whereas the lowest (9.81%) was observed from V_2. The highest amylose content (22.29%) was observed from V_1 which was statistically similar to V_3 while the lowest (21.62%) was recorded from V_2. The highest proline content (23.80 mg g^{-1}), based on dry weight, was recorded from V_3 which was statistically similar to V_1, whereas the lowest (23.18 mg g^{-1}) was found from V_2. The highest 2-AP content (0.95 µg g^{-1}), based on dry weight, was found from V_1 while the lowest (0.93 µg g^{-1}) was recorded from V_3.

Significant variation was noticed on plant height of fragrant rice at 20, 60 DAT, and at harvest due to the combined effect of different combinations of fertilizers and rice varieties but in case of 40 DAT it showed non-significant result compared to 20 and 60 DAT and at harvest. At 20, 40, 60 DAT and harvest, the tallest plant (57.06, 95.53, 125.93, and 124.58 cm, respectively) was found from T_5V_1 while the shortest plant (46.52, 87.25, 116.83, and 115.23cm, respectively) was recorded from T_1V_3 combination. A significant variation was noticed in the tiller number of fragrant rice at 20, 60 DAT due to the combined effect of different combinations of fertilizers and rice varieties but in case of harvest it showed non-significant result compared to 20,40 and 60 DAT. At 20, 40, 60 DAT and harvest, the maximum number of tillers $hill^{-1}$ (10.94, 14.56, 16.72, and 17.31, respectively) was observed from T_5V_3 and the minimum number (6.82, 9.54, 11.17, and 10.09, respectively) was recorded from T_1V_1 treatment combination. Significant variation was noticed on dry matter weight of fragrant rice at 20 and 60 DAT due to the combined effect of different combinations of fertilizers and rice varieties but in case of 40 DAT it showed non-significant result compared to 20 and 60 DAT. At 20, 40 and 60 DAT, the maximum dry weight (5.90, 49.55 and 96.17g, respectively) was observed from T_5V_1, and the minimum number (3.71, 28.44 and 6040g, respectively) was recorded from T_2V_3 treatment combination

Significant variation was noticed on chlorophyll content, the highest chlorophyll content in flag leaf (40.56 mg g^{-1}) was observed from T_4V_2, while the lowest (36.20 mg g^{-1}) was recorded from the T_1V_3 treatment combination.

Non-significant variation was noticed on effective tillers number. The highest number of effective tillers $hill^{-1}$ (14.81) was recorded from T_5V_3 and the lowest number (9.56) was found from the T_1V_1 treatment combination. Non-significant variation was noticed on non-effective tillers number. The highest number of non-effective tillers $hill^{-1}$ (2.50) was found from T_5V_3, whereas the lowest number (0.53) was recorded from the T_1V_1 treatment combination.

Significant variation was noticed on panicle length by treatment combinations where the longest panicle (29.93 cm) was observed from T_5V_3, while the shortest panicle (20.75 cm) was found from the T_1V_1 treatment combination. Significant variations were noticed on flag leaf length by treatment combinations where the highest flag leaf length (43.10 cm) was found from T_4V_3, whereas the lowest flag leaf length (28.56 cm) was recorded from the T_3V_2 treatment combination.The combined effect of different combinations of fertilizers and rice varieties showed statistically non-significant variation in terms of the flag leaf breadth. The highest flag leaf breadth of fragrant rice (1.60) was found from T_3V_3, whereas the lowest flag leaf breadth of fragrant rice (0.70 cm) was recorded from the T_2V_2 treatment combination. Significant variations of combined doses were observed in filled grain. The highest number of filled grains $panicle^{-1}$ (138.56) was recorded from T_5V_3 and the lowest number (85.94) was observed from the T_1V_1 treatment combination.

Significant variations of combined doses were observed in unfilled grain. The highest number of unfilled grains $panicle^{-1}$ (49.50) was observed from T_5V_1, whereas the lowest number (16.73) was found from the T_4V_3 treatment combination. Statistically, significant variation was recorded on the weight of 1000-grains of fragrant rice due to the combined effect of different combinations of fertilizers and rice varieties. The highest weight of 1000-grains (26.37 g) was observed from T_5V_3 which was statistically similar to T_4V_3 and the lowest weight (17.18 g) was found from the T_2V_1 treatment combination.

