YIELD, QUALITY AND MORPHO-PHYSIOLOGICAL TRAITS OF LOCAL AND IMPROVED AROMATIC RICE UNDER ORGANIC CULTURE

SUMAIYA TABASSUM EMA

DEPARTMENT OF AGRICULTURAL BOTANY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA -1207

JUNE, 2020

YIELD, QUALITY AND MORPHO-PHYSIOLOGICAL TRAITS OF LOCAL AND IMPROVED AROMATIC RICE UNDER ORGANIC CULTURE

BY

SUMAIYA TABASSUM EMA

REGISTRATION NO: 13-05442

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, 2020

Approved by:

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

Prof. Dr. Kamal Uddin Ahamed
Co-Supervisor
Dept. of Agricultural Botany
Sher-e-Bangla Agricultural University
Dhaka-1207

Dr. Kamrun Nahar
Chairman
Department of Agricultural Botany
Sher-e-Bangla Agricultural University
Dhaka-1207

DEPARTMENT OF AGRICULTURAL BOTANY

Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that the thesis entitled " **YIELD, QUALITY AND MORPHO-PHYSIOLOGICAL TRAITS OF LOCAL AND IMPROVED AROMATIC RICE UNDER ORGANIC CULTURE"** submitted to the **Department of Agricultural Botany**, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE (M.S.)** in **AGRICULTURAL BOTANY**, embodies the result of a piece of bonafide research work carried out by **SUMAIYA TABASSUM EMA**, Registration No. **13-05442** 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.

June, 2020
Dhaka, Bangladesh

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

Dedicated to
My
Beloved Parents

ACKNOWLEDGEMENTS

The author seems it a much privilege to express his enormous sense of gratitude to the almighty Allah for the ever ending blessings for the successful completion of the research work.

The author wishes to express her gratitude and best regards to her respected Supervisor, ***Dr. Md. Moinul Haque****, Professor, Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, for his continuous direction, constructive criticism, encouragement and valuable suggestions in carrying out the research work and preparation of this thesis.*

The author wishes to express her earnest respect, sincere appreciation and enormous indebtedness to her reverend Co-supervisor, ***Dr. Kamal Uddin Ahamed****, Professor, Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, for his scholastic supervision, helpful commentary and unvarying inspiration throughout the research work and preparation of the thesis.*

The author feels to express her heartfelt thanks to the honorable Chairman, ***Dr. Kamrun Nahar****, Associate Professor, Department of Agricultural Botany along with all other teachers and staff members of the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, for their co-operation during the period of the study.*

The author expresses her heartfelt thanks to her beloved parents, elder sister and brother and all other family members for their prayers, encouragement, constant inspiration and moral support for her higher study. May Almighty bless and protect them all.

The Author

YIELD, QUALITY AND MORPHO-PHYSIOLOGICAL TRAITS OF LOCAL AND IMPROVED AROMATIC RICE UNDER ORGANIC CULTURE

SUMAIYA TABASSUM EMA

ABSTRACT

A study was conducted at the Research Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh in *Boro* (dry) season, 2018-2019 to evaluate the physiological characteristics, yield and quality of local (Kataribhog, Badshabhog and Chinigura) and improved (BRRI dhan37, BRRI dhan38 and BRRI dhan50) aromatic rice varieties under organic cultivation. The experiment was laid out in a randomized complete block design with four replications. Irrespective of cultivars, organic cultivation provided higher plant height (140.74 cm) at maturity in comparison to traditional cultivation (136.23 cm). The highest tillers hill^{-1} (14.53 and 14.40) was obtained from BRRI dhan38 under both organic and traditional cultivation methods, respectively and it was statistically identical with BRRI dhan50 (14.27 and 13.67). BRRI dhan38 (4.41), BRRI dhan37 (5.22) and BRRI dhan50 (4.86) exhibited significantly higher LAI under organic cultivation compared to the same varieties with traditional method. Similar trend was found in case of local aromatic one. Panicles hill^{-1} rose up 18% under organic cultivation, regardless of cultivars. The maximum spikelets panicle^{-1} (159.67) was achieved from Badshabhog with organic cultivation and the minimum (93.3) was obtained from Chinigura (86.82) under traditional cultivation. The highest grains panicle^{-1} (141.60) was obtained from Badshabhog followed by BRRI dhan50 (136.81) and Kataribhog-1 (130.47) with organic cultivation and the lowest grains panicle^{-1} (78.13) was counted from Chinigura with traditional cultivation. The highest grain yield (3.91 t ha^{-1}) was obtained from BRRI dhan50 under organic cultivation that was statistically at par with BRRI dhan37 (3.49 t ha^{-1}) and BRRI dhan38 (3.45 t ha^{-1}) under same cultivation. Organic cultivation increased grain yield (*ca.*28%), straw yield (*ca.*41%) and biological yield (*ca.*34%) in all cultivars compared to traditional method. The highest milling rice yield (72.10%) was recorded in Kataribhog-1 with organic cultivation. BRRI dhan38 gave the highest head rice yield (69.5%) and it was statistically similar to Badshabliog and Kataribhog-1 under organic cultivation. Highest grain length (5.40 mm) and length breadth ratio (2.6) was obtained from BRRI dhan50 with organic cultivation followed by Kataribhog-1 (4.90 mm and 2.51) under same cultivation method. Whereas volume expansion ratio (*ca.* 7%) was decreased under organic cultivation compared to traditional one. Only the local cultivars, Kataribhog-1, Badshabhog and Chinigura exhibited slight aroma under organic cultivation in *Boro* season.

LIST OF CONTENTS

LIST OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSIR	=	Bangladesh Council of Scientific and industrial Research
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agriculture Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter square
ml	=	Millilitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celsius
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Milligrams
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
ca.	=	Circa (approximately)
L	=	Litre
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization
viz.	=	Videlicet (namely)

CHAPTER I

INTRODUCTION

Aromatic rice constitutes small but a special group of rice, considered as of best quality. It occupies an important status in domestic as well as in international market and also very much popular among the users due to its several outstanding qualities (Ashraf *et al*., 2017; Sarkar *et al.,* 2016; Ali *et al.,* 2016). In Bangladesh, a number of fine rice cultivars have special appeal for their aroma. Aroma quality of scented rice is the major character, which increases the value of rice. Its demand is increasing more rapidly compared to coarse rice both in national and international markets. As the choice of grain quality depends on the consumers' income, most of the well-off people prefer long, slender, scented fine grain rice but their price is 2-3 times higher than that of coarse grained rice (Roy *et al.,* 2018; Islam *et al.,* 2015; BRRI*,* 2013).

The economic condition of the south Asian countries including Bangladesh is rapidly increasing compared to other countries. The demand for scented fine grain rice has been increased due to economic development of the people of Bangladesh (IRRI, 2006). In fact aromatic or fine rice is very popular in the national and international markets. Whole international market of aromatic or fine rice is controlled by four countries *viz.* China, India, Pakistan, and Thailand. They earn huge amount of foreign by currency selling aromatic or fine rice every year (Laila *et al.,* 2020; Sinha *et al.* 2018; Yoshihitoi, 2005). Bangladesh has a bright prospect for export of fine rice thereby earning foreign currency. So, the priority has been given on production of aromatic rice in our country (Islam *et al.,* 2013; BRRI, 2013).

The geographical, climatic and edaphic conditions of Bangladesh are favorable for year-round rice cultivation. *Boro* season are favorable for higher yield (Sumon *et al.,* 2018; BRRI, 2013). To meet up the increasing demand of the scented fine rice in the country and fetching the foreign currency by increasing

its export, aromatic rice cultivation is to be expanded in *Boro* season. Most of the traditional fine-grained rice genotypes are photoperiod-sensitive, well adapted to the local environment and suitable for growing in the *Aman* season (Salam *et al.,* 1992; Islam and Islam, 2004).

But the crop faces heading or flowering problem due to gradual increasing of day length in *Boro* season. These photoperiod sensitive cultivars need short day length for flowering. These cultivars will not flower when seeded beyond the cutoff date in November (Mannan 2005; Das and Baqui, 2000). Mannan *et al.* (2012) reported that some modern and traditional cultivar performed well in *Boro* season. In the last year, we also found that few traditional fine-grained aromatic rice genotypes/ landraces produced around four tons grain yield when seeded in third to fourth week of November and transplanted in the second half of December. But most of them lost their aroma quality partially or completely. It is a major problem identified for growing them in *Boro* season. Understanding and solution of these factors is must for producing the finest quality aromatic rice.

The biochemical basis of aroma was identified as 2-acetyl1-pyrroline (Tsuzaki *et al.,* 1977; Arumugachamy *et al.,* 1992). Expression of aroma and other quality traits is dependent upon environmental factors the aroma formation (and retention) in grain is enhanced at lower temperature during the grain filling stage. They require relatively cooler temperature (25°C/21°C-day/night temperature during crop maturity) for better retention of aroma. There is a significant negative correlation between 2-AP (aroma) content and sunshine hours. Treatments having higher 2-AP content also have higher free proline content and higher proline dehydrogenase activities in grain (Parikh *et al.,* 2012). A few foreign researchers opined that organic culture favoured in expression of aroma and other quality traits in aromatic rice (Yang *et al.,* 2014). Other quality traits like grain amylose and protein contents (Hoover and Ratnayayake, 2001). Amylose content is the indicator of stickiness of cooked rice. More than 25% amylose content gives non sticky cooked rice; 20 - 25% amylose rice gives soft

and comparatively sticky cooked rice (Dutta *et al.,* 1998). In indica type rice consuming countries, intermediate amylose is preferred since it is soft and fluffy after cooking. Effects of temperature on amylose content of different rice cultivars were recorded significantly variable. The grain quality of fine rice also affected by applied nitrogen level. Higher doses of nitrogen and other fertilizers adversely affected the grain quality affect the cooking in terms of elongation after cooking, texture and stickiness.

Aromatic rice quality also includes kernel length: breadth ratio (L:B), grain length after cooking (GLAC), length: breadth ratio of cooked rice, milling %, head rice recovery %, elongation ratio, elongation index, alkali spreading value. All these grain quality characters are affected by seasonal factors and also with higher doses of inorganic fertilizer.

Organic farming focuses on the integration between agriculture and animal husbandry in ensuring optimum nutrient cycling. Organic farming system is not only an environmentally safe alternative but also improve quality traits of crop. At present this culture is vastly used in Indonesia, Veitnam, China and Thailand for quality aromatic rice prpduction.

For expanding aromatic rice cultivation in *Boro* season, suitable cultivars/ varieties and appropriate production technology are to be found out or developed. Unfortunately both national and international arena, no publication is available which deals exclusively with this rice. Most of the information on this group of rice is scattered widely in literature. Improvement of this group of rice is also very slow compared to coarse rice. However, research work on adaptability improvement, aroma formation, grain quality of aromatic rice cultivars in *Boro* season is meager in our country. Considering this situation, the present research project was prepared and performed to evaluate the performance of traditional and modern aromatic rice genotypes under organic culture in *Boro* season.

Objectives

The present project proposal has been designed to achieve the following objectives -

1. To observe the physiological behaviour and yield performance of selected local and improved aromatic rice cultivars under organic culture (farming) in *Boro* season;
2. To observe the influence of organic culture on aroma formation (retention) in fine-grained scented rice cultivars/varieties in *Boro* season.

CHAPTER II

REVIEW OF LITERATURE

One of the major reasons of yield reduction of rice is varietal performance. So, variety is the most important factor needed to be considered in rice cultivation. Some of the important and informative works and research findings related to the variety done at home and abroad have been reviewed as follows-

Rashid *et al*. (2017) conducted an experiment to evaluate the yield performance of seven aromatic rice varieties of Bangladesh viz. Jirakatari, Chiniatab, Chinigura, Kataribhog, Kalizara, Badshabhog and BRRI dhan34. The entire yield contributing attributes and quality parameters varied significantly among the aromatic rice varieties. The highest plant height (167.0 cm) was found in the variety Chinigura and the lowest (120.1 cm) in the variety Chiniatab. In the variety Kataribhog number of filled grains panicle^{-1} was found highest (255.6) and the lowest (130.7) was recorded in the variety Badshabhog. Badshabhog produced the highest 1000-grain weight (18.3 g) and the lowest (11.4 g) was recorded from the variety Kataribhog. The highest grain yield (2.54 t ha^{-1}) was obtained from Kataribhog and the lowest grain yield (1.83 t ha^{-1}) was obtained from Kalizara. Among the seven aromatic rice varieties under North-west condition Kataribhog and BRRI dhan34 are suitable in respect of yield.

Murshida *et al*. (2017) conducted an experiment with three varieties (*cv*. BRRI dhan28, BRRI dhan29 and Binadhan-14) and four water management systems to examine the effect of variety and water management system on the growth and yield performance of boro rice. At 100 DAT, the highest plant height, maximum number of tillers hill^{-1}, dry matter of shoot hill^{-1} and dry matter of root hill^{-1} were obtained from BRRI dhan29 and the lowest values were found in Binadhan-14. Variety had significant effect on all the crop characters under study except 1000-grain weight. The highest grain yield was obtained from BRRI dhan29 and the lowest value was recorded from Binadhan-14.

Yield test of 41 entries, 32 new hybrids, 8 male parents restore lines and 1 inbred variety, was conducted by Hien (2006) 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.

