EVALUATION OF TEN AROMATIC RICE CULTIVARS IN RELATION TO MORPHOLOGICAL TRAITS AND YIELD IN *AMAN* RICE

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CERTIFICATE

This is to certify that the thesis entitled **"EVALUATION OF TEN AROMATIC RICE CULTIVARS IN RELATION TO MORPHOLOGICAL TRAITS AND YIELD IN *AMAN* RICE"** 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 *bona fide* research work carried out by **ZAKIA SULTANA**, Registration No. **12-05192** 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

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Dedicated to

My

Beloved Parents

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The Author

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ABSTRACT

The experiment was carried out in the Experimental Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka during June to November (*Aman* season), 2019 to study the morphological characteristics and yield of ten aromatic rice cultivars in rice. Ten traditional aromatic rice cultivars *viz*., Chinigura, Begunbichi, Madhumala, Katarivog-2, Kalijira, Badshavog, Katarivog-1, Dolavog, Shadasone and Khaisone were used as the treatment of this experiment. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Data on different morphological traits and yield were recorded and marked differences were observed for different cultivars. Plant height at 30, 60 and 90 DAT and at harvest, the tallest plant 55.61, 108.20, 142.40 and 161.40 cm, respectively) was found from the cultivar Madhumala, while the shortest plant (41.81, 81.36, 115.30 and 136.00 cm, respectively) from Dolavog. At 30, 60 and 90 DAT and at harvest, the maximum number of tillers hill^{-1} (8.72, 17.70, 24.56 and 25.06, respectively) was found from Kalijira and the minimum number (6.80, 10.50, 16.00 and 16.50, respectively) from Madhumala. The maximum effective tillers (18.24) were found from Kalijira, while the minimum number (12.67) from Madhumala. The longest panicle (21.00 cm) was recorded from Kalijira, whereas the shortest from Dolavog. The maximum number of filled grains panicle^{-1} (148.20) was found from Kalijira and the minimum number (78.60) from Katarivog-2. The lowest sterility percentage (7.26%) was recorded from Kalijira, whereas the highest (25.71%) from Katarivog-2. The highest weight of 1000 grains (22.76 g) was observed from Madhumala and the lowest weight (9.12 g) from Shadasone. The highest grain yield (3.42 t ha^{-1}) was found from Kalijira, whereas the lowest (2.11 t ha^{-1}) from Madhumala. The highest straw yield (6.12 t ha^{-1}) was recorded from V_5 (Kalijira), while the lowest (4.70 t ha^{-1}) from Madhumala. Kalijira produced longest panicle, highest number of effective tillers, filled grains, total grains panicle^{-1} (166.50) and consequently, provided the highest grain yield, straw yield and biological yield. So, the rice cultivar Kalijira can be considered as best among the studied aromatic rice cultivars.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan’s Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	Mililitre
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Cultivar
^oC	=	Degree Celceous
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Miligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Litre
Mg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.), belongs to the family Gramineae, is the most important food in tropical and subtropical regions (Singh et al., 2012). It is grown in more than a hundred countries with a total area of about 160 million hectares, producing more than 700 million tons every year (IRRI, 2013). More than three billion people in the world are taking rice as their main food (IRRI, 2009). In Asia, more than 90% of all produced rice has been consumed (FAO, 2006).

The population of our country is increasing but the cultivable land is decreasing due to urbanization and industrialization resulting in more shortage of food. Thus, Bangladesh will require about 27.26 million tons of rice for the year 2020. Since it is not possible to have horizontal expansion of rice area, rice yield should be increased to meet this ever increasing demand of food. The rainfed Aus, the rainfed *Aman* and irrigated Boro rice are cultivated in 10%, 51% and 39% in the total cropped area in Bangladesh, respectively (BADC, 2008). But according to BBS Report 2008 Aus, *Aman* and Boro produced 1.51, 9.66 and 17.76 million metric tons of rice.

Rice is grown in Bangladesh in three rice growing seasons namely Aus, *Aman* and Boro. Among these seasons, *Aman* rice covers the area of 5.66 million hectares with a production of 13.3 million tons (AIS, 2012). But the yield of transplant *Aman* rice per unit area is much lower in our country as compared to other rice growing countries of the world. It is mainly due to selection of potential cultivars and judicious application of fertilizers. Selection of potential cultivar, planting in appropriate method and application of optimum amount of nutrient elements can play an important role to increase the rice yield and national income.

Rice is the large scale cultivated crop which provides half of the daily food for one of every three persons on the earth (Sangeetha *et al.*, 2013). It is consumed as the staple food and has been given the highest priority in meeting the demand of the ever increasing population in Bangladesh. It has been reported that the production of milled rice reached around 33.803 million tons in the FY 2016-17 (BBS, 2017). Among the total rice production, *Aman* rice occupies 13.48 million tons in 2016-2017 (BBS, 2017) and aromatic rice constitutes 12.50 % of the total transplanted *Aman* rice (Roy et. al. 2018) which has greater potential to attract rice consumer and boost up the economic condition of the rice grower in the developing countries.

Cultivar plays an important role in augmenting yield of rice. Use of HYV has been increased remarkably in recent years and the country has almost reached a level of self sufficiency in food. National Commission of Agriculture projected that to remain self-sufficient Bangladesh we will need to produce 47 million MT of paddy (31.6 million MT of rice) by the year 2020, implying a required rate of growth of production at 1.7% per year.

The growth process of rice plants under a given agro-climatic condition differs due to specific rice cultivar (Alam *et al.*, 2012). Hybrid rice cultivar also showed high yield potentiality. Hossain and Deb (2003) reported that although farmers got about 16% yield advantage in the cultivation of hybrids compared to the popularly grown inbred cultivars, the yield gains was not stable. Now a days different high yielding rice cultivar are available in Bangladesh which have more yield potential than conventional rice cultivars (Akbar, 2004). During vegetative growth, high yielding rice cultivar accumulates more dry matter in the early and middle growth stages which results in more spikelets panicle^{-1}. They have bigger panicles and more spikelets panicle^{-1}. Very recently various new rice cultivars were developed by BRRI and available as BRRI dhan and maximum of them is exceptionally high yield potentially. Compared with conventional cultivars, the high yielding cultivars have larger panicles, heavier seeds, resulting in an average rice grain yield increase of 7.27% (Bhuiyan *et al*., 2014).

To get the maximum benefit from *Aman* rice, it is essential to develop appropriate package of practices for successful cultivation and yield maximization. Among the various cultural practices, cultivar along with appropriate nutrient management is necessary for yield maximization.

In this study, attempts have been made to test the possibility of optimizing and improving the yield of aromatic fine rice by exploring different aromatic rice cultivars. However, the following objectives was taken for the present study

1. To study the morphological characteristics of ten aromatic rice *cultivars* in *Aman* season.
2. To compare the yield performance of ten aromatic rice cultivars in *Aman* season.

CHAPTER II

REVIEW OF LITERATURE

One of the major reasons of yield reduction of rice is varietal performance. So, cultivar 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 cultivar done at home and abroad have been reviewed under the following headings:

2.1 Morpho-physiological traits and yield

Khatun *et al*. (2020) conducted a field experiment with six rice cultivars to determine their growth and yield performance. The experiment was laid out in a randomized complete block design (RCBD) with four replications. All the growth and yield contributing attributes varied significantly among the six rice cultivars. The results revealed that in all rice cultivars maximum growth performance observed at 58-68 Days after transplanting and maximum dry matter production was observed at 68 days after transplanting. Maximum number of filled spikelet observed in Binadhan-17 (164.89 penicle^{-1}) and that was significantly different from other cultivars. Percent of sterile spikelet was highest in BRRI dhan39 (12.9%) and that was statistically similar with Binadhan-16 (11.96%) and BRRI dhan33 (12.36%). Maximum 1000-seed weight was observed in Binadhan-17 (27.25 g). Highest grain yield was obtained from Binadhan-17 (6.13 t ha^{-1}) that was significantly different from other cultivars. Lowest grain yield observed in BRRI dhan39 (4.49 t ha^{-1}) that was statistically similar to BRRI dhan33 (4.57 t ha^{-1}) and Binadhan-7 (4.86 t ha^{-1}).

Laila and Sarkar (2020) conducted an experiment to study the combined effect of vermicompost with inorganic fertilizers on the yield and yield contributing characters of aromatic fine rice cultivars. The experiment comprised three cultivars viz. BRRI dhan34, Binadhan-13 and Kalizira and five nutrient managements *viz*. control (no application of manures and fertilizer), recommended dose of inorganic fertilizers (i.e. 150, 95, 70, 60, 12 kg ha^{-1} of Urea, TSP, MOP, Gypsum and Zinc Sulphate respectively), vermicompost @ 3 t ha^{-1} , 25% less than recommended dose of inorganic fertilizer + vermicompost @ 1.5 t ha-1 , 50 % less than recommended dose of inorganic fertilizer + vermicompost @ 3 t ha^{-1} . The experiment was laid out in a randomized complete block design with three replications. Result showed that, yield and yield components of aromatic fine rice were significantly influenced by cultivar, nutrient management and interaction of cultivar and nutrient management. In case of cultivar, the highest and the lowest value of grain yield (3.89, 2.80 t ha^{-1}) and straw yield (5.29, 4.03 t ha^{-1}) were found in Binadhan-13 and Kalizira, respectively. In case of nutrient managements, the highest yield and yield component were obtained from 50% less than the recommended dose of inorganic fertilizers + vermicompost @ 3 t ha^{-1} treatment. The highest number of total tillers $hill^{-1}$, effective tillers $hill^{-1}$, number of grains $panicle^{-1}$, panicle length, grain yield (4.04 t ha^{-1}) and straw yield (6.20 t ha^{-1}) were obtained from the interaction of Binadhan-13 and 50% less than the recommended dose of inorganic fertilizers + vermicompost @ 3 t ha^{-1}. The lowest values related to yield were found in Kalizira with control condition. Binadhan-13 along with 50% less than the recommended dose of inorganic fertilizers + vermicompost @ 3 t ha^{-1} might be a promising practice for aromatic fine rice cultivation.

Peter *et al*. (2019) reported that the aromatic group of Asian cultivated rice is a distinct population with considerable genetic diversity on the Indian subcontinent and includes the popular Basmati types characterized by pleasant fragrance. Genetic and phenotypic associations with other cultivated groups are ambiguous, obscuring the origin of the aromatic population. From analysis of genome-wide diversity among over 1,000 wild and cultivated rice accessions, we show that aromatic rice originated in the Indian subcontinent from hybridization between a local wild population and examples of domesticated japonica that had spread to the region from their own center of origin in East Asia. Most present-day aromatic accessions have inherited their cytoplasm along with 29-47% of their nuclear genome from the local Indian rice. We infer that the admixture occurred 4,000-2,400 years ago, soon after japonica rice reached the region. We identify aus as the original crop of the Indian subcontinent, indica and japonica as later arrivals, and aromatic a specific product of local agriculture. These results prompt a reappraisal of our understanding of the emergence and development of rice agriculture in the Indian subcontinent. The aromatic group of Asian cultivated rice is a distinct population with considerable genetic diversity on the Indian subcontinent and includes the popular Basmati types characterized by pleasant fragrance. Genetic and phenotypic associations with other cultivated groups are ambiguous, obscuring the origin of the aromatic population. From analysis of genome-wide diversity among over 1,000 wild and cultivated rice accessions, we show that aromatic rice originated in the Indian subcontinent from hybridization between a local wild population and examples of domesticated japonica that had spread to the region from their own center of origin in East Asia. Most present-day aromatic accessions have inherited their cytoplasm along with 29-47% of their nuclear genome from the local Indian rice. We infer that the admixture occurred 4,000-2,400 years ago, soon after japonica rice reached the region. We identify aus as the original crop of the Indian subcontinent, indica and japonica as later arrivals, and aromatic a specific product of local agriculture. These results prompt a reappraisal of our understanding of the emergence and development of rice agriculture in the Indian subcontinent.

