GENOTYPIC VARIATION IN MORPHO-PHYSIOLOGICAL TRAITS AND YIELD IN TRADITIONAL AROMATIC RICE CULTIVARS

A THESIS

BY

SONIA AKTER

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

JUNE, 2018

GENOTYPIC VARIATION IN MORPHO-PHYSIOLOGICAL TRAITS AND YIELD IN TRADITIONAL AROMATIC RICE CULTIVARS

BY

SONIA AKTER

REGISTRATION NO. : 12-04980

A Thesis

Submitted to the Department of Agricultural Botany
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfillment of the requirements
for the degree
of

MASTER OF SCIENCE (MS)

IN

AGRICULTURAL BOTANY

SEMESTER: JANUARY-JUNE, 2018

Approved by:

Prof. Dr. Md. Moinul Haque	**Prof. Dr. Md. Kamal Uddin Ahmed**
Department of Agricultural Botany	Department of Agricultural Botany
Sher-e-Bangla Agricultural University	Sher-e-Bangla Agricultural University
Dhaka-1207	Dhaka-1207
Supervisor	**Co-supervisor**

Dr. Kamrun Nahar
Associate Professor
Chairman
Examination Committee

DEPARTMENT OF AGRICULTURAL BOTANY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

*This is to certify that the thesis entitled '**Genotypic Variation in Morpho-physiological Traits and Yield in Traditional Aromatic Rice Cultivars**' submitted to the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in AGRICULTURAL BOTANY**, embodies the results of a piece of bonafide research work carried out by **SONIA AKTER**, Registration No. **12-04980** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2018
Dhaka, Bangladesh

Prof. Dr. Md. Moinul Haque
Department of Agricultural Botany
Sher-e-Bangla Agricultural University
Dhaka-1207

Supervisor

DEDICATED

TO

MY BELOVED PARENTS

ACKNOWLEDGEMENTS

All praises are due to the Omnipotent Allah, the Supreme Ruler of the universe who enables the author to complete this present piece of work. The author deems it a great pleasure to express her profound gratefulness to her respected parents, who entiled much hardship inspiring for prosecuting her studies, receiving proper education.

The author feels proud to express her heartiest gratitude, sincere appreciation and immense indebtedness to her supervisor **Dr. Md. Moinul Haque**, Professor, Department of Agricultural Botany, Sher-e-Bangla Agricultural University (SAU), Dhaka, for his continuous scholastic and intellectual guidance, cooperation, constructive criticism and suggestions in carrying out the research work and preparation of the thesis.

The author also feels proud to express her deepest respect, sincere appreciation and immense indebtedness to her Co-supervisor **Dr. Md. Kamal Uddin Ahmed**, Professor, Department of Agricultural Botany, SAU, Dhaka, and Vice Chancellor, SAU for his scholastic and continuous guidance, constructive criticism and valuable suggestions during the entire period of course and research work and preparation of this thesis.

The author expresses her sincere respect and gratitude to **Dr. Kamrun Nahar**, Honorable Chairman and Associate Professor, Departement of Agricultural Botany, SAU, Dhaka for her valuable suggestions and cooperation during the study period.

The author also expresses her heartfelt thanks to all other faculty members of the Department of Agricultural Botany, SAU, for their valuable teaching, suggestions and encouragement during the study period.

The author would like to expresses her sincere appreciation and thankfulness to her classmates, relatives, well wishers and all of her friends for their inspiration, help and encouragement throughout the study.

The Author

GENOTYPIC VARIATION IN MORPHO-PHYSIOLOGICAL TRAITS AND YIELD IN TRADITIONAL AROMATIC RICE CULTIVARS

ABSTRACT

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period of July to November 2017 to find out the genotypic variation in morpho-physiological traits and yield in traditional aromatic rice cultivars. Twelve traditional aromatic rice cultivars viz., Kalizira, Chiniatab (awned), Chiniatab (awnless), Kataribhog (awned), Kataribhog (awnless), Madhumala, Zirabhog, Shakhorkora, Badshabhog, BRRI dhan37, BRRI dhan38 and BRRI dhan50 were used as the treatment of this experiment. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Data on different morpho-physiological traits and yield were recorded and statistically significant differences was observed for different cultivars. Plant height at 20, 40, 60 and 80 DAT and at harvest, the tallest plant (45.80 cm, 84.82, 128.64, 147.00 and 150.75 cm) was recorded from Shakhorkora and that was minimum (35.26, 72.19, 100.94, 104.54 and 107.19 cm) in BRRI dhan50, respectively. At 20, 40, 60 and 80 DAT, the maximum number of tillers hill^{-1} (5.07, 9.93, 13.87 and 14.53) was found in BRRI dhan50 and the minimum number (4.07, 7.07, 10.13 and 11.00) in Shakhorkora. The highest shoot reserve translocation (15.23%) was found from BRRI dhan50, whereas the lowest (11.03%) from Shakhorkora. The maximum number of effective tillers hill^{-1} (10.80) was found from BRRI dhan50, while the minimum number (8.33) from Shakhorkora. The longest panicle (25.97 cm) was recorded from BRRI dhan50, whereas the shortest (20.30 cm) from Shakhorkora. The maximum number of filled grains panicle^{-1} (181.60) was found in BRRI dhan50 and the minimum number (155.33) in Madhumala. The highest spikelet (9.77%) was recorded from BRRI dhan50, whereas the lowest (7.97%) from Shakhorkora. The highest weight of 1000 grains (15.92 g) was observed from BRRI dhan50 and the lowest weight (10.31 g) from Chiniatab (awned). The highest grain yield (4.73 t ha^{-1}) was found from BRRI dhan50, whereas the lowest (1.86 t ha^{-1}) from Shakhorkora. The highest straw yield (6.52 t ha^{-1}) was recorded from BRRI dhan50, while the lowest (4.32 t ha^{-1}) from Shakhorkora. BRRI dhan50 produced the highest number of tillers, the highest number of filled grains, longest panicle and highest weight of 1000 grains, and consequently provided the highest grain yield.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURE

LIST OF APPENDIX

LIST OF ABBREVIATIONS

AEZ	Agro-Ecological Zone
BBS	Bangladesh Bureau of Statistics
BRRI	Bangladesh Rice Research Institute
Cont'd	Continued
CV%	Percentage of Coefficient of Variance
DAF	Days after flowering
DAT	Days after transplanting
DF	Degree of freedom
DM	Dry matter
et al.	and others
FAO	Food and Agriculture Organization
FAOSTAT	Food and Agriculture Organization Corporate
GDP	Gross Domestic Product
IRRI	International Rice Research Institute
Kg	Kilogram
LAI	Leaf area index
LSD	Least significant difference
m^2	Square meter
Mt/ha	Million ton per hectare
MV	Modern varieties
PE	Panicle Emergence
PI	Panicle Initiation
t ha^{-1}	Ton per hectare
UNDP	United Nations Development Program
USDA	United States Department of Agriculture
viz.	Namely
%	Percent

Chapter I

Introduction

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) belongs to the family Poaceae, is the staple food crop in Bangladesh and it is rank the 4^{th} largest country of the world in rice production (BBS, 2017). It is one of the world's most essential cereal food crop growing in at least 114 countries under diverse condition (Anis *et al*., 2016) with exceptional agricultural and economic importance as being is the staple food for more than 50% of the world's population (Jahan *et al.*, 2017). Rice crop provides for 21% of the calorific intake of the world and 76% of the calorific intake of the world population of south-east Asia (Fitzgerald *et al*., 2009). Bangladesh ranks 4^{th} in both area and production and 6^{th} in the production of per hectare yield of rice (Sarkar *et al*., 2016). The country is said to have among the highest per capita consumption of rice is about 170 kg annually and its food security and economy largely depend on good harvests year after year (BBS, 2017).

In Bangladesh, 11.39 million hectares of land is used for rice cultivation which is about 72.24% of total cropped area, with annual production of 34.71 million tons (BBS, 2017). The average yield of rice in Bangladesh is about 2.92 t ha^{-1} which is very low compared to other rice growing countries like Korea (6.30 t ha^{-1}), China (6.30 t ha^{-1}) and Japan (6.60 t ha^{-1}) (FAO, 2014). About two millions of people are adding every year which will be 30 million over the next 20 years and thus, to meet up the food supply for this over population, Bangladesh needs additional 37.26 million tons of rice by the year 2020 (BRRI, 2011). So, a continuous increase of rice production and the highest priority has been given for this (Bhuiyan, 2004). There are two general ways to increase rice production either to increase productivity through improving management practices or to increase cropping intensity. Rice production has to be increased at least 60% by 2020 to meet up food requirement of increasing population (Masum, 2009). Thus, the population by the year 2030 will swell progressively to 223 million which will demand additional 48 million tons of food grains (Julfiquar *et al*., 2008).

Rice yields are either stagnating or declining in post green revolution era mainly due to different factors that are related to crop production (Prakash, 2010). The reasons for low productivity of rice includes various factors like unpredictable rainfall, drought, weed, insect pest diseases, unavailability of quality seeds and seedlings, non-adoption of recommended production technology and plant protection measure but the major reason attributed to prevalence of local varieties instead of high yielding varieties and without practicing proper management (Mandira *et al*., 2016). The growth process of rice under a given agro-climatic condition differs due to specific rice variety (Alam *et al*., 2012). Improving and increasing the world's supply will also depend upon the development and improvement of rice varieties with better yield potential, and having resistance against biotic and abiotic stresses (Khush, 2005). In Bangladesh high yielding rice variety has been introduced through BRRI, BINA, IRRI and different seed companies and it gains positive momentum in rice production in three distinct growing seasons (Haque and Biswas, 2011).

Aromatic rice is precious for its special aroma, unique flavor and good quality (Baradi and Martinez, 2015; Ashraf *et al*., 2017). Thai 'jasmine' and Pak-Indian 'basmati' varieties are highly valued by consumers globally and gaining popularities in international markets (Huang *et al*., 2012), while the sale-price of aromatic rice is higher than non-aromatic rice (You *et al*., 2012). Depending on the aroma and fineness, two types of rice varieties viz. aromatic (fine) and nonaromatic (coarse) rice are producing in Bangladesh. The market price of aromatic rice is much higher than non-aromatic rice due to its best quality like scent (aroma), fineness, taste etc. The most important aromatic rice varieties in Bangladesh are Chinisagara, Badshabhog, Kataribhog, Kalizira, Tulsimla, Dulabhog, Basmati, Banglamoti (BRRI dhan50), BRRI dhan34, BRRI dhan37 and BRRI dhan38 (Sarkar *et al*., 2014). The production of aromatic rice in Bangladesh during 2013 is approximately 0.30 million tons from 0.16 million ha of land which is so far below the national demand, and hence the yield needs to be increased by 53.3% (Mahamud *et al*., 2013).

Cultivation of aromatic rice has been gaining popularity in Bangladesh over the recent years, because of its huge demand both for internal consumption and export (Das and Baqui, 2000; Dutta *et al*., 2002). The demand for scented fine grain rice has been increased due to economic development of the people of Bangladesh (Ali *et al*., 2016). Most of the well-off people preferred long, slender scented fine grain rice (Mannan *et al*., 2012; Sarkar *et al*., 2014). Despite the general favorable ago-climatic conditions and huge market demand of aromatic rice covers less than 2% of the national rice coverage of Bangladesh (Singh *et al*., 2004; Ashrafuzzaman *et al*., 2009). Considering the present situation, higher yielding aromatic rice varieties need to be developed although a few HYVs are available. But selection in new more HYVs or yield level of existing cultivars need to be improved through manipulation of agronomic cultural management practices. Details information on morpho-physiological characters and their relation with grain yield of aromatic rice genotypes are needed to serve the above purposes, although research work regarding aromatic rice cultivar is limited in Bangladesh. Based on the above proposition, the present research program has been chalked out to investigate the variations in morpho-physiological characters in aromatic rice cultivars and their relation with grain yield with the following objectives:

- To investigate the growth and yield parameters of some indigenous and HYVs rice cultivars/varieties in *Aman* season;
- To relate the flag and penultimate leaf area with yield parameters;
- To study yield variation and it causes in test aromatic rice cultivars.

Chapter II

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Rice crop is interwoven in the cultural, social and economic lives of millions of Bangladeshis and it holds the key for food and nutritional security of the country. It is consumed as the staple food and has been given the highest priority in meeting the demands of its ever-increasing population in Bangladesh. In recent years, aromatic rice has been introduced to the global market. Aromatic rice has great potential to attract rice consumer for its taste and deliciousness, and high price to boost up the economic condition of the rice grower in the developing countries like Bangladesh. Bangladesh produces different local and high yielding aromatic (fine) and nonaromatic (coarse) rice varieties. Different researcher reported the effect of rice varieties on yield contributing component and grain yield of aromatic and nonaromatic rice. However, some of the important and informative works and research findings related to the morpho-physiological attributes, yield contributing characters and yield, so far been done at home and abroad, reviewed in this chapter under the following headings-

2.1 Plant height of different rice varieties

Sumon *et al*. (2018) conducted a study to evaluate 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 three aromatic rice varieties in main plots and six fertilizer levels in subplots. From the findings they sated that 'Raniselute' variety produced the highest plant height.

Sarkar *et al*. (2014) conducted an experiment at Bangladesh Agricultural University, Mymensingh, to study the yield and quality of aromatic fine rice as affected by variety and nutrient management. The experiment comprised three aromatic fine rice varieties viz. BRRI dhan34, BRRI dhan37 and BRRI dhan38 and eight nutrient managements. Results revealed that the tallest plant (142.7 cm) were recorded in BRRI dhan34.

Jisan *et al*. (2014) carried out an experiment at Bangladesh Agricultural University, Mymensingh with a view to examine the yield performance of some transplant *Aman* rice varieties as influenced by different levels of nitrogen. The experiment consisted of four varieties viz. BRRI dhan49, BRRI dhan52, BRRI dhan56, BRRI dhan57. Data revealed that among the varieties, BRRI dhan52 produced the tallest plant (117.20 cm), whereas the lowest by BRRI dhan57.

An experiment was conducted by Haque and Biswash (2014) with five varieties of hybrid rice and one hybrid and two checks from Bangladesh Rice Research Institute (BRRI). Varieties was Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid dhan1 and two checks was BRRI dhan28 and BRRI dhan29 and the highest plant height was 101.5 cm was recorded from BRRI dhan28 and the lowest plant height from Richer (82.5 cm).

Bhuiyan *et al*. (2014) carried out an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety in terms of plant growth. Based on the findings of the study it was revealed that the different hybrid rice varieties had significant effects on plant height at maturity.

To study the effect of nitrogen fertilizer and seedling age on Giza 178, H1 and Sakha 101 field experiments was conducted by Salem *et al*. (2011) at the Rice Research and Training Center (RRTC), Sakha, Kafr-El Sheikh Governorate, Egypt during summer seasons. The results indicated that Sakha 101 variety surpassed than other varieties in terms of plant height.

Khalifa (2009) conducted a field experiment at the experimental farm of Rice research and training centre (RRTC), Sakha, Kafr-El sheikh governorate, Egypt rice season for physiological evaluation of some hybrid rice varieties under different sowing dates. Four hybrid rice H_1, H_2, GZ 6522 and GZ 6903 was evaluated at six different sowing dates. Results indicated that H_1 hybrid rice variety surpassed other varieties in terms of plant height.