Grain yield of fragrant rice showed statistically significant differences due to the combined effect of different combinations of fertilizers and rice varieties. The highest grain yield (4.94 t ha^{-1}) was found from T_5V_3 which was statistically similar to T_4V_3, whereas, the lowest grain yield (3.09 t ha^{-1}) was recorded from the T_1V_2 treatment combination. The significant straw yield was observed where the highest straw yield (8.64t ha^{-1}) was recorded from T_5V_1 which was statistically similar to T_4V_3, whereas the lowest straw yield (3.96 t ha^{-1}) was observed from the T_1V_3 treatment combination. The highest biological yield (12.20 t ha^{-1}) was found from T_5V_1 which was statistically similar to T_4V_1 and T_5V_2 while the lowest biological yield (8.13 t ha^{-1}) was found from the T_1V_3 treatment combination. The highest harvest index (51.27%) was observed from T_1V_3 and the lowest harvest index (29.02%) was found from the T_3V_1 treatment combination.

Significant Variations are observed from different combinations in terms of protein, amylose, proline and 2-AP content. The highest protein content (12.29%) was recorded from T_5V_1 and the lowest protein content (8.58%) was observed from the T_1V_2. The highest amylose content (24.32%) was recorded from T_1V_3 which was statistically similar to $T_1V_{1,}$ whereas the lowest amylose (20.04%) was observed from the T_5V_2 treatment combination.

The combined effect of different combinations of fertilizers and rice varieties showed statistically significant variation in terms of the proline content of fragrant rice. The highest proline content (24.97 mg g^{-1}) was observed from T_5V_3, while the lowest (21.10 mg g^{-1}) was found from the T_1V_1 treatment combination. Significant differences in terms of grain 2-AP content of fragrant rice were found for combined treatment combinations. The highest grain 2-AP content (0.99 µg g^{-1}) was recorded from T_5V_1 and the lowest (0.89 µg g^{-1}) was observed from T_1V_1 which was statistically similar to T_1V_3.

From the 15 treatment combinations, T_5V_3 and T_4V_3 produced maximum yield however 70% N through urea+30% N through vermicompost may be used for producing maximum yield. Although T_5V_1, T_5V_2, T_5V_3 and T_4V_1 showed excellent performance when considering proline, and 2-AP content but farmer may use 70% N through urea+30% N through vermicompost for the production of good quality aromatic rice. Based on the results of this experiment, further studies in the following areas may be suggested:

1. Such kinds of study is needed to be repeated in different agroecological zones (AEZ) of Bangladesh to evaluate the regional adaptability,

2. Other management practices may be used to reveal better results of further studies, and

3. Other combinations of organic manures and chemicals fertilizer may be used for further study to specify the specific combinations that are cost-effective and eco-friendly

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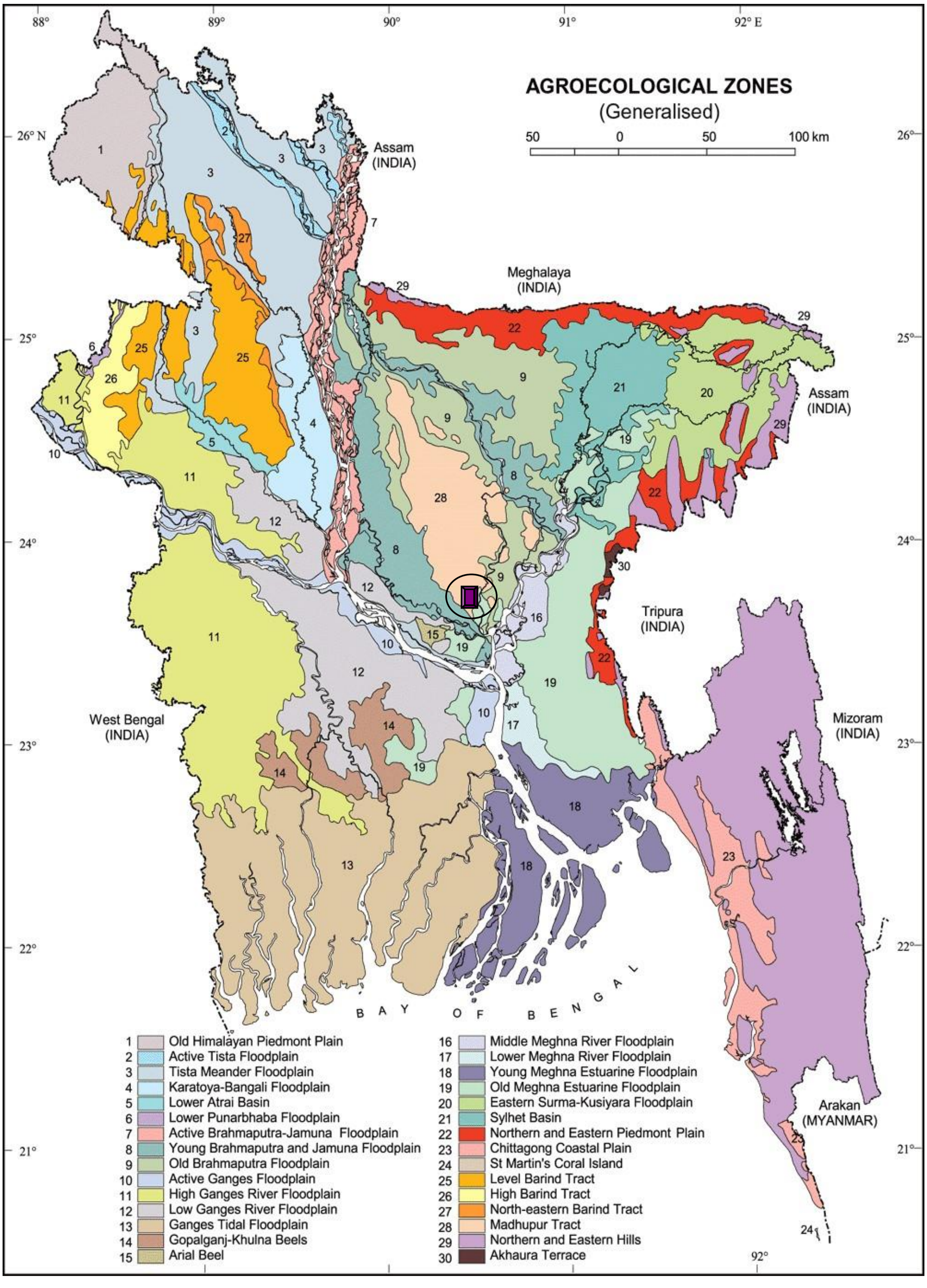
APPENDICES