Kader *et al.* (2018) observed that BRRI dhan70 is a new aromatic, high yielding and extra-long slender grain containing transplanted *Aman* rice cultivar which is an improvement over existing premium quality rice BRRI dhan37. BRRI dhan70 has pleasingly passed in the proposed cultivar trial conducted in the farmers' field. As a result National Seed Board (NSB) approved this cultivar for commercial cultivation in the wet season (T. *Aman*) of Bangladesh in 2015. The important feature of BRRI dhan70 is the straw colored extra-long slender, higher elongation ability and aroma of the cooked rice. The growth duration of BRRI dhan70 is 130 days which is 10-15 days earlier growth duration than BRRI dhan37. Thousand grain weight of the cultivar is 20 gm and it has colored grain tip and pointed awn. The rice has 21.7% amylose content with 9.5% protein content. The special character of the cultivar is lodging tolerance. It has long, erect deep green flag leaf. BRRI dhan70 can produce 4.8-5.0 ha^{-1}yield with proper management which is approximately 1.0-1.35 tha^{-1}higher yield than BRRI dhan37. The exportable aromatic rice BRRI dhan70 is an excellent cultivar for cultivating in the wet (T. *Aman*) season and farmers can be benefited by the cultivation of BRRI dhan70.

Islam *et al.* (2018) reported that the pleasant scent of aromatic rice is making it more popular, with demand for aromatic rice expected to rise in future, cultivars of this have low yield potential. Genetic diversity and population structure of aromatic germplasm provide valuable information for yield improvement which has potential market value and farm profit. Here, we show diversity and population structure of 113 rice germplasm based on phenotypic and genotypic traits. Phenotypic traits showed that considerable variation existed across the germplasm. Based on Shannon–Weaver index, the most variable phenotypic trait was lemma-palea color. Detecting 140 alleles, 11 were unique and suitable as a germplasm diagnostic tool. Phylogenetic cluster analysis using genotypic traits classified germplasm into three major groups. Moreover, model-based population structure analysis divided all germplasm into three groups, confirmed by principal component and neighbors joining tree analyses. An analysis of molecular variance (AMOVA) and pair wise FST test showed significant differentiation among all population pairs, ranging from 0.023 to 0.068, suggesting that all three groups were differed.

Significant correlation coefficient was detected between phenotypic and genotypic traits which could be valuable to select further improvement of germplasm. Findings from this study have the potential for future use in aromatic rice molecular breeding programs.

Halder *et al*. (2018) conducted an experiment at the Agronomy Field of Patuakhali Science and Technology University, Dumki, Patuakhali from June to December, 2013 to find out the effect of cultivar and planting density on the yield and yield attributing characters of local aromatic rice. The experiment was laid out in a factorial randomized complete block design with three replications, which consisted of three local aromatic rice cultivars (Chinigura, Shakhorkhora and Kalizira) and four planting densities were viz. S1 (25 cm × 20 cm), S2 (20 cm × 20 cm), S3 (20 cm × 15 cm) and S4 (20 cm × 10 cm). The results revealed that the local aromatic rice var. Shakhorkhora cultivar produced the highest number of grains per panicle (131) and 1000-grain weight (13.8 g), consequently higher grain (2.63 t ha^{-1}), followed by Kalizira (2.56 t ha^{-1}) and straw yield (4.21 t ha^{-1}). One the other hand, higher number of tillers per hill (14.8), number of grains per panicle (140 nos.) were found in 20 cm × 20 cm spacing with higher grain yield.

Chowdhury *et al*. (2016) conducted an experiment with a view to finding out the effect of cultivar and level of nitrogen on the yield performance of fine aromatic rice. The experiment consisted of three cultivars *viz*. Kalizira, Binadhan-13 and BRRI dhan34. Cultivar significantly influenced the yield of aromatic rice. The highest grain yield (3.33 t ha^{-1}) was obtained from Binadhan-13 followed by BRRI dhan34 (3.16 t ha^{-1}) and the lowest grain yield was found in Kalizira (2.11 t ha^{-1}).

Dou *et al*. (2016) carried out an experiment with the objective to determine the effects of water regime/soil condition (continuous flooding, saturated, and aerobic), cultivar (‘Cocodrie’ and ‘Rondo’), and soil texture (clay and sandy loam) on rice grain yield, yield components and water productivity using a greenhouse trial. The spikelet number of Cocodrie was 29% greater than that of Rondo, indicating that rice cultivar had greater effect on spikelet number. Results indicated that cultivar selection is an important factors in deciding what water management option to practice.

Sarkar *et al*. (2016) conducted an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, to study the yield and quality of aromatic fine rice as affected by cultivar and nutrient management during the period from June to December 2013. The experiment comprised three aromatic fine rice cultivars viz. BRRI dhan34, BRRI dhan37 and BRRI dhan38, and eight nutrient managements viz. control (no manures and fertilizers), recommended dose of inorganic fertilizers, cow-dung at 10 t ha^{-1}, poultry manure at 5 t ha^{-1}, 50% of recommended dose of inorganic fertilizers + 50% cow-dung, 50% of recommended dose of inorganic fertilizers + 50% poultry manure, 75% of recommended dose of inorganic fertilizers + 50% cow-dung and 75% of recommended dose of inorganic fertilizers + 50% poultry manure. The experiment was laid out in a randomized complete block design with three replications. 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. The highest grain protein content (8.17%) was found in BRRI dhan34 whereas the highest aroma was found in BRRI dhan37 and BRRI dhan38. The highest number of effective tillers $hill^{-1}$ (11.59), number of grains $panicle^{-1}$ (157.6), panicle length (24.31 cm) and grain yield (3.97 t ha^{-1}) were recorded in the nutrient management of 75% recommended dose of inorganic fertilizers + 50% cowdung (5 t ha^{-1}). The treatment control (no manures and fertilizers) gave the lowest values for these parameters. The highest grain yield (4.18 t ha^{-1}) was found in BRRI dhan34 combined with 75% recommended dose of inorganic fertilizers + 50% cow-dung, which was statistically identical to BRRI dhan34 combined with 75% of recommended dose of inorganic fertilizers + 50% poultry manure and the lowest grain yield

(2.7 t ha^{-1}) was found in BRRI dhan37 in control (no manures and fertilizers). The highest grain protein content (10.9 %) was obtained in the interaction of BRRI dhan34 with recommended dose of inorganic fertilizers which was as good as that of BRRI dhan38 and 75% of recommended dose of inorganic fertilizers + 50% poultry manure. The highest aroma was found in BRRI dhan38 combined with 75% recommended dose of inorganic fertilizers + 50% cow-dung.

Yield test of 41 entries, 32 new hybrids, 8 male parents restore lines and 1 inbred cultivar, was conducted by Huang and Yan (2016) on the farm of University of Arkansas at Pine Bluff (UAPB). Results showed that the yields of 7 hybrids were 25.7%-30.7% higher than check Francis. Hybrid 28s /BP23R had the highest yield, 10846.6 kg/hectare and over check by 30.7%. The yield of hybrid 28s/PB-24, was 10628.9 kg/hectare and over check by 28.1%. The yields of hybrid 28s/PB-22 and 33A/PB24 were 10549.8 and 10539.8 kg/hectare and over check by 27.1% and 27.0%, respectively.

A study was conducted by Mandira *et al.* (2016) in South Tripura district of Tripura for three consecutive kharif seasons to evaluate the performance of rice cultivar gomati at farmers field under rainfed conditions. The gomati cultivar of rice was found superior over farmers' existing practices with local cultivars. Rice cultivar gomati with improved production technologies followed in FLDs, increased mean grain yield by 41.62% over farmers' existing practices with only Rs. 1817 ha^{-1} extra expenditure on inputs.

Islam *et al*. (2015) carried an experiment at Mymensingh, Bangladesh with four aromatic fine rice viz. 'Chinisagar', 'Chiniatab', 'Basmati' and 'AwnlessMinicat' with three different date of transplanting 20 January, 5 February and 20 February. Among the aromatic fine rice 'awnlessMinicat' gave the highest yield (3.10 t ha^{-1}) but that was at parwith those of Basmati (1.77 t ha^{-1}) Netam*et al.* (2008) reported that cultivar 'Dubraj' registered higher grain yield (33.33 q ha^{-1}) and straw yield (74.10 q ha^{-1}) than

‘Badshahbhog’ but net return (15226 ha^{-1}) because ‘Badshahbhog’ received higher price than the ‘Dubraj’ due to short slender fineness and higher scent in nature.

Saha *et al*. 2015) conducted a study to evaluate the extent of variability among the small grain aromatic (SGA) rice (*Oryza sativa* L.) genotypes for yield and yield components. Twenty four popular SGA rice genotypes were evaluated for yield and yield contributing characters in BRAC Agricultural Research and Development Centre, Gazipur, Bangladesh. BRRI dhan34 was used as check cultivar. Highest grain yield per plant was observed in Chinikanai-1, which was followed by Kalijira PL-9, Kalijira PL3 and Badshabhog. Chinikanai-1 had the highest number of grains per panicle. Correlation analysis revealed that the number of panicles per plant (r = 0.646) and number of grains per panicle (r = 0.525) had the positive contribution to grain yield. Based on sensory test, it was found that 18 genotypes were scented and six were lightly scented. After evaluation of yield components, four genotypes namely Chinikanai-1, Kalijira PL-9, Kalijira PL-3 and Badshabhog were selected as outstanding genotypes, which can be used as potential breeding materials for sub-tropical environment of Bangladesh.

Yuni Widyastuti *et al.* (2015) conducted a study with twenty-four experimental hybrid rice cultivars. The results showed that grains yields were affected by locations, seasons, and genotypes. The genotypes × locations × seasons interaction effect was significant; therefore, the best hybrid was different for each location and season. A7/PK36 hybrid has the best performance in Batang during the dry season, while A7/PK40 and A7/PK32 are the best hybrids in the rainy season. In Sukamandi, nine hybrids were identified as better yielder than that of the check cultivar in the dry season, but not so in the rainy season.

Bony *et al*. (2015) conducted an experiment to evaluate the performance of local aromatic rice cultivars viz. Kalijira, Khaskani, Kachra, Raniselute, Morichsail and Badshabhog. The rice cultivars varied considerably in terms of crop growth characteristics as well as yield and yield contributing characters. The highest plant height (116.00 cm) was found in the cultivar Morichsail and the lowest in the cultivar Khaskani. Number of filled grains panicle-1 was found highest (100) with the cultivar Khaskani and the lowest was recorded in the cultivar Raniselute. Raniselute produced the highest 1000-grain weight (32.09 g) and the lowest (13.32 g) was recorded from the cultivar Kalijira. The cultivar Morichsail produced the highest grain yield (2.53 t ha^{-1}) followed by Kachra (2.41 t ha^{-1}), Raniselute (2.13 t ha^{-1}) and Badshabhog (2.09 t ha-1) and the lowest grain yield (1.80 t ha^{-1}) was obtained from Kalijira. The results of various characters studied in the experiments suggested that some good characters exist in local aromatic rice cultivars which can be exploited through breeding.

A study was design by Wagan *et al.* (2015) 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.