Masum *et al*. (2008) observed that plant height of rice affected by varieties in *Aman* season where Nizershail produced the taller plant height than BRRI dhan44 at different days after transplanting (DAT).

Mandavi *et al.* (2004) found from their experiment that plant height was negatively correlated with grain yield. Thus, in improved genotypes, plant height was not a limiting factor for grain yield because of reduced lodging and conducted better translocation of assimilates.

Murthy *et al.* (2004) conducted an experiment with six varieties of rice genotypes namely Mangala, Madhu, J-13, Sattari, CR 666-16 and Mukti, and the findings revealed that the variety Mukti gave the longest plant compared to the others variety of their experiment.

Ghosh (2001) carried out an experiment with four rice hybrids and four high yielding rice cultivars and concluded that hybrids have higher plant height as compared with high yielding varieties.

Pruneddu and Spanu (2001) conducted an experiment with different rice varieties and found that plant height ranged from less than 65 cm to 80-85 cm in Mirto, Tejo, Gladio, Lamone and Timo variety.

Patel (2000) studied the varietal performance of Kranti and IR36. He observed that Kranti produced significantly tallest plant than IR36 plant height. The mean plant height increased with Kranti over IR36 was 6.75%.

2.2 Tillering pattern of different rice varieties

Sumon *et al*. (2018) conducted a study was conducted to evaluate 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 three aromatic rice varieties in main plots and six fertilizer levels in subplots. From the findings they sated that ‘BRRI dhan34’ gave the maximum number of effective tillers hill^{-1} (12.74).

Sarkar *et al*. (2016) carried out an experiment to evaluate the performance of five hybrid rice varieties namely Shakti 2, Suborna 8, Tia, Aloron and BRRI hybrid dhan 2 in *Aman* season with an inbred BRRI dhan33 as checked. The result showed that the hybrid varieties exhibited superiority in respect of tillers hill^{-1} and these hybrid varieties showed higher effective tillers hill^{-1}.

Haque and Biswash (2014) experimented with five varieties of hybrid rice which was collected from different private seed companies and one hybrid and two checks from Bangladesh Rice Research Institute (BRRI). Varieties were Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid dhan1 and two checks was BRRI dhan28 and BRRI dhan29. In case of no. of effective tillers, Hira showed the best performance (17.7) and Sonarbangla-1 showed the least performance (13.3).

Bhuiyan *et al*. (2014) conducted an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety in terms of yield and recommend it to rice farmers. Based on the findings of the study, the different hybrid rice varieties evaluated had significant effects on number of tillers, number of productive tillers.

Sarkar *et al*. (2014) conducted an experiment at Bangladesh Agricultural University, Mymensingh, to study the yield and quality of aromatic fine rice as affected by variety and nutrient management. The experiment comprised three aromatic fine rice varieties viz. BRRI dhan34, BRRI dhan37 and BRRI dhan38 and eight nutrient managements. Results revealed that the highest number of effective tillers hill^{-1} (10.02) was recorded in BRRI dhan34.

Jisan *et al*. (2014) carried out and experiment at Bangladesh Agricultural University, Mymensingh with a view to examine the yield performance of some transplant *Aman* rice varieties as influenced by different levels of nitrogen. The experiment consisted of four varieties viz. BRRI dhan49, BRRI dhan52, BRRI dhan56, BRRI dhan57. Among the varieties, BRRI dhan52 produced the highest number of effective tillers hill^{-1} (11.28), while the lowest values of these parameters were produced by BRRI dhan57.

A field experiment was conducted by Khalifa (2009) at the experimental farm of Rice research and training centre (RRTC), Sakha, Kafr-El sheikh governorate, Egypt for physiological evaluation of some hybrid rice varieties under different sowing dates. Four hybrid rice H_1, H_2, GZ 6522 and GZ 6903 was evaluated. Results indicated that H_1 hybrid rice variety surpassed other varieties in consideration of effective and total tillers hill^{-1}.

Masum *et al*. (2008) stated that number of total tillers hill^{-1} was significantly influenced by cultivars at all stages of crop growth when they conducted an experiment with different rice varieties. Nizersail was achieved maximum (25.63) tiller at 45 DAT, then with advancement to age it declined up to maturity, whereas in the case of BRRI dhan44, maximum (18.92) tiller production was observed around panicle initiation stage at 60 DAT.

Murthy *et al.* (2004) conducted an experiment with six varieties of rice genotypes Mangala, Madhu, J-13, Sattari, CR 666-16 and Mukti to assess their performance in terms of yield attributes and yield and observed that Mukti gave the highest tillers hill^{-1} compared to the others.

Song *et al.* (2004) found that hybrid rice varieties produced a significantly higher number of tillers than their parental species and Minghui-63 had the least number of tillers.

Bhowmick and Nayak (2000) conducted an experiment with two hybrids (CNHR2 and CNHR3) and two high yielding varieties (IR36 and IR64) of rice and five levels of nitrogenous fertilizers in relation to yield attributes and yield. They observed that CNHR2 produced more number of productive tillers (413.4 m^{-2}) than other tested varieties.

2.3 Dry matter content in different rice varieties

Sumon *et al*. (2018) conducted a study to evaluate 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 three aromatic rice varieties. From the findings they sated that 'Raniselute' variety produced the highest dry matter weight $hill^{-1}$.

Sarkar *et al*. (2016) carried out an experiment to evaluate the performance of five hybrid rice varieties namely Shakti 2, Suborna 8, Tia, Aloron and BRRI hybrid dhan 2 in *Aman* season with an inbred BRRI dhan33 as checked. The result showed that the hybrid varieties exhibited superiority in respect of total dry matter (TMD) $hill^{-1}$ and the highest TDM $hill^{-1}$ (84.0 g) was observed Tia and lowest TDM $hill^{-1}$ (70.10 g) was observed in BRRI dhan33.

Field experiments were conducted by Haque *et al*. (2015) including two popular indica hybrids (BRRI hybrid dhan2 and Heera2) and one elite inbred (BRRI dhan45) rice varieties. Both hybrids accumulated higher amount of biomass before heading and exhibited greater remobilization of assimilates to the grain in early plantings compared to the inbred variety.

In order to evaluate the response to planting date in rice hybrids line dry method of working, was carried out by Shaloie *et al*. (2014) at the Agricultural Research Station, Agriculture and Natural Resources Research Center of Khuzestan Shavuor. Results showed traits was significantly affected in terms of dry matter and mentioned trait was more in hybrid Hb_2 than Hb_1.

Masum *et al*. (2008) found that total dry matter production differed due to varieties. Total dry matter of BRRI dhan44 and Nizershail significantly varied at different sampling dates.

Xie *et al.* (2007) conducted an experiment with different rice varieties and found that Shanyou-63 variety gave the higher TDM compared to the variety of Xieyou46.

Amin *et al.* (2006) conducted a field experiment to find out the influence of variable doses of N fertilizer on growth, tillering and yield of three traditional rice varieties (*viz.* Jharapajam, Lalmota, Bansful Chikon) was compared with that of a modern variety (*viz.* KK-4) and reported that traditional varieties accumulated higher amount of vegetative dry matter than the modern variety.

Mandavi *et al.* (2004) carried out an experiment to study on the morphological and physiological indicators of rice genotypes and reported that Onda had the greater total dry matter (TDM) among other genotypes. Higher TDM was obtained from improved genotype than traditional genotypes (1445 and 1626 GDD, respectively). At flowering the dry matter weight was higher for Jasesh and was lower for Ramazan Ali Tarom (923.93 g m^{-2} and 429 g m^{-2}, respectively).

Sharma and Haloi (2001) conducted an experiment in Assam during the kharif season with 12 varieties of scented rice cultivars and observed that cv. Kunkuni Joha consistently maintained a higher rate of dry matter production at all growth stages and the highest dry matter accumulation at the panicle initiation stage.

2.4 Yield attributes in different rice varieties

Sumon *et al*. (2018) conducted a study to evaluate the growth, yield and proximate composition of aromatic rice varieties in Aman season at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh with three aromatic rice varieties and six fertilizer levels. From the findings they sated that 'BRRI dhan34' gave the highest panicle length (27.93 cm), number of filled grains $panicle^{-1}$ (192.5), 1,000-grain weight (17.22 g), grain yield (2.26 t ha^{-1}).

Sarkar *et al*. (2016) carried out an experiment to evaluate 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 and these hybrid varieties also showed higher 1000-grain over the inbred.

Dou *et al*. (2016) carried out an experiment with the objective to determine the effects of water regime/soil condition (continuous flooding, saturated, and aerobic), cultivar ('Cocodrie' and 'Rondo'), and soil texture on rice grain yield, yield components and water productivity. The spikelet number of Cocodrie was 29% greater than that of Rondo, indicating that rice cultivar had greater effect on spikelet number.

Field experiments were conducted by Haque *et al*. (2015) including two popular indica hybrids (BRRI hybrid dhan2 and Heera2) and one elite inbred (BRRI dhan45) rice varieties. Filled grain (%) declined significantly at delayed planting in the hybrids compared to elite inbred due to increased temperature impaired inefficient transport of assimilates.

An experiment was conducted by Hosain *et al*. (2014) at Sher-e-Bangla Agricultural University (SAU), Dhaka during *Aus* season to observe the effect of transplanting dates on the yield and yield attributes of exotic hybrid rice varieties. The experiment comprised of three rice varieties (two hybrids-Heera2, Aloron and one inbred- BRRI dhan48). Hybrid varieties Heera2 (3.03 t ha^{-1}) and Aloron (2.77 t ha^{-1}) gave the higher spikelet sterility.

Sarkar *et al*. (2014) conducted an experiment at Bangladesh Agricultural University, Mymensingh, to study the yield and quality of aromatic fine rice as affected by variety and nutrient management. The experiment comprised three aromatic fine rice varieties viz. BRRI dhan34, BRRI dhan37 and BRRI dhan38 and eight nutrient managements. Results revealed that the number of grains $panicle^{-1}$ (152.3), panicle length (22.71 cm) and 1000-grain weight (15.55 g) were recorded in BRRI dhan34.

Haque and Biswash (2014) experimented with five varieties of hybrid rice which was collected from different private seed companies and one hybrid and two checks from Bangladesh Rice Research Institute (BRRI). Varieties were Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid dhan1 and two checks were BRRI dhan28 and BRRI dhan29. In panicle length status, Richer showed the best performance (27.7 cm) while BRRI dhan28 showed the least performance (26 cm). Number of filled grains panicle^{-1} was the highest for BRRI dhan29 (163.3), whereas, Jagoron only 118. Number of total grains was highest in BRRI dhan29 (201.7) and for Jagoron it was only 133.7. On the other hand, for 1000-grain weight, Aloron was the best than other hybrids.

Bhuiyan *et al*. (2014) conducted an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety in terms of yield and recommend it to rice farmers. Based on the findings of the study, the different hybrid rice varieties evaluated had significant effects on number of filled and unfilled grains, length of panicle and yield. RGBU010A × SL8R is therefore recommended as planting material among hybrid rice varieties because it produced longer panicles and heavy seeds. In the absence of this variety, RGBU02A × SL8R, RGBU003A × SL8R and RGBU0132A × SL8R may also be used as planting material.

In order to evaluate the response to planting date in rice hybrids Line dry method of working, was carried out by Shaloie *et al*. (2014) at the Agricultural Research Station, Agriculture and Natural Resources Research Center of Khuzestan Shavuor. Hybrid rice Hb2 and Hb1 was used in the sub plots. Results showed traits was significantly affected in terms of panicle length, fertility percentage, and mentioned traits was more in hybrid Hb_2 than Hb_1.

Jisan *et al*. (2014) carried out and experiment at Bangladesh Agricultural University, Mymensingh with a view to examine the yield performance of some transplant *Aman* rice varieties as influenced by different levels of nitrogen. The experiment consisted of four varieties viz. BRRI dhan49, BRRI dhan52, BRRI dhan56, BRRI dhan57 and four levels of N. Data revealed that variety exerted significant influence on yield contributing characters. Among the varieties, BRRI dhan52 produced the grains panicle^{-1} (121.5) and 1000-grain weight (23.65 g), whereas the lowest values of these parameters was produced by BRRI dhan57.

Forty five aromatic rice genotypes were evaluated by Fatema *et al*. (2011) to assess the genetic variability and diversity on the basis of nine characters. Significant variations were observed among the genotypes for all the characters. Thousand grain weight have been found to contribute maximum towards genetic diversity in 45 genotypes of aromatic rice.

Two field experiments was conducted by Salem *et al*. (2011) at the Rice Research and Training Center (RRTC), Sakha, Kafr-El Sheikh Governorate, Egypt during summer seasons to study the effect of nitrogen fertilizer and seedling age on Giza 178, H1 and Sakha 101. The results indicated that Sakha 101 variety surpassed than other varieties in terms of 1000 seeds weight.

Islam *et al.* (2010) studied yield potential of 16 rice genotypes including 12 hybrids, 3 inbreds and 1 New Plant Type (NPT) at the International Rice Research Institute (IRRI) farm under optimum crop management to achieve maximum attainable yield during the wet season (WS) of 2004 and dry season (DS) of 2005. Yield and yield components was determined at maturity. Hybrid produced higher spikelets panicle^{-1} and 1000-grain weight than inbred rice. Spikelet filling percent was higher in inbred than hybrid rice. The NPT rice genotype had the lowest spikelet filling percent, but the highest 1000-grain weight across the season.

A field experiment was conducted by Khalifa (2009) at the experimental farm of Rice research and training centre (RRTC), Sakha, kafr-El sheikh governorate, Egypt for physiological evaluation of some hybrid rice varieties under different sowing dates. Four hybrid rice H_1, H_2, GZ 6522 and GZ 6903 was evaluated and results indicated that H_1 hybrid rice variety surpassed other varieties for studied yield attributing characters except for number of days to panicle initiation and heading date.

Islam *et al.* (2009) conducted pot experiments during T. *Aman* season in net house at Bangladesh Rice Research Institute (BRRI). Hybrid variety Sonarbangla-1 and inbred modern variety BRRI dhan31 was used in both the seasons. BRRI dhan3l had higher panicles plant^{-1} than Sonarbangla-1, but Sonarbangla-1 had higher number of grains panicle^{-1} and 1000-grain weight.

Wang *et al*. (2006) studied the effects of plant density and row spacing on the yield and yield components of hybrids and conventional cultivars of rice. Compared with conventional cultivars, the hybrids had larger panicles, highest total grains and heavier seeds.

Myung (2005) worked with four different panicle types of rice varieties and observed that the primary rachis branches (PRBs) panicle^{-1} and grains was more on Sindongjinbyeo and Iksan467 varieties, but secondary rachis branches (SRBs) was fewer than in Dongjin1 and Saegyehwa varieties.

Chaturvedi *et al.* (2004) evaluated newly released commercial rice hybrids (DRRH 1, PHB 71, Pro-Agro 6201, KHR 2, ADTHR 1, UPHR 1010 and Pant Sankar Dhan 1) and two high yielding varieties as checks (Pant Dhan 4 and Pant Dhan 12) for their agronomic and morpho-physiological traits. Hybrids although could not excel the best HYV owing to high percentage of spikelet sterility but they showed potential for higher yield as these produced large sink (higher number of spikelets m^{-2}).