Haque *et al.* (2015) evaluated the 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. Filled grain (%) declined significantly at delayed planting in the hybrids compared to elite inbred due to increased temperature impaired- inefficient transport of assimilates. Results suggest that greater remobilization of shoot reserves to the grain rendered higher yield of hybrid rice varieties.

Ferdous *et al*. (2004) conducted an experiment with three varieties *viz*., BRRI dhan28 (V_1), BRRI dhan29 (V_2) and BRRI dhan45 (V_3); and five rates of nitrogen *viz*., control (N_0), 50 kg (N_1), 100 kg (N_2), 150 kg (N_3) and 200 kg (N_4) N ha^{-1} to study the effect of variety and rate of nitrogen on the performance of *Boro* rice. The growth analysis results indicate that the tallest plant (80.88 cm) and the highest number of total tillers $hill^{-1}$ (13.80) were observed in BRRI dhan29 at 70 DATs and the highest total dry matter (66.41 g m^{-2}) was observed in BRRI dhan45. The shortest plant (78.15 cm) and the lowest number of tillers $hill^{-1}$ (12.41) were recorded from BRRI dhan45 and the lowest dry matter (61.24 g) was observed in BRRI dhan29. The harvest data reveal that variety had significant effect on total tillers $hill^{-1}$, effective tillers $hill^{-1}$, non-effective tillers $hill^{-1}$, panicle length, grain yield, straw yield and harvest index. The highest grain yield (4.84 t ha^{-1}) was recorded from BRRI dhan29.

A study was design by Wagan *et al.* (2014) to compare the economic performance of hybrid and conventional rice production and reported that total costs per hectare of hybrid rice was 148992.23 Rs per hectare which was more then conventional rice was 140661.68 Rs per hectare. 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.

Jisan *et al*. (2014) carried out an experiment 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 tallest plant (117.20 cm), highest number of effective tillers hill^{-1} (11.28), grains panicle^{-1} (121.5) and 1000-grain weight (23.65 g) whereas the lowest values of these parameters were produced by BRRI dhan57. 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 one (4.25 t ha^{-1}) was obtained from BRRI dhan57.

Hossain *et al.* (2012) conducted an experiment at the research farm of SAU on the yield and yield attributes of exotic hybrid rice varieties. Significantly longer panicle was recorded from Heera2 (24.70 cm) which was statistically identical with Aloron (24.52 cm). Both hybrid rice varieties Heera2 (119.8) and Aloron (111.8) produced the highest spikelets panicle^{-1} than that of BRRI dhan48 (105.5). In BRRI dhan48, the highest filled spikelets panicle^{-1} (79.53) was recorded. This was may be due to lower sensitiveness of BRRI dhan48 to high temperature and low sunshine hour at grain filling stage compared to test hybrid varieties. The highest spikelet filling percent was recorded from BRRI dhan48 (74.43%) due to favorable environmental condition at grain filling stage. Aloron produced heavier grain size than that of Heera2 and BRRI

dhan48. BRRI dhan48 gave significantly higher grain yield 3.51 t ha^{-1} over the tested hybrid varieties Heera2 (3.03 t ha^{-1}) and Aloron (2.77 t ha^{-1}). Biological yield did not varied significantly among studied hybrid and inbred rice varieties. The highest HI was obtained from BRRI dhan48 while it was lowest in Aloron.

Hossain *et al.* (2014) evaluated the five rice cultivars (one hybrid: WR96, three modern: BR16, BR26, and BRRI Dhan27 and one local: Pari). Most of the yield- contributing characters examined and showed wide variations among the cultivars whereas modern cultivar BR16 produced the highest panicle length, number of grain $panicle^{-1}$ and grain yield ha^{-1}. At the same time as local cultivar Pari generated the lowest number of tiller $plant^{-1}$, panicle length, grain number $panicle^{-1}$ and grain yield ha^{-1}. Moreover, hybrid cultivar WR96 produced the highest percentage of spotted grain $panicle^{-1}$.

Akter (2014) investigated the growth, yield and nutrient content of 15 *Boro* rice cultivars. BR 15, BRRI dhan29 and BRRI dhan28 were the three rice cultivars having high potentials for grain and straw production during *Boro* season. The highest yield was recorded 5.26 t ha^{-1} which is still very low compared to other rice growing countries of the world. Chola *Boro* and Sada bore are two local land races having potentials for producing higher number of effective tillers and higher 1000 grain weight. Sada *Boro* and Chola *Boro,* two local cultivars were found very high in grain nitrogen content compared to other test cultivars.

Sarkar *et al*. (2014) conducted an experiment 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. The tallest plant (142.7 cm), the highest number of effective tillers $hill^{-1}$ (10.02), number of grains $panicle^{-1}$ (152.3), panicle length (22.71cm), 1000-grain weight (15.55g) and grain yield (3.71 t ha^{-1}) were recorded in BRRI dhan34.

Roy *et al.* (2014) evaluated 12 indigenous *Boro* rice varieties where the plant height and tillers hill^{-1} at different DAT varied significantly among the varieties up to harvest. At harvest, the tallest plant (123.80 cm) was recorded in Bapoy and the shortest (81.13 cm) in GS. The maximum tillers hill^{-1} (46.00) was observed in Sylhety *Boro* and the minimum (19.80) in Bere Ratna. All of the parameters of yield and yield contributing characters differed significantly at 1% level except grain yield, biological yield and harvest index. The maximum effective tillers hill^{-1} (43.87) was recorded in the variety Sylhety *Boro* while Bere Ratna produced the lowest effective tillers hill^{1} (17.73). The highest (110.57) and the lowest (42.13) filled grains panicle^{-1} was observed in the variety Koijore and Sylhety *Boro,* respectively. Thousand grain weight was the highest (26.35 g) in Kali *Boro* and the lowest (17.83 g) in GS one. Grain did not differ significantly among the varieties but numerically the highest grain yield (5.01 t ha^{-1}) was found in the variety Koijore and the lowest in GS one (3.17 t ha^{-1}).

Sarker *et al.* (2016) conducted an experiment to study morphological, yield and yield contributing characters of four *Boro* rice varieties of which three were local *viz*., Bashful, Poshursail and Gosi; while another one was a high yielding variety (HYV) BRRI dhan 28. The BRRI dhan 28 were significantly superior among the cultivars studied. The BRRI dhan 28 was shorter in plant height, having more tillering capacity, higher leaf number which in turn showed superior growth character and yielded more than those of the local cultivars. The HYV BRRI dhan 28 produced higher number of grains panicle^{-1} and bolder grains resulted in higher grain yield over the local cultivars. Further, BRRI dhan28 had more total dry mass than those of local varieties. The BRRI dhan28 produced higher grain yield (7.41 t ha^{-1}) than Bashful, Poshurshail and Gosi, respectively. Among the local rice cultivars, Gosi showed the higher yielding ability than Bashful and Poshursail.

Khushik *et al.* (2011) studied to assess the performance of rice hybrid and other varieties planted in rice growing areas of Sindh and Balochistan. The results

revealed that average yield of hybrid rice was 195 mds ha^{-1}, followed by IRRI-6 (151 mds ha^{-1}), B-2000 (91 mds ha^{-1}) and Rosi (94 mds ha^{-1}). This indicates that the yield of hybrid rice was higher by 29% than the major variety IRRI-6.

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.

Islam (2011) conducted a field experiment at BINA, Mymensingh on five aromatic rice genotypes viz., BRRIdhan34, Ukunimadhu, RM-100/16, KD5 18-150 and Kalozira by at BINA, Mymensingh. Among the varieties, KD5 18-150 showed higher grain yield, total dry matter $plant^{-1}$ and harvest index under temperature stress.

Islam *et al.* (2010) found that the rice cultivar 1R76712H produced the highest grain yield (7.7 t ha^{-1}) followed by 1R75217H and Magat (7.6 t ha^{-1}) in WS; in DS, 1R79118H produced the highest grain yield (9.17 t ha^{-1}) followed by 1R73855H (8.9 t ha^{-1}) and SL-8H (8.8 t ha^{-1}) due to high harvest index. Hybrid produced higher spikelets $panicle^{-1}$ and 1000-grain weight than inbred rice. Spikelet filling percent was higher in inbred than hybrid rice.

Islam *et al*. (2009) conducted a pot experiments with Hybrid variety Sonarbangla-1 and inbred modern variety BRRI dhan31 and BRRI hybrid dhan-l to compare the growth and yield behavior of hybrid and inbred rice varieties under controlled condition. BRRI dhan3l had about 10-15% higher plant height, very similar tillers/plant, 15-25% higher leaf area at all days after transplanting (DAT) compared to Sonarbangla-1. Sonarbangla-1 had about 40% higher dry matter production at 25 DAT but had very similar dry matter production at 50 and 75 DAT, 4-11% higher rooting depth at all DATs, about 22% higher root dry weight at 25 DAT, but 5-10% lower root dry weight at 50 and 75 DAT compared to BRRI dhan31. The photosynthetic rate was higher

(20 μ mol m^{-2} sec^{-1}) in BRRI dhan3l at 35 DAT (maximum tillering stage) but at 65 DAT, Sonarbangla-l had higher photosynthetic rate of 19.5 μ mol m^{-2} sec^{-1}. BRRI dhan3l had higher panicles $plant^{-1}$ than Sonarbangla-1, but Sonarbangla-1 had higher number of grains $panicle^{-1}$, 1000-grain weight and grain yield than BRRI dhan31.

Razzaque *et al.* (2009) studied on salt tolerant genotypes PVSB9, PVSB19, PNR381, PNR519, Iratom24 and salt sensitive genotype NS15 along with one standard check salt tolerant rice cultivar Pokkali. The different morphological characters studied include plant height, total number of tillers, Root Dry Weight (RDW), Shoot Dry Weight (SDW) and Total Dry Matter (TDM) content of the selected rice genotypes in view to evaluate their response at different salinity levels. The genotypes Pokkali, PVSB9, PVSB19 showed significantly higher values and the lowest value of all these characters were recorded in NS15.

Obaidullah *et al*. (2009) conducted a field experiment to study the growth and yield of inbred and hybrid rice with clonal tillers different of age. They found highest grain yield (5.10 t ha^{-1}) from the clonal tiller of 25 days old and the lowest grain yield (4.31 t ha^{-1}) from 40 days old clonal tillers. Irrespective of variety 25 to 35 days old clonal tiller showed superior performance. Hybrid variety transplanted with 25 days old clonal tiller gave significantly higher grain yield.

Hossain *et al*. (2008) conducted the study to observe the yield and quality of ten popular aromatic rice varieties of Bangladesh. The varieties were Kataribhog (Philippines), Kataribhog (Deshi), Badshabhog, Chinigura, Radhunipagal, Kalizera, Zirabhog, Madhumala, Chiniatab and Shakhorkora. All the yield contributing attributes and quality parameters varied significantly among the aromatic rice varieties. The highest grain yield was obtained from Kataribhog (Philippines) which identically followed by Badshabhog. In respect of quality, Zirabhog gave the highest head rice outturn that was statistically

similar to Badshabhog and Chiniatab. All the tested varieties had bold type shape. Grain protein content ranged from 6.6-7.0 % in brown rice. The cooking time of tested varieties varied from 12 to 16 minutes. Aroma intensity differed due to variety. Kalizera, Badshabhog, Chiniatab contained high level of aroma while, rests of the varieties had moderate type aroma.

Ashrafuzzaman *et al.* (2009) conducted a field experiment to study the growth and yield of inbred and hybrid rice with tiller separation at different growth periods. The experiment was conducted with two levels of treatments *viz.* (a) Variety: BRRI dhan32 and Sonarbangla-1; and (b) tiller separation days: 20, 25, 30, 35 and 40 days after mother plant transplantation. Maximum filled grains panicle^{-1} (144.28) was observed from the tiller separation at 20 DAT. Total and effective tillers hill^{-1} was affected by tiller separation beyond 30 DAT. Delayed tiller separation extended the flowering and maturity duration. Therefore, it was concluded that earlier tiller separation (20-30 DAT) resulted higher grain yield in hybrid variety but no such variations was observed in inbred variety.

Tabien and Samonte (2007) observed that several elite lines at the multi-state trials had high yield potential relative to the check varieties and these can be released as new varieties after series of yield trials. With improved yield, the new varieties are expected to increase rice production. The elite lines generated are also potential germplasm for rice improvement projects. The initial effort to identify high biomass rice will enhance the development of dedicated feedstock for bioenergy production.

Khan *et al*. (2006) reported that the variety Rachna showed the highest yield of 4009.590 kg ha^{-1} followed by Basmati-385, Shaheen and Super with the production of 3678.983, 2939.257 and 2175.303 kg ha^{-1}, respectively. However, the plant height (cm) of Rachna was at 2nd position (125.400 cm) after Basmati-385 at 129.767 cm. The maximum tiller plant^{-1} (18) was obtained by variety Rachna, which significantly differ from variety Super that produced

10 tillers plant^{-1}. The maximum spike plant^{-1} 18 were shown by variety Rachna and the number of tiller plant^{-1} produced by Rice variety Basmati-385 i.e., 17. The highest yield of Rachna variety was due to the best performance in terms of tillers plant^{-1}, spike plant^{-1} and weight of 1000 grains.

Wang *et al.* (2006) studied the effects of plant density on the yield and yield components of hybrids and conventional cultivars of rice. Compared with conventional cultivars, the hybrids had larger panicles, heavier seeds, resulting in an average yield increase of 7.27%.