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

Samwal *et al.* (2014) conducted a study to assess the variation in agro-morphological and grain quality traits among traditional and Basmati type aromatic/quality rice and to investigate plausible relationships between the traits. A set of 12 cultivars, comprising ten traditional and two Basmati type, were studied. Highest variation was observed for grains/panicle followed by grain yield/plant. Cluster analysis grouped all traditional cultivars except ‘Tulaipanji’, which clustered with Basmati cultivars. Selection for long grain with slender shape will simultaneously increase amylose content and alkali spreading value or gelatinization temperature. Aroma score categorized rice cultivars as mild and strongly aromatic, which also was similar to aroma genotyping with gene based marker for *betaine aldehyde dehydrogenase 2* (*BADH2*). Sequence analysis of *BADH2* revealed that all strongly aromatic and two mild aromatic rice cultivars contain characteristic 8-bp deletion and three SNPs in exon 7 of *BADH2* gene. Multiple alignment of the DNA sequences revealed the addition of AT in ‘Gobindabhog’ and a T/A SNP in ‘Gobindabhog’ and ‘Tulsibhog’ exon 8.

Samal *et al.* (2014) was found that the genus *Oryza* has 21 species of which *Oryza sativa* and *Oryzaglaberrima* are the only cultivated species derived respectively from their perennial wild progenitors *Oryzarufipogan* and *Oryzalongistaminata*. The diversification of *O. sativa* does not confined to these three sub-species only but develops into many more varietal groups through selection under diverse agro-climatic conditions, cultural practices and quality preferences. The present study implies that the divergences of 78 genotypes of aromatic rice including International check cultivars, traditional Basumati and evolved Basumati on the basis of morphological, biochemical and genetical variations. The plant height among the genotypes ranged from 85.91cm to 159.67 cm whereas the panicles/plant ranged from 6.06 to 16.22 with the mean value of 9.56. The grain length is highest in all evolved Basmati genotypes followed by indigenous aromatic rice. The lowest grain length was found in ‘Jala’, ‘Magura’, ‘Ratnasundari’ and highest in ‘Kusumabhog’ and ‘Gatia’. The lowest grain breadth was recorded in eight genotypes. The alkali spreading value (ASV) varied from 2.0 (IR-64) to 6.17 (Jalaka) indicating very wide variability. The present investigation also highlighted the inter- and intrapopulation diversity among 78 rice genotypes with a view to assess the potentials and consequences of on farm management of rice landraces in traditional farming.

Hasan *et al.* (2014) carried out an experiment to study the performance of two *Aman* rice cultivars (BRRI dhan31 and BRRI dhan41) under different planting methods (line sowing with sprouted seeds by drum seeder, haphazard transplanting and transplanting in line). The highest no. of total tillers m^{-2} (421.12), effective tillers m^{-2} (410.65) and grain yield (5.08 t $ha^{-}1$) were recorded due to effect of the interaction of line sowing method with sprouted seeds by drum seeder and the cultivar BRRI dhan41.

Sarkar and Sarkar (2014) conducted an experiment to study the yield and quality of aromatic fine rice as affected by cultivar and nutrient management during the period from June to December 2013. The experiment comprised three aromatic fine rice cultivars viz. BRRI dhan34, BRRI dhan37 and BRRI dhan38, and eight nutrient managements viz. control (no manures and fertilizers), recommended dose of inorganic fertilizers, cowdung at 10 t ha^{-1}, poultry manure at 5 t ha^{-1}, 50% of recommended dose of inorganic fertilizers + 50% cowdung, 50% of recommended dose of inorganic fertilizers + 50% poultry manure, 75% of recommended dose of inorganic fertilizers + 50% cowdung and 75% of recommended dose of inorganic fertilizers + 50% poultry manure. The experiment was laid out in a randomized complete block design with three replications. The tallest plant (142.7 cm), the highest number of effective tillers hill (10.02), number of grains panicle (152.3), panicle length (22.71cm), 1000-grain weight (15.55g) and grain yield (3.71 t ha^{-1}) were recorded in BRRI dhan34.

An experiment was conducted by Hosain *et al.* (2014) at the research farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during *Aus* season to observe the effect of transplanting dates on the yield and yield attributes of exotic hybrid rice cultivars. The experiment comprised of three rice cultivars (two hybrids-Heera2, Aloron and one inbred- BRRI dhan48). Hybrid cultivars Heera2 (3.03 t ha^{-1}) and Aloron (2.77 t ha^{-1}) gave the higher spikelet sterility. BRRI dhan48 produced the highest grain yield (3.51 t ha^{-1}).

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

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

Garba *et al.* (2013) studied on the effects of cultivar, seeding rate and row spacing on growth and yield of rice. Cultivar Ex-China produced significantly ($P<0.05$) higher numbers of tillers $plant^{-1}$ and spikes $hill^{-1}$. However, NERICA-1 produced significantly ($P<0.05$) higher number of spikelets $spike^{-1}$, seeds $spike^{-1}$, weight of seed $spike^{-1}$, weight of seed $hill^{-1}$, 1000 grain weight and yield in kg ha^{-1} than Ex-China.

Das *et al*. (2012) suggested that the aromatic rice is one of the most widely accepted rice due its pleasant aroma. Traditionally, many cultivars of aromatic rice are grown by the farmers of Assam maintaining a diverse gene pool. In the present study, morphological variation was studied in 22 aromatic rice landraces using qualitative and quantitative traits. KetekiJoha is very popular indigenous aromatic rice grown in a small pocket of Assam for its high yield. Though Kola KunkuniJoha is relatively smaller grain size and low yield but have high demand due to its high aroma as compared to other landraces. Significant positive correlations was occurred at 0.05 level between kernel length and seed weight with seed width (r = 0.6734*) and (0.5881*) as well as seed weight with kernel width (r = 0.5433*). The correlation between seed width and kernel width (0.9663**) showed significantly positive relationship which shown at 0.01 level. Characterization of aromatic rice landraces of Assam would be a boon for the breeders for designing further rice improvement programme.

An experiment was carried out by Alam *et al.* (2012) at Agronomy Field Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi during the kharif season to study the effect of cultivar, spacing and number of seedlings hill^{-1} on the yield potentials of transplant *Aman* rice. The experiment consisted of three high yielding cultivars viz. BRRI dhan32, BRRI dhan33 and BR11, four levels of spacing and four levels of number of seedlings hill^{-1} viz. 2 seedlings hill^{-1}, 3 seedlings hill^{-1}, 4 seedlings hill^{-1} and 5 seedlings hill^{-1}. Cultivar had significant effects on almost all the yield component characters and yield. Cultivar BR11 produced the highest grain yield (5.92 t ha^{-1}).

Yao *et al.* (2012) found insignificant difference in grain yield between the cv. AWD and CF. On average, YLY6 produced 21.5% higher yield than HY3 under AWD conditions. Like grain yield, YLY6 showed consistently higher water productivity and physiological nitrogen use efficiency than HY3. Both total dry weight and harvest index contributed to higher grain yield of YLY6.

Sritharan and Vijayalakshmi (2012) evaluated the physiological traits and yield potential of six rice cultivars *viz.*, PMK 3, ASD 16, MDU 3, MDU 5, CO 47 and RM 96019. The plant height, total dry matter production and the growth attributes like leaf area index, crop growth rate and R:S ratio were found to be higher in the rice cultivar PMK 3 that showed significant correlation with yield. Yield and yield components like number of productive tillers, fertility co-efficient, panicle harvest index, grain weight and harvest index were found to be higher in PMK 3.

Panwar *et al.* (2012) studied to evaluate the performance of rice cultivars. Growth parameters *viz.* plant height (cm), No. of tillers m , leaf area index and dry matter accumulation (g) was highest in JGL-3844 over rest of cultivars. The effective tillers m^{-2} (331.6), panicle length (25.63), grains $panicle^{-1}$ (68.23), sterility percent (12.1%), grain yield (60.9 q ha^{-1}) and straw yield (92.58 q ha^{-1}) yield were also highest in cultivar JGL-3844.

Oka *et al.* (2012) assessed the agronomic characteristics of 15 selected indigenous and newly introduced hybrid rice cultivars in Ebonyi State, Nigeria. Significant variation ($P<0.05$) was detected among the 20 rice cultivars for all the traits evaluated. The results showed that plant height ranged between 144.01 cm in “Mass (I)” and 76.00 cm in “Chinyeugo”. Cv. “E4197” had the highest value of 38±0.02 cm for panicle length and “Chinyereugo” had the highest value of 6.3g ± 0.03 for panicle weight. Leaf area showed the highest value of $63.8cm^2 \pm 0.01$ in “Mass (I)”. Cv. “Co-operative” had high number of seeds $panicle^{-1}$ (139 ± 0.19). “Chinyereugo” had the highest value of 25.9g ±1.4 for 1000-grains weight. The grain of “E4314” was the longest (8.00 mm ± 0.89) of the cultivars studied.

Mannan *et al.* (2012) reported that the Badshabhog and Kalijira showed taller plants and Chinigura was shorter while Chinigura produced the greatest tillers at early, mid and at later growth stages and the lower tillers was observed in Badshabhog. Chinigura produced the highest amount of DM and while least amount of DM was observed in Kataribhog. The Chinigura produced significantly the highest panicles but it was statistically identical with Kalijira, while, Kataribhog exhibited lower number of panicles but number of grains panicle^{-1} was found more in Badshabhog. The heaviest grain was found in Kataribhog while the light grain was observed in Badshabhog. The grain yield of Chinigura and Kalijira was almost identical. Lower grain yield was found in Kataribhog which may be attributed to the lower number of panicles and grain panicle^{-1}.

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

Baset Mia and Shamsuddin (2011) reported that the aromatic rice cultivars showed tallest plant stature, profuse tillers hill^{-1}, panicle hill^{-1} and larger panicle but smaller grain, higher grain yield, lowest straw yield and harvest index compare modern rice. Modern rice cultivars generally had higher TDM, LAI, LAR, CGR, RGR whereas aromatic cultivars resulted in higher NAR. The highest grain yield of modern rice cultivars was due to the higher harvest index. Poor yield in aromatic rice cultivars was due to lower translocation of assimilates.

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

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

Anwar and Begum (2010) reported that time of tiller separation of rice significantly influenced plant height, total number of tiller hill^{-1}, number of bearing tillers and panicle length but grain and straw yields were unaffected. Therefore, Sonarbangla-1 appeared to be tolerant to tiller separation and separation should be done between 20 to 40 DAT without hampering grain yield.

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

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 cultivar 25 to 35 days old clonal tiller showed superior performance. Hybrid cultivar transplanted with 25 days old clonal tiller gave significantly higher grain yield.

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

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

Jeng *et al.* (2009) found that the cultivar Tainung 67 had greater yield (7.2 mg ha^{-1}) than SA419 (6.2 mg ha^{-1}). The greater yield of SA419 than Tainung 67 in autumn was due to its higher net assimilation rate and better dry matter partitioning during grain filling. Significant panicle branch effects on the distribution pattern of grain weight were also found between Tainung 67 and SA419 with greater variation for the former than the latter.

Hossain *et al*. (2008) conducted the study to observe the yield and quality of ten popular aromatic rice cultivars of Bangladesh. The cultivars 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 cultivars. 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 cultivars had bold type shape. Grain protein content ranged from 6.6-7.0 % in brown rice. The cooking time of tested cultivars varied from 12 to 16 minutes. Aroma intensity differed due to cultivar. Kalizera, Badshabhog, Chiniatab contained high level of aroma while, rests of the cultivars had moderate type aroma.