Appendix I. The Map of the experimental site



Appendix II. Monthly record of air temperature, relative humidity, rainfall, and sunshine (average) of the experimental site during the period from June to December 2019.

Month (2019)	Air temperature (^0C)		Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
June	32.4	25.5	81	228	5.7
July	36.8	24.9	87	573	5.5
August	35.2	23.3	85	303	6.2
September	33.7	22.6	82	234	6.8
October	26.6	19.5	79	34	6.5
November	25.1	16.2	77	07	6.7
December	22.6	13.4	74	00	6.6

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka–1207

Appendix III. Soil characteristics of the experimental field as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Experimental field, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	26
% Silt	43
% clay	31
Textural class	Sandy loam
pH	5.9
Cation exchange capacity	2.64 meq 100 g/soil
Organic matter (%)	1.15
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Appendix IV. Analysis of variance of the data on plant height at different days after transplanting (DAT) and harvest as an influence by different combinations of nitrogenous fertilizer and vermicompost and aromatic rice varieties.

Source of variation	Degrees of freedom	Mean square			
		Plant height (cm) at			
		20 DAT	40 DAT	60 DAT	Harvest
Replication	2	5.3490	43.0651	0.7980	0.6584
Fertilizer Dose (A)	4	76.0513*	19.3770*	20.7961*	57.7587**
Error (a)	8	1.9069	5.9296	0.9941	1.1545
Variety (B)	2	73.2824*	56.5999*	81.2027*	42.1561**
Interaction (A×B)	8	0.8641*	0.9651 NS	0.9146*	0.6155**
Error (b)	20	3.2541	1.9536	1.2452	1.0991

** : Significant at 0.01 level of significance   * : Significant at 0.05 level of significance   NS: Non significant

Appendix V. Analysis of the variance of the data on the number of tillers hill^{-1} at different days after transplanting (DAT) and harvest as influenced by different combinations of nitrogenous fertilizer and vermicompost and aromatic rice varieties.

Source of variation	**Degrees of freedom**	**Mean square**			
		Number of tillers hill^{-1}			
		20 DAT	40 DAT	60 DAT	Harvest
Replication	2	0.6004	0.2871	0.0119	0.5444
Fertilizer Dose (A)	4	12.6887*	21.4563**	33.2296*	52.8480*
Error (a)	8	0.2434	0.0524	0.0268	1.0366
Variety (B)	2	1.3539*	1.6669**	1.2061**	4.0603*
Interaction (A×B)	8	0.1888*	0.0895**	0.0564*	0.1667^{NS}
Error (b)	20	0.1107	0.0194	0.0167	0.1255

** : Significant at 0.01 level of significance. * : Significant at 0.05 level of significance. NS: Non significant

Appendix VI. Analysis of variance of the data on Dry weight at different days after transplanting (DAT) and harvest as influenced by different combinations of nitrogenous fertilizer and vermicompost and aromatic rice varieties