Guilani *et al*. (2003) carried out an experiment on crop yield and yield components of rice cultivars (Anboori, Champa and LD183) in Khusestan, Iran. The highest grain number panicle^{-1} was obtained with Anboori. Grain fertility percentages were different among cultivars. Among cultivars, LD183 had the highest grain weight.

2.5 Yield of different rice varieties

Sumon *et al*. (2018) conducted a study to evaluate the growth, yield and proximate composition of aromatic rice varieties in Aman season at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh with three aromatic rice varieties and six fertilizer levels. Results revealed 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}).

Chowdhury *et al*. (2016) conducted an experiment was at Bangladesh Agricultural University, Mymensingh with a view to finding out the effect 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 highest grain yield (3.33 t ha^{-1}) was obtained from Binadhan-13 followed by BRRI dhan34 (3.16 t ha^{-1}) and the lowest grain yield was found in Kalizira (2.11 t ha^{-1}).

Yield test of 41 entries, 32 new hybrids, 8 male parents restore lines and 1 inbred variety, was evaluated by Huang and Yan (2016) on the farm of University of Arkansas at Pine Bluff (UAPB). Results 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/hectare and over check by 30.7%. The yield of hybrid 28s/PB-24, was 10628.9 kg/hectare and over check by 28.1%. The yields of hybrid 28s/PB-22 and 33A/PB24 were 10549.8 and 10539.8 kg/hectare and over check by 27.1% and 27.0%, respectively.

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

A study was conducted by Mandira *et al*. (2016) in South Tripura district of Tripura for three consecutive kharif seasons to evaluate the performance of rice variety gomati at farmer's field under rainfed conditions. The gomati variety of rice was found superior over local varieties. Rice variety gomati increased mean grain yield by 41.62%.

A study was carried out by Wagan *et al*. (2015) to compare the economic performance of hybrid and conventional rice production and observed that on an average higher yield (196.14 monds per hectare) was obtained from hybrid rice while conventional rice yield (140.14 monds per hectare) was less then hybrid rice. There was 16.64 percent increase in hybrid rice yield comparing with conventional rice which gives additional income to poor farmers.

Field experiments were conducted by Haque *et al*. (2015) including two popular indica hybrids (BRRI hybrid dhan2 and Heera2) and one elite inbred (BRRI dhan45) rice varieties. Both hybrid varieties out yielded the inbred. However, the hybrids and inbred varieties exhibited statistically identical yield in late planting. Results suggest that greater remobilization of shoot reserves to the grain rendered higher yield of hybrid rice varieties.

Sarkar *et al*. (2014) conducted an experiment at Bangladesh Agricultural University, Mymensingh, to study the yield and quality of aromatic fine rice as affected by variety and nutrient management. The experiment comprised three aromatic fine rice varieties viz. BRRI dhan34, BRRI dhan37 and BRRI dhan38 and eight nutrient managements. Results revealed that the highest grain yield (3.71 t ha^{-1}) were recorded in BRRI dhan34.

Kanfany *et al*. (2014) conducted an experiment by at the Africa Rice Sahel Regional Station during two wet seasons with the aim of assessing the performances of introduced hybrid cultivars along with an inbred check cultivar under low input fertilizer levels. The grain yield of rice hybrids was not significantly higher than that of the check cultivar widely grown in Senegal.

An experiment was conducted by Hosain *et al*. (2014) at Sher-e-Bangla Agricultural University (SAU), Dhaka to observe the effect of transplanting dates on the yield and yield attributes of exotic hybrid rice varieties. The experiment comprised of three rice varieties (two hybrids-Heera2, Aloron and one inbred-

BRRI dhan48) and reported that BRRI dhan48 produced the highest grain yield (3.51 t ha^{-1}).

Jisan *et al*. (2014) carried out and experiment at Bangladesh Agricultural University, Mymensingh with a view to examine the yield performance of some transplant *Aman* rice varieties as influenced by different levels of nitrogen. The experiment consisted of four varieties viz. BRRI dhan49, BRRI dhan52, BRRI dhan56, BRRI dhan57 and four levels of N. Data revealed that highest grain yield (5.69 t ha^{-1}) was obtained from BRRI dhan52 followed by BRRI dhan49 (5.15 t ha^{-1}) and the lowest (4.25 t ha^{-1}) from BRRI dhan57.

Bhuiyan *et al*. (2014) conducted an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety in terms of yield. Findings revealed that different hybrid rice varieties had significant effects on yield.

Haque and Biswash (2014) experimented with five varieties of hybrid rice which was collected from different private seed companies and one hybrid and two checks from Bangladesh Rice Research Institute (BRRI). Varieties were Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid dhan1 and two checks were BRRI dhan28 and BRRI dhan29. In case of biological yield (g), BRRI dhan29 showed highest yield (49.6 g) and Hira only 18 g.

An experiment was carried out by Alam *et al*. (2012) at University of Rajshahi to study the effect of variety, spacing and number of seedlings $hill^{-1}$ on the yield potentials of transplant *Aman* rice. The experiment consisted of three high yielding varieties viz. BRRI dhan32, BRRI dhan33 and BR11, four levels of spacing and four levels of number of seedlings $hill^{-1}$. Variety had significant effects on almost all the yield component characters and yield. Variety BR11 produced the highest grain yield (5.92 t ha^{-1}).

Samonte *et al*. (2011) reported that the two elite lines recommended for release are high yielding in Texas. RU0703190 is also very early maturing conventional long grain rice. The high yield potential of these new releases will impact grain production of rice farmers and their income.

Swain *et al*. (2006) reported from their experiment that the control cultivar IR64, with high translocation efficiency and 1000-grain weight and the lowest spikelet sterility recorded a grain yield of 5.6 t ha^{-1} that was statistically similar to the hybrid line PA6201.

Several *indica/japonica* (I/J) lines was screened and evaluated by Roy (2006) for higher grain yield in the *Boro* season. The highest grain yield of 9.2 t ha^{-1} was obtained from selected I/J line IR58565-2B-12-2-2, which was equal to that of indica hybrid CNHR3 and significantly higher than that of modern variety IR36.

Patel (2000) studied the varietal performance of Kranti and IR36. He observed that Kranti produced significantly higher grain and straw yield than IR36 did. The mean yield increased with Kranti over IR36 was 7.1 and 10.0% for grain and straw, respectively.

From the above literature, it is evident that varieties have a significant influence on yield and yield components of aromatic and nonaromatic rice. The literature suggests that suitable variety increases the grain yield for both aromatic and nonaromatic rice. Increase the grain yield is mainly attributed by the increases of number of tiller $hill^{-1}$, grains $panicle^{-1,}$ panicle length, thousand grain weights and other yield attributes due to the effect of variety itself.

Chapter III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to find out the genotypic variation in morpho-physiological traits and yield in traditional aromatic rice cultivars. The details of the materials and methods i.e. experimental period, location, soil and climatic condition of the experimental area, experimental treatment and design, growing of crops, data collection and analysis procedure that followed for the conduction of this experiment has been presented below:

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted during the period from July to November 2017.

3.1.2 Experimental location

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

3.1.3 Climatic condition

The geographical location of the experimental site was under the subtropical climate and its climatic conditions is characterized by three distinct seasons, namely winter season from the month of November to February, the pre-monsoon period or hot season from the month of March to April and monsoon period from the month of May to October (Edris *et al.*, 1979). During the experimental period the maximum temperature (36.8^{0}C), highest relative humidity (87%) and highest rainfall (573 mm) was recorded for the month of July, 2017, whereas the minimum temperature (25.1^{0}C), minimum relative humidity (77%) and no rainfall was recorded for the month of November, 2017. Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during study period has been presented in Appendix II.

3.1.4 Soil characteristics

The soil of the experimental field belonged to "The Modhupur Tract", AEZ-28 (FAO, 1988). Top soil was Silty Clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles with general soil type shallow red brown terrace soil. The experimental area was flat having available irrigation and drainage system and situated above flood level. The soil was having a texture of sandy loam with pH and organic matter 5.9 and 1.15%, respectively. The results showed that the soil composed of 26% sand, 43% silt and 31% clay. Details morphological, physical and chemical properties of the soil of experimental field are presented in Appendix III.

3.2 Experimental details

3.2.1 Planting material

Total 12 traditional aromatic rice cultivars were used as the test crops in this experiment.

3.2.2 Treatment of the experiment

Twelve traditional aromatic rice cultivars that were used in this experiment and they are the treatment of this experiment:

3.2.3 List of rice varieties used in the experiment

Sl. #	Rice cultivars	SL. #	Rice cultivars
01.	V_1: Kalizira	07.	V_7: Zirabhog
02.	V_2: Chiniatab (awned)	08.	V_8: Shakhorkora
03.	V_3: Chiniatab (awnless)	09.	V_9: Badshabhog
04.	V_4: Kataribhog (awned)	10.	V_{10}: BRRI dhan37
05.	V_5: Kataribhog (awnless)	11.	V_{11}: BRRI dhan38
06.	V_6: Madhumala	12.	V_{12}: BRRI dhan50

3.2.4 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The entire experimental area was divided into three blocks representing the replications to reduce soil heterogenetic effects. Each block was divided into 12 unit plots demarked with raised bunds and thus the total numbers of plots were 36. The unit plot size was 3.5 m × 1.75 m. The distance maintained between two blocks and two plots were 0.75 m and 0.5 m, respectively. The layout of the experiment presented in Figure 1.

3.3 Growing of crops

3.3.1 Seed collection and sprouting

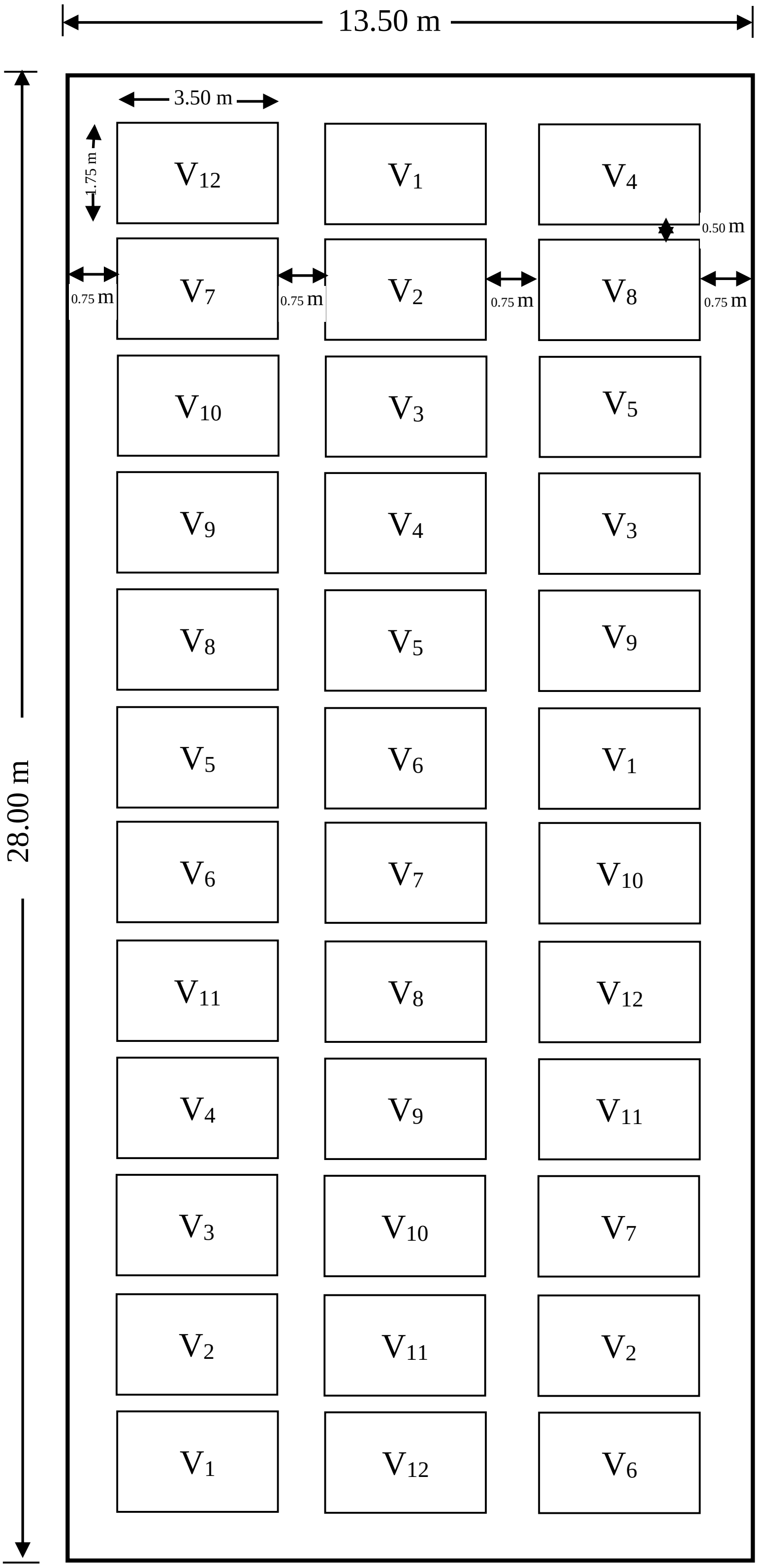
Seeds were collected from BRRI (Bangladesh Rice Research Institute), Gazipur and local market just 20 days ahead of the sowing of seeds in seed bed. For seedlings clean seeds were immersed in water in a bucket for 24 hours. The imbibed seeds were then taken out of water and kept in gunny bags. The seeds started sprouting after 48 hours which were suitable for sowing in the seed bed in 72 hours.

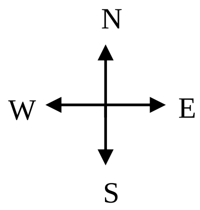
3.3.2 Raising of seedlings

The nursery bed was prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown on beds as uniformly as possible at 2th July, 2017. Irrigation was gently provided to the bed when needed. No fertilizer was used in the nursery bed.

3.3.3 Land preparation

The plot selected for conducting the experiment was opened in the 24th July 2017 with a power tiller, and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain good puddle condition. Weeds and stubbles were removed. The experimental plot was partitioned into unit plots in accordance with the experimental design. Organic and inorganic manures as indicated below were mixed with the soil of each unit plot.





Plot size: 3.50 m × 1.75 m

Plot spacing: 0.50 m

Between block: 0.75 m

Treatment of the experiment

V_1: Kalizira

V_2: Chiniatab (awned)

V_3: Chiniatab (awnless)

V_4: Kataribhog (awned)

V_5: Kataribhog (awnless)

V_6: Madhumala

V_7: Zirabhog

V_8: Shakhorkora

V_9: Badshabhog

V_{10}: BRRI dhan37

V_{11}: BRRI dhan38

V_{12}: BRRI dhan50

Figure 1. Layout of the experimental 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 were applied @ 80 kg, 60 kg, 90 kg, 12 kg, 2.0 kg and 10 kg (BRRI, 2016). The entire amount of TSP, MoP, gypsum, zinc sulphate and borax were applied during the final preparation of experimental plot. Urea was applied in two equal installments as top dressing at tillering and panicle initiation stages.