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

Sumit *et al.* (2004) worked with newly released four commercial rice hybrids (DRRH 1, PHB 71, Pro-Agro 6201, KHR 2, ADTHR 1, UPHR 1010 and Pant Sankar dhan1) and two high yielding cultivars (HYV) as controls (Pant dhan 4 and Pant dhan 12) and reported that KHR 2 gave the best yield (7.0 t/ha) among them.

Dongarwar *et al.* (2003) comprised an experiment to investigate the response of hybrid rice KJTRH-1 in comparison with 2 traditional cultivars, Jaya and Swarna, to 4 fertilizer rates, i.e. 100:50:50, 75:37.5:37.5, 125:62.5:62.5 and 150:75:75 kg NPK ha^{-1} and reported that KJTRH-1 produced significantly higher yield (49.24 q ha^{-1}) than Jaya (39.64 q ha^{-1}) and Swarna (46.06 q ha^{-1}).

Siddiquee *et al.* (2002) conducted a study to evaluate the difference between hybrid and inbred rice in respect of their growth duration, yield and quality in *Boro* season, 1999. Among the varieties, Aalok 6201 had the highest grain yield followed by BRRI dhan29 and IR68877H but statistically they were similar. BRRI dhan28 had the lowest grain yield, which was statistically similar to Loknath503. BRRI dhan28 and the tested hybrid rice had lower

growth duration than BRRI dhan29. Milling out turn varied from 67 to 70% among the tested varieties. Loknath 503 had the lowest milling out turn (70%) and, BRRI dhan28 and BRRI dhan29 had the highest milling out turn (70%) for unparboiled but parboiled rice the highest milling out turn(73%) were found in BRRI dhan28 and IR68877H . All tested hybrid rice were medium bold, whereas BRRI dhan29 and BRRI dhan28 were medium slender and long slender, respectively in both parboiled and unparboiled condition. Among the varieties, amylose content (%) was higher in BRRI dhan29 and protein content (%) was higher in IR68877H for both under parboiled and unparboiled condition.

Rahman *et al.* (2002) carried out an experiment with 4 varieties of transplant *Aman* rice *viz.,* BR1l, BR22, BR23 and Tuishimala and 6 structural arrangement of rows *viz.,* 25 cm + 25 cm, 30 cm + 20 cm, 35 cm + 1 5 cm, 40 cm + 10 cm) 45 cm + 05 cm and haphazard planting at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh. Thousand grains weight and grain yield were highest in BR23 and these were lowest in Tulshirnaia.

Obulamma *et al.* (2002) performed an experiment with hybrid rice DRRHI and APHR-2 at Andhra Pradesh, India. The treatments were 4 spacing (15x10, 2U x10, 15x15 and 20cm x15 cm) and 3 seedling densities (1, 2 and 3 seedlings $hill^{-1}$). APHR-2 was found to produce higher yield than DRRH-l.

Biswas and Salokhe (2002) conducted an experiment in a Bangkok clay soil to investigate the influence of N rate, light intensity, tiller separation, and plant density on the yield and yield attributes of parent and clone plants of transplanted rice. Application of 75 kg N and 120 kg N ha^{-1} resulted in similar yields. The 50% reduction of light intensity reduced grain yield to 43.5% compared with normal light intensity. Separation of more than 4 tillers $hill^{-1}$ had an adverse effect on the mother crop. Nitrogen fertilizer had no influence

on grain weight, per cent filled grains, and panicle size of the mother crop, but increased N produced a higher number of tillers. Reduction of light intensity and higher tiller separation adversely affected grain weight and panicle number. Variation of N rate and light intensity of the mother crop had no influence on grain yield, grain weight, and panicle number of clonal tillers transplanted with 75 kg N ha^{-1} and with normal light intensity.

Molla (2001) reported that Pro-Agro6201 (hybrid) had a significant higher yield than IET4786 (HYV), due to more mature panicles m^{-2}, higher number of filled grains $panicle^{-1}$ and greater seed weight.

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. They observed that CNHR2 produced more number of productive tillers (413.4 m^{-}) and filled grains $panicle^{-1}$ (111.0) than other varieties, whereas IR36 gave the highest 1000- grain weight (21.07 g) and number of panicles m^{-} than other tested varieties. In a trial, varietal differences in harvest index and yield examined using 60 Japanese varieties and 20 high yielding varieties bred in Asian countries. It was reported that harvest index varied form 36.8% to 53.4%. Mean values of harvest index were 43.5% in the Japanese group and 48.8% in high yielding group. Yield ranged from 22.6 g $plant^{-1}$ to 40.0 g $plant^{-1}$.

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.

Julfiquar *et al.* (1998) reported that BRRI evaluated 23 hybrids along with three standard checks during *Boro* season. It was reported that five hybrids (IR58025A/IR54056, IR54883, PMS8A/IR46R) out yielded the check varieties

(BR14 and BR16) with significant yield difference. Two hybrids out yielded the check variety of same duration yielded by more than 1 t ha^{-1}.

Kamal *et al.* (1998) conducted an experiment to assess the yield of 9 modern varieties (MV) and 6 local improved varieties (LIV) and observed that modern variety BR11 gave the highest grain yield followed by BR10, BR23, Binasail and BR4.

Chowdhury (1997) undertook a research on BINA-19, BR14, BR3 and Iratom-24 varieties with different methods of transplanting. He found that the yields for BINA-19, BR14, BR3 and Iratom-24 was 6.49 t ha^{-1}, 6.22 t ha^{-1}, 6.22 t ha^{-1}, 5.75 t ha^{-1} and 5.60 t ha^{-1}, respectively.

Nematzadeh *et al*. (1997) reported that local high quality rice cultivars Hassan Sarai and Sang-Tarom was crossed with improved high yielding cultivars Amol 3, PND160-2-1 and RNR1446 in all possible combinations and released in 1996 under the name Nemat, which gave an average grain yield of 8 t ha^{-1}, twice as much as local cultivars.

Chowdhury *et al.* (1995) studied seven varieties of rice, of which three was native (Maloti, Nizersail and Chandrashail) and four was improved (BR3, BR11, Pasam and Mala). Straw and grain yields was recorded and found that both the grain and straw yields were higher in the improved than the native varieties. Liu (1995) conducted a field trial with new indica hybrid rice You 92 and found an average yield of 7.5 t ha^{-1} which was 10% higher than that of standard hybrid Shanyou 64.

Leenakumari *et al.* (1993) evaluated eleven hybrid cultivars against four standard check varieties-Jaya, Rasi, IR20 and Margala. They concluded that hybrid cultivar OR 1002 gave the highest yield of 7.9 t ha^{-1} followed by the hybrid cultivar OR 1001 (6.2 t ha^{-1}). Among the control varieties, Jaya gave the highest yield (8.4 t ha^{-1}). Among the cv. BR22 gave the highest grain yield from most of the sowing dates for both of the years (Ali *et al.,* 1993).

Suprihatno and Sutaryo (1992) conducted an experiment with seven IRRI hybrids and 13 Indonesian hybrids using IR64 and way-seputih. They observed that TR64 was highest yielding, significantly out yielding IR64616H, IR64618, IR64610H and IR62829A/IR54 which in turn out yielded way-seputih.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka in *Boro* (dry) season, 2018-2019 to study aroma quality and physiological characteristics of local and improved aromatic rice cultivars under organic culture compared to traditional cultivation. Details of different materials used and methodologies followed to conduct the study are presented in this chapter.

3.1 Site description

The experiment was conducted at the Sher-e-Bangla Agricultural University research field, Dhaka, under the Agro-ecological zone of Modhupur Tract, AEZ-28. The land area is situated at 23°41' N latitude and 90°22' E longitude at an altitude of 8.6 meter above sea level. The experimental site is shown in the AEZ Map of Bangladesh in Appendix I.

3.2 Climate

The experimental area is under the sub-tropical climate that is characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in kharifseason (April-September) and less rainfall associated with moderately low temperature during the Rabi season (October-March). The weather data during the study period of the experimental site is shown in Appendix II.

3.3 Soil

The farm belongs to the general soil type, shallow red brown terrace soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to 20 medium distinct dark yellowish brown mottles. The experimental area was flat having available irrigation and drainage system. The land was above flood level and sufficient sunshine was available during the experimental

period. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done by Soil Resources and Development Institute (SRDI), Dhaka. The physicochemical properties of the soil are presented in Appendix III.

3.4 Treatments

Two factors experiment was considered for the present study which is as follows:

Factor A: Variety – 6 cultivars

1. V_1 = Badshabhog
2. V_2 = Chinigura
3. V_3 = Kataribhog -1
4. V_4 = BRRI dhan37
5. V_5 = BRRI dhan38
6. V_6 = BRRI dhan50

Factor B: Kind of cultivations – 2 methods

1. T_1 = Organic cultivation (culture)
2. T_2 = Conventional cultivation

3.5 Plant materials and collection of seeds

Three local/traditional aromatic rice cultivars *viz.* Badshabhog, Chinigura, Kataribhog (awnless), and three improved/modern aromatic rice varieties *viz.* BRRI dhan37, BRRI dhan38, BRRI dhan50 (Banglamoti) were used in this study. Seeds of afore-mentioned cultivars/varieties were collected from BRRI, Gazipur. The experiment was carried out within October, 2018 to June, 2019.

3.6 Seed sprouting

Healthy seeds were treated in water bucket for 24 hours and then it was kept tightly in gunny bags. The seeds started sprouting after 48 hours and were sown after 72 hours.

3.7 Preparation of nursery bed and seed sowing

As per BRRI recommendation, seedbed was prepared with 1m wide adding nutrients as per the requirements of soil. Seeds were sown in the seed bed on 2nd week of November, 2018 in order to transplant the seedlings in the main field.

3.8 Preparation of experimental land

The plot selected for the experiment was opened in the 2nd week of December 2018 with a three wheeler power tiller, and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed, and finally obtained a desirable field for transplanting of the seedlings.

3.9 Fertilizer application

Amount of 10 ton cow-dung was applied for organic cultivation and @ 90-60-45-8-3 kg N, P_2O_5, K_2O, S and Zn ha^{-1} (BRRI, 2013) for conventional cultivation. All fertilizers except urea were applied as basal during final land preparation. Urea was top-dressed in three equal splits at early tillering, mid tillering and at 4-5 days before panicle initiation stages.

3.10 Experimental design and layout

This factorial experiment was arranged in a randomized complete block design with four replications. The first factor was the two cultivation methods and the second was the six aromatic cultivars/ varieties. Unit plot size was 4m × 2.5m. A buffer (ails or levee) of 50 cm and 100 cm was maintained in between unit plots and replications respectively.

3.11 Uprooting of seedlings

The nursery bed was made wet by application of water one day before uprooting the seedlings. The seedlings were uprooted on 11 December, 2018 without causing much mechanical injury to the roots.

3.12 Transplanting of seedlings in the field

Thirty (30) days old seedlings were transplanted on 11 December, 2018 keeping 25cm × 15cm spacing.

3.13 Intercultural operations

Proper intercultural operations were done to ensure the normal growth of the crops.

Gap filling

Dead Seedlings were replaced by new one within one week of transplanting with seedlings from the respective source.

Weeding

The crop field was kept weed free by three hands weeding at 15, 35 and 55 days after transplanting, respectively.

Plant protection

Plant protection measures *viz.* insecticide and fungicide were sprayed as per requirement to keep the crop free from insect and pathogen attack.

Irrigation and drainage

Irrigation was done by inundation up to the full panicle phase. Two weeks before harvest, the water was drained.

3.14 Harvesting, threshing and cleaning

The rice plant was harvested depending upon the maturity of the plant and harvesting was done manually from each plot. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken for harvesting, threshing and also cleaning of rice seed. Fresh weight of grain and straw were recorded plot wise. The grains were cleaned and finally the weight was adjusted to a moisture content of 12%. The straw was sun dried and the yields of grain and straw plot-1 were recorded and converted to ton ha^{-1}.

3.15 General observation of the experimental field

The field was observed time to time to detect visual difference among the treatments and any kind of infestation by weeds, insects and diseases so that considerable losses by pest was minimized.

3.16 Recording of data

The following data were recorded during the study period:

3.16.1 Growth parameters

1. Plant height
2. Number of tillers hill^{-1} at heading
3. Number of leaves hill^{-1} at heading
4. Leaf area at heading

3.16.2 Yield contributing parameters

1. Number of non-effective tillers hill^{-1}
2. Number of effective tillers hill^{-1}
3. Number of panicles hill^{-1}
4. Panicle length
5. Number of spikelets panicle^{-1}
6. Number of grains panicle^{-1}
7. Weight of 1000 grains

3.16.3 Yield parameters

1. Grain yield
2. Straw yield
3. Biological yield
4. Harvest index (%)

3.16.4 Physical quality aspects

1. Milling rice yield (%)
2. Head rice yield (%)

3. Grain length
4. Length and breath ratio
5. Grain elongation ratio
6. Volume Expansion ratio

3.16.5 Biochemical quality aspects

1. Aroma intensity

3.17 Procedures of recording data

A brief outline of the data recording procedure is given below:

Plant height

The height of plant was recorded in centimeter (cm) at the time of 30, 60, 90 DAT and at harvest. Data were recorded as the average of same 4 plants pre-selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the plant.