Masum *et al.* (2008) reported that that Nizershail produced the taller plant height than BRRI dhan44 at different DAT. Total tillers hill^{-1} was significantly influenced by cultivar at all stages. At 30 and 60 DAT, Nizershail had significant by higher amount of DM (35.46% higher at 30 DAT and 18.01% higher at 60 DAT) than BRRI dhan44 but at harvest BRRI dhan44 had significantly higher amount of DM (39.85 g $hill^{-1}$) that was 18.42% higher than Nizershail. BRRI dhan44 produced higher (4.85 t ha^{-1}) grain yield than Nizershail (2.46 t ha^{-1}). Nizershail produced higher (7. 22 t ha^{-1}) straw yield compared to BRRI dhan44 (6.34 t ha^{-1}).

Kamal and Anwar (2007) conducted an experiment to determine the effect of cultivar and planting method on the yield of boro rice. Four cultivars viz., BINADHAN-5, BINADHAN-6, BRRI dhan28 and BRRI dhan29, and three planting methods viz., transplanting method, drum seeding and line sowing were included as experimental treatments. The experiment was laid out in a randomized complete block design with three replications. BINADHAN-5 produced the highest grain yield (4.61 t ha^{-1}) which was the consequence of highest number of effective tillers hill-1 and highest number of grains $panicle^{-1}$. Among the planning methods, transplanting method produced the maximum grain yield (4.59 t ha^{-1}) because of highest number of grains $panicle^{-1}$. In case of effect of interaction of BINADHAN-5 and transplanting method produced the highest grain (5.20 t ha^{-1}) yield. It may be concluded that the cultivar BINADHAN-5 may be grown following transplanting method for higher grain yield in boro season.

Tabien and Samonte (2007) observed that several elite lines at the multi-state trials had high yield potential relative to the check cultivars and these can be released as new cultivars after series of yield trials. With improved yield, the new cultivars 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.

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%.

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

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

Wang *et al.* (2006) studied the effects of plant density and row spacing (equal row spacing and one seedling hill^{-1}, equal row spacing and 3 seedlings hill^{-1}, wide-narrow row spacing and one seedling hill^{-1}, and wide-narrow row spacing and 3 seedlings hill^{-1} on the yield and yield components of hybrids and conventional cultivars of rice. Compared with conventional cultivars, the hybrids had larger panicles, highest total grains, heavier seeds, resulting in an average yield increase of 7.27%.

Chowdhury *et al*. (2005) conducted an experiment to study their effect on the yield and yield components of rice cultivars BR23 and Pajam with 2, 4 and 6 seedlings hill^{-1} during the *Aman* season. They reported that the cv. BR23 showed superior performance over Pajam in respect of yield and yield contributing characters i.e. number of productive tillers hill^{-1}, length of panicle, l000-grain weight, grain yield and straw yield. On the other hand, the cultivar Pajam produced significantly the tallest plant, total number of grains panicle^{-1}, number of filled grains panicle^{-1} and number of unfilled grains panicle^{-1}.

Myung (2005) worked with four different panicle types of rice cultivars and observed that the primary rachis branches (PRBs) panicle^{-1} and grains were more on Sindongjinbyeo and Iksan467 cultivars, but secondary rachis branches

(SRBs) were fewer than in Dongjin1 and Saegyehwa cultivars.

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Murthy *et al.* (2004) conducted an experiment with six cultivars of rice genotypes Mangala, Madhu, J-13, Sattari, CR 666-16 and Mukti and observed that Mukti (5268 kg ha^{-1}) out yielded the other genotypes and recorded the maximum number of filled grains and had lower spikelet sterility (25.85%) compared to the others.

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.

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

Obulamma *et al.* (2004) recorded hybrid APHR 2 significantly higher grain yield than hybrid DRRH 1. The increased grain yield was due to increase in number of panicles m^{-2} and number of filled grain panicle^{-1} in hybrid APHR 2 than hybrid DRRH 1.

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}).

Guilani *et al.* (2003) carried out an experiment on crop yield and yield components of rice cultivars (Anboori, Champa and LD183) in Khusestan, Iran. They observed that grain number $panicle^{-1}$ was not significantly different among cultivars. The highest grain number $panicle^{-1}$ was obtained with Anboori. Grain fertility percentages were different among cultivars. Among cultivars, LD183 had the highest grain weight.

Rahman *et al.* (2002) carried out an experiment with 4 cultivars 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.

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.

Ahmed *et al*. (1997) conducted an experiment to compare the grain yield and yield components of seven modern rice cultivars (BR4, BR5, BR10, BR11, BR22, BR23, and BR25) and a local improved cultivar, Nizersail. The fertilizer dose was 60-60-40 kg ha^{-1} of N, P_2O_5 and K_2O, respectively for all the cultivars and found that percent filled grain was the highest in Nizersail followed by BR25 and the lowest in BR11 and BR23.

Anonymous (1994) studied the performance of BR14, BR5, Pajam, and Tulsimala and reported that Tulsimala produced the highest number of filled grains $panicle^{-1}$ and BR14 the lowest.

Anonymous (1993) evaluated the performance of four cultivars IRATOM 24, BR14, BINA13 and BINA19. They found that cultivars differed significantly on panicle length and sterile spikelets $panicle^{-1}$. It was also reported that cultivars BINA13 and BINA19 each had better morphological characters like more grains $panicle^{-1}$ compared to their better parents which contributed to yield improvement in hybrid lines of rice.

Anonymous (1991) reported that the filled grains panicle^{-1} of different modern cultivars was 95-100 in BR3, 125 in BR4 , 120-130 in BR22 and 110-120 in BR23 when they was cultivated in the *Aman* season. Idris and Matin (1990) also observed that panicle length differed among the six rice cultivars and it was longer in IR20 than in indigenous high yielding cultivars.

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out at the experimental field under the Department of Agricultural Botany of Sher-e-Bangla Agricultural University, Dhaka during the period June to November 2019 to study the evaluation of ten aromatic rice cultivars in terms of morphological traits and yield in *Aman* rice. Details of different materials used and methodologies followed to conduct the studies are presented in this chapter.

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.

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 Kharif season (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.

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.

Treatments

Single factor experiment was considered regarding 10 aromatic rice cultivars were used as experimental treatments which are as follows:

1. V_1 = Chinigura
2. V_2 = Begunbichi
3. V_3 = Madhumala
4. V_4 = Katarivog-2
5. V_5 = Kalijira
6. V_6 = Badshavog
7. V_7 = Katarivog-1
8. V_8 = Dolavog
9. V_9 = Sadasone
10. V_{10} = Khaisone

Plant materials and collection of seeds

Ten aromatic rice cultivars *viz*. Chinigura, Begunbichi, Madhumala, Katarivog-2, Kalijira, Badshavog, Katarivog-1, Dolavog, Sadasone and Khaisone were used as plant materials for the present study. The seeds of these cultivars were collected from BRRI, Joydebpur, Gazipur, Bangladesh and personal collection.

Seed sprouting

Healthy seeds were stored 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.

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 7 June, 2019 in order to transplant the seedlings in the main field.

Preparation of experimental land

The plot selected for the experiment was opened in the last week of June 2019 with a 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.

Fertilizer application

The following doses of fertilizer were applied for cultivation of crop as recommended by BRRI, 2016.

Fertilizer	Recommended doses (kg ha^{-1})
Urea	150
TSP	100
MoP	100
Zinc sulphate	10
Gypsum	60
Borax	10

The fertilizers N, P, K, S, Zn and B in the form of urea, TSP, MP, gypsum, zinc sulphate and borax, respectively were applied. The entire amount of TSP, MP, gypsum, zinc sulphate and borax were applied during the final preparation of land. Mixture of cow-dung and compost was applied at the rate of 10 ton ha^{-1} during 15 days before transplanting. Urea was applied in three equal installments at seedling establishment, tillering and before panicle initiation.

Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications (block). Each block was first divided into 12 sub plots where cultivars of rice were assigned. Thus the total number of unit plots was 12×3=36. The size of the unit plot was 3m × 2m. The distance maintained between the row was 0.5m and between column was 0.5m. The treatments (cultivars) were randomly assigned to the plots within each block.

Uprooting of seedlings

The nursery bed was made wet by application of water one day before uprooting the seedlings. The seedlings were uprooted on 2 July, 2019 without causing much mechanical injury to the roots.

Transplanting of seedlings in the field

The seedlings were transplanted in the main field on 3rd July, 2019 with a spacing 15 cm from hill to hill and 20 cm from row to row.

Intercultural operations

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the rice seedlings.

Irrigation and drainage

Flood irrigation was given to maintain a constant level of standing water upto 3 cm at the early stages to enhance tillering and 4-5 cm in the later stage to discourage late tillering. The field was finally dried out at 15 days before harvesting.

Gap filling

Gap filling was done for all of the plots at 10 days after transplanting (DAT) by planting same aged seedlings.

Weeding

The crop was infested with some common weeds, which were controlled by uprooting and remove them three times from the field during the period of experiment. Weeding was done after 16, 34 and 54 days of transplanting.

Plant protection

There were some incidence of insects specially stem borer which was controlled by Furadan 5G @ 10 kg ha^{-1} at 30 days after transplanting. Brown spot of rice was controlled by spraying tilth.

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}.

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.

Recording of data

The following data were recorded during the study period:

Growth parameters

1. Plant height
2. Number of leaves hill^{-1}
3. Number of tillers hill^{-1}

4. Leaf area index
5. Length of flag leaf
6. Breadth of flag leaf

Yield contributing parameters

1. Total number of tillers hill^{-1}
2. Number of non-effective tillers hill^{-1}
3. Number of effective tillers hill^{-1}
4. Panicle length
5. Number of total grains panicle^{-1}
6. Number of filled grains panicle^{-1}
7. Number of unfilled grains panicle^{-1}
8. Sterility percentage

Yield parameters

1. 1000 grain weight
2. Grain yield
3. Straw yield
4. Biological yield
5. Harvest index (%)

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 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 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.

Leaf area

Leaf area was measured by the following formula

LA = leaf length × leaf breadth × correction value 0.76

Flag leaf length

Flag leaf length was measured with a meter scale from 4 pre-selected plants from the inner rows of each plot.

Flag leaf breadth

Flag leaf breadth was measured with a meter scale from 4 pre-selected plants 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 total 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 grain panicle^{-1} was recorded.

Number of filled grains panicle^{-1}

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

Sterility percentage

At the time of harvesting, 10 panicles were harvested at maturity from five randomly selected plants in each plot and number of filled, unfilled and total grain was counted. Spikelets fertility percentage was then calculated as

$$\text{Sterility percentage} = \frac{\text{No. of unfilled grains panicle}^{-1}}{\text{Total no. of grains panicle}^{-1}} \times 100$$

Number of unfilled grains panicle^{-1}

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

Weight of 1000 grains

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.

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

Statistical analysis

Collected data from the experiment field were statistically analyzed to find out the significant difference among the treatment by using the MSTAT-C computer package program. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatments means was estimated by the Least Significant Difference Test (LSD) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to study the evaluation of ten aromatic rice cultivars in terms of morphological traits and yield in *Aman* rice. The results found from the study have been presented and discussed in this chapter through different tables, figures and appendices. The results have been presented and discussed and possible interpretation has been given under the following headings.

Growth parameters

Plant height

Plant height of different aromatic rice cultivars at different days after transplanting showed statistically significant variation (Fig. 1 and Appendix 5). It was observed that the highest plant height (55.61, 108.20, 142.40 and 161.40 cm at 30, 60, 90 DAT and at harvest, respectively) was found from the cultivar V_3 (Madhumala). At 30 DAT, it was significantly different from other cultivars. Similarly at 60 DAT and 90 DAT, it was significantly different from other cultivars. At harvest it was statistically identical with V_6 (Badshavog). On the other hand, the lowest plant height (41.81, 81.36, 115.30 and 136.00 cm at 30, 60, 90 DAT and at harvest, respectively) was found from the cultivar V_8 (Dolavog). At 30 DAT, it was statistically similar with V_2 (Begunbichi) and V_6 (Badshavog) but at 60 DAT, similar result was observed by V_9 (Shadasone) and V_{10} (Khaisone) while at 90 DAT, similar result was also found from V_6 (Badshavog), V_7 (Katarivog-1) and V_{10} (Khaisone). At harvest it showed statistically same result with V_7 (Katarivog-1). Similar result was also observed by Anwar and Begum (2010) and Chowdhury *et al*. (2005) who found that cultivar had significant effect on plant height of rice.