3.3.5 Transplanting of seedling

Seedlings were carefully uprooted from the nursery bed and transplanted on 3rd August, 2017 in well puddled plot with spacing of 25 × 15 cm. Two seedlings hill^{-1} was transplanted in each hill. After one week of transplanting all plots were checked for any missing hill, which was filled up with extra seedlings of the same source whenever required.

3.3.6 Intercultural operations

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

3.3.6.1 Irrigation and drainage

In the early stages to establishment of the seedlings irrigation was provided to maintain a constant level of standing water upto 6 cm and then maintained the amount drying and wetting system throughout the entire vegetative phase. No water stress was encountered in reproductive and ripening phase. The plot was finally dried out at 15 days before harvesting.

3.3.6.2 Weeding

Weeding was done to keep the plots free from weeds, which ultimately ensured better growth and development of the seedlings. The newly emerged weeds were uprooted carefully at 30 DAT (days after transplanting) and 50 DAT by mechanical means.

3.3.6.3 Insect and pest control

Leaf roller (*Chaphalocrosis medinalis*) was found and used Malathion @ 1.12 L ha^{-1} at 30 DAT using sprayer but no diseases infection was observed in the field.

3.4 Harvesting, threshing and cleaning

The crop was harvested at full maturity based on variety when 80-90% of the grains were turned into straw color. The harvested crop was bundled separately, properly tagged and brought to threshing floor. The grains were dried, cleaned and weighed for individual plot. The weight was adjusted to a moisture content of 12%. Yields of rice grain and straw were recorded from each plot.

3.5 Data recording

3.5.1 Plant height

The height of plant was measured in centimeter (cm) from the ground level to the tip of the plant at 20, 40, 60, 80 DAT and at harvest. Data were recorded from 5 plants selected at random from the inner rows of each plot.

3.5.2 Number leaves $hill^{-1}$

Number of leaves $hill^{1}$ was recorded at 20, 40, 60 and 80 DAT as the average of randomly selected 5 plants from the inner rows of each plot.

3.5.3 Number of tillers $hill^{-1}$

Number of tillers $hill^{-1}$ was recorded at 20, 40, 60 and 80 DAT as the average of randomly selected 5 plants from the inner rows of each plot.

3.5.4 Leaf area index

Leaf area index (LAI) was measured at the time of 20, 40, 60 and 80 DAT. Data were recorded on leaf length and leaf breadth as the average of 05 plants selected at random the inner rows of each plots and total leaf area was calculated by multiplying leaf length and leaf breadth. The leaf area index (LAI) was worked out by using the formula of Yoshida (1981):

$$\text{Leaf area index} = \frac{\text{Total leaf area (cm}^2\text{)}}{\text{Unit land area (cm}^2\text{)}}$$

3.5.5 SPAD value

SPAD value was determined from plant samples by using an automatic SPAD meter immediately after removal of leaves from plants to avoid rolling and shrinkage. SPAD was recorded at 20, 40, 60 and 80 DAT.

3.5.6 Flag leaf area

Flag leaf area was estimated by multiplying flag leaf length and breadth of 5 sample plant at flowering stage.

3.5.7 Penultimate leaf area

Penultimate leaf area was estimated by multiplying penultimate leaf length and breadth of 5 sample plant at flowering stage.

3.5.8 Duration from transplanting to anthesis

Duration from transplanting to anthesis were recorded by counting the number of days required from transplanting to starting anthesis in each plot.

3.5.9 Duration from transplanting to maturity

Duration from transplanting to maturity were recorded by counting the number of days required from transplanting to maturity of rice in each plot.

3.5.10 Shoot dry matter at pre-anthesis

Shoot dry matter at pre-anthesis period was recorded from 5 randomly collected shoot of each plot from inner rows leaving the boarder row. Collected shoot were oven dried at 70^0C for 72 hours then transferred into desiecator and allowed to cool down at room temperature, final weight was taken and converted into shoot dry matter content m^{-2}.

3.5.11 Shoot dry matter at maturity

Shoot dry matter at maturity period was recorded from 5 randomly collected shoot of each plot from inner rows leaving the boarder row. Collected shoot were oven dried at 70^0C for 72 hours then transferred into desiecator and allowed to cool down at room temperature, final weight was taken and converted into shoot dry matter content m^{-2}.

3.5.12 Changes in shoot dry matter

Changes in shoot dry matter was estimated by deducting shoot dry matter at pre-anthesis period to shoot dry matter at maturity period.

3.5.13 Shoot reserve translocation

Plants from 1 m^2 were sampled from each plot at pre-anthesis and maturity. The harvested plants were separated into leaf blades (leaf), culm and sheath (stem) and panicles. Dry matter of each component was determined after drying at 72^0C for 72 hours. The shoot reserve translocation was calculated by net loss in dry weight of vegetative organs between pre-anthesis and maturity stage of rice plant (Bonnett and Incoll, 1992) using the following:

$$\text{Shoot reserve translocation (\%)} = \frac{A-M}{A} \times 100$$

Where,

A = Total shoot dry matter at pre-anthesis, g m^{-2}

M = Total shoot dry matter at maturity, g m^{-2}

3.5.14 Effective tillers $hill^{-1}$

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

3.5.15 Non-effective tillers $hill^{-1}$

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

3.5.16 Total tillers hill^{-1}

The total number of tillers hill^{-1} was counted by adding the number of effective tillers hill^{-1} and ineffective tillers hill^{-1}. Data on total tillers hill^{-1} were counted from 5 selected hills and average value was recorded.

3.5.17 Panicle length

The length of panicle was measured with a meter scale from 5 selected panicle and the average length was recorded as per panicle in cm.

3.5.18 Filled grains panicle^{-1}

The total numbers of filled grain were collected randomly from selected 5 panicle of a plot on the basis of grain in the spikelet and then average numbers of filled grains panicle^{-1} was recorded.

3.5.19 Unfilled grains panicle^{-1}

The total numbers of unfilled grain was collected randomly from selected 5 plants of a plot on the basis of not grain in the spikelet and then average numbers of unfilled grains panicle^{-1} was recorded.

3.5.20 Total grains panicle^{-1}

The total numbers of grain was collected randomly from selected 5 plants of a plot by adding filled and unfilled grain and then average numbers of grains panicle^{-1} was recorded.

3.5.21 Spikelet sterility

Spikelet sterility was computed using the formula:

$$\text{Spikelet sterility (\%)} = \frac{\text{Unfilled grains panicle}^{-1}}{\text{Total grains panicle}^{-1}} \times 100$$

3.5.22 Weight of 1000-grain

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

3.5.23 Grain yield

Grains obtained from each unit plot were sun-dried and weighed carefully. The dry weight of grains of each plot were taken the final grain yield plot^{-1} and finally converted to ton hectare^{-1} (t ha^{-1}).

3.5.24 Straw yield

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

3.5.25 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.

3.5.26 Harvest index

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

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

3.6 Statistical Analysis

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

Chapter IV

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the genotypic variation in morpho-physiological traits and yield in traditional aromatic rice cultivars. Data on different morpho-physiological traits and yield are presented in Appendix IV-XIII. The results have been presented and discussed under following headings:

4.1 Crop growth characters

4.1.1 Plant height

Plant height at 20, 40, 60 and 80 days after transplanting (DAT) and at harvest showed statistically significant variation for different aromatic rice cultivars (Appendix IV). At 20 DAT, the tallest plant (45.80 cm) was recorded from V_8 (Shakhorkora) which was statistically similar (43.95, 43.91, 42.40, 41.87 and 40.05 cm, respectively) to V_9 (Badshabhog), V_5 (Kataribhog-awnless), V_4 (Kataribhog-awned), V_2 (Chiniatab-awned) and V_7 (Zirabhog), respectively, while the shortest plant (35.26 cm) was found from V_{12} (BRRI dhan50) which was statistically similar (36,72, 37.85, 38.55, 38.96 and 39.82 cm, respectively) to V_{11} (BRRI dhan38), V_{10} (BRRI dhan37), V_3 (Chiniatab-awnless), V_6 (Madhumala) and V_1 (Kalizira), respectively (Figure 2). Similar trend of plant height was also recorded for 40, 60, 80 DAT and at harvest. At harvest, the tallest plant (150.75 cm) was observed from V_8 was statistically similar with other rice cultivars except V_{12}, V_{11} and V_{10} and the shortest plant (107.19 cm) was found from V_{12} which was followed (123.75 and 127.28 cm, respectively) by V_{11} and V_{10}, respectively and they were statistically similar. Cultivars is the key component for producing plant height based on their genotypic characters and off course the prevailing environmental conditions of growing season. Sarkar *et al*. (2014) recorded the tallest plant (142.7 cm) from BRRI dhan34 compared with aromatic rice BRRI dhan37 and BRRI dhan38. Similarly different researchers recorded different size of plant in earlier for different rice cultivars (Sumon *et al*., 2018; Haque and Biswash, 2014; Khalifa, 2009).

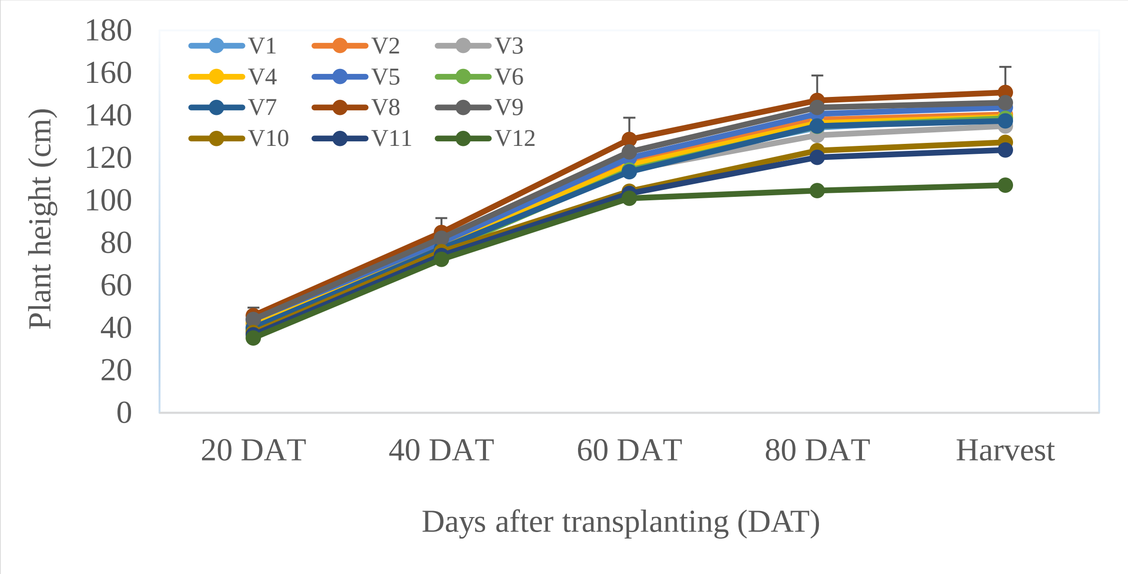


Figure 2. Plant height of twelve aromatic rice cultivars. Vertical bars represents LSD value at 0.05 level of probability

4.1.2 Leaves hill^{-1}

Statistically significant variation was recorded in terms of leaves hill^{-1} at 20, 40, 60 and 80 DAT due to different aromatic rice cultivars (Appendix V). At 20, 40, 60 and 80 DAT, the maximum number of leaves hill^{-1} (23.40, 41.33, 54.80 and 56.80, respectively) was observed from V_{12} which was statistically similar (22.73, 40.07, 53.40 and 54.27, respectively) to V_{10}, whereas the minimum number (19.27, 34.13, 42.73 and 45.00, respectively) was recorded from V_8 which was statistically similar (19.93, 35.20, 43.53 and 45.80, respectively) to V_6 at 20, 40, 60 and 80 DAT (Table 1). Masum *et al*. (2008) reported that H_1 hybrid rice variety produced highest number of leaves compared in inbred.

4.1.3 Tillers hill^{-1}

Different aromatic rice cultivars varied significantly in terms of tillers hill^{-1} at 20, 40, 60 and 80 DAT (Appendix VI). At 20, 40, 60 and 80 DAT, the maximum number of tillers hill^{-1} (5.07, 9.93, 13.87 and 14.53, respectively) was found from V_{12} which was statistically similar (5.00, 9.53, 13.67 and 14.40, respectively) to V_{10} and (4.87, 9.47, 13.47 and 14.27, respectively) to V_{11}. On the other hand, the minimum number (4.07, 7.07, 10.13 and 11.00, respectively)

Table 1. Number of leaves hill^{-1} at different days after transplanting (DAT) of twelve aromatic rice cultivars

Rice variety	Leaves hill^{-1} (No.) at			
	20 DAT	40 DAT	60 DAT	80 DAT
V_1	20.27 b-d	35.80 e-g	44.13 d	46.00 cd
V_2	20.80 a-d	36.47 d-g	45.20 cd	48.13 b-d
V_3	21.27 a-d	35.07 fg	46.73 b-d	48.00 b-d
V_4	21.40 a-d	37.93 c-f	50.00 a-c	51.27 a-c
V_5	20.00 cd	38.67 b-e	50.40 a-c	51.60 a-c
V_6	19.93 d	35.20 fg	43.53 d	45.80 cd
V_7	20.80 a-d	37.27 c-g	49.87 a-c	51.80 a-c
V_8	19.27 d	34.13 g	42.73 d	45.00 d
V_9	21.67 a-d	42.73 a	50.93 ab	52.27 ab
V_{10}	22.73 ab	40.07 a-c	53.40 a	54.27 ab
V_{11}	22.60 abc	39.33 b-d	52.40 a	53.73 ab
V_{12}	23.40 a	41.33 ab	54.80 a	56.80 a
$LSD_{(0.05)}$	2.303	2.899	4.718	5.523
Level of significance	0.05	0.01	0.01	0.01
CV(%)	6.42	4.53	5.72	6.47

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

V_1 : Kalizira
V_2 : Chiniatab (awned)
V_3 : Chiniatab (awnless)
V_4 : Kataribhog (awned)
V_5 : Kataribhog (awnless)
V_6 : Madhumala
V_7 : Zirabhog
V_8 : Shakhorkora
V_9 : Badshabhog
V_{10}: BRRI dhan37
V_{11}: BRRI dhan38
V_{12}: BRRI dhan50

was recorded from V_8 which was statistically similar (4.13, 7.20, 10.53 and 11.00, respectively) to V_6 at 20, 40, 60 and 80 DAT (Table 2). Masum *et al*. (2008) reported maximum (25.63) tiller at 45 DAT, then with advancement to age it declined up to maturity, whereas, in the case of BRRI dhan44, maximum (18.92) tiller production was observed around panicle initiation stage at 60 DAT. Khalifa (2009) reported that H_1 hybrid rice variety surpassed other varieties in consideration of tillers hill^{-1}. Sumon *et al*. (2018) sated that 'BRRI dhan34' gave the maximum number of effective tillers hill^{-1} (12.74).