Number of total tillers hill^{-1}

Total tillers which had at least one leaf visible were counted. It includes both productive and unproductive tillers. It was counted from the average of same4 plants pre-selected at random from the inner rows of each plot.

Number of leaves hill^{-1}

Number of leaves plant-1 was counted from the average of same 4 plants pre-selected at random from the inner rows of each plot.

Number of effective tillers hill^{-1}

The total number of effective tillers hill^{-1} was counted from 4 selected hills at harvest and average value was recorded.

Number of non-effective tillers hill^{-1}

The total number of effective tillers hill^{-1} was counted from 4 selected hills at harvest and average value was recorded.

Panicle length

The length of the panicle was measured with a meter scale from 10 selected panicles and the average value was recorded

Number of grains panicle^{-1}

The total number of filled and unfilled grains were counted together randomly from selected 4 plants of a plot and then average number of total grains panicle^{-1} was recorded.

Weight of 1000 grain

One thousand cleaned dried grains were counted randomly from each plot and weighed by using a digital electric balance when the grains retained 12% moisture and the mean weight was expressed in gram.

Grain yield

Grain from each plot area was thoroughly sun dried till constant weight was attained. Then yield per hectare was determined based on net plot area.

Straw yield

After separation of grains from plants of each plot the straw was sun dried till a constant weight is obtained and expressed as t ha^{-1}.

Biological yield

Biological yield was determined using the following formula

Biological yield = Grain yield + Straw yield

Harvest index (%)

It denotes the ratio of grain yield to biological yield and was calculated with the following formula.

$$\text{Harvest index (\%)} = \frac{\text{Grain yield}}{\text{Total biological yield}} \times 100$$

Grain length and breadth and length-breadth ratio

Grain length and breadth were measured using digital micrometer and then ratio of grain length to grain breadth (L: B ratio) was computed.

Grain elongation ratio

Grain length after cooking, ten cooked rice was taken and individual length was measured. Ratio of length of cooked rice to breadth of cooked rice was also computed. Grain elongation ratio was computed as length of cooked kernel to length of grain and grain elongation index were also computed as length: breadth ratio of cooked rice to length: breadth ratio of milled rice.

Milled rice yield

Milled rice yield (MRY %) was calculated as follows-

$$\text{Milled rice yield} = \frac{\text{Mass}_{\text{Milled Rice}}}{\text{Mass}_{\text{Rough Rice}}} \times 100$$

Milled rice = all kernels in a sample, including head rice and broken after milling (removed bran);

Rough rice= all kernels in a sample, prior to dehulling

Head rice yield

Milled rice yield (HRY %) was calculated as follows-

$$\text{Head rice yield} = \frac{\text{Mass}_{\text{Head Rice}}}{\text{Mass}_{\text{Rough Rice}}} \times 100$$

Head rice=all unbroken kernels in a sample, after milling;

Rough rice= all kernels in a sample, prior to dehulling

Grain aroma test

Forty grains of each cultivar were soaked in 10ml 1.7% KOH solution at room temperature in a covered glass petri-plate for about 1 hour. The sample was

scored on 1-4 scale with 1, 2, 3 and 4 corresponding to absence of aroma, slight to moderate aroma, and strong aroma, respectively. The five panels of students and staffs were invited to score the aroma in each cultivar.

Aroma of rice was detected by olfactory test following the method developed by Nagaraju et al. (1991). In this method, a panel of five judges estimated the intensity of aroma of the chemical treated rice samples by olfaction and gave a score individually for each sample according to the following Table.

Degree of Aroma	Score	Type of Quality
+	1	Good
++	2	Better
+++	3	Best

Their scores were averaged to obtain the numerical value of aroma for each treatment.

3.18 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 Least Significant Difference (LSD) Test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University to study the growth behaviour and productivity of fine rice varieties in *Boro* season. The results obtained from the study have been presented and discussed in this chapter through different tables, figures and appendices. The results have been presented and possible interpretation has been given under the following headings.

4.1 Growth parameters

4.1.1 Plant height

Plant heights at maturity of the test varieties showed significant variation among the cultivars under different cultivation methods in *Boro* season (Fig. 1). Plant heights at maturity ranged from 102.42 cm to 165.87 cm in different treatment combinations. Under organic cultivation, highest plant height (165.87 cm) was observed from Chinigura and the lowest (107.75 cm) from BRRI dhan50. Local aromatic rice varieties at maturity stage exhibited higher plant height (152.85 cm) compared to BRRI released aromatic varieties (*ca*.123.82 cm). Irrespective of cultivars, organic cultivation provided higher plant height (140.74 cm) at maturity in comparison to traditional cultivation (136.23 cm). These might be happened due to genetic characteristics of the genotypes. This result is in consonant with Mannan *et al.* (2012). Similar result was also observed by Chamely *et al*. (2015) who observed significant variation on plant height due to varietal difference.

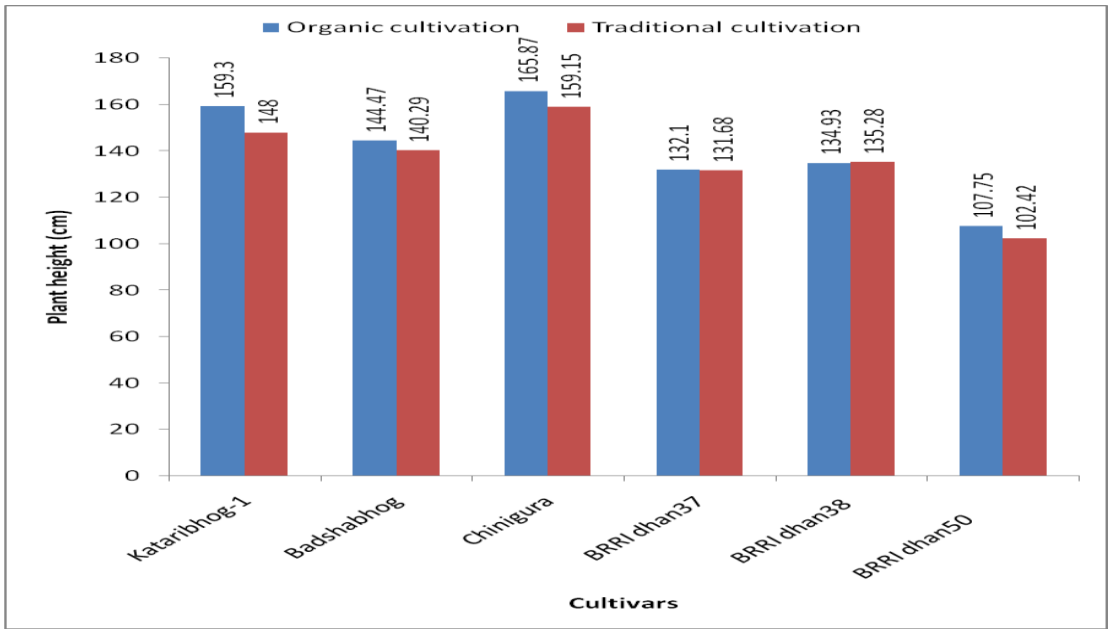

Fig. 1. Plant height of local and modern aromatic rice varieties influenced by organic and traditional cultivation methods in *Boro* season ($LSD_{0.05}$ = 12.97)

4.1.2 Number of tillers hill^{-1}

Recorded data on number of tillers hill^{-1} of rice cultivars at harvest showed significant variation (Table 1). Results revealed that the number of tillers hill^{-1} ranged from 11.00 to 14.53 among the cultivars under two cultivation methods. Maximum number of tillers hill^{-1} (14.53 and 14.40) was obtained from BRRI dhan38 under both organic and traditional cultivation methods, respectively and it was statistically similar with BRRI dhan50 (14.27 and 13.67, respectively). The lowest number of tillers hill^{-1} was found from Badshabhog (11.00) under traditional cultivation which was statistically identical with Chinigura (11.20) under traditional cultivation. It was observed that under organic cultivation; cultivar Kataribhog-1, Chinigura and BRRI dhan37 gave statistically identical result with each other on tiller number but significantly different from Badshabhog that showed the lowest result. Hossain (2008) and Ghosh *et al.* (2003) reported that modern rice variety surpassed other varieties in consideration of tillers hill^{-1}. The result obtained from the present study was also similar with the findings of Murshida *et al*. (2017) who reported that tiller number per hill varied significantly due to varietal difference.

4.1.3 Number of leaves hill^{-1} at heading

Significant variation was found on number of leaves hill^{-1} at heading among different treatment combinations (Table 1). Maximum number of leaves hill^{-1} (56.80 and 53.73) was recorded from BRRI dhan37 under which were statistically similar to BRRI dhan38 (54.37 and 51. 60) under both cultivation methods, but with BRRI dhan 50 (51.27) and Chinigura (52.27) under organic cultivation and also with Kataribhog-1 under traditional cultivation. However, the minimum number of leaves hill^{-1} (45.00) was recorded from Badshabhog which was statistically similar to Chinigura (46.00) and BRRI dhan50 (45.80) under traditional cultivation and also similar to Kataribhog (48.00) and Badshabhog (48.13) under organic cultivation. Critical observation of the data reveals that organic cultivation method produced higher number of leaves per hill compared to traditional cultivation method irrespective of cultivars. Davari *et al*. (2010) reported that modern rice variety produced higher number of effective leaves compared to local one. The result was also similar with the findings of Sarker *et al.* (2014).

4.1.4 Leaf area index (LAI) at heading

Leaf area index (LAI) is an important determinant for production of photosynthates (Tyeb *et al.*, 2013). LAI varied markedly among the studied cultivars under two cultivation methods (Table 1). It ranged from 2.69 to 5.41 among different treatment combination at heading stage. Significantly highest leaf area index (5.41) was achieved under organic cultivation from modern aromatic rice variety, BRRI dhan38, which was statistically identical with BRRI dhan37 (5.22) and BRRI dhan50 (4.86) under organic cultivation and also closely followed by BRRI dhan37 (4.50) and BRRI dhan38 (4.52) under traditional cultivation. On the other hand, the lowest LAI (2.69) was found from local cultivar, Chinigura (2.69) under traditional cultivation which was statistically identical with Kataribhog-1 (2.70) under traditional cultivation. Local cultivar Badshabhog under organic cultivation also showed similar result (3.44) with Chinigura under traditional cultivation. Regardless of varieties, organic cultivation exhibited higher leaf area index compared to traditional cultivation.

Table 1. Effect of organic cultivation on the growth attributes of local and modern aromatic rice varieties in *Boro* season

Treatment (Variety)	Tillers hill^{-1}	Leaf hill^{-1} at heading	LAI at heading
Organic cultivation			
Kataribhog-1	13.21 bc	48.00 bcd	3.66 bc
Badshabhog	12.55 cd	48.13 bcd	3.44 cd
Chinigura	13.53 bc	52.27 ab	3.69 bc
BRRI dhan37	13.27 bc	56.80 a	5.22 a
BRRI dhan38	14.53 a	54.37 ab	5.41 a
BRRI dhan50	14.27 ab	51.27 abc	4.86 a
Traditional cultivation			
Kataribhog-1	11.80 de	51.80 abc	2.70 d
Badshabhog	11.00 e	45.00 d	2.83 c
Chinigura	11.20 e	46.00 cd	2.69 d
BRRI dhan37	12.67 cd	53.73 ab	4.50 ab
BRRI dhan38	14.40 a	51.60 abc	4.52 ab
BRRI dhan50	13.67 abc	45.80 cd	3.74 bc
$LSD_{(0.05)}$	1.16	5.50	0.92
CV(%)	10.21	7.24	10.96

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.

4.2 Yield components

4.2.1 Number of non-effective tillers hill^{-1}

Recorded data on number of non-effective tillers hill^{-1} of rice cultivars at harvest showed significant variation (Table 2). Results revealed that the number of non-effective tillers hill^{-1} ranged from 0.49 to 2.80 among the cultivars under two cultivation methods. Maximum number of non-effective tillers hill^{-1} (2.80) was obtained from Chinigura under traditional cultivation which was statistically identical with Kataribhog-1, Badshabhog and BRRI dhan37 under same cultivation method and also with Badshabhog and Chinigura under organic cultivation. The lowest number of non-effective tillers hill^{-1} was found from BRRI dhan50 under organic cultivation followed by traditional cultivation. Jisan *et al*. (2014) also found similar result with the present study.

4.2.2 Number of effective tillers hill^{-1}

Number of effective tillers hill^{-1} of rice cultivars at harvest showed significant variation as influenced by different cultivars with different cultivation method (Table 2). Results revealed that the number of effective tillers hill^{-1} ranged from 8.40 to 13.68 among the cultivars under two cultivation methods. Maximum number of effective tillers hill^{-1} (13.68) was obtained from BRRI dhan50 under organic cultivation which was statistically identical with BRRI dhan38 with both cultivation methods. The cultivar Chinigura under traditional cultivation gave the lowest number of effective tillers hill^{-1} (8.40) which was statistically identical with Badshabhog under same cultivation method. The result obtained from the present study was also similar with the findings of Murshida *et al*. (2017) who reported that effective tiller number per hill varied significantly due to varietal difference. Similar result was also observed by Chamely *et al*. (2015) and Jisan *et al*. (2014).