Source of variation	**Degrees of freedom**	**Mean square**		
		Dry Weight (g) at		
		20 DAT	40 DAT	60 DAT
Replication	2	0.00702	7.188	31.026
Fertilizer Dose (A)	4	2.29095**	289.265*	735.049*
Error (a)	8	0.04576	12.638	5.761
Variety (B)	2	2.38411**	115.188*	744.580*
Interaction (A×B)	8	0.07771**	5.694NS	20.444*
Error (b)	20	0.01535	4.156	7.451

** : Significant at 0.01 level of significance. * : Significant at 0.05 level of significance. NS: Non significant

Appendix VII. Analysis of variance of the data on chlorophyll content in flag leaf, effective, non-effective tillers hill^{-1} and panicle length as influenced by different combinations of nitrogenous fertilizer and vermicompost and aromatic rice varieties

Source of variation	**Degrees of freedom**	**Mean square**			
		Chlorophyll content in flag leaf (mg g^{-1})	Effective tillers hill^{-1} (No.)	Non-effective tillers hill^{-1} (No.)	Panicle length (cm)
Replication	2	0.4916	0.3106	1.10822	0.0140
Fertilizer Dose (A)	4	25.2522**	30.2344*	3.16833*	33.7836**
Error (a)	8	0.4957	0.8123	0.22350	3.9105
Variety (B)	2	0.4469^{NS}	2.1551*	0.30822*	9.8441**
Interaction (A×B)	8	0.5311*	0.1010^{NS}	0.04517^{NS}	2.3106**
Error (b)	20	0.7036	0.0693	0.03711	1.6178

** : Significant at 0.01 level of significance * : Significant at 0.05 level of significance NS: Non significant

Appendix VIII. Analysis of variance of the data on filled, unfilled, and total grains panicle^{-1}, flag leaf length, flag leaf breadth, and weight of 1000-grains as influenced by different combinations of vermicompost and nitrogenous fertilizer and aromatic rice

Source of variation	**Degrees of freedom**	**Mean square**				
		Filled grains panicle^{-1} (No.)	Unfilled grains panicle^{-1} (No.)	Flag leaf length (cm)	Flag leaf breath(cm)	Weight of 1000-grains (g)
Replication	2	6.27	39.861	11.117	0.00800	0.029
Fertilizer Dose (A)	4	2775.61**	197.316*	82.579*	0.06778*	0.046**
Error (a)	8	3.26	82.260	23.867	0.03244	0.006
Variety (B)	2	198.39**	477.221*	298.260*	0.88867*	39.394**
Interaction (A×B)	8	4.70**	257.596*	71.099*	0.06561^{NS}	0.002**
Error (b)	20	1.72	97.488	19.194	0.02856	0.010

** : Significant at 0.01 level of significance   * : Significant at 0.05 level of significance   NS: Non significant

Appendix IX. Analysis of variance of the data on grain, straw, biological yield and harvest index as influenced by different combinations of nitrogenous fertilizer and vermicompost and aromatic rice varieties.

Source of variation	**Degrees of freedom**	**Mean square**			
		Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	0.00982	0.0032	0.0028	0.51
Fertilizer Dose (A)	4	0.47952*	10.2141*	15.0685*	58.47**
Error (a)	8	0.00421	0.0051	0.0153	0.16
Variety (B)	2	7.42724*	30.2757*	8.6094**	1363.05*
Interaction (A×B)	8	0.02566*	0.4657*	0.5553*	8.76*
Error (b)	20	0.00728	0.0126	0.0210	0.35

** : Significant at 0.01 level of significance * : Significant at 0.05 level of significance

Appendix X. Analysis of variance of the data on protein, amylose content, proline, and grain 2-AP as influenced by different combinations of nitrogenous fertilizer and vermicompost and aromatic rice varieties.

Source of variation	**Degrees of freedom**	**Mean square**			
		Protein content (%)	Amylose content (%)	Proline content (mg g^{-1})	Grain 2-AP (µg g^{-1})
Replication	2	1.10402	0.9783	1.4502	1.756
Fertilizer Dose (A)	4	6.71569**	17.7910**	12.0879**	9.453**
Error (a)	8	0.04604	0.1446	0.1999	7.000
Variety (B)	2	8.97993**	1.7877**	1.7482**	7.022**
Interaction (A×B)	8	0.12526**	0.1658**	0.1153**	4.133**
Error (b)	20	0.12846	0.1094	0.5096	2.511

** : Significant at 0.01 level of significance * : Significant at 0.05 level of significance

A list of Plates

Plate 1 : Overall View of the experimental plots.

Plate 2: Uprooting hills from different plots for dry weight.

Plate 3: Net installation in the experimental field.

Plate 4: Panicle initiation stage.

Plate 5: Ripening stage.

Plate 6: Panicle of differen varities.

Plate 6: Chemical analysis for quality parameter at laboratory.