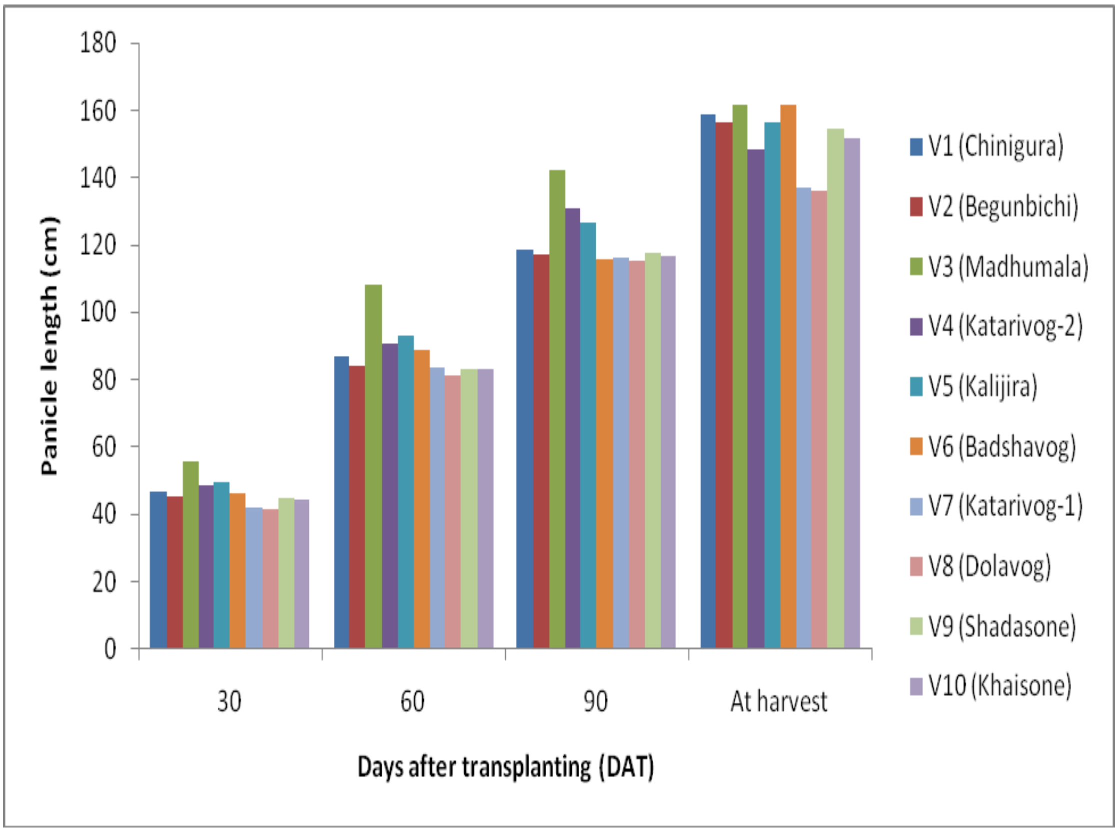

Fig. 1. Plant height of 10 aromatic rice as influenced by different cultivars in *Aman* season

Number of leaves hill^{-1}

Significant variation was recorded on number of leaves hill^{-1} of rice cultivars at different growth stages (Table 1 and Appendix 6). It was evident that at 30 DAT, the highest number of leaves hill^{-1} (27.80) was found from the cultivar V_6 (Badshavog) which was significantly different from others whereas the lowest (23.65) was found from V_8 (Dolavog) which was statistically similar with V_5 (Kalijira) and V_{10} (Khaisone). At 60 DAT, V_6 (Badshavog) also showed highest number of leaves hill^{-1} (68.50) which was significantly different from others but the lowest number of leaves hill^{-1} (50.43) was recorded from V_8 (Dolavog). At 90 DAT, the highest number of leaves hill^{-1} (66.18) observed from V_6 (Badshavog) which was significantly different from others whereas the lowest (43.30) was found from V_8 (Dolavog). At harvest, the highest number of leaves hill^{-1} (65.86) was found from the cultivar V_6 (Badshavog) which was statistically similar with V_5 (Kalijira) and V_{10} (Khaisone). On the other hand, the lowest number of leaves hill^{-1} (43.45) was found from the cultivar V_8 (Dolavog) which was significantly different from others.

Table 1. Number of leaves hill^{-1} of 10 aromatic rice as influenced by different cultivars in *Aman* season

Treatments	Number of leaves hill^{-1}			
	30 DAT	**60 DAT**	**90 DAT**	**At harvest**
V_1 (Chinigura)	24.82 cd	54.88 e	64.90 b	65.55 a
V_2 (Begunbichi)	25.50 bc	58.00 d	56.29 d	57.30 d
V_3 (Madhumala)	25.18 cd	53.14 f	54.50 e	54.60 e
V_4 (Katarivog-2)	25.04 cd	61.11 c	59.25 c	59.29 c
V_5 (Kalijira)	24.44 de	53.57 ef	64.40 b	65.96 a
V_6 (Badshavog)	27.80 a	68.50 a	66.18 a	65.86 a
V_7 (Katarivog-1)	26.40 b	65.13 b	63.49 b	63.69 b
V_8 (Dolavog)	23.65 e	50.43 g	43.30 f	43.45 f
V_9 (Shadasone)	25.64 bc	61.85 c	60.10 c	59.74 c
V_{10} (Khaisone)	23.80 e	61.20 c	64.51 b	64.23 ab
$LSD_{0.05}$	0.95	1.34	1.37	1.67
CV(%)	5.88	7.29	6.14	8.37

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

Number of tillers hill^{-1}

Recorded data on number of tillers hill^{-1} of rice cultivars at different growth stages showed significant variation (Table 2 and Appendix 7). Results revealed that at 30 DAT the highest number of tillers hill^{-1} (8.72) was found from the cultivar V_5 (Kalijira) which was statistically similar with V6 (Badshavog) and V7 (Katarivog-1) whereas lowest number of tillers hill^{-1} (6.80) was found from the cultivar V_3 (Madhumala).

Similarly, at 60 DAT, highest number of tillers hill^{-1} (17.70) was recorded fsrom V_5 (Kalijira) which was significantly different from others whereas the lowest (10.50) was found from the cultivar V_3 (Madhumala). At 90 DAT, highest number of tillers hill^{-1} (24.56) was found from V_5 (Kalijira) which was significantly different from others whereas the lowest (16.00) was found from V_3 (Madhumala) which was statistically identical with V_4 (Katarivog-2). At harvest the highest number of tillers hill^{-1} (25.06) was found from the cultivar V_5 (Kalijira) which was statistically similar with V_6 (Badshavog) whereas the lowest number of tillers hill^{-1} (16.50) was found from the cultivar V_3 (Madhumala) which was significantly different from others. Similar result was also observed by Chowdhury *et al*. (2005). Hasan *et al.* (2014) also found similar result with the present study who reported that cultivar had significant influence on number of total tillers m^{-2}.

Table 2. Number of tillers hill^{-1} of 10 aromatic rice as influenced by different cultivars in *Aman* season

Treatments	Number of tillers hill^{-1}			
	30 DAT	60 DAT	90 DAT	At harvest
V_1 (Chinigura)	7.16 de	14.02 de	18.88 e	20.42 d
V_2 (Begunbichi)	7.00 de	13.70 e	20.60 d	22.10 c
V_3 (Madhumala)	6.80 e	10.50 f	16.00 g	16.50 g
V_4 (Katarivog-2)	7.58 c	14.49 c	15.27 g	17.77 f
V_5 (Kalijira)	8.72 a	17.70 a	24.56 a	25.06 a
V_6 (Badshavog)	8.63 a	13.88 de	22.85 b	24.25 ab
V_7 (Katarivog-1)	8.41 ab	13.61 e	17.68 f	19.12 e
V_8 (Dolavog)	8.16 b	16.00 b	19.80 de	21.48 c
V_9 (Shadasone)	7.00 de	13.80 e	21.75 c	23.25 b
V_{10} (Khaisone)	7.30 cd	14.25 cd	20.44 d	22.07 c
$LSD_{0.05}$	0.34	0.40	0.94	1.05
CV(%)	4.92	6.54	7.37	8.11

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

Leaf area index

Leaf area index of different aromatic rice cultivars showed statistically significant variation except at 30 DAT (Table 3 and Appendix 8). However, at 30 DAT, the highest leaf area index (1.12) was found from V_8 (Chiniatap-2) whereas the lowest (0.54) was found from the cultivar V_3 (Madhumala). At 60 and 90 DAT, the highest leaf area (5.38 and 5.19, respectively) was found from the cultivar V_8 (Chiniatap-2) which was statistically identical with V_5 (Kalijira) and V_6 (Badshavog) at all growth stages (at 30 and 90 DAT). The lowest leaf area at 60 and 90 DAT (3.28 and 3.25, respectively) was found from the cultivar V_3 (Madhumala) which was statistically identical with V_2 (Begunbichi), V_4 (Katarivog-2), V_7 (Katarivog-1) and V_{10} (Khaisone) at 90 DAT.

Table 3. Leaf area index of 10 aromatic rice as influenced by different cultivars in *Aman* season

Treatments	Leaf area index		
	30 DAT	60 DAT	90 DAT
V1 (Chinigura)	0.86	4.34 b	4.20 b
V2 (Begunbichi)	0.75	3.88 bc	3.66 c
V3 (Madhumala)	0.54	3.28 d	3.25 c
V4 (Katarivog-2)	0.65	3.65 cd	3.52 c
V5 (Kalijira)	1.05	5.28 a	5.12 a
V6 (Badshavog)	0.97	5.08 a	4.94 a
V7 (Katarivog-1)	0.70	3.70 cd	3.60 c
V8 (Dolavog)	1.12	5.38 a	5.19 a
V9 (Shadasone)	0.85	4.32 b	4.21 b
V10 (Khaisone)	0.75	3.70 cd	3.56 c
LSD0.05	NS	0.46	0.50
CV(%)	3.84	6.29	6.71

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

Length of flag leaf

Length of flag leaf of different aromatic rice cultivars showed statistically significant variation (Fig. 2 and Appendix 9). It was observed that the highest length of flag leaf (33.00 cm) was found from the cultivar V_5 (Kalijira) which was statistically similar with V_7 (Katarivog-1) and V_{10} (Khaisone) whereas the lowest length of flag leaf (29.50 cm) was found from the cultivar V_3 (Madhumala) which was significantly different from others.