Table 2. Effect of organic cultivation on number of effective and non-effective tillers hill^{-1} of local and modern aromatic rice varieties in *Boro* season

Treatment (Variety)	Number of non effective tillers hill^{-1}	Number of effective tillers hill^{-1}
Organic cultivation		
Kataribhog-1	1.93 ab	11.28 b
Badshabhog	2.41 a	10.14 c
Chinigura	2.07 ab	11.46 b
BRRI dhan37	1.63 c	11.64 b
BRRI dhan38	0.93 de	13.60 a
BRRI dhan50	0.49 e	13.68 a
Traditional cultivation		
Kataribhog-1	2.44 a	9.36 d
Badshabhog	2.57 a	8.43 e
Chinigura	2.80 a	8.40 e
BRRI dhan37	2.63 a	10.04 c
BRRI dhan38	0.88 de	13.52 a
BRRI dhan50	0.55 e	13.12 a
$LSD_{(0.05)}$	0.42	1.21
CV(%)	7.39	8.46

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.

4.2.3 Panicle length

Different cultivation methods with different rice cultivars showed significant influence on panicle length of local and modern aromatic rice (Fig. 2). The maximum panicle length (25.90 cm) was obtained from Kataribhog with organic cultivation that was statistically similar to Badshabhog, BRRI dhan37 and BRRI dhan38 under same cultivation method. The minimum panicle length (20.70 cm) was recorded from Chinigura under traditional cultivation which was statistically identical with Chinigura under organic cultivation. This variation was associated with different cultivation methods and genetic makeup of the cultivars. Similar result was recorded by Idris and Motin (1990). The result obtained from the present study was also similar with the findings of Sarkar *et al*. (2014).

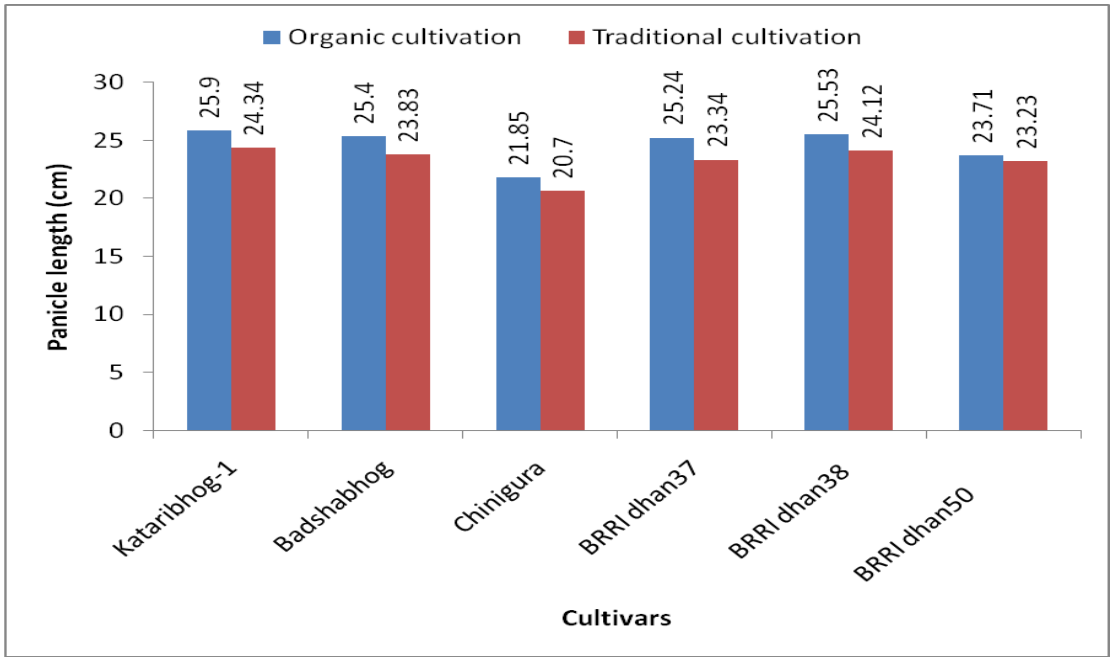

Fig. 2. Panicle length of local and modern aromatic rice varieties influenced by organic and traditional cultivation methods in *Boro* season ($LSD_{0.05}$ = 1.38)

4.2.4 Number of panicles hill^{-1}

Variety and cultivation methods exhibited significant influence on number of panicles hill^{-1} of local and modern aromatic rice cultivars (Table 3). Number of panicles hill^{-1} under different cultivation methods ranged from 7.48 to 10.50.

Results showed that the highest number of panicles hill^{-1} (10.50) was found in BRRI dhan50, which was statistically identical to BRRI dhan37, BRRI dhan38 and Chinigura under organic cultivation. Conversely, the lowest number of panicles hill^{-1} was found in Kataribhog-1 under traditional cultivation which was statistically similar to Badshabhog, BRRI dhan37 and BRRI dhan50 under traditional cultivation. Results also showed that the number of panicles hill^{-1} rose up 18% under organic cultivation regardless of cultivars. Hosain *et al*. (2012) stated that BRRI dhan37 gave the higher number of panicle hill^{-1} compared to local aromatic ones.

4.2.5 Number of spikelets panicle^{-1}

Variety and cultivation methods exhibited significant influence on number of spikelets panicle^{-1} of local and modern aromatic rice cultivars (Table 3). The recorded data showed that the maximum number of spikelets panicle^{-1} (159.67) was found in Badshabhog with organic cultivation which was statistically similar to Kataribhog-1 under same cultivation method. The minimum number of spikelets panicle^{-1} (93.30) was obtained from Chinigura (86.82) with traditional cultivation which was significantly different from others.

4.2.6 Number of grains panicle^{-1}

Recorded data on number of grains panicle^{-1} of rice showed significant difference due to varietal difference with cultivation methods (Table 3). Results revealed that the highest number of grains panicle^{-1} (141.60) was obtained from Badshabhog followed by BRRI dhan50 (136.81) and Kataribhog-1 (130.47) with organic cultivation and the lowest number of grains panicle^{-1} (78.13) was counted from Chinigura with traditional cultivation which was statistically identical with Badshabhog at same cultivation method. It was also observed that short bold type (small) grains densely arranged higher number in a panicle. The number of grains panicle^{-1} is the most important criteria of high yield in rice cultivars (Dahiphale *et al.,* 2004). The result was also similar with the findings of Ashrafuzzaman *et al.* (2009).

Table 3. Effect of organic cultivation on the yield contributing attributes of local and modern aromatic rice cultivars in *Boro* season

Treatment (Variety)	Yield contributing attributes		
	Panicles hill^{-1}	Spikelets panicle^{-1}	Grains panicle^{-1}
Organic cultivation			
Kataribhog-1	9.10b	151.93ab	130.47ab
Badshabhog	8.45bc	159.67a	141.60a
Chinigura	10.25a	124.50d	110.85c
BRRI dhan37	10.33a	147.83b	125.29b
BRRI dhan38	10.33a	134.51c	126.78b
BRRI dhan50	10.50a	147.12 b	136.81a
Traditional cultivation			
Kataribhog-1	7.48c	108.51e	100.83cd
Badshabhog	8.29bc	93.34ef	82.05e
Chinigura	7.81c	86.82f	78.13e
BRRI dhan37	8.05bc	106.30e	99.10d
BRRI dhan38	8.97b	121.00d	104.54d
BRRI dhan50	8.53bc	120.27d	98.24d
$LSD_{(0.05)}$	1.13	9.95	12.27
CV(%)	13.99	8.14	9.81

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

4.2.7 Weight of 1000 grains

Signification variation was observed on 1000 grain weight of rice due to combination of different variety with cultivation methods (Fig. 3). Results revealed that the highest 1000 grains weight (15.92g) was found in BRRI dhan50 under organic cultivation which was statistically similar to BRRI dhan50 (15.04 g) under traditional cultivation. On the other hand the lowest 1000 grains weight (10.21 g) was found in Chiniguraunder traditional cultivationwhich was statistically similar to BRRI dhan37 under same cultivation method and also similar to Chinigura with traditional cultivation. 1000-grain weight is a varietal character (Yoshida, 1981). The result obtained from the present study was similar with the findings of Jisan *et al*. (2014) and Sarkar *et al*. (2014).

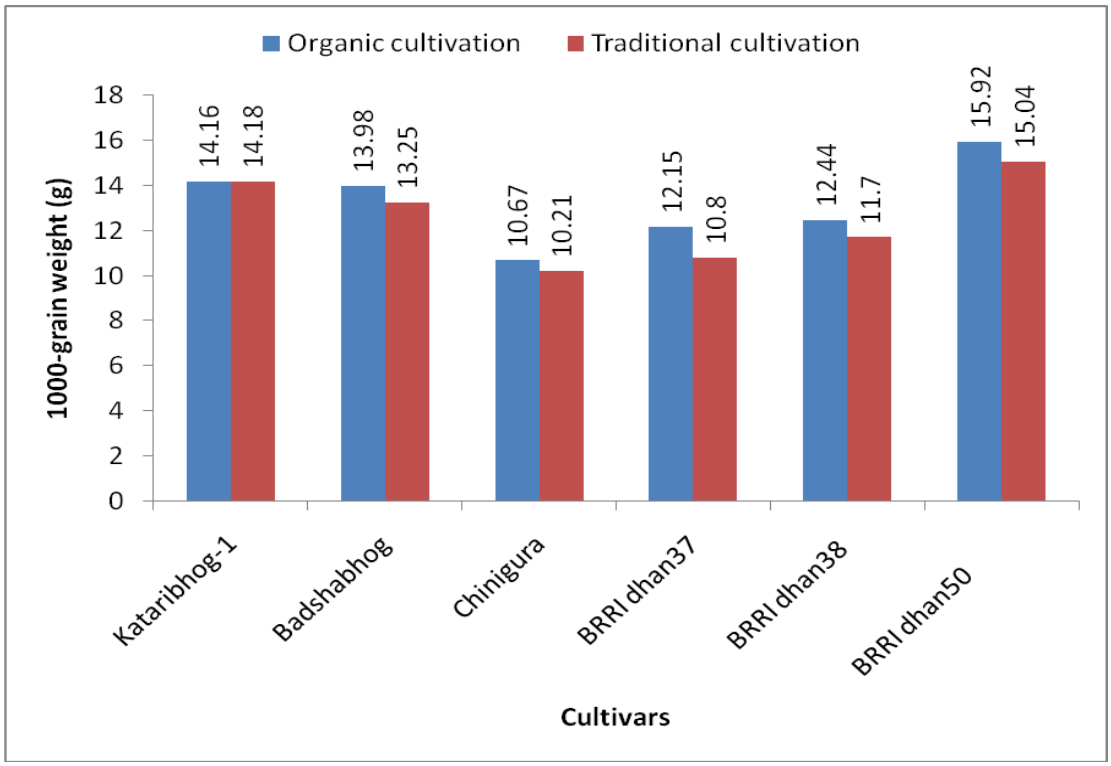

Fig. 3. 1000 seed weight of local and modern aromatic rice varieties influenced by organic and traditional cultivation methods in *Boro* season ($LSD_{0.05}$ = 0.092)

4.3 Yield parameters

4.3.1 Grain yield

Table 4 shows that organic cultivation and variety had marked influence on yield of local and modern aromatic rice varieties in *Boro* season. Among, the six aromatic rice varieties the highest grain yield (3.91 t ha^{-1}) was obtained from BRRI dhan50 under organic cultivation that was statistically at par with BRRI dhan37 (3.49 t ha^{-1}) and BRRI dhan38 (3.45 t ha^{-1}) under same method. This result is in agreement with Sarkar *et al.* (2014). However, modern variety, BRRI dhan50 gave higher yield under organic cultivation due to higher numbers panicles $hill^{-1}$, grains $panicle^{-1}$ and higher 1000-grain weight whereas local cultivar, Badshabhog due to higher grains $panicle^{-1}$ and higher 1000-grain weight. The lowest grain yield (1.91 t ha^{-1}) was obtained from Chinigura under traditional cultivation. The result obtained from the present study was also

similar with the findings of Murshida *et al*. (2017), Chamely *et al*. (2015), Sarkar *et al*. (2014) and Jisan *et al*. (2014).

4.3.2 Straw yield

Different variety and cultivation methods exhibited significant influence on straw yield of rice (Table 4). The highest straw yield (8.50 t ha^{-1}) was obtained from BRRI dhan37 under organic cultivation which was statistically similar to BRRI dhan38 (8.41 t ha^{-1}) and Badshabhog (7.90 t ha^{-1}) with same method. It might be due to their higher plant height and total tillers $hill^{-1}$. On the other hand, the lowest straw yield (4.21 t ha^{-1}) was found from Chinigura under traditional cultivation which was statistically similar with Kataribhog-1 (4.44 t ha^{-1}) and Badshabhog (5.10 t ha^{-1}) under same cultivation practice. It was probably happened due to supplying balance nutrients and improvement soil health by the added organic matter. Similar result was also observed by Chamely *et al*. (2015).

4.3.3 Biological yield

Significant variation was recorded on biological yield of rice affected by different cultivation methods in combination with different variety (Table 4). It was evident that the highest biological yield (12.10 t ha^{-1}) was found from BRRI dhan37 under organic cultivation which was statistically identical with Badshabhog and BRRI dhan38 under same cultivation practice. On the other hand, the lowest biological yield (6.39 t ha^{-1}) was found from Chinigura under traditional cultivation which was statistically identical with Kataribhog-1 and Badshabhog under same cultivation practice. It was probably happened due to supplying balance nutrients and improvement soil health by the added organic matter.