4.1.4 Leaf area index

Statistically significant variation was recorded for leaf area index at 20, 40, 60 and 80 DAT due to different aromatic rice cultivars (Appendix VII). At 20, 40, 60 and 80 DAT, the highest leaf area index (1.67, 8.40, 16.75 and 17.42, respectively) was observed from V_{12} which was statistically similar (1.61, 8.27, 16.39 and 17.20, respectively) to V_{10} and (1.57, 8.18, 16.23 and 17.09, respectively) to V_{11}, while the lowest leaf area index (1.14, 6.23, 13.16 and 13.59, respectively) was recorded from V_8 which was statistically similar (1.21, 6.41, 13.53 and 14.37, respectively) to V_6 at 20, 40, 60 and 80 DAT (Table 3). Haque *et al*. (2015) observed that hybrids exhibited higher leaf area index compared to the inbred variety.

4.1.5 SPAD value

SPAD value at 20, 40, 60 and 80 DAT showed statistically significant variation for different aromatic rice cultivars (Appendix VIII). At 20, 40, 60 and 80 DAT, the highest SPAD value (30.12, 42.19, 49.61 and 35.58, respectively) was recorded from V_{12} which was statistically similar (29.78, 41.94, 48.90 and 34.72, respectively) to V_{10} and (28.22, 40.85, 47.39 and 34.37, respectively) to V_{11}, whereas the lowest SPAD value (25.15, 32.60, 40.33 and 28.30, respectively) was found from V_8 which was statistically similar (25.56, 33.30, 41.75 and 29.19, respectively) to V_6 at 20, 40, 60 and 80 DAT (Figure 3). Sarkar *et al*. (2014) revealed that the highest SPAD value in BRRI dhan34.

Table 2. Number of tillers hill^{-1} at different days after transplanting (DAT) of twelve aromatic rice cultivars

Rice variety	Tillers hill^{-1} (No.) at			
	20 DAT	40 DAT	60 DAT	80 DAT
V_1	4.20 c-e	7.47 de	11.07 d-f	11.80 ef
V_2	4.33 b-e	7.60 de	11.87 c-e	12.53 de
V_3	4.53 a-e	7.73 de	12.20 b-d	12.67 c-e
V_4	4.60 a-e	8.27 cd	12.53 a-d	13.27 b-d
V_5	4.67 a-e	8.60 c	12.87 a-c	13.53 a-d
V_6	4.13 de	7.20 e	10.53 ef	11.20 f
V_7	4.53 a-e	8.20 cd	12.47 a-d	13.20 cd
V_8	4.07 e	7.07 e	10.13 f	11.00 f
V_9	4.80 a-d	8.73 bc	13.07 a-c	13.67 a-c
V_{10}	5.00 ab	9.53 ab	13.67 ab	14.40 a
V_{11}	4.87 a-c	9.47 ab	13.47 ab	14.27 ab
V_{12}	5.07 a	9.93 a	13.87 a	14.53 a
$LSD_{(0.05)}$	0.601	0.772	1.343	0.959
Level of significance	0.05	0.01	0.01	0.01
CV(%)	7.77	5.49	6.44	4.35

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

V_1 : Kalizira V_2 : Chiniatab (awned) V_3 : Chiniatab (awnless)
V_4 : Kataribhog (awned) V_5 : Kataribhog (awnless) V_6 : Madhumala
V_7 : Zirabhog V_8 : Shakhorkora V_9 : Badshabhog
V_{10}: BRRI dhan37 V_{11}: BRRI dhan38 V_{12}: BRRI dhan50

Table 3. Leaf area index at different days after transplanting (DAT) of twelve aromatic rice cultivars

Rice variety	Leaf area index at			
	20 DAT	40 DAT	60 DAT	80 DAT
V_1	1.22 ef	6.92 d-f	13.85 de	14.50 cd
V_2	1.37 de	7.17 c-e	14.04 de	14.37 cd
V_3	1.39 cd	7.43 b-d	14.37 c-e	15.20 bc
V_4	1.47 b-d	7.85 a-c	15.41 a-c	16.33 ab
V_5	1.51 a-d	7.58 a-d	15.64 a-c	16.17 ab
V_6	1.21 ef	6.41 ef	13.53 e	14.37 cd
V_7	1.44 b-d	7.46 b-d	15.15 b-d	15.83 a-c
V_8	1.14 f	6.23 f	13.16 e	13.59 d
V_9	1.53 a-d	7.93 a-c	15.75 a-c	16.72 ab
V_{10}	1.61 ab	8.27 ab	16.39 ab	17.20 a
V_{11}	1.57 a-c	8.18 ab	16.23 ab	17.09 a
V_{12}	1.67 a	8.40 a	16.75 a	17.42 a
$LSD_{(0.05)}$	0.161	0.746	1.256	1.427
Level of significance	0.01	0.01	0.01	0.01
CV(%)	6.59	5.88	4.94	5.36

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

V_1 : Kalizira
V_2 : Chiniatab (awned)
V_3 : Chiniatab (awnless)
V_4 : Kataribhog (awned)
V_5 : Kataribhog (awnless)
V_6 : Madhumala
V_7 : Zirabhog
V_8 : Shakhorkora
V_9 : Badshabhog
V_{10}: BRRI dhan37
V_{11}: BRRI dhan38
V_{12}: BRRI dhan50

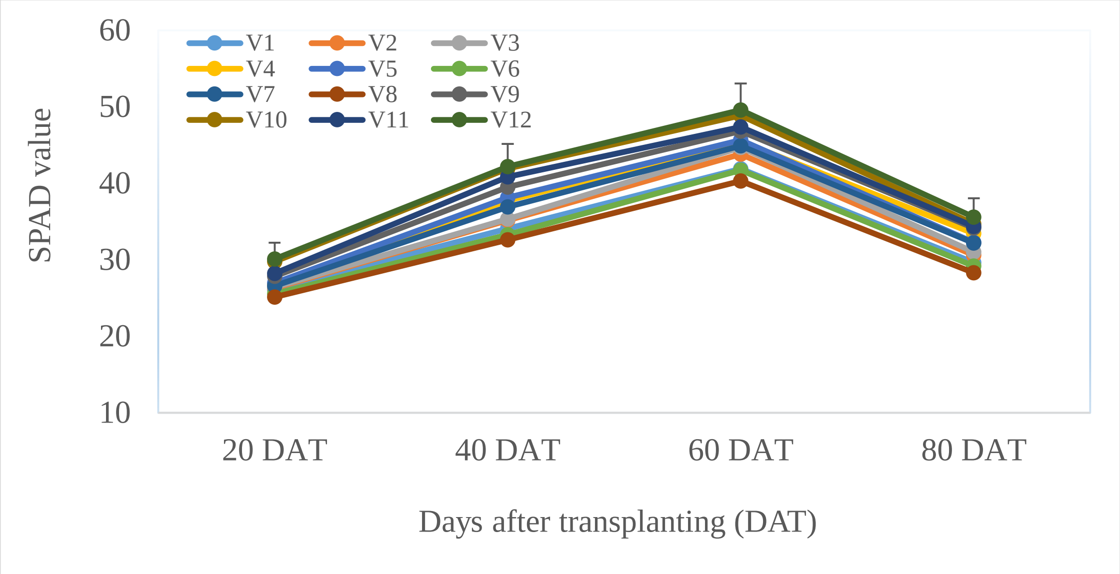


Figure 3. SPAD value of twelve aromatic rice cultivars. Vertical bars represents LSD value at 0.05 level of probability

4.1.6 Flag leaf area

Different aromatic rice cultivars showed statistically significant variation in terms of flag leaf area (Appendix IX). The highest flag leaf area (34.99 cm^2) was found from V_{12} which was statistically similar (34.32 cm^2, 33.90 cm^2, 33.40 cm^2 and 32.61 cm^2, respectively) to V_{10}, V_{11}, V_9 and V_5, while the lowest flag leaf area (29.01 cm^2) was recorded from V_8 which was statistically similar (29.87 cm^2, 30.28 cm^2, 30.85 cm^2 and 31.10 cm^2, respectively) to V_6, V_1, V_2 and V_3 (Table 4).

4.1.7 Penultimate leaf area

Penultimate leaf area showed statistically significant variation for different aromatic rice cultivars (Appendix IX). The highest penultimate leaf area (55.76 cm^2) was observed from V_{12} which was statistically similar (54.56 cm^2, 52.80 cm^2 and 51.50 cm^2, respectively) to V_{10}, V_{11} and V_9. On the other hand, the lowest penultimate leaf area (40.72 cm^2) was observed from V_8 which was statistically similar (42.68 cm^2, 43.68 cm^2 and 46.04 cm^2, respectively) to V_6, V_1 and V_2 cultivars (Table 4).

Table 4. Flag and penultimate leaf area, duration from transplanting to anthesis and maturity of twelve aromatic rice cultivars

Rice variety	Flag leaf area (cm^2)	Penultimate leaf area (cm^2)	Duration from transplanting to anthesis (days)	Duration from transplanting to maturity (days)
V_1	30.28 d-f	43.68 e-g	67.00 bc	118.67 c-f
V_2	30.85 c-f	46.04 d-g	70.33 a-c	121.00 a-e
V_3	31.10 c-f	47.49 c-f	66.67 bc	116.00 d-f
V_4	32.40 b-e	49.75 b-d	70.67 a-c	122.67 a-d
V_5	32.61 a-d	49.90 b-d	72.00 ab	126.00 a-c
V_6	29.87 ef	42.68 fg	68.33 a-c	117.33 c-f
V_7	31.88 b-e	48.52 c-e	68.67 a-c	119.33 b-f
V_8	29.01 f	40.72 g	74.33 a	128.67 ab
V_9	33.40 a-c	51.50 a-d	74.67 a	130.00 a
V_{10}	34.32 ab	54.56 ab	64.33 c	110.67 f
V_{11}	33.90 ab	52.80 a-c	66.67 bc	112.00 ef
V_{12}	34.99 a	55.76 a	71.00 a-c	124.67 a-d
$LSD_{(0.05)}$	2.285	5.179	5.952	8.391
Level of significance	0.01	0.01	0.05	0.01
CV(%)	4.21	6.29	5.05	4.11

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

V_1 : Kalizira
V_2 : Chiniatab (awned)
V_3 : Chiniatab (awnless)
V_4 : Kataribhog (awned)
V_5 : Kataribhog (awnless)
V_6 : Madhumala
V_7 : Zirabhog
V_8 : Shakhorkora
V_9 : Badshabhog
V_{10}: BRRI dhan37
V_{11}: BRRI dhan38
V_{12}: BRRI dhan50

4.1.8 Duration from transplanting to anthesis

Statistically significant differences was observed in terms of duration from transplanting to anthesis for different aromatic rice cultivars (Appendix IX). The highest duration from transplanting to anthesis (74.67 days) was recorded from V_9 which was statistically similar with other cultivars except V_{10}, V_{11}, V_3 and V_1, while the lowest duration (64.33 days) was found from V_{10} which was statistically similar (66.67 days and 67.00 days, respectively) to V_{11}, V_3 and V_1 (Table 4).

4.1.9 Duration from transplanting to maturity

Duration from transplanting to maturity showed statistically significant variation for different aromatic rice cultivars (Appendix IX). The highest duration from transplanting to maturity (130.00 days) was found from V_9 which was statistically similar with other cultivars except V_{10}, V_{11}, V_3, V_6, V_1 and V_7, whereas the lowest duration (110.67 days) was observed from V_{10} which was statistically similar (112.00 days, 116.00 days, 117.33 days, 118.67 days and 119.33 days, respectively) to V_{11}, V_3, V_6, V_1 and V_7 (Table 4).

4.1.10 Shoot dry matter at pre-anthesis

Different aromatic rice cultivars varied significantly in terms of shoot dry matter at pre-anthesis (Appendix X). The highest shoot dry matter at pre-anthesis (32.04 g m^{-2}) was observed from V_{12} which was statistically similar (30.85 g m^{-2} and 30.39 g m^{-2}) to V_{10} and V_{11}. On the other hand, the lowest shoot dry matter at pre-anthesis (22.46 g m^{-2}) was found from V_8 which was statistically similar (23.59 g m^{-2}) to V_6 (Table 5). Amin *et al.* (2006) reported that traditional varieties accumulated higher amount of dry matter than the modern variety.

4.1.11 Shoot dry matter at maturity

Statistically significant variation was observed in terms of shoot dry matter at maturity due to different aromatic rice cultivars (Appendix X). The highest shoot dry matter at maturity (27.16 g m^{-2}) was found from V_{12} which was statistically similar (26.35 g m^{-2} 25.96 g m^{-2} and 25.78 g m^{-2}) to V_{10}, V_{11} and V_9, whereas the lowest shoot dry matter at maturity (19.98 g m^{-2}) was recorded from V_8 which was statistically similar (20.89 g m^{-2} and 21.05 g m^{-2}) to V_6 and V_1 (Table 5).

Table 5. Pre-anthesis dry matter accumulation in shoot and its translocation to the grain of twelve aromatic rice cultivars

Rice variety	Shoot dry matter at pre-anthesis (g m^{-2})	Shoot dry matter at maturity (g m^{-2})	Changes in shoot dry matter (g m^{-2})	Shoot reserve translocation (%)
V_1	24.60 fg	21.05 gh	3.55 b	14.49 a
V_2	25.44 f	21.93 f-h	3.50 b	13.77 ab
V_3	26.04 ef	22.62 e-g	3.43 b	13.19 a-c
V_4	28.46 cd	24.72 b-d	3.75 b	13.23 a-c
V_5	28.04 cd	24.28 c-e	3.76 b	13.42 a-c
V_6	23.59 gh	20.89 gh	2.70 c	11.47 bc
V_7	27.23 de	23.71 d-f	3.52 b	12.96 a-c
V_8	22.46 h	19.98 h	2.48 c	11.03 c
V_9	29.60 bc	25.78 a-c	3.82 b	12.90 a-c
V_{10}	30.85 ab	26.35 ab	4.50 a	14.59 a
V_{11}	30.39 ab	25.96 a-c	4.43 a	14.57 a
V_{12}	32.04 a	27.16 a	4.88 a	15.23 a
$LSD_{(0.05)}$	1.578	1.812	0.511	2.279
Level of significance	0.01	0.01	0.01	0.05
CV(%)	3.40	4.51	8.17	10.04

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

V_1 : Kalizira
V_2 : Chiniatab (awned)
V_3 : Chiniatab (awnless)
V_4 : Kataribhog (awned)
V_5 : Kataribhog (awnless)
V_6 : Madhumala
V_7 : Zirabhog
V_8 : Shakhorkora
V_9 : Badshabhog
V_{10}: BRRI dhan37
V_{11}: BRRI dhan38
V_{12}: BRRI dhan50

4.1.12 Change in shoot dry matter

Change in shoot dry matter showed statistically significant variation for different aromatic rice cultivars (Appendix X). The highest change in shoot dry matter (4.88 g m^{-2}) was observed from V_{12} which was statistically similar (4.50 g m^{-2} and 4.43 g m^{-2}) to V_{10} and V_{11}, while the lowest change in shoot dry matter (2.48 g m^{-2}) was recorded from V_8 which was statistically similar (2.70 g m^{-2}) to V_6 (Table 5).

4.1.13 Shoot reserve translocation

Statistically significant differences was observed in terms of shoot reserve translocation due to different aromatic rice cultivars (Appendix X). The highest shoot reserve translocation (15.23%) was found from V_{12} which was statistically similar with other cultivars except V_8 and V_6, whereas the lowest shoot reserve translocation (11.03%) was recorded from V_8 which was statistically similar (11.47%) to V_6 (Table 5). Haque *et al*. (2015) observed that hybrids accumulated higher amount of biomass before heading and exhibited greater remobilization of assimilates to the grain in early plantings compared to the inbred variety.