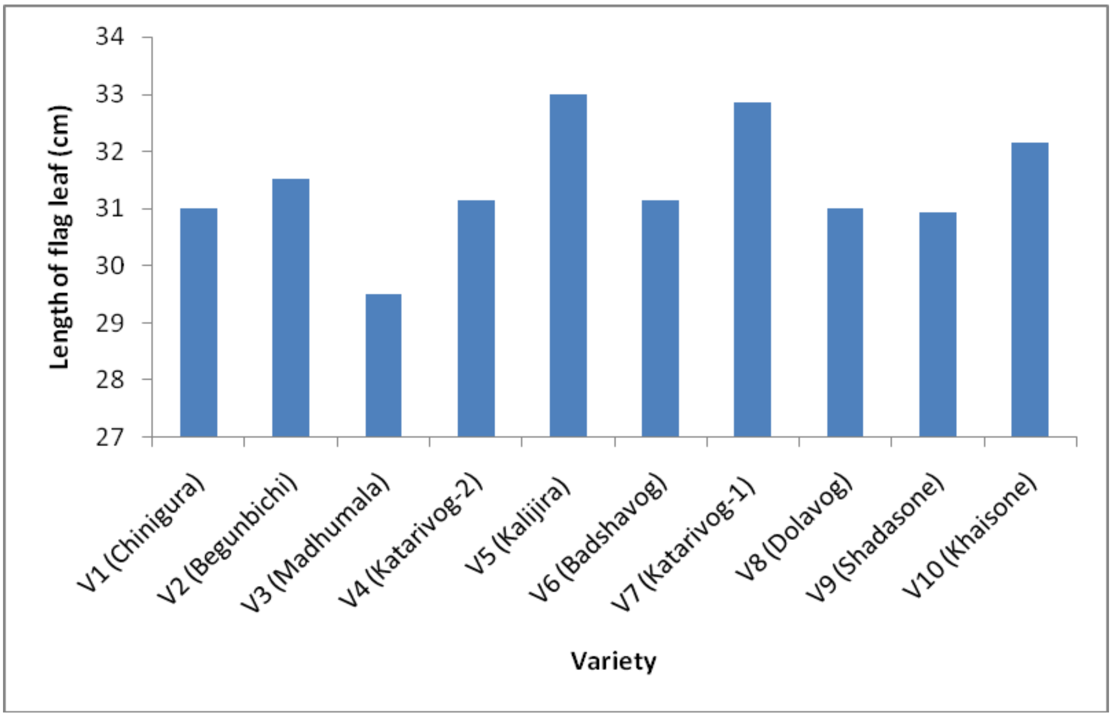

Fig. 2. Length of flag leaf (cm) as influenced by different aromatic rice cultivars in *Aman* season

Breadth of flag leaf

Significant variation was recorded on breadth of flag leaf of rice affected by varietal difference (Fig. 3 and Appendix 9). It was evident that the highest breadth of flag leaf (1.32 cm) was found from the cultivar V_7 (Katarivog-1) which was statistically similar with V_1 (Chinigura), V_2 (Begunbichi) and V_9 (Shadasone) whereas the lowest breadth of flag leaf (0.72 cm) was found from the cultivar V_3 (Madhumala) which was statistically identical with V_4 (Katarivog-2), V_6 (Badshavog) and V_9 (Shadasone).

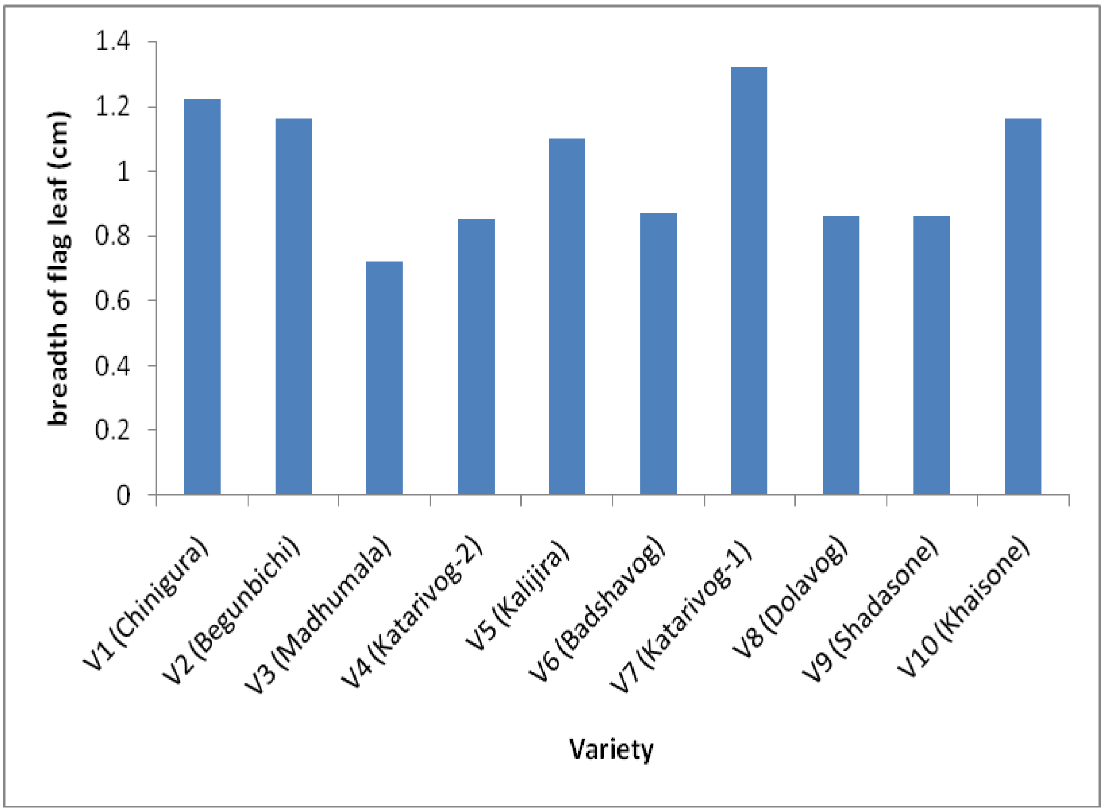

Fig. 3. Breadth of flag leaf as influenced by different aromatic rice cultivars in *Aman* season

Yield contributing parameters

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

Recorded data on number of non effective tillers hill^{-1} of rice showed significant difference due to varietal difference (Table 4 and Appendix 10). Results revealed that the highest number of non effective tillers hill^{-1} (7.67) was found from the cultivar V_1 (Chinigura) which was significantly different from others. The lowest number of non effective tillers hill^{-1} (3.83) was found from the cultivar V_3 (Madhumala) which was significantly different from others. Anwar and Begum (2010) and Hasan *et al.* (2014) also found similar result with the present study.

Number of effective tillers hill^{-1}

Number of effective tillers hill^{-1} of different aromatic rice cultivars showed statistically significant variation (Table 4 and Appendix 10). It was observed that the highest number of effective tillers hill^{-1} (18.24) was found from the cultivar V_5 (Kalijira) which was statistically similar with V_6 (Badshavog). The lowest number of effective tillers hill^{-1} (12.67) was found from the cultivar V_3 (Madhumala) which was statistically identical with V_1 (Chinigura). Similar result was also observed by Hasan *et al.* (2014) and Anwar and Begum (2010).

Table 4. Number of tillers hill^{-1} (effective and non-effective) of 10 aromatic rice as influenced by different cultivars in *Aman* season

Treatment	Yield	
	Number of non effective tillers hill^{-1}	Number of effective tillers hill^{-1}
V_1 (Chinigura)	7.67 a	12.75 e
V_2 (Begunbichi)	5.90 d	16.20 c
V_3 (Madhumala)	3.83 g	12.67 e
V_4 (Katarivog-2)	4.44 f	13.33 de
V_5 (Kalijira)	6.82 b	18.24 a
V_6 (Badshavog)	6.92 b	17.33 ab
V_7 (Katarivog-1)	5.22 e	13.90 d
V_8 (Dolavog)	5.81 d	15.67 c
V_9 (Shadasone)	6.75 b	16.50 bc
V_{10} (Khaisone)	6.27 c	15.80 c
$LSD_{0.05}$	0.16	0.96
CV(%)	5.72	8.33

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

Length of panicle

Significant variation was recorded on panicle length of rice affected by varietal difference (Fig. 4 and Appendix 11). It was evident that the highest panicle length (30.12 cm) was found from the cultivar V_5 (Kalijira) which was significantly different from others followed by V_2 (Begunbichi), V_4 (Katarivog-2) and V_7 (Katarivog-1). The lowest panicle length (21.00 cm) was found from the cultivar V_8 (Dolavog) which was significantly different from others. Anwar and Begum (2010) and Chowdhury *et al*. (2005) also found similar result with the present study.

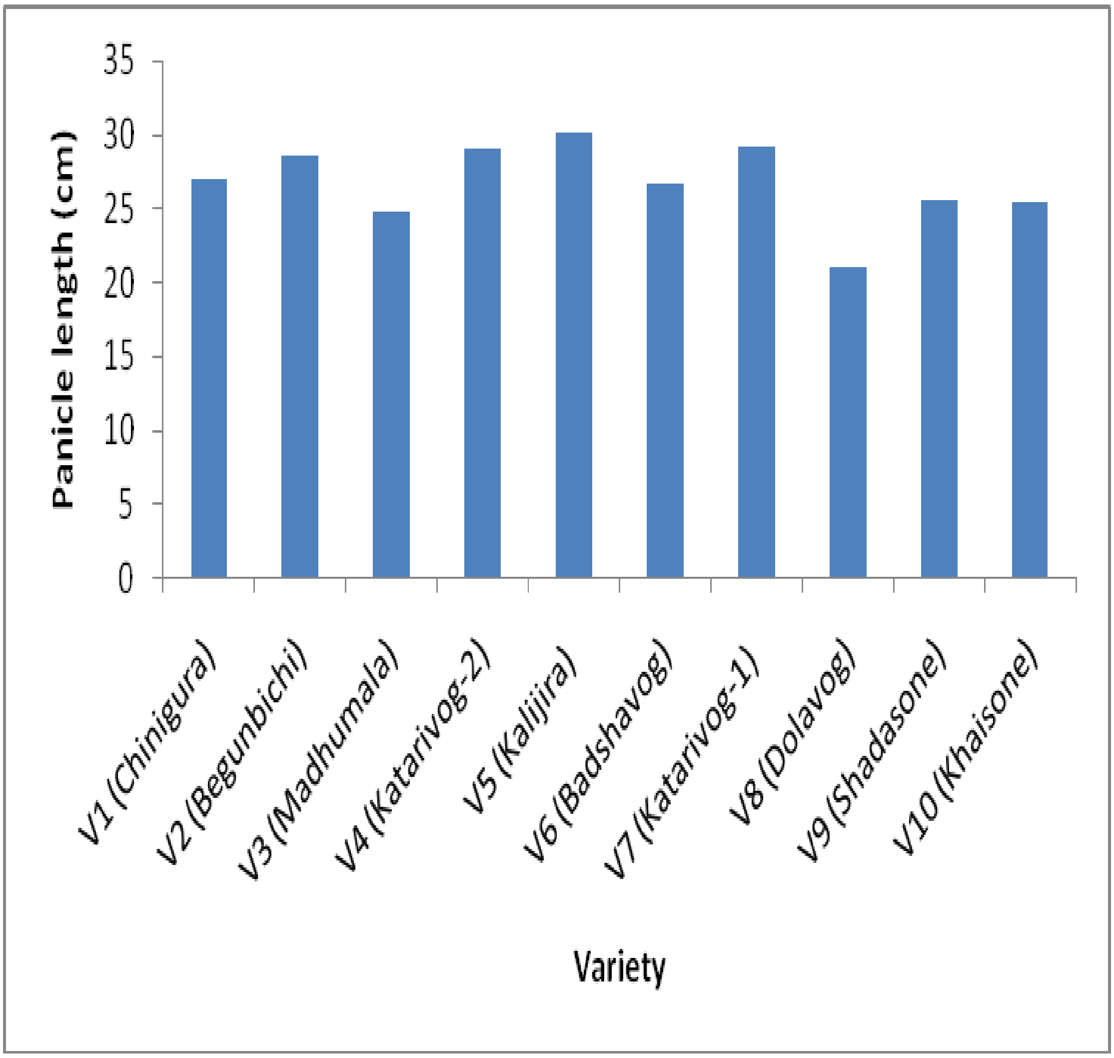

Fig. 4. Panicle length of 10 aromatic rice as influenced by different cultivars in *Aman* season

Number of total grains panicle^{-1}

Recorded data on number of total grains panicle^{-1} of rice showed significant difference due to varietal difference (Table 5 and Appendix 11). Results revealed that the highest number of total grains panicle^{-1} (166.50) was found from the cultivar V_5 (Kalijira) which was statistically similar with V_6 (Badshavog) whereas the lowest number of total grains panicle^{-1} (105.80) was found from the cultivar V_4 (Katarivog-2) which was significantly different from others. Similar result was also observed by Chowdhury *et al*. (2005)

Number of filled grains panicle^{-1}

Number of filled grains panicle^{-1} of different aromatic rice cultivars showed statistically significant variation (Table 5 and Appendix 11). It was observed that the highest number of filled grains panicle^{-1} (148.20) was found from the cultivar V_5 (Kalijira) which was statistically identical with V_6 (Badshavog) and V_8 (Dolavog). The lowest number of filled grains panicle^{-1} (78.60) was found from the cultivar V_4 (Katarivog-2) which was significantly different from others. Chowdhury *et al*. (2005) also found similar result with the present study.