Table 4. Effect of organic cultivation on the yield of local and modern aromatic rice varieties in *Boro* season

Treatment (Variety)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
Organic cultivation			
Kataribhog-1	3.20 b	7.23 b	10.51 b
Badshabhog	3.12 ab	7.90 ab	11.25 a
Chinigura	2.34 ef	5.50 cd	7.95 c
BRRI dhan37	3.49 a	8.50 a	12.10 a
BRRI dhan38	3.45 a	8.41 a	11.89 a
BRRI dhan50	3.91 a	5.92 cd	9.92 bc
Traditional cultivation			
Kataribhog-1	2.17 cf	4.44 e	6.85 e
Badshabhog	2.21 f	5.10 de	7.42 e
Chinigura	1.91 g	4.21 e	6.39 e
BRRI dhan37	2.75 c	5.79 cd	8.70 d
BRRI dhan38	2.59 cd	5.37 d	8.94 cd
BRRI dhan50	3.45 a	5.53 c	9.12 cd
$LSD_{(0.05)}$	0.70	0.75	1.16
CV(%)	7.20	13.88	5.83

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

4.3.4 Harvest index (%)

Recorded data on harvest index of rice showed significant variation due to different cultivation methods association with different variety (Fig. 4). Results revealed that the harvest index exhibited inconsistent results. BRRI dhan50 provided significantly higher harvest index (39.41%) under organic cultivation which was statistically identical with BRRI dhan50 (37.63%) under traditional methods. Again, the cultivar Badshabhog under organic cultivation showed lowest harvest index (27.73%) which was statistically similar to Chinigura, BRRI dhan37 and BRRI dhan38 under organic cultivation and to BRRI dhan38 under traditional cultivation. Chamely *et al*. (2015) and Bhowmick and Nayak (2000) also found similar result with the present study.

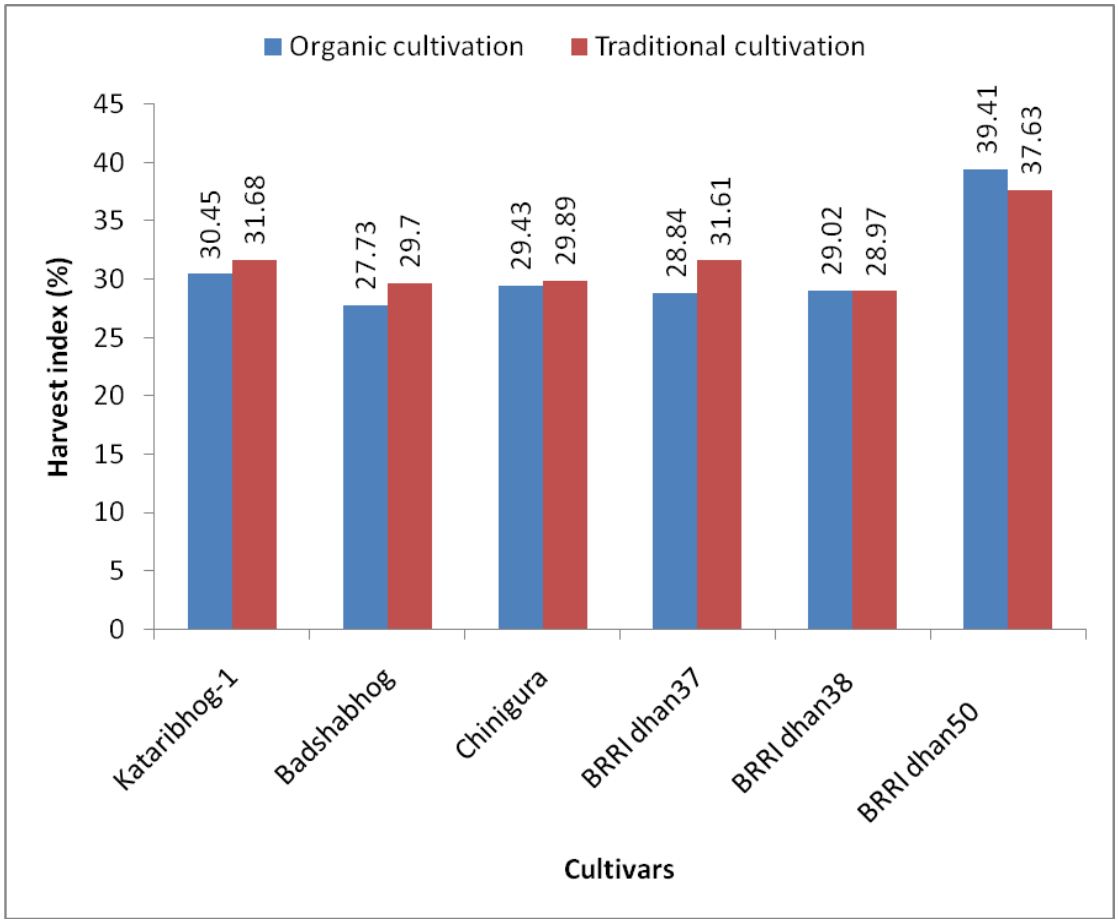

Fig. 4. Harvest index of local and modern aromatic rice varieties influenced by organic and traditional cultivation methods in *Boro* season ($LSD_{0.05}$ = 2.09)

4.4 Physical quality aspects of grain

4.4.1 Milling rice yield (%)

Milling rice yield was significantly influenced by cultivation method and variety (Table 5). Milling rice yield ranged from 70.03- 72.10% among the test varieties. The highest milling outturn (72.10%) was recorded in Kataribhog-1 with organic cultivation which was statistically similar to Badshabhog, BRRI dhan50, BRRI dhan37 and BRRI dhan38 under organic cultivation and also with Kataribhog-1, Badshabhog, BRRI dhan38 and BRRI dhan50 under traditional cultivation. The lowest milling outturn (70.03%) was recorded in BRRI dhan37 under traditional cultivation which was statistically identical with same cultivar under organic cultivation.

4.4.2 Head rice yield (%)

Different cultivation methods with different rice cultivars showed significant influence on % head rice yield (Table 5). Results showed that BRRI dhan38 gave the highest head rice yield (69.5%) and it was statistically similar to Badshabliog and Kataribhog-1 under organic cultivation. The lowest head rice yield (66.32%) was obtained from BRRI dhan37and it was significantly different from others. Head rice yield was dependent on grain size and shape, moreover it is a varietals characteristic (Ferdous *et al.,* 2004; Sidhue *et al.,* 2004).

4.4.3 Grain length

Grain length was significantly influenced by the combination of cultivation method and variety (Table 5). The highest grain length (5.40 mm) was obtained from BRRI dhan 50 with organic cultivation which was statistically identical with the same variety (5.20 mm) under traditional cultivation. The lowest grain length (3.60 mm) was obtained from Badshabhog under traditional cultivation which was statistically identical with Chinigura and BRRI dhan38 under organic cultivation and also with Chinigura under traditional cultivation. Grains of short to medium length usually, but not always, break than long grains during milling.

4.4.4 Length - breath ratio

Length-breath ratio (L:B) was affected significantly by the combination of cultivation method and variety (Table 5). The highest length breadth ratio (2.6) was obtained from BRRI dhan 50 with organic cultivation followed by Kataribhog-1 (2.51) under same cultivation method. The lowest length breadth ratio (2.02) was obtained from BRRI dhan37 which was statistically identical with Kataribhog-1, Badshabhog, Chinigura and BRRI dhan38 under same cultivation method.

4.4.5 Grain elongation ratio

Grain elongation ratio was significantly influenced by the combination of cultivation method and variety (Table 5). The grain elongation ratio of the treatment combinations varied from 1.91-2.13. Erratic effects of two cultivation methods were observed in different aromatic cultivars in case of grain elongation

ratio. The highest grain elongation ratio (2.13) was recorded from Badshabhog under organic cultivation and from BRRI dhan50 under traditional cultivation whereas the lowest (1.91) was recorded from Chinigura under traditional cultivation.

4.4.6 Volume Expansion ratio

Volume expansion ratio was affected significantly by the combination of cultivation method and variety (Table 5). Maximum volume expansion ratio (4.12) was observed in BRRI dhan 50 under traditional cultivation which was statistically similar to BRRI dhan50 under organic cultivation whereas the lowest (3.50) was found from Chinigura under the same method which was statistically identical with Kataribhog-1 (3.54) under organic cultivation. On an average, volume expansion ratio was 7% higher in under traditional cultivation compared to organic cultivation.

Table 5. Effect of organic cultivation on the physical quality aspects of grain in local and modern aromatic rice varieties in *Boro* season

Treatment (Variety)	Physical quality aspects					
	Milling rice yield (%)	Head rice yield (%)	Grain length (mm)	Length and breath ratio	Grain elongation ratio	Volume Expansion ratio
Organic cultivation						
Kataribhog-1	72.10 a	69.51 a	4.90 b	2.51 ab	1.97 bc	3.54 d
Badshabhog	71.34 ab	68.34 ab	3.70 e	2.27 bc	2.13 a	3.63 cd
Chinigura	70.12 c	67.37 b	3.70 e	2.10 c	2.05 ab	3.70 c
BRRI dhan37	71.10 abc	66.32 d	3.90 c	2.35 b	1.94 c	3.50 d
BRRI dhan38	71.07 abc	69.67 a	3.70 e	2.10 c	2.05 ab	3.55 cd
BRRI dhan50	71.30 ab	67.50 b	5.40 a	2.60 a	2.11 a	3.87 ab
Traditional cultivation						
Kataribhog-1	71.82 ab	68.15 ab	3.80 cd	2.10 c	2.02 abc	3.81 b
Badshabhog	71.01 abc	67.51 b	3.60 e	2.13 c	1.93 c	3.76 b
Chinigura	70.85 bc	66.81 c	3.70 e	2.24 c	1.91 c	3.50 d
BRRI dhan37	70.03 c	67.32 b	3.90 c	2.02 c	2.05 ab	3.69 cd
BRRI dhan38	71.33 ab	67.29 b	3.80 cd	2.10 c	2.08 ab	3.97 ab
BRRI dhan50	71.67 ab	67.0 8b	5.20 a	2.30 b	2.13 a	4.12 a
$LSD_{(0.05)}$	1.17	1.50	0.21	0.24	0.14	0.25
CV (%)	3.39	4.76	2.29	3.12	4.55	2.91

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

4.5 Aroma intensity

Different cultivation method and variety showed significant influence on the aroma quality of the test aromatic rice cultivars (Table 6). Aroma intensity ranged from 1.00-1.40. Only the local cultivars, Kataribhog-1, Badshabhog and Chinigura exhibited slight aroma under organic cultivation in *Boro* season, while, grain of all the test cultivars had no aroma under traditional cultivation. The result agreed with the earlier findings of Sumon *et al.,* 2018, Ashrafuzzaman *et al.,* 2009 and Datta *et al.* (2002).

Table 6. Effect of variety and organic cultivation on the biochemical quality aspects of local and modern aromatic rice cultivars of Bangladesh

Treatment (Variety)	Aroma intensity
Organic cultivation	
Kataribhog-1	1.33 a
Badshabhog	1.27 a
Chinigura	1.40 a
BRRI dhan37	1.03 bc
BRRI dhan38	1.05 bc
BRRI dhan50	1.00 c
Traditional cultivation	
Kataribhog-1	1.12 bc
Badshabhog	1.15 b
Chinigura	1.09 bc
BRRI dhan37	1.0 c
BRRI dhan38	1.0 c
BRRI dhan50	1.0 c
$LSD_{(0.05)}$	0.13
CV (%)	2.25

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

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the Farm of Sher-e-Bangla Agricultural University, Dhaka in *Boro* (dry) season to study aroma quality and morpho-physiological characteristics of local and improved aromatic rice under organic culture. The experiment consisted of two cultivation methods *viz*. (i) organic cultivation and (ii) traditional cultivation with 6 rice cultivars *viz*. (i) Kataribhog-1, (ii) Badshabhog, (iii) Chinigura, (iv) BRRI dhan37, (v) BRRI dhan38 and (vi) BRRI dhan50. The experiment was laid out in a Randomized complete Block Design (RCBD) with three replications. Data on different growth, yield and quality parameters were recorded. The collected data were statistically analyzed for evaluation of the treatment effect. Significant variation among the treatment combinations were observed regarding different parameters affected by different cultivation methods with different local and modern cultivars of rice.

Different growth parameters affected significantly due to the combination of variety and cultivation methods. It was observed that plant heights at maturity ranged from 165.87 cm to 102.42 cm in different treatment combinations. The maximum plant height (165.87 cm) was observed from Chinigura under organic cultivation whereas the lowest (102.42 cm) was from BRRI dhan50 under traditional cultivation. In case of number of tillers hill^{-1}, it was ranged from 14.53 to 11.00 among the cultivars under two cultivation methods. The maximum number of tillers hill^{-1} (14.53) was obtained from BRRI dhan38 under organic cultivation, whereas the lowest (11.00) was from Badshabhog. Similarly, results showed that organic cultivation method produced higher number of leaves per hill compared to traditional cultivation method irrespective of cultivars. The maximum number of leaves hill^{-1} (56.80) was

recorded from BRRI dhan37 under organic cultivation, whereas the minimum number (45.00) was recorded from Badshabhog under traditional cultivation. Leaf area index (LAI) ranged from 5.41 to 2.69 among different treatment combination at heading stage and significantly higher leaf area index was achieved from modern aromatic rice varieties, BRRI dhan38 (5.41) under organic cultivation whereas the lowest (2.69) was recorded from Chinigura under traditional cultivation.