4.2 Yield contributing characters and yield

4.2.1 Effective tillers hill^{-1}

Effective tillers hill^{-1} showed statistically significant variation for different aromatic rice cultivars (Appendix XI). The maximum number of effective tillers hill^{-1} (10.80) was found from V_{12} which was statistically similar with other cultivars except V_8, V_6, V_1 and V_2. On the other hand, the minimum number (8.33) was recorded from V_8 which was statistically similar (8.40 and 8.80) to V_6 and V_1 (Table 6). Generally different cultivars produced different number of effective tillers hill^{-1} although different biotic and abiotic factors also influenced it. Khalifa (2009) reported that H_1 hybrid rice variety surpassed other varieties in consideration of effective tillers hill^{-1}.

Table 6. Effective, non-effective and total tillers hill^{-1} and panicle length of twelve aromatic rice cultivars

Rice variety	Effective tillers hill^{-1} (No.)	Non-effective tillers hill^{-1} (No.)	Total tillers hill^{-1} (No.)	Panicle length (cm)
V_1	8.80 cd	2.20 c-e	11.00 de	21.61 e-g
V_2	9.60 bc	2.20 c-e	11.80 cd	22.54 d-f
V_3	9.67 a-c	2.40 b-d	12.07 b-d	23.03 c-e
V_4	10.13 ab	2.40 b-d	12.53 a-c	24.30 a-d
V_5	10.20 ab	2.60 a-c	12.80 a-c	24.50 a-c
V_6	8.40 d	2.07 de	10.47 e	20.92 fg
V_7	9.93 ab	2.47 a-d	12.40 bc	23.76 b-d
V_8	8.33 d	1.80 e	10.13 e	20.30 g
V_9	10.27 ab	2.67 a-c	12.93 a-c	25.32 ab
V_{10}	10.53 ab	2.73 ab	13.27 ab	25.70 a
V_{11}	10.33 ab	2.73 ab	13.07 a-c	25.53 ab
V_{12}	10.80 a	2.93 a	13.73 a	25.97 a
$LSD_{(0.05)}$	0.999	0.418	1.124	1.682
Level of significance	0.01	0.01	0.01	0.01
CV(%)	6.05	10.14	5.45	4.21

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

V_1 : Kalizira
V_2 : Chiniatab (awned)
V_3 : Chiniatab (awnless)
V_4 : Kataribhog (awned)
V_5 : Kataribhog (awnless)
V_6 : Madhumala
V_7 : Zirabhog
V_8 : Shakhorkora
V_9 : Badshabhog
V_{10}: BRRI dhan37
V_{11}: BRRI dhan38
V_{12}: BRRI dhan50

4.2.2 Non-effective tillers hill^{-1}

Different aromatic rice cultivars showed statistically significant differnces in terms of non-effective tillers hill^{-1} (Appendix XI). The maximum number of non-effective tillers hill^{-1} (2.93) was observed from V_{12} which was statistically similar (2.73, 2.67, 2.60 and 2.47) to V_{10}, V_{11}, V_9, V_5 and V_7, whereas the minimum number (1.80) was recorded from V_8 which was statistically similar (2.07 and 2.20) to V_6, V_1 and V_2 (Table 6).

4.2.3 Total tillers hill^{-1}

Statistically significant variation was observed in terms of total tillers hill^{-1} due to different aromatic rice cultivars (Appendix XI). The maximum number of total tillers hill^{-1} (13.73) was found from V_{12} which was statistically similar (13.27, 13.07, 12.93, 12.80 and 12.53) to V_{10}, V_{11}, V_9, V_5 and V_4, while the minimum number (10.13) was observed from V_8 which was statistically similar (10.47 and 11.00) to V_6 and V_1 (Table 6).

4.2.4 Panicle length

Panicle length varied significantly for different aromatic rice cultivars (Appendix XI). The longest panicle (25.97 cm) was recorded from V_{12} which was statistically similar (25.70, 25.53, 25.32, 24.50 and 24.30 cm) to V_{10}, V_{11}, V_9, V_5 and V_4, while the shortest panicle (20.30 cm) was found from V_8 which was statistically similar (20.92 and 21.61 cm) to V_6 and V_1 (Table 6). Sumon *et al*. (2018) sated that BRRI dhan34 gave the longest panicle (27.93 cm).

4.2.5 Filled grains panicle^{-1}

Different aromatic rice cultivars varied significantly in terms of filled grains panicle^{-1} (Appendix XII). The maximum number of filled grains panicle^{-1} (181.60) was found from V_{12} which was statistically similar (179.53, 176.47, 174.13, 172.60, 169.67 and 166.60) to V_{10}, V_{11}, V_9, V_4, V_5 and V_7. On the other hand, the minimum number (155.33) from V_6 which was statistically similar (156.13, 156.93, 159.67 and 160.87) to V_8, V_1, V_3 and V_2 (Table 7). Sarkar *et al*. (2014) revealed that the number of grains panicle^{-1} (152.3) in BRRI dhan34.

Table 7. Filled and unfilled grains panicle^{-1}, spikelet sterility and weight of 1000 grains of twelve aromatic rice cultivars

Rice variety	Filled grains panicle^{-1} (No.)	Unfilled grains panicle^{-1} (No.)	Spikelet sterility (%)	Weight of 1000 grains (g)
V_1	156.93 cd	14.93 d-f	8.70 a-c	12.18 c
V_2	160.87 b-d	15.60 c-f	8.84 a-c	10.31 e
V_3	159.67 b-d	16.27 b-e	9.25 ab	10.50 e
V_4	172.60 a-d	17.73 a-c	9.32 ab	13.92 b
V_5	169.67 a-d	17.73 a-c	9.47 a	13.82 b
V_6	155.33 d	14.07 ef	8.30 bc	11.56 cd
V_7	166.60 a-d	17.20 a-d	9.36 ab	10.70 de
V_8	156.13 d	13.47 f	7.97 c	12.40 c
V_9	174.13 a-c	18.53 ab	9.60 a	10.90 de
V_{10}	179.53 a	19.27 a	9.69 a	14.60 b
V_{11}	176.47 ab	18.93 a	9.69 a	15.54 a
V_{12}	181.60 a	19.67 a	9.77 a	15.92 a
$LSD_{(0.05)}$	15.26	2.296	1.031	0.915
Level of significance	0.01	0.01	0.05	0.01
CV(%)	5.38	8.00	6.65	4.26

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

V_1 : Kalizira V_2 : Chiniatab (awned) V_3 : Chiniatab (awnless)
V_4 : Kataribhog (awned) V_5 : Kataribhog (awnless) V_6 : Madhumala
V_7 : Zirabhog V_8 : Shakhorkora V_9 : Badshabhog
V_{10}: BRRI dhan37 V_{11}: BRRI dhan38 V_{12}: BRRI dhan50

4.2.6 Unfilled grains panicle^{-1}

Statistically significant differences was observed in terms of unfilled grains panicle^{-1} for different aromatic rice cultivars (Appendix XII). The maximum number of unfilled grains panicle^{-1} (19.67) was found from V_{12} which was statistically similar (19.27, 18.93, 18.53, 17.73 and 17.20) to V_{10}, V_{11}, V_9, V_4, V_5 and V_7, whereas the minimum number (13.47) was observed from V_8 which was statistically similar (14.07, 14.93 and 15.60) to V_6, V_1 and V_2 (Table 7).

4.2.7 Total grains panicle^{-1}

Different aromatic rice cultivars showed statistically significant variation in terms of total grains panicle^{-1} (Appendix XII). The maximum number of total grains panicle^{-1} (201.27) was found from V_{12} which was statistically similar (198.80, 195.40, 192.67, 190.33, 187.40 and 183.80) to V_{10}, V_{11}, V_9, V_4, V_5 and V_7, while the minimum number (169.60) was observed from V_8 which was statistically similar (160.40, 171.87, 175.93 and 176.47) to V_6, V_1, V_3 and V_2 (Figure 5).

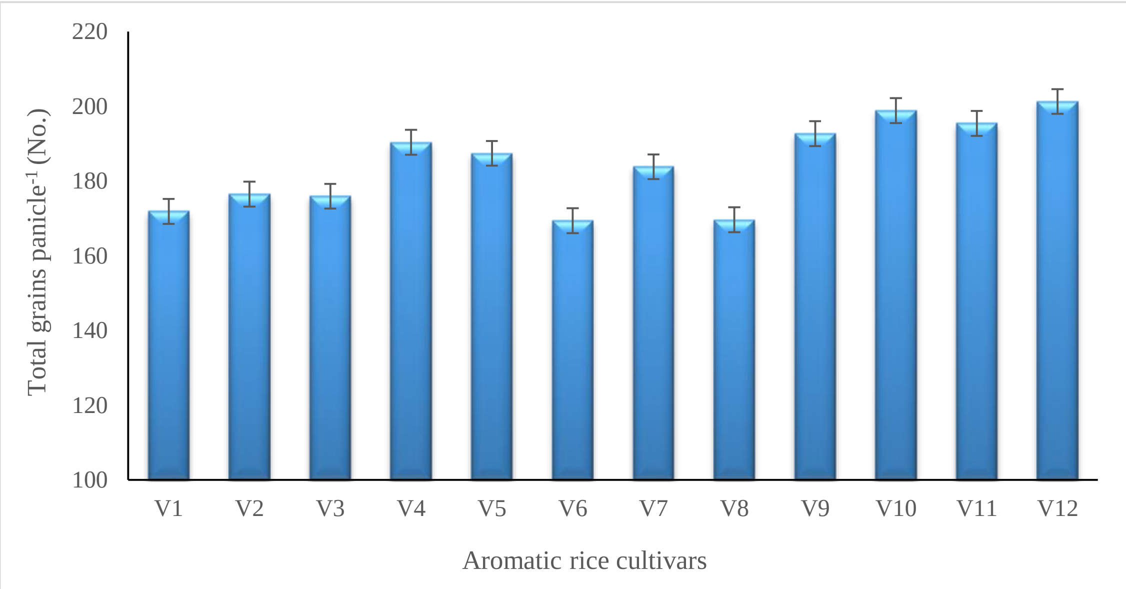


Figure 4. Total grains panicle^{-1} of twelve aromatic rice cultivars. Vertical bars represents LSD value at 0.05 level of probability

4.2.8 Spikelet sterility

Spikelet sterility showed statistically significant variation for different aromatic rice cultivars (Appendix XII). The highest spikelet (9.77%) was recorded from V_{12} which was statistically similar with other cultivars except V_8 and V_6, whereas the lowest spikelet sterility (7.97%) was found from V_8 which was statistically similar (8.30%) to V_6 (Table 7). Hosain *et al*. (2014) reported that Aloron (2.77 t ha^{-1}) gave the higher spikelet sterility.

4.2.9 Weight of 1000 grains

Statistically significant variation was observed in terms of weight of 1000 grains due to different aromatic rice cultivars (Appendix XII). The highest weight of 1000 grains (15.92 g) was observed from V_{12} which was statistically similar (15.54 g) to V_{11}. On the other hand, the lowest weight (10.31 g) was recorded from V_2 which was statistically similar (10.50 g, 10.70 g and 10.90 g) to V_3, V_7 and V_9 (Table 7). Sumon *et al*. (2018) sated that 'BRRI dhan34' gave the highest 1,000-grain weight (17.22 g).

4.2.10 Grain yield

Grain yield showed statistically significant variation for different aromatic rice cultivars (Appendix XIII). The highest grain yield (4.73 t ha^{-1}) was found from V_{12} which was followed (3.49 t ha^{-1} and 3.45 t ha^{-1}) by V_{10} and V_{11}, whereas the lowest grain yield (1.86 t ha^{-1}) was recorded from V_8 which was statistically similar (1.96 t ha^{-1} and 2.08 t ha^{-1}) to V_6 and V_1 (Table 8). It was revealed that BRRI dhan50 produced the highest value of yield attributes and ultimately produced the highest yield among the studied cultivars. Chowdhury *et al*. (2016) obtained the highest grain yield (3.33 t ha^{-1}) from Binadhan-13 followed by BRRI dhan34 (3.16 t ha^{-1}) and the lowest grain yield was found in Kalizira (2.11 t ha^{-1}). Sarkar *et al*. (2016) achieved the highest grain yield from Tia (7.82 t ha^{-1}), which was closely followed by Shakti 2 (7.65 t ha^{-1}).

Table 8. Grain, straw and biological yield and harvest index of twelve aromatic rice cultivars

Rice variety	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1	2.08 ef	4.50 de	6.58 ef	31.68 c
V_2	2.27 de	4.58 de	6.86 d-f	33.16 c
V_3	2.31 de	4.69 c-e	6.99 d-f	32.99 c
V_4	2.42 d	5.03 b-d	7.45 cd	32.53 c
V_5	2.43 d	5.03 b-d	7.46 cd	32.54 c
V_6	1.96 f	4.42 de	6.38 ef	30.68 c
V_7	2.27 de	4.79 b-e	7.06 de	32.11 c
V_8	1.86 f	4.32 e	6.19 f	30.12 c
V_9	2.93 c	5.06 b-d	7.99 c	36.70 b
V_{10}	3.49 b	5.37 b	8.86 b	39.44 ab
V_{11}	3.45 b	5.32 b	8.76 b	39.32 ab
V_{12}	4.73 a	6.52 a	11.25 a	42.08 a
$LSD_{(0.05)}$	0.283	0.591	0.755	2.688
Level of significance	0.01	0.01	0.01	0.01
CV(%)	6.29	7.02	5.83	4.61

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

V_1 : Kalizira
V_2 : Chiniatab (awned)
V_3 : Chiniatab (awnless)
V_4 : Kataribhog (awned)
V_5 : Kataribhog (awnless)
V_6 : Madhumala
V_7 : Zirabhog
V_8 : Shakhorkora
V_9 : Badshabhog
V_{10}: BRRI dhan37
V_{11}: BRRI dhan38
V_{12}: BRRI dhan50

4.2.11 Straw yield

Different aromatic rice cultivars showed statistically significant variation in terms of straw yield (Appendix XIII). The highest straw yield (6.52 t ha^{-1}) was recorded from V_{12} which was followed (5.37 t ha^{-1} and 5.32 t ha^{-1}) by V_{10} and V_{11}, while the lowest straw yield (4.32 t ha^{-1}) was found from V_8 which was statistically similar (4.42 t ha^{-1}) to V_6 (Table 8).

4.2.12 Biological yield

Biological yield showed statistically significant variation for different aromatic rice cultivars (Appendix XIII). The highest biological yield (11.25 t ha^{-1}) was observed from V_{12} which was followed (8.86 t ha^{-1} and 8.76 t ha^{-1}) by V_{10} and V_{11}. On the other hand the lowest biological yield (6.19 t ha^{-1}) was recorded from V_8 which was statistically similar (6.38 t ha^{-1}) to V_6 (Table 8). Sumon *et al.* (2018) revealed that 'Raniselute' variety produced the highest biological yield (9.05 t ha^{-1}) compared to the other variety that studied under the experiment.