Number of unfilled grains panicle^{-1}

Significant variation was recorded on number of unfilled grains panicle^{-1} of rice affected by varietal difference (Table 5 and Appendix 11). It was evident that The highest number of unfilled grains panicle^{-1} (29.35) was found from the cultivar V_7 (Katarivog-1) which was significantly different from others whereas the lowest number of unfilled grains panicle^{-1} (10.86) was found from the cultivar V_9 (Shadasone) which was statistically identical with V_8 (Dolavog) and V_{10} (Khaisone)

Table 5. Yield contributing parameters of 10 aromatic rice as influenced by different cultivars in *Aman* season

Treatment	Yield			
	Panicle length (cm)	Number of total grains panicle^{-1}	Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}
V_1 (Chinigura)	27.00	128.2 d	111.0 d	17.20 cd
V_2 (Begunbichi)	28.58	137.3 c	121.5 c	15.82 d
V_3 (Madhumala)	24.70	112.0 e	95.30 f	16.70 cd
V_4 (Katarivog-2)	29.00	105.8 f	78.60 g	27.20 b
V_5 (Kalijira)	30.12	166.5 a	148.2 a	18.30 c
V_6 (Badshavog)	26.60	161.0 ab	142.6 a	18.36 c
V_7 (Katarivog-1)	29.12	130.8 d	101.4 e	29.35 a
V_8 (Dolavog)	21.00	155.6 b	144.3 a	11.30 e
V_9 (Shadasone)	25.54	141.4 c	130.5 b	10.86 e
V_{10} (Khaisone)	25.33	136.9 c	124.6 bc	12.32 e
$LSD_{0.05}$	0.64	6.00	6.02	1.90
CV(%)	7.42	8.49	6.56	4.73

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

Sterility percentage

Significant variation was recorded on sterility percentage of rice affected by varietal difference (Fig. 5 and Appendix 11). It was evident that the highest sterility percentage (25.71%) was found from the cultivar V_4 (Katarivog-2) whereas the lowest sterility percentage (7.26%) was found from the cultivar V_5 (Kalijira) which was statistically similar with V_9 (Shadasone) which was statistically similar with V_9 (Shadasone). Murthy *et al.* (2004) also found similar result with the present study.

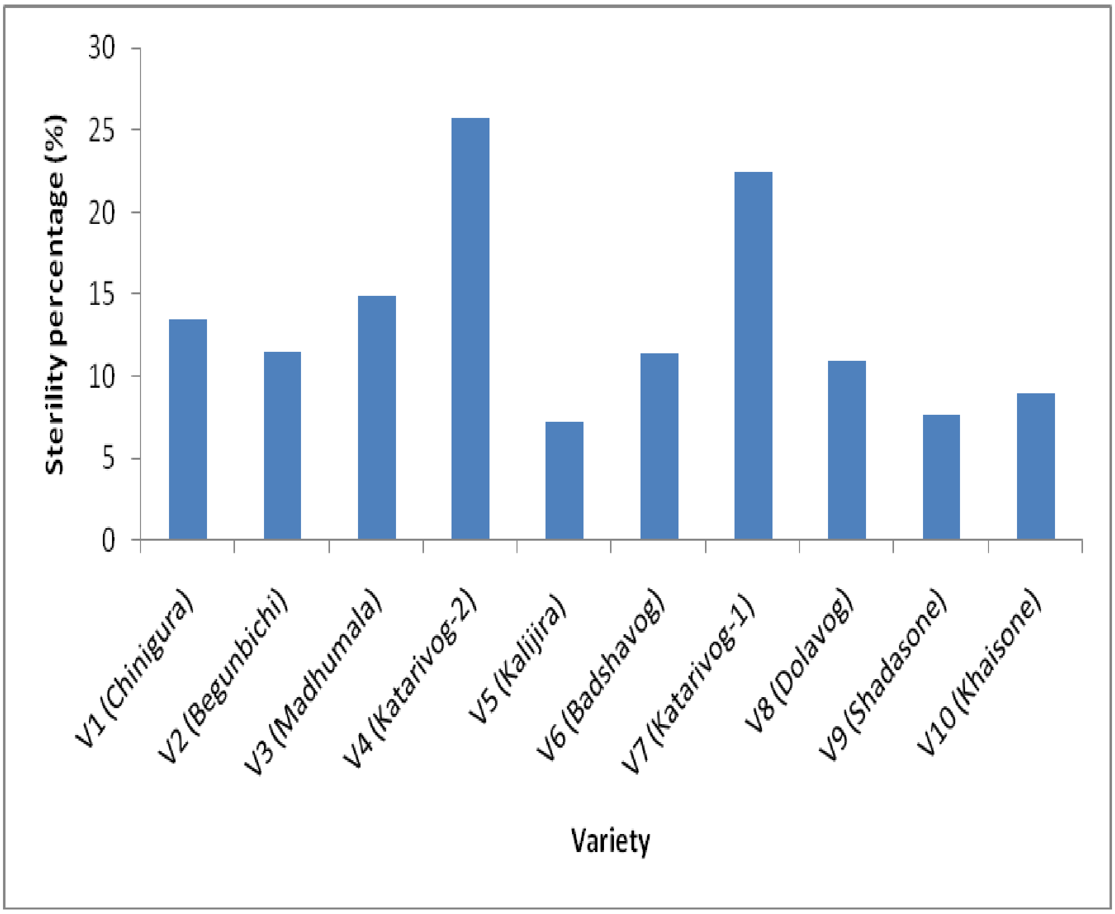

Fig. 5. Sterility percentage of 10 aromatic rice as influenced by different cultivars in *Aman* season

Yield parameters

Weight of 1000 grains

Recorded data on 1000 grain weight of rice showed significant difference due to varietal difference (Table 6 and Appendix 12). Results revealed that the highest 1000 grain weight (22.76 g) was found from the cultivar V_3 (Madhumala) which was significantly different from others whereas the lowest 1000 grain weight (9.12 g) was found from the cultivar V_9 (Shadasone) which was significantly different from others. Supported result also found by Chowdhury *et al*. (2005).

Grain yield

Significant variation was recorded on grain yield of rice affected by varietal difference (Table 6 and Appendix 12). It was evident that the highest grain yield (3.42 t ha^{-1}) was found from the cultivar V_5 (Kalijira) which was significantly different from others followed by V_6 (Badshavog). The lowest grain yield (2.11 t ha^{-1}) was found from the cultivar V_3 (Madhumala) which was statistically identical with V_4 (Katarivog-2). Similar result was also observed by Chowdhury *et al*. (2016) who reported that cultivar significantly influenced the yield of aromatic rice. Yuni Widyastuti *et al.* (2015) and Hasan *et al.* (2014) also found similar result with the present study.

Straw yield

Straw yield of different aromatic rice cultivars showed statistically significant variation (Table 6 and Appendix 12). It was observed that the highest straw yield (6.12 t ha^{-1}) was found from the cultivar V_5 (Kalijira) which was statistically identical with V_6 (Badshavog) whereas the lowest straw yield (4.70 t ha^{-1}) was found from the cultivar V_3 (Madhumala) which was statistically similar with V_4 (Katarivog-2). Chowdhury *et al*. (2005) also found similar result with the present study.

Biological yield

Significant variation was recorded on biological yield of rice affected by varietal difference (Table 6 and Appendix 12). It was evident that the highest biological yield (9.54 t ha^{-1}) was found from the cultivar V_5 (Kalijira) which was significantly different from others. The lowest biological yield (6.81 t ha^{-1}) was found from the cultivar V_3 (Madhumala) which was significantly different from others.

Harvest index (%)

Recorded data on harvest index of rice showed significant difference due to varietal difference (Table 6 and Appendix 12). Results revealed that the highest harvest index (35.94%) was found from the cultivar V_2 (Begunbichi) which was statistically similar with V_5 (Kalijira), V_9 (Shadasone) and V_{10} (Khaisone). The lowest harvest index (30.98%) was found from the cultivar V_3 (Madhumala) which was statistically identical with V_1 (Chinigura).

Table 6. Yield parameters of 10 aromatic rice as influenced by different cultivars in *Aman* season

Treatment	Yield				
	1000 grain weight (g)	**Grain yield (t ha^{-1})**	**Straw yield (t ha^{-1})**	**Biological yield (t ha^{-1})**	**Harvest index (%)**
V_1 (Chinigura)	11.90 d	2.54 d	5.50 b	8.04 d	31.59 c
V_2 (Begunbichi)	10.61 e	2.90 c	5.17 cd	8.07 cd	35.94 a
V_3 (Madhumala)	22.76 a	2.11 e	4.70 f	6.81 e	30.98 c
V_4 (Katarivog-2)	13.70 c	2.20 e	4.90 ef	7.10 e	30.99 c
V_5 (Kalijira)	12.88 c	3.42 a	6.12 a	9.54 a	35.85 a
V_6 (Badshavog)	11.10 de	3.18 b	6.00 a	9.18 b	34.64 b
V_7 (Katarivog-1)	13.60 c	2.44 d	5.42 b	7.86 d	31.04 c
V_8 (Dolavog)	11.25 de	2.80 c	5.38 bc	8.18 cd	34.23 b
V_9 (Shadasone)	9.12 f	2.94 c	5.44 b	8.38 c	35.08 ab
V_{10} (Khaisone)	20.10 b	2.74 c	5.12 de	7.86 d	34.86 ab
$LSD_{0.05}$	0.95	0.19	0.23	0.30	1.05
CV(%)	6.24	5.88	7.79	8.71	6.55

In a column means having similar letters) arc 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 during the period from June to November 2019 to study the evaluation of ten aromatic rice cultivars in terms of morphological traits and yield in *Aman* rice. Ten aromatic rice cultivars were considered as treatment of the experiment *viz.* V_1 (Chinigura), V_2 (Begunbichi), V_3 (Madhumala), V_4 (Katarivog-2), V_5 (Kalijira), V_6 (Badshavog), V_7 (Katarivog-1), V_8 (Dolavog), V_9 (Shadasone) and V_{10} (Khaisone). The experiment was laid out in a Randomized complete Block Design (RCBD) with three replications. Data on different growth and yield parameters were recorded. The collected data were statistically analyzed for evaluate the varietal performance. Significant variation among the cultivars was observed regarding different parameters.