Variety and cultivation methods showed significant influence on the yield contributing characters. The highest number of panicles hill^{-1} (10.50) was found in BRRI dhan50, under organic cultivation whereas the lowest (7.48) was found from Kataribhog-1 under traditional cultivation. The maximum panicle length (25.90 cm) was recorded from Kataribhog-1 with organic cultivation while the minimum panicle length (20.7cm) was recorded from Chinigura under traditional cultivation. The maximum number of spikelets panicle^{-1} (159.67) was recorded in Badshabhog with organic cultivation and the minimum (93.3) was obtained from Chinigura (86.82) with traditional cultivation. The highest number of grains panicle^{-1} (141.60) was obtained from Badshabhog with organic cultivation and the lowest number of grains panicle^{-1} (78.13) was counted from Chinigura with traditional cultivation. The highest number of grains panicle^{-1} (141.60) was found from Badshabhog under organic cultivation whereas the lowest (78.13) was recorded from Chinigura under traditional cultivation. The highest 1000 grains weight (15.92g) was found in BRRI dhan50 under organic cultivation and the lowest (10.21g) was in Chinigura under traditional cultivation.

Different yield parameters were influenced significantly due to different cultivation methods and varieties. Among, the six aromatic rice varieties the highest grain yield (3.91 t ha^{-1}) was obtained from BRRI dhan50 under organic cultivation whereas the lowest grain yield (1.91 t ha^{-1}) was obtained from

Chinigura under traditional cultivation. The highest straw yield (8.5 t ha^{-1}) was obtained from BRRI dhan37 (3.49 t ha^{-1}) under organic cultivation while the lowest straw yield (4.21 t ha^{-1}) was obtained from Chinigura under traditional cultivation. BRRI dhan37 provided the maximum biological yield (12.10 t ha^{-1}) under organic cultivation and Chinigura provided the minimum biological yield (6.39 t ha^{-1}) under traditional cultivation. BRRI dhan50 provided significantly higher harvest index (39.41%) under organic cultivation and Badshabhog provided lowest harvest index (27.73%) with same cultivation method.

Regarding physical and biochemical quality parameters, all were significantly influenced by cultivation method and variety. Milling rice yield ranged from 70.03- 72.10% among the cultivars and the highest (72.10%) was recorded in Kataribhog-1 with organic cultivation and the lowest (70.03%) was recorded in BRRI dhan37 under traditional cultivation. BRRI dhan38 gave the highest head rice yield (69.5%) under organic cultivation and lowest (66.32%) was recorded in BRRI dhan37 under same cultivation method. Highest grain length (5.40 mm) and length breadth ratio (2.60) was obtained from BRRI dhan 50 with organic cultivation but the lowest (3.60 mm and 2.02, respectively) were found in Badshabhog and BRRI dhan37, respectively. The grain elongation ratio of the treatment combinations varied from 1.91-2.13. The maximum grain elongation ratio (2.13) was found in BRRI dhan50 under traditional cultivation while the lowest (1.91) was found in Chinigura under same cultivation method. Maximum volume expansion ratio (4.12) was observed in BRRI dhan 50 under traditional cultivation while the lowest (3.50) was found in BRRI dhan37 under organic cultivation and also in Chinigura under traditional cultivation.

Both cultivation method and variety exerted significant influence on the aroma quality. Aroma intensity ranged from 1.40-1.00 and Chinigura under organic cultivation showed highest aroma intensity. Results also revealed that only the local cultivars, Kataribhog-1, Badshabhog and Chinigura exhibited slight aroma

under organic cultivation, while grain of all the test cultivars had no aroma under traditional cultivation.

Conclusion:

1. BRRI dhan50 gave higher yield (3.91 t ha^{-1}) under organic cultivation due to higher number of effective tillers $hill^{-1}$, panicles $hill^{-1}$, grains $panicle^{-1}$ and higher 1000-grain weight. The highest harvest index (39.41%) also found from BRRI dhan50 under organic cultivation. On the other hand, the lowest yield (1.91 t ha^{-1}) was found from under traditional cultivation due to lower panicles $hill^{-1}$, panicle length, spikelets $panicle^{-1}$, grains $panicle^{-1}$ and 1000-grain weight.
2. Among three local cultivars, Kataribhog-1 provided higher yield (3.20 t ha^{-1}) due to panicle length, spikelets $panicle^{-1}$, grains $panicle^{-1}$ and higher 1000-grain weight under organic cultivation. It is also suitable in respect of higher head rice yield.
3. Between two cultivation methods, organic cultivation significantly improved aroma quality in local aromatic rice cultivars *viz.* Kataribhog-1, Badshabhog and Chinigura in *Boro* season compared to traditional cultivation.

REFERENCES

AIS (Agricultural Information Service). (2012). Krishi Dairy. Agric. Info. Service. Khamarbari, Farmgate, Dhaka. pp. 10-15.

Akter, S. (2014). Effects of nitrogen supplied from manures and fertilizers on the growth and yield of BRRI dhan29. MS thesis, Department of Soil Science, Bangladesh Agricultural University, Mymensingh. Pp-12-25.

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.

Ali, M. (1993). An economic evaluation of green manure use in the rice based farming system. (Terminal Report, Social Sciences Division. Los Baños, Laguna, Philippines: IRRI.

Ali, M.G., Mannan, M.A., Halder, K.P. and Siddique, S.B. (1993). Effect of planting dates on the growth and yield of modern transplanted *Aman* rice. *Ann. Bangladesh Agric.,* **3**(2): 103-108.

Arumugachamy S., Vairavan S., Vivekanandan P. and Palanisamy S. (1992). Aromatic and quality rice improvement in Tamil Nadu. Intl. *Rice Res. Newsl.* **17**(6):11-12.

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

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

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

Biswas, P. K. and Salokhe, V. M. (2002). Effects of N rate, shading, tiller separation, and plant density on the yield of transplant rice. *Top Agric.* (Trinidad). **79**(3): 279-287.

BRRI (Bangladesh Rice Research Institute), (2013). *Adunick Dhanar Chash* (Bangla), Bangladesh Rice Res. Inst.Gazipur, Pub. No. 5. Pp.12-15.

Chamely, S.G., Islam, N., Hoshain, S., Rabbani, M.G., Kader, M.A. and Salam, M.A. (2015). Effect of variety and nitrogen rate on the yield performance of *Boro* rice. *Progressive Agric.,* 26(1): 6-14.

Chowdhury, M.R.I. (1997). Agronomic parameters of some selected rice varieties/mutants as affected by method of transplanting in *Boro* season. M.S. thesis, Dept. Agron., BAU, Mymensingh. p. 82.

Chowdhury, S.A., Majid, M.A., Huque, K.S., Islam, M. and Rahman, M.M. (1995). Effect of variety on yield and nutritive value of rice straw. *Asian- Australasian J. Ani. Sci.,* **8**(4): 329-335.

Dahiphale A. V., Giri, D. G., Thakre G. V. and Kubde K. J. (2004). Yield and yield parameters of scented rice as influenced by integrated nutrient management. *Ann. Plant Physiol.,* **18**(1): 207-208.

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

Davari M. R. and Sharma, S. N. 2010. Effect of different combination of organic materials and biofertilizers on productivity, grain quality and economics in organic farming of basmati rice (*Oryza sativa*). *Indian J. Agron*., **55**(4): 290-294.

Dongarwar, U.R., Patankar, M.N and Pawar, W. S. (2003). Response of hybrid rice to different fertility levels. *J. Soils and Crops.* **13** (1): 120-122.

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

Dutta R.K., Lahiri B.P. and Mia M.A.D. (1998). Characterization of some aromatic rice cultivars in relation to their physio-chemical quality of grains. *Indian J. Plant Physiol*. **3**(1): 61-64.

FAO (Food and Agricultural Organization). (2014). FAO Country sector fact sheets placeholder. National Aquaculture Sector Overview: Bangladesh.

Ferdous N., Biswas S.K. and Kabir K.A. (2004). Effect of milling on physiological properties of rice. In: Proc. Seminar. Bangladsh Rice. Res. Inst. Gazipur. pp. 1-5.

Ghosh M., Pal A. K., Pal S. K. and De D. K. (2003). Relationship of leaf area and chlorophyll content with yield of aromatic rice. *Indian J. Plant Physiol*., **8**(2):199-200.

Gomez K.A., and Gomez A.A. (1984). Statistical Procedures for Agricultural Research. Int. Rice Res. Inst., John Wiley and Sons. New York, Chichester, Brisbane, Toronto, Singapore. 680p.

Haque, M.M., Pramanik, H.R., Biswas, J.K., Iftekharuddaula, K.M. and Hasanuzzaman, M. (2015). Comparative performance of hybrid and elite inbred rice varieties with respect to their source-sink relationship. *The Scientific World J.* PP. 1-11.

Hien, N.L., Yoshihashi, T. and Sarhadi, W.A. (2006). Evaluation of aroma in rice using KOH method, molecular markers and measurement of 2-acetyl1-pyrroline concentration. *Japanese J. Trop. Agric*., **50**: 190-198.

Hossain M.F. (2008). Improving the yield and quality of aromatic rice through manipulation of cultural practices. Ph.D. dissertation. Bangladesh Agricultural University (BAU), Mymensingh, Bangladesh, pp. 126-130.

Hossain S. T., Bhuiya M. S. U., Islam M. A., Kashem M. A. and Mannan M. A. (2002). Effect of water stress on the performance of yield of fine rice. *Bangladesh J. Environ. Sci.,* **6**: 251-257.

Hossain, M.F., Islam, M.S., Rahman, M.M., Faruk, M.O. and Ershad, M.G. (2008). Yield and quality performance of some aromatic rice varieties of *Bangladesh. J. Agrofor. Enviro.,*. **2**(2): 155-158.

Hossain, M.M., Sultana, F. and Rahman, A.H.M.A. (2014). A comparative screening of hybrid, modern varieties and local rice cultivar for brown leaf spot disease susceptibility and yield performance. *Archives of Phytopathology and Plant Protection.* **47**(7): 795-802.

Idris M. and Matin M. (1990). Response of four exotic strains of *Aman* rice to Urea, *Bangladesh J. Agril. Sci.,* **17**(2):271-275.

IRRI (International Rice Research Institute), (2006). Aromatic winter (*Boro*) rice production, (*www.knowledgebank.irri.org*)

Islam M. S., Sarkar M. A. R., Ullah M. A. and Khanam S. (2015). Effect of transplanting date on the growth and yield of aromatic rice in irrigated ecosystem. *IOSR J. Agric. Vet. Sci.,* **8**(1):59-65.

Islam M.S. and Islam A.K.M.S. (2004). Fine and aromatic rice in Bangladesh; Production, Processing and export potential. Thursday Seminar, 10 August, Bangladesh Rice Res. Inst. Gazipur. Pp. 1-5.

Islam N., Kabir M. Y., Adhikary S. K. 2013. Yield performance of six local aromatic rice cultivars. *IOSR J. Agric. Vet. Sci.,* **6**(3):58-62.

Islam, M. S., Parvin, S. and Sarkar, M. A. R. (2009). Yield of fine rice varieties as influenced by integrated management of poultry manure, urea super granules and prilled urea. *J. Environ. Sci. Nat. Res.,* **5**(1): 203-212.

Islam, M.S., Peng, S., Visperas, R.M., Bhuiya, M.S.U., Hossain, S.M.A. and Julfiqur, A.W. (2010). Comparative study on yield and yield attributes of hybrid, inbred, and NTP rice genotypes in a tropical irrigated ecosystem. *Bangladesh J. Agric. Res.,* **35**(2): 343-353.

Islam, M.T. (2011). Effect of temperature on photosynthesis, yield attributes and yield of aromatic rice genotypes. *Int. J. Sustain. Crop Prod.,* **6**(1): 14-16.

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. (1998). 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, 12-13, April, 1998.

Kamal, A.M.A., Azam, M.A. and Islam, M.A. (1988). Effect of cultivar and NPK combinations on the yield contributing characters of rice. *Bangladesh J. Agril. Sci.,* **15**(1): 105-110.

Khan, T.N., Razzaq, A., Shahbaz, M., Ajmal, S., Ali, G.M. and Joyia, M.F. (2006). Performance of four varieties of fine rice for best yield and yield components under climatic conditions of Bahawalpur (Pakistan). *J. our Agric. Social Sci.,* **2**(3): 187-188.

Khushik, A.M., Lashari, M.I. and Memon, A. (2011). Performance of rice hybrid and other varieties in Sindh and Balochistan. *J. Agric. Res.,* **49**(4): 561-570.

Laila N., Sarkar A. M. R., Paul S.K. and Rahman A. (2020). Yield performance of aromatic fine rice as influenced by integrated use of vermicompost and inorganic fertilizers, *J. Bangladesh Agril. Univ.,* **18**(2): 260-265

Leenakumari, S., Mahadevappa, M., Vadyachandra, B.J. and Krishnamurthy, R.A. (1993). Performance of experimental rice hybrid in Bangalore, Karnataka, India. *Intl. Rice Res. Newsl.,* **18**(1): 16.