4.2.13 Harvest index

Statistically significant variation was observed in terms of harvest index due to different aromatic rice cultivars (Appendix XIII). The highest harvest index (42.08%) was recorded from V_{12} which was statistically (39.44% and 39.32%) to V_{10} and V_{11}, whereas the lowest harvest index (30.12%) was observed from V_6 which was statistically similar with other cultivars except V_{12}, V_{11}, V_{10} and V_9 (Table 8).

Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during the period from July to November 2017 to find out the genotypic variation in morpho-physiological traits and yield in traditional aromatic rice cultivars. Twelve traditional aromatic rice cultivars viz., V_1: Kalizira, V_2: Chiniatab (awned), V_3: Chiniatab (awnless), V_4: Kataribhog (awned), V_5: Kataribhog (awnless), V_6: Madhumala, V_7: Zirabhog, V_8: Shakhorkora, V_9: Badshabhog, V_{10}: BRRI dhan37, V_{11}: BRRI dhan38 and V_{12}: BRRI dhan50 were used as the treatment of this experiment. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Data on different morpho-physiological traits and yield were recorded and statistically significant differences was observed for different cultivars.

Plant height at 20, 40, 60 and 80 DAT and at harvest, the tallest plant (45.80 cm, 84.82, 128.64, 147.00 and 150.75 cm) was recorded from V_8, while the shortest plant (35.26, 72.19, 100.94, 104.54 and 107.19 cm) was found from V_{12}. At 20, 40, 60 and 80 DAT, the maximum number of leaves hill^{-1} (23.40, 41.33, 54.80 and 56.80, respectively) was observed from V_{12}, whereas the minimum number (19.27, 34.13, 42.73 and 45.00, respectively) was recorded from V_8. At 20, 40, 60 and 80 DAT, the maximum number of tillers hill^{-1} (5.07, 9.93, 13.87 and 14.53, respectively) was found from V_{12} and the minimum number (4.07, 7.07, 10.13 and 11.00, respectively) was recorded from V_8. At 20, 40, 60 and 80 DAT, the highest leaf area index (1.67, 8.40, 16.75 and 17.42, respectively) was observed from V_{12}, while the lowest leaf area index (1.14, 6.23, 13.16 and 13.59, respectively) was recorded from V_8. At 20, 40, 60 and 80 DAT, the highest SPAD value (30.12, 42.19, 49.61 and 35.58, respectively) was recorded from V_{12}, whereas the lowest SPAD value (25.15, 32.60, 40.33 and 28.30, respectively) was found from V_8.

The highest flag leaf area (34.99 cm^2) was found from V_{12}, while the lowest flag leaf area (29.01 cm^2) was recorded from V_8. The highest penultimate leaf area (55.76 cm^2) was observed from V_{12} and the lowest penultimate leaf area (40.72 cm^2) was recorded from V_8. The highest duration from transplanting to anthesis (74.67 days) was recorded from V_9, while the lowest duration (64.33 days) was found from V_{10}. The highest duration from transplanting to maturity (130.00 days) was found from V_9, whereas the lowest duration (110.67 days) was observed from V_{10}. The highest shoot dry matter at pre-anthesis (32.04 g m^{-2}) was observed from V_{12} hand the lowest shoot dry matter at pre-anthesis (22.46 g m^{-2}) was found from V_8. The highest shoot dry matter at maturity (27.16 g m^{-2}) was found from V_{12}, whereas the lowest shoot dry matter at maturity (19.98 g m^{-2}) was recorded from V_8. The highest change in shoot dry matter (4.88 g m^{-2}) was observed from V_{12}, while the lowest change in shoot dry matter (2.48 g m^{-2}) was found from V_8. The highest shoot reserve translocation (15.23%) was found from V_{12}, whereas the lowest shoot reserve translocation (11.03%) from V_8.

The maximum number of effective tillers $hill^{-1}$ (10.80) was found from V_{12} and the minimum number (8.33) was recorded from V_8. The maximum number of non-effective tillers $hill^{-1}$ (2.93) was observed from V_{12}, whereas the minimum number (1.80) was recorded from V_8. The maximum number of total tillers $hill^{-1}$ (13.73) was found from V_{12}, while the minimum number (10.13) was observed from V_8. The longest panicle (25.97 cm) was recorded from V_{12}, whereas the shortest panicle (20.30 cm) was found from V_8. The maximum number of filled grains $panicle^{-1}$ (181.60) was found from V_{12} and the minimum number (155.33) was recorded from V_6. The maximum number of unfilled grains $panicle^{-1}$ (19.67) was found from V_{12}, whereas the minimum number (13.47) was observed from V_8. The maximum number of total grains $panicle^{-1}$ (201.27) was found from V_{12}, while the minimum number (169.60) was observed from V_8. The highest spikelet (9.77%) was recorded from V_{12}, whereas the lowest spikelet sterility (7.97%) was found from V_8. The highest weight of 1000 grains (15.92 g) was observed from V_{12} and the lowest weight (10.31 g) was recorded from V_2. The highest grain yield

(4.73 t ha^{-1}) was found from V_{12}, whereas the lowest grain yield (1.86 t ha^{-1}) was recorded from V_8. The highest straw yield (6.52 t ha^{-1}) was recorded from V_{12}, while the lowest straw yield (4.32 t ha^{-1}) from V_8. The highest biological yield (11.25 t ha^{-1}) was observed from V_{12} and the lowest biological yield (6.19 t ha^{-1}) was recorded from V_8. The highest harvest index (42.08%) was recorded from V_{12}, whereas the lowest harvest index (30.12%) was observed from V_6.

Conclusion:

- All the BRRI released aromatic rice varieties exhibited higher values for growth and yield parameters compared to land races.
- BRRI dhan50 produced the highest grain yield (4.73 t ha^{-1}) among the test varieties and it was 48% than the land races.

Recommendation:

- Modern aromatic rice variety, BRRI dhan50 should be cultivated for getting higher grain yield.

- Such type of study is needed in different agro-ecological zones (AEZ) of Bangladesh for testing the regional compliance and other quality attributes.

References

REFERENCES

Alam, M.S., Biswas, B.K., Gaffer, M.A. and Hossain, M.K. (2012). Efficiency of weeding at different stages of seedling emergence in direct-seeded aus rice. *Bangladesh J. Sci. Ind. Res.*, **30**(4): 155-167.

Ali, H., Sawar, N., Hasnain, Z., Ahmad, S. and Hussain, A. (2016). Zinc fertilization under optimum soil moisture condition improved the aromatic rice productivity. *Philippine J. Crop Sci.*, **41**(2): 71-78.

Amin, M.R., Hamid, A., Choudhury, R.U., Raquibullah, S.M. and Asaduzzaman M. (2006). Nitrogen Fertilizer Effect on Tillering, Dry Matter Production and Yield of Traditional Varieties of Rice. *Intl. J. Suatain. Crop Prod.*, **1**(1): 17-20.

Anis, G.E.L., Sabagh, A. El-Badry, A. and Barutçular, C. (2016). Improving grain yield in rice (*Oryza Sativa* L.) by estimation of heterosis, genetic components and correlation coefficient. *Intl. J. Current Res.*, **8**(1): 25080-25085.

Ashraf, U., Kanu, A.S., Deng, Q., Mo, Z., Pan, S., Tian, H., Tang, X. (2017). Lead (Pb) toxicity; physio-biochemical mechanisms, grain yield, quality, and pb distribution proportions in scented rice. *Frontiers Plant Sci.*, **8**: 1-17.

Ashrafuzzaman, M., Islam, M.R., Ismail, M.R., Shahidullah, S.M. and Hanafi, M. (2009). Evaluation of six aromatic rice varieties for yield and yield contributing characters. *Intl. J. Agric. Biol.*, **11**: 616-620.

Baradi, M.A.U. and Martinez, N.G.T. (2015). 2-Acetyl-1-pyrroline levels in fragrant rice as affected by storage condition and packaging. *Philippine Agril. Sci.*, **98**(2): 142-147.

BBS (Bangladesh Bureau of Statistics). (2017). The Yearbook of Agricultural Statistics of Bangladesh. Bangladesh Bureau of Statistic, Statistics

Division, Ministry of Planning, Government of. Peoples Republic of Bangladesh. Dhaka, Bangladesh.

Bhowmick, N. and Nayak, R.L. (2000). Response of hybrid rice (*Oryza sativa*) varieties to nitrogen, phosphorus and potassium fertilizers during dry (boro) season in West Bengal. *Indian J. Agron.*, **45**(2): 323-326.

Bhuiyan, M.S.H., Zahan, A., Khatun, H., Iqbal, M., Alam, F. and Manir, M.R. (2014). Yield performance of newly developed test crossed hybrid rice variety. *Intl. J. Agron. Agril. Res*., **5**(4): 48-54.

Bhuiyan, N.I. (2004). The Hybrid Rice Program for Bangladesh. **In**: 'Hybrid Rice in Bangladesh: Progress and Future Strategies'. pp. 3-5. Bangladesh Rice Res. Inst. Publication No. 138.

Bonnett, G.D. and Incoll, L.D. (1992). The potential pre-anthesis and post-anthesis contribution of stem internodes to grain yield in crop of winter barley. *Ann. Bot.*, **69**: 219-225.

BRRI (Bangladesh Rice Research Institute). (2011). Annual Report for 2009-10. Bangladesh Rice Research Institute, Joydebpur, Gazipur, Bangladesh.

BRRI. (2016). Adhunik Dhaner Chash, Joydevpur, Gazipur. P. 34.

Chaturvedi, S., Lal, P., Singh, A.P. and Tripathi, M.K. (2004). Agronomic and morpho-physiological analysis of growth and productivity in hybrid rice (*Oryza sativa* L.). *Ann. Biol*., 8**0**(2): 233-238.

Chowdhury, S.A., Paul, S.K. and Sarkar, M.A.R. (2016). Yield performance of fine aromatic rice in response to variety and level of nitrogen. *J. Environ. Sci. Natural Resources*, **9**(1): 41-45.

Das, T. and Baqui, M.A. (2000). Aromatic rice of Bangladesh. *In*: Aromatic rice, Oxford and IBM publishing Co. Pvt. Ltd., New Delhi. pp. 184-187.

Dou, F., Soriano, J., Tabien, R.E., Chen, K. (2016). Soil texture and cultivar effects on rice (*Oryza sativa*, L.) grain yield, yield components and water productivity in three water regimes. *Plos One*., **11**(3): 15-21.

Dutta, R.K., Baset, M.A., Khanam, S. (2002). Plant architecture and growth characteristics of fine grain and aromatic rice and their relation with grain yield. *IRC Newslett*., **51**: 51-56.

Edris, K.M., Islam, A.T.M.T., Chowdhury, M.S. and Haque, A.K.M.M. (1979). Detailed Soil Survey of Bangladesh, Dept. Soil Survey, Govt. People's Republic of Bangladesh. p.118.

FAO (Food and Agriculture Organization). (1988). Production Yearbook for 1998. FAO, UN. Rome, Italy. p. 118.

FAO (Food and Agriculture Organization). (2014). FAO Production Yearbook, Food and Agriculture Organization, Rome, Italy. pp. 59-78.

Fatema, K., Rasul, M.G., Mian M.A.K. and Rahman, M.M. (2011). Genetic Variability for grain quality traits in aromatic rice (*Oryza sativa* L). *Bangladesh J. Pl. Breed. Genet*., **24**(2): 19-24.

Fitzgerald, M.A., McCouch, S.R. and Hall, R.D. (2009). Not just a grain of rice: The quest for quality. *Cell Press,* **3**: 133-39.

Ghosh, M. (2001). Performance of hybrid and high-yielding rice varieties in Teraj region of West Bengal. *J. Intl. Academicians*. **5**(4): 578-581.

Gomez, K.A. and Gomez, A.A. (1984). Statistically Procedures for Agricultural Research. 2nd edition. An International Rice Research Institute Book. A wiley-Inter science Publication, New York, 28. 1984. pp. 442-443.

Guilani, A.A., Siadat, S.A. and Fathi, G. (2003). Effect of plant density and seedling age on yield and yield components in 3 rice cultivars in Khusestan growth conditions. *Iranian J. Agric. Sci*., **34**(2): 427-438.

Haque, M. and Biswash, M.R. (2014). Characterization of commercially cultivated hybrid rice in Bangladesh. *World J. Agric. Sci.*, **10**(5): 300-307.

Haque, M.M. and Biswas, J.K. (2011). Annual Research Review. Plant Physiology Division. Bangladesh Rice Research Institute, Joydebpur, Gazipur, Bangladesh. p. 23.

Haque, M.M., Pramanik, H.R., Biswas, J.K., Iftekharuddaula, K.M. and Mirza Hasanuzzaman, M. (2015). Comparative Performance of Hybrid and Elite Inbred Rice Varieties with respect to Their Source-Sink Relationship. *The Scientific World J*., **15**: 1-11.

Hosain, M.T., Ahamed, M.T., Haque, K.U., Islam, M.M., Fazle Bari, M.M. and Mahmud, J.A. (2014). Performance of Hybrid Rice (*Oryza sativa* L.) Varieties at Different Transplanting Dates in *Aus* Season. *App. Sci. Report.* **1**(1): 1-4.

Huang, M. and Yan, K. (2016). Leaf photosynthetic performance related higher radiation use efficiency and grain yield in hybrid rice. *Field Crops Res.,* **193**: 87-93.

Huang, Z.L., Tang, X.R., Wang, Y.L., Chen, M.J., Zhao, Z.K., Duan, M.Y., Pan, S.G. (2012). Effects of increasing aroma cultivation on aroma and grain yield of aromatic rice and their mechanism. *Scientia Agric. Sci*., **45**(6): 1054-1065.

Islam, M.S., Bhuiya, M.S.U., Rahman, S. and Hussain, M.M. (2010). Evaluation of SPAD and LCc based nitrogen management in rice (*Oryza sativa* L.),” *Bangladesh J. Agril. Res.,* **34**(4): 661-672.

Islam, M.S.H., Bhuiyan, M.S.U., Gomosta, A.R., Sarkar, A.R. and Hussain, M.M. (2009). Evaluation of growth and yield of selected hybrid and inbred rice varieties grown in net house during transplanted aman season. *Bangladesh J. Agril. Res*., **34**(1): 67-73.

Jahan, S., Sarkar, M.A.R. and Paul, S.K. (2017). Variations of growth parameters in transplanted Aman rice (cv. BRRI dhan39) in response to plant spacing and fertilizer management. *Archives of Agric. & Env. Sci*., **2**(1): 1-5.

Jisan, M.T., Paul, S.K. and Salim, M. (2014). Yield performance of some transplant aman rice varieties as influenced by different levels of nitrogen. *J. Bangladesh Agril. Univ*., **12**(2): 321-324

Julfiquar, A.W., Haque, M.M., Haque, A.K.G.M.E. and Rashid, M.A. (2008). Current Status of Hybrid Rice Research and Future Program in Bangladesh. Proc. Workshop on use and development of hybrid rice in Bangladesh, held at BARC, 18-19, May, 2008.

Kanfany, G., El-Namaky, R., Ndiaye, K., Traore, K. and Ortiz, R. (2014). Assessment of Rice Inbred Lines and Hybrids under Low Fertilizer Levels in Senegal. *Sustainability*. **6**: 1153-1162.

Khalifa, A.A.B.A. (2009). Physiological evaluation of some hybrid rice varieties under different sowing dates. *Australian J. Crop Sci.*, **3**(3):178-183.