Mannan M. A., Bhuiya M. S. U., Akand M.I.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

Mannan M.A. (2005). Effects of planting date, nitrogen fertilization and water stress on the growth, yield and quality of fine rice. A Ph. D. Dissertation. Dept. Agron. Bangladesh Agril. Univ., Mymensingh. Bangladesh

Molla, M.A.H. (2001). Influence of seedling age and number of seedling on yield attributes and yield of hybrid rice in the wet season. *Intl. Rice. Res. Notes.* **26**(2): 73-74.

Murshida, S., Uddin, M.R., Anwar, M.P., Sarker, U.K., Islam, M.M. and Haque, M.M.I. (2017). Effect of variety and water management on the growth and yield of *Boro* rice. *Progressive Agric*., **28** (1): 26-35.

Myung, K. (2005). Yearly variation of genetic parameters for panicle characters of Japonica rice *(Oryza sativa* L.). *Japanese J. Crop Sci.* **69**(3): 357-358.

Nematzadeh, G.A., Arefi, H.A., Amani, R and Mahi, B.C. (1997). Release of a new variety of rice, namely "Nemat" with superiority in yield and quality. *Iranian J. Agric. Sci.,* **28**(4): 79-86.

Obaidullah, M., Biswas, P. K. and Ruhul Amin, A. K. M. (2009). Influence of clonal tiller age on growth and yield of *Aman* rice varieties. *J. Sher-e-Bangla Agric. Univ.* **3**(1): 35-39.

Obulamma, U., Reddeppa, R. and Reddy, R. (2002). Effect of spacing and seedling number on growth and yield of hybrid rice. *J. Res. Angrau.,* **30**(1): 76-78.

Parikh M, Rastogi N. K. and Sarawgi A. K. (2012). Variability in grain quality traits of aromatic rice (*Oryza sativa* L.) *Bangladesh J. Agril. Res.,* **37**(4): 551-558

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

Rahman, M.A., Hossain, S.M.A., Sarkar, N.A.R., Hossain, M.S. and Islam, M.S. (2002). Effect of variety and structural arrangement of rows on the yield and yield components of transplant *Aman* rice. *Bangladesh .J. Agril. Sci.,* **29**(2): 303-307.

Rahman, M.M. and Yakupitiyage, A. (2006). Use of fishpond sediment for sustainable aquaculture-agriculture farming. International Journal of Sustainable Development Planning, **1**: 192-202

Rashid, M.M., Ghosh, A.K., Roni, M.N., Islam, M.R and Alam, M.M. (2017). Yield performance of seven aromatic rice varieties of Bangladesh. *Inter. J. Agric. Environ. Res.,* **3**(2): 2637.

Razzaque, M.A., Talukder, N.M., Islam, M.S., Bhadra, A.K. and Dutta, R.K. (2009). The effect of salinity on morphological characteristics of seven rice (*Oryza sativa*) genotypes differing in salt tolerance. *Pak. J. Biol. Sci*., **12**(5): 406-412.

Roy, A., Sarkar, M.A.R. and Paul, S.K. (2018). Effect of age of seedlings at staggered transplanting and nutrient management on yield performance of aromatic fine rice (cv. BRRI dhan38). *SAARC J. Agric*., **16**(1): 49-59.

Roy, S.K., Ali, M.Y., Jahan, M.S., Saha, U.K., Ahmad-Hamdani, M.S., Hasan. M.M. and Alam, M.A. (2014). Evaluation of growth and yield attributing characteristics of indigenous *Boro* rice varieties. *Life Sci. J.* **11**(4): 122-126.

Salam M. A., Kabir M. A. and Miah N. M. (1992). Adaptability of photoperiod-sensitive modern rice varieties in the *Boro* season, *Bangladesh Rice J*., **3**(1&2): 144-147.

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 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.

Sarkar S.K., Sarkar M.A.R., Islam N. and Paul S.K. (2016). Morphophysiological attributes of three HYV aromatic fine rice varieties as affected by integrated nutrient management. *J. Agrofor. Environ.,* **10**(1): 57-61

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.

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

Siddiquee, M.A., Biswas, S.K., Kabir, K. A., Mahbub, A.A., Dipti, S.S., Ferdous, N., Biswas, J.K. and Banu, B. (2002). A Comparative Study Between Hybrid and Inbred Rice in Relation to Their Yield and Quality. *Pakistan J. Biol. Sci.* **5**: 550-552.

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

Sinha, T., Paul, S.K. and Sarkar, M.A.R. (2018). Effect of age of seedlings at staggered transplanting and weed management on the growth and yield of aromatic *Boro* rice (cv. BRRI dhan50). *J. Bangladesh Agric. Univ*., **16**(1): 5-11

Sumit, C; Pyare, L; 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.* **20** (2): 233-238.

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.

Suprihatno, B. and Sutaryo, B. (1992). Yield performance of some new rice hybrids varieties in Indonesia. *Intl. Rice Res. Newsl.,* **17**(3): 12.

Tabien, R.E. and Samonte, S.O.P.B. (2007). Flowering traits and head rice yield. *Texas Rice Newsl.,* **7**(7): 8-9.

Tsuzuki, E., Morinaga and Shida S. (1977). Studies on the characteristics of scented rice. III Varietal differences of some carbonyl compounds evolved in cooking scented varieties. *Bull. Fac. Agric. Miyazaki Univ.* 24:35-39.

Tyeb, A., Paul, S.K. and Samad, M.A. (2013). Performance of variety and spacing on the yield and yield contributing characters of transplanted *Aman* rice. *J. Agrofor. Environ.* **40**(4): 595-597.

Wagan, S.A., Mustafa, T., Noonari, S., Ain Memon, Q. A. and Wagan, T.A. (2014). Performance of Hybrid and Conventional Rice Varieties in Sindh, Pakistan. *J. Econ. Sust. Dev*., 6(3): 114-117.

Wang, L.J., Xu, J.Z. and Yi,Z.X. (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.

Yang, X. J., Tang X. R. and Wen, X. C. (2014). Effects of sowing date on aroma formation, quality and yield of early season aromatic rice. *Acta Agriculturae Boreali-Sinica*, **29**(3):128-135

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

Yoshihitoi, T. (2005). Does drought condition induce the aroma quality of aromatic rice. Japan Intl. Res. Center for Agril. Sci. (JIRCAS). Food Sci. Divn. *News Letter for Intl. Collaboration*. No. 45. Japan. 4p.

APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

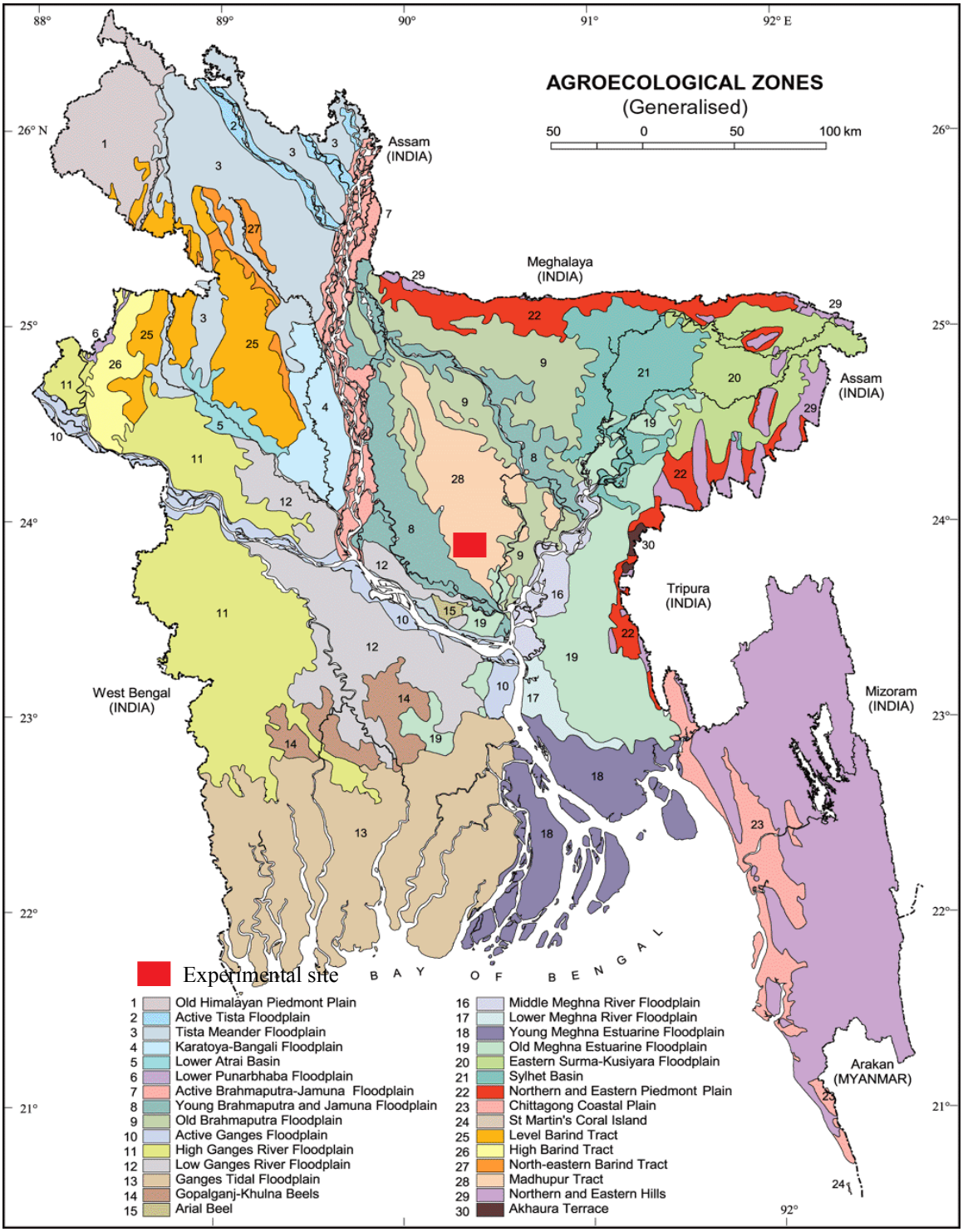

Fig. 5. Experimental site

Appendix II. Monthly records of air temperature, relative humidity and rainfall during the period from July to December 2019.

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max.	Min.	Mean.		
2018	December	25.50	6.70	16.10	54.80	0.0
2019	January	23.80	11.70	17.75	46.20	0.0
2019	February	22.75	14.26	18.51	37.90	0.0
2019	March	35.20	21.00	28.10	52.44	20.4
2019	April	34.70	24.60	29.65	65.40	165.0
2019	May	32.64	23.85	28.25	68.30	182.2

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Effect of organic cultivation on the growth attributes of local and modern aromatic rice varieties in *Boro* season

Sources of variation	Degrees of freedom	Mean square			
		Plant height (cm)	Tillers hill^{-1}	Leaf number hill^{-1} at heading	LAI at heading
Replication	2	3.214	1.311	4.162	0.385
Factor AB	9	42.403**	67.28**	87.32*	31.46*
Error	18	2.147	1.312	3.114	0.152

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

Appendix V. Effect of organic cultivation on number of effective and non-effective tillers hill^{-1} of local and modern aromatic rice varieties in *Boro* season

Sources of variation	Degrees of freedom	Mean square	
		Number of non effective tillers hill^{-1}	Number of effective tillers hill^{-1}
Replication	2	0.032	1.622
Factor A	9	5.328**	16.056**
Error	18	0.371	0.674

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

Appendix VI. Effect of organic cultivation on the yield contributing attributes of local and modern aromatic rice cultivars in *Boro* season

Sources of variation	Degrees of freedom	Mean square				
		Panicles hill^{-1}	Panicle length (cm)	Spikelets panicle^{-1}	Grains panicle^{-1}	1000-grain weight (g)
Replication	2	0.476	2.014	2.118	3.085	0.214
Factor A	9	42.71*	18.337*	36.244*	228.33*	14.372**
Error	18	1.344	2.217	2.716	5.076	0.536

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

Appendix VII. Effect of organic cultivation on the yield of local and modern aromatic rice varieties in *Boro* season

Sources 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	0.042	0.141	1.056	0.879
Factor A	9	6.371**	10.376*	14.67*	22.36*
Error	18	0.209	0.547	0.871	1.052

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

Appendix VIII. Effect of organic cultivation on the physical quality aspects of local and modern aromatic rice cultivars of Bangladesh

Sources of variation	Degrees of freedom	Mean square					
		Milling rice yield (%)	Head rice yield (%)	Grain length (mm)	Length and breath ratio (L:B)	Grain elongation ratio	Volume Expansion ratio
Replication	2	2.514	1.812	0.075	0.039	0.053	0.084
Factor A	9	48.52*	57.33*	1.402**	1.607**	1.071**	3.149**
Error	18	2.032	2.172	0.036	0.052	0.062	0.076

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

Appendix IX. Effect of variety and organic cultivation on the biochemical quality aspects of local and modern aromatic rice cultivars of Bangladesh

Sources of variation	Degrees of freedom	Mean square
		Aroma intensity
Replication	2	0.003
Factor A	9	0.734**
Error	18	0.007

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