Khush, G.S. (2005). What it will take to Feed 5.0 Billion Rice consumers in 2030. *Plant Molecular Biol*., **59**: 1-6.

Mahamud J.A., Haque, M.M. and Hasanuzzaman, M. (2013). Growth, dry matter production and yield performance of transplanted aman rice varieties influenced by seedling densities per hill. *Intl. J. Sustain. Agric*., **5**(1): 16-24.

Mandavi, F., Eamaili, M.A., Pirdashti, H. and Fallah, A. (2004). Study on the physiological and morphological indices among the modern and old rice (*Oryza sativa* L.) genotypes: New directions for a diverse planet. Proc. 4th Int. Crop Sci. Congress; Brisbane, Australia**.**

Mandira, B., Kumar, S., Chakraborty, D., Kapil, A.C. and Nath, D.J. (2016). Performance of rice variety Gomati in front line demonstration under rainfed condition of South Tripura district. *Intl. J. Agric. Sci*., **8**(63): 3555-3556.

Mannan, M.A., Bhuiya, M.S.U., Akand, M.M. and Rana, M.M. (2012). Influence of date of planting on the growth and yield of locally popular traditional aromatic rice varieties in *Boro* season. *J. Sci. Foundation*. **10**(1): 20-28.

Masum, M. (2009). Impact of hybrid rice on Bangladesh. In: 'The Guardian". pp. 56-58.

Masum, S.M., Ali, M.H. and Ullah, J. (2008). Growth and yield of two T. aman rice varieties as affected by seedling number per hill and urea supper granules. *J. Agric. Educ. Technol*., **11**(1&2): 51-58.

Murthy, K.N.K., Shankaranarayana, V., Murali, K. and Jayakumar, B.V. (2004). Effect of different dates of planting on spikelet sterility in rice genotypes (*Oryza sativa* L.). *Res. Crops.* **5**(2/3): 143-147.

Myung, K. (2005). Yearly variation of genetic parameters for panicle characters of Japonica rice (*Oryza sativa* L.). *Australian J. Crop Sci*., **2**(1): 65-71.

Patel, J.R. (2000). Effect of water regime, variety and blue green algae on rice (*Oryza sativa). Indian J. Agron*., **45**(1): 103-106.

Pruneddu, G. and Spanu, A. (2001). Varietal comparison of rice in Sardinia. *Informatore Agrario*., **57**(5): 47-49.

Roy, D. and Bandyopadhyay, A.K. (2014). Factors contributing towards adoption of aromatic rice production technology in Nadia district of West Bengal. *J. Crop and Weed*., **10**(2): 166-169.

Salem, A.K.M., Elkhoby, W.M., Abou-Khalifa, A.B. and Ceesay, M. (2011). Effect of Nitrogen Fertilizer and Seedling Age on Inbred and Hybrid Rice Varieties. *American-Eurasian J. Agric. Environ. Sci*., **11**(5): 640-646**.**

Samonte, S.O.P.B., Tabien, R.E. and Wilson, L.T. (2011). Variation in yield related traits within variety in large rice yield trials. *Texas Rice*. **11**(5): 9-11.

Sarkar, S.C., Akter, M., Islam, M.R. Haque, M.M. (2016). Performance of five selected hybrid rice varieties in *Aman* season. *J. Plant Sci*., **4**(2): 72-79.

Sarkar, S.K., Sarkar, M.A.R., Islam, N. and Paul, S.K. (2014). Yield and quality of aromatic fine rice as affected by variety and nutrient management. *J. Bangladesh Agril. Univ*. **12**(2): 279-284.

Shaloie, M., Gilani, A. and Siadat, S.A. (2014). Evaluation of sowing date effect on hybrid rice lines production in dry-bed of Khuzestan. *Intl. Res. J. Appl. Basic Sci*., **8**(7): 775-779.

Sharma, S.K. and Haloi, B. (2001). Characterization of crop growth variables in some selected rice cultivars of Assam. *Indian J. Plant Physiol.*, **6**(2): 166-171.

Singh, T., Sikka, R. and Sidhue, M.S. (2004). Performance of transplanted Basmati rice in cropping systems as affected by N application. *Intl. Rice Res. Notes*, **29**(1): 63-65.

Song, Z.P., Lu, B.R., Wang, B. and Chen, J.K. (2004). Fitness estimation through performance comparison of F_1 hybrids with their parental species *Oryza rufipogon* and *O. sativa*. *Ann. Bot.*, **93**(3): 311–316.

Sumon, M.J.I., ROY, T.S., Haque, M.N., Ahmed, S. and Mondal, K. (2018). Growth, yield and proximate composition of aromatic rice as influenced by inorganic and organic fertilizer management. *Not Sci. Biol.*, **10**(2): 211-219.

Swain, P., Annie, P. and Rao, K.S. (2006). Evaluation of rice (*Oryza sativa*) hybrids in terms of growth and physiological parameters and their relationship with yield under transplanted condition. *Indian J. Agric. Sci*., **76**(8): 496-499.

Wagan, S.A., Mustafa, T., Noonari, S., Memon, Q.U. and Wagan, T.A. (2015). Performance of hybrid and conventional rice varieties in Sindh, *Pakistan. J. Econ. Sustain. Dev*., **6**: 114-117.

Wang, J.L., Xu, Z.J. and Yi, X.Z. (2006). Effects of seedling quantity and row spacing on the yields and yield components of hybrid and conventional rice in northern China. *Chinese J. Rice Sci*., **20**(6): 631-637.

Witham, H., Blaydes, D.F. and Devlin, R.M. (1986). Excerises in plant physiology. 2nd edition. PWS Publishers, Boston. USA. p. 128-131.

Xie, W., Wang, G. and Zhang, Q. (2007). Potential production simulation and optimal nutrient management of two hybrid rice varieties in Jinhua, Zhejiang Province. *J. Zhejiang Univ. Sci.*, **8**(7): 486-492.

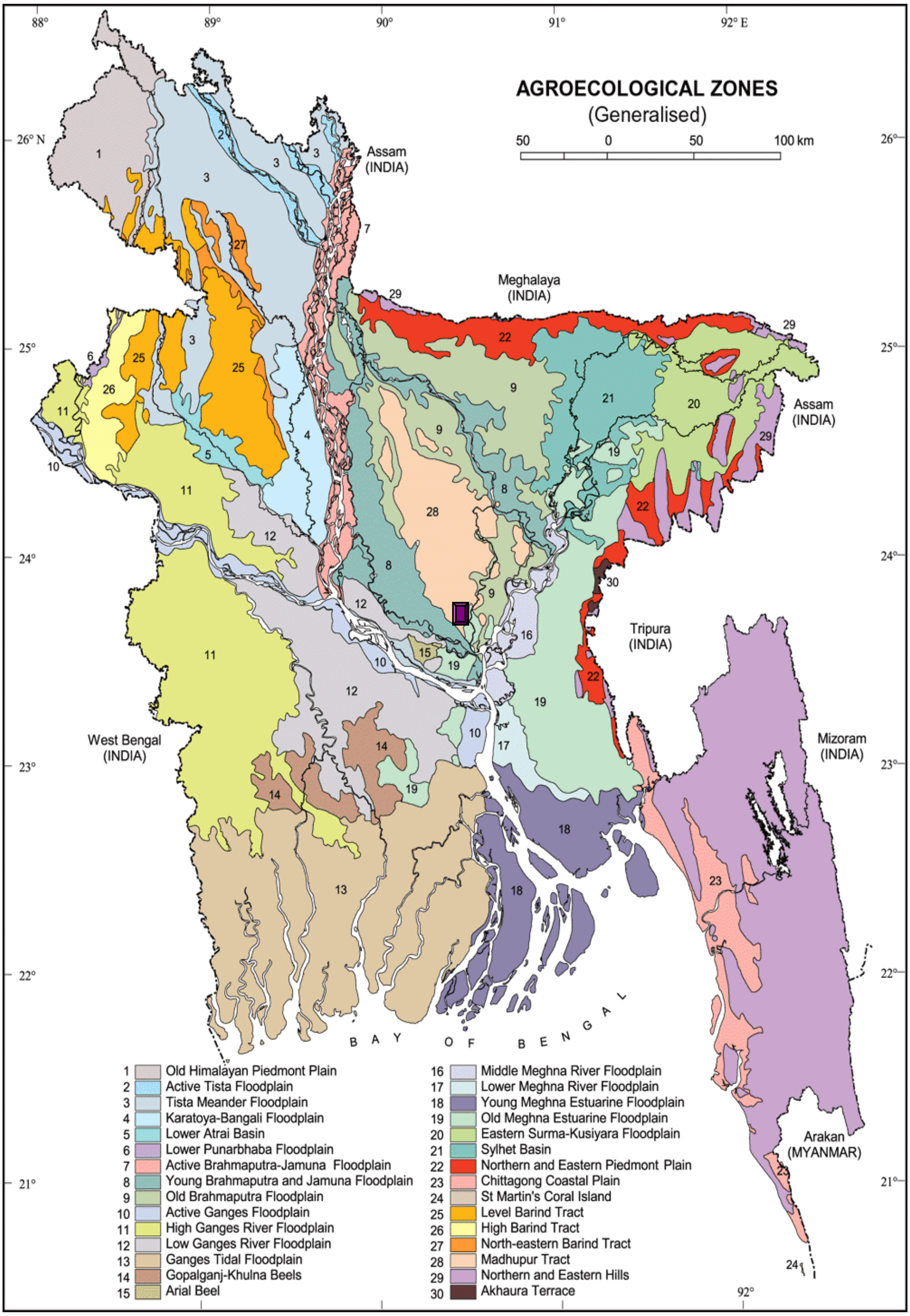
Yoshida, S. (1981). Fundamentals of Rice Crop Science, IRRI (International Rice Research Institute), Philippines. pp. 1-41.

You Z.L., Xiao, D.Y., Mei, E.W. and Qing, S.Z. (2012). Effects of lodging at different filling stages on rice yield and grain quality. *Rice Sci*., **19**(4): 315-319.

Appendices

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 July to November 2017

Month (2017)	Air temperature (^{0}c)		Relative humidity (%)	Rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
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	00	6.7

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

Appendix III. Soil characteristics of 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
Catayan 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 influenced by twelve aromatic rice cultivars

Source of variation	Degrees of freedom	Mean square				
		Plant height (cm) at				
		20 DAT	40 DAT	60 DAT	80 DAT	Harvest
Replication	2	7.665	5.763	3.457	38.724	18.312
Rice cultivars	11	30.711**	35.203**	198.421**	403.538**	404.302**
Error	22	9.193	10.391	36.280	86.384	69.141

**: Significant at 0.01 level of probability

Appendix V. Analysis of variance of the data on number of leaves hill^{-1} at different days after transplanting (DAT) and harvest as influenced by twelve aromatic rice cultivars

Source of variation	Degrees of freedom	Mean square			
		Leaves hill^{-1} (No.) at			
		20 DAT	40 DAT	60 DAT	80 DAT
Replication	2	0.008	0.923	0.218	0.981
Rice cultivars	11	4.740*	21.492**	49.958**	42.337**
Error	22	1.850	2.932	7.762	10.637

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data on number of tillers hill^{-1} at different days after transplanting (DAT) and harvest as influenced by twelve aromatic rice cultivars

Source of variation	Degrees of freedom	Mean square			
		Tillers hill^{-1} (No.) at			
		20 DAT	40 DAT	60 DAT	80 DAT
Replication	2	0.120	0.053	0.108	0.008
Rice cultivars	11	0.333*	2.747**	4.420**	4.299**
Error	22	0.126	0.208	0.629	0.321

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data on leaf area index at different days after transplanting (DAT) and harvest as influenced by twelve aromatic rice cultivars

Source of variation	Degrees of freedom	Mean square			
		Leaf area index at			
		20 DAT	40 DAT	60 DAT	80 DAT
Replication	2	0.009	0.058	0.273	0.379
Rice cultivars	11	0.084**	1.481**	4.326**	5.048**
Error	22	0.009	0.194	0.550	0.710

**: Significant at 0.01 level of probability

Appendix VIII. Analysis of variance of the data on SPAD value at different days after transplanting (DAT) and harvest as influenced by twelve aromatic rice cultivars

Source of variation	Degrees of freedom	Mean square			
		SPAD Value at			
		20 DAT	40 DAT	60 DAT	80 DAT
Replication	2	0.174	0.846	1.072	1.091
Rice cultivars	11	7.305*	32.933**	24.405**	17.085**
Error	22	2.839	2.486	5.629	2.154

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix IX. Analysis of variance of the data on flag and penultimate leaf area, and duration from transplanting to anthesis and maturity as influenced by twelve aromatic rice cultivars

Source of variation	Degrees of freedom	Mean square			
		Flag leaf area (cm^2)	Penultimate leaf area (cm^2)	Duration from transplanting to anthesis (days)	Duration from transplanting to maturity (days)
Replication	2	0.662	0.401	7.111	3.250
Rice cultivars	11	10.631**	66.821**	30.444*	112.735**
Error	22	1.821	9.353	12.354	24.553

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix X. Analysis of variance of the data on pre-anthesis dry matter accumulation in shoot and its translocation to the grain as influenced by twelve aromatic rice cultivars

Source of variation	Degrees of freedom	Mean square			
		Shoot dry matter at pre-anthesis (g m^{-2})	Shoot dry matter at maturity (g m^{-2})	Changes in shoot dry matter (g m^{-2})	Shoot reserve translocation (%)
Replication	2	0.756	0.502	0.026	0.050
Rice cultivars	11	27.607**	17.136**	1.429**	4.736*
Error	22	0.868	1.145	0.091	1.811

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix XI. Analysis of variance of the data on effective, non-effective and total tillers hill^{-1} and panicle length as influenced by twelve aromatic rice cultivars

Source of variation	Degrees of freedom	Mean square			
		Effective tillers hill^{-1} (No.)	Non-effective tillers hill^{-1} (No.)	Total tillers hill^{-1} (No.)	Panicle length (cm)
Replication	2	0.023	0.010	0.013	0.228
Rice cultivars	11	2.037**	0.316**	3.867**	11.302**
Error	22	0.348	0.061	0.441	0.987

**: Significant at 0.01 level of probability

Appendix XII. Analysis of variance of the data on filled, unfilled and total grains panicle^{-1}, spikelet sterility and weight of 1000 grains as influenced by twelve aromatic rice cultivars

Source of variation	Degrees of freedom	Mean square				
		Filled grains panicle^{-1} (No.)	Unfilled grains panicle^{-1} (No.)	Total grains panicle^{-1} (No.)	Spikelet sterility (%)	Weight of 1000 grains (g)
Replication	2	8.882	0.191	10.582	0.031	0.005
Rice cultivars	11	271.021**	12.894**	398.581**	1.025*	12.075**
Error	22	81.210	1.838	93.977	0.371	0.292

**: Significant at 0.01 level of probability; *: Significant at 0.05 level of probability

Appendix XIII. Analysis of variance of the data on grain, straw and biological yield and harvest index as influenced by twelve aromatic rice cultivars

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	0.005	0.007	0.024	0.008
Rice cultivars	11	2.089**	1.063**	6.040**	46.138**
Error	22	0.028	0.122	0.199	2.519

**: Significant at 0.01 level of probability