Considering growth parameters influenced by different cultivars, most of the parameters were affected significantly. It was observed that at 30, 60, 90 DAT and at harvest the highest plant height (55.61, 108.20, 142.40 and 161.40 cm, respectively) was found from the cultivar V_3 (Madhumala) whereas the highest number of leaves hill^{-1} (27.80, 68.50, 66.18 and 65.86 respectively) was found from the cultivar V_6 (Badshavog) and the highest number of tillers hill^{-1} (8.72, 17.70, 24.56 and 25.06, respectively) was found from the cultivar V_5 (Kalijira). Again, the highest leaf area (1.12, 5.38 and 5.19 at 30, 60 and 90 DAT, respectively) was found from the cultivar V_8 (Chiniatap-2). On the other hand, at 30, 60, 90 DAT and at harvest the lowest plant height (41.81, 81.36, 115.30 and 136.00 cm, respectively) and number of leaves hill^{-1} (23.65, 50.43, 43.30 and 43.45, respectively) were found from the cultivar V_8 (Dolavog). Similarly, at 30, 60, 90 DAT and at harvest the lowest number of tillers hill^{-1} (6.80, 10.50, 16.00 and 16.50, respectively) and leaf area (0.54, 3.28 and 3.25, respectively) were found from the cultivar V_3 (Madhumala). Again, the highest length of flag leaf (33.00 cm) and breadth of flag leaf (1.32 cm) were found from V_5 (Kalijira) and V_7 (Katarivog-1), respectively whereas the lowest length of flag leaf (29.50 cm) and breadth of flag leaf (0.72 cm) were found from the cultivar V_3 (Madhumala).

Considering yield contributing parameters influenced by different cultivars, most of the parameters were affected significantly. Results revealed that the highest number of effective tillers hill^{-1} (18.24), panicle length (30.12 cm), number of total grains panicle^{-1} (166.50) and number of filled grains panicle^{-1} (148.20) were found from the cultivar V_5 (Kalijira). On the other hand, the lowest number of effective tillers hill^{-1} (12.67) was found from the cultivar V_3 (Madhumala) whereas the lowest number of total grains panicle^{-1} (105.80) and number of filled grains panicle^{-1} (78.60) were found from the cultivar V_4 Katarivog-2) but the lowest panicle length (21.00 cm) was found from the cultivar V_8 (Dolavog). Similarly, the lowest number of non effective tillers hill^{-1} (12.67) and number of unfilled grains panicle^{-1} (10.86) were found from the cultivar V_3 (Madhumala). But the lowest sterility percentage (7.26%) was found from the cultivar V_5 (Kalijira) whereas the highest number of non effective tillers hill^{-1} (7.67), number of unfilled grains panicle^{-1} (29.35) and sterility percentage (25.71%) were found from the cultivar V_1 (Chinigura), V_7 (Katarivog-1) and V_4 (Katarivog-2), respectively.

In case of yield parameters, the highest 1000 grain weight (22.76 g) was found from the cultivar V_3 (Madhumala) but the highest grain yield (3.42 t ha^{-1}), straw yield (6.12 t ha^{-1}) and biological yield (9.54 t ha^{-1}) were found from the cultivar V_5 (Kalijira) whereas the highest harvest index (35.94%) was found from the cultivar V_2 (Begunbichi). On the other hand, the lowest 1000 grain weight (9.12 g) was found from the cultivar V_9 (Shadasone) but the lowest grain yield (2.11 t ha^{-1}), straw yield (4.70 t ha^{-1}), biological yield (6.81 t ha^{-1}) and harvest index (30.98%) was found from the cultivar V_3 (Madhumala).

From the above findings, it can be concluded that the cultivar, Kalijira showed the best performance in terms of morphological characters, yield and yield components.

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APPENDICES

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

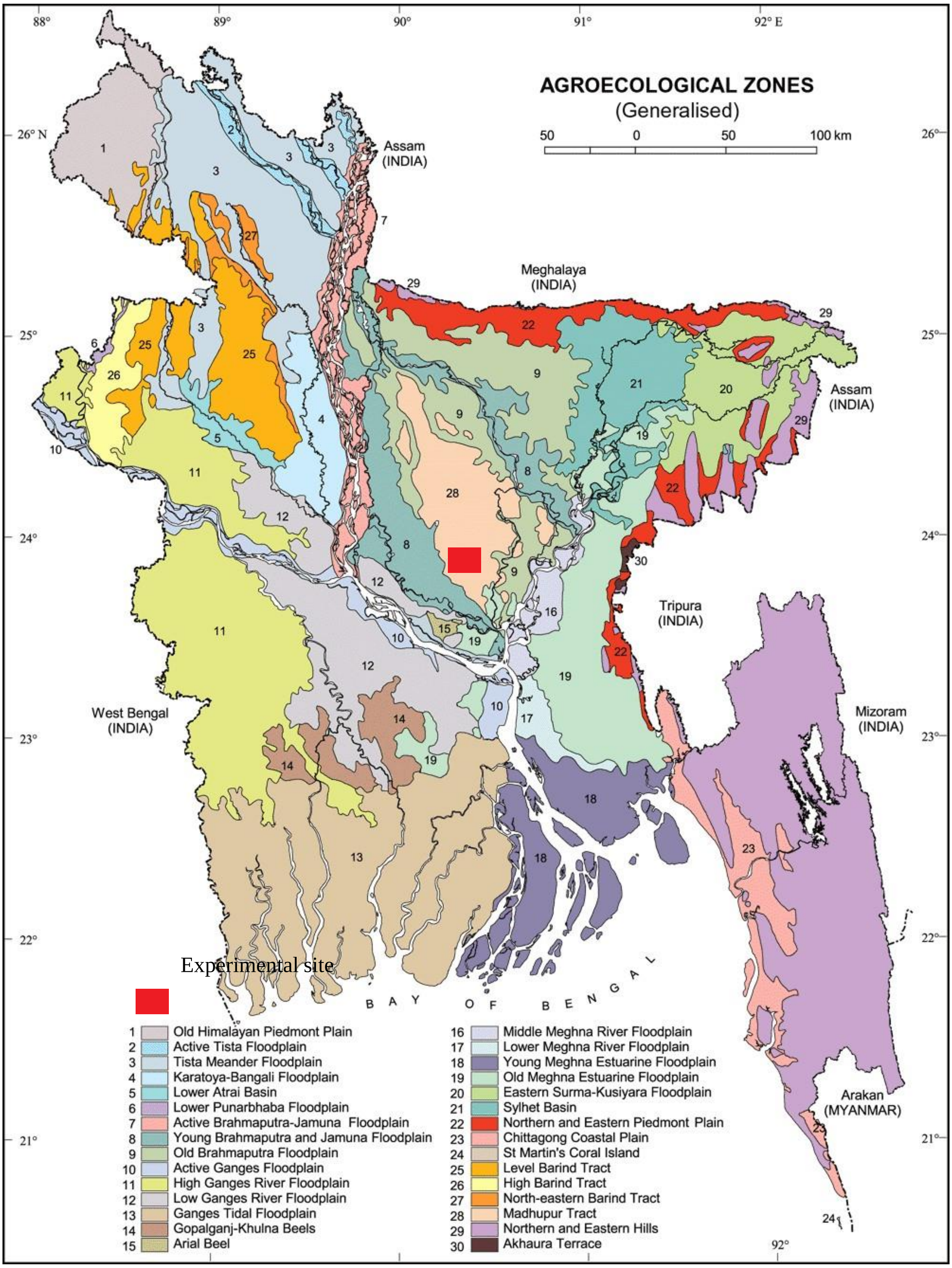


Fig. 6. Experimental site

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

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)
		Max	*Min*	*Mean*		
2019	June	27.40	23.44	25.42	71.28	190
2019	July	30.52	24.80	27.66	78.00	536
2019	August	31.00	25.60	28.30	80.00	348
2019	September	30.8	21.80	26.30	71.50	78.52
2019	October	30.42	16.24	23.33	68.48	52.60
2019	November	28.60	8.52	18.56	56.75	14.40

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

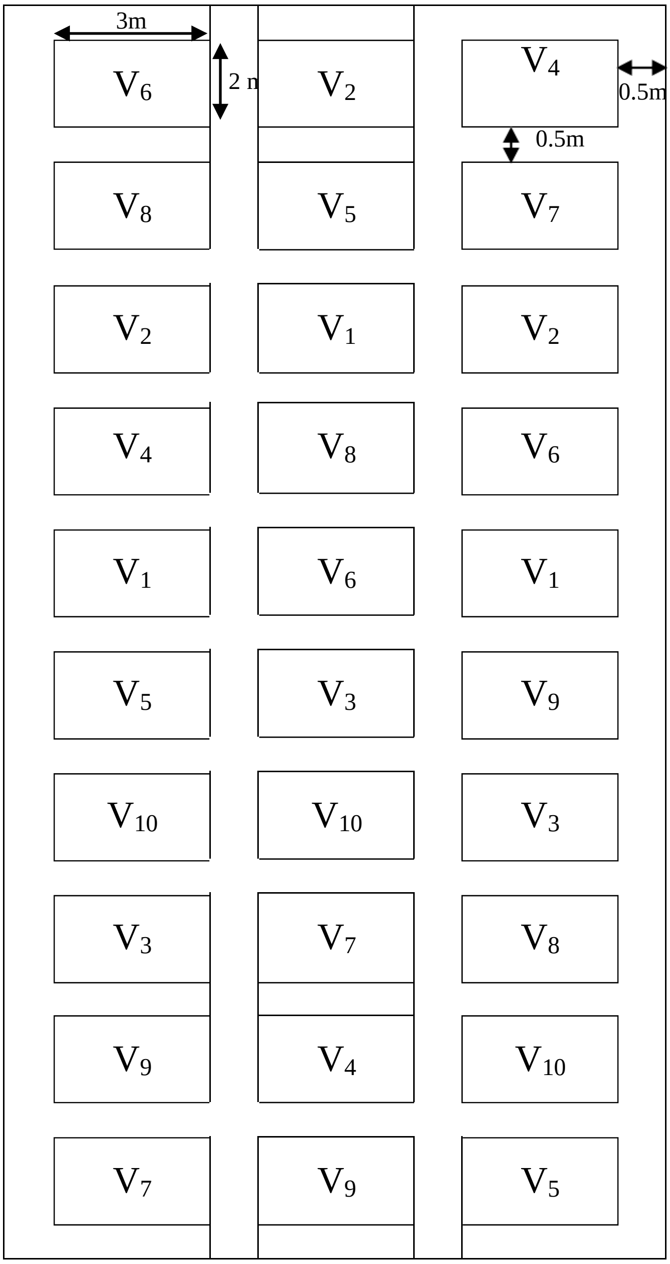
Source: Soil Resource Development Institute (SRDI)

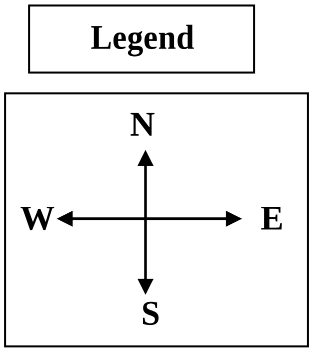
B. Physical and chemical properties of the initial soil

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. Layout of the experiment field





Cultivar

V_1 = Chinigura

V_2 = Begunbichi

V_3 = Madhumala

V_4 = Katarivog-2

V_5 = Kalijira

V_6 = Badshavog

V_7 = Katarivog-1

V_8 = Dolavog

V_9 = Sadasone

V_{10} = Khaisone

Fig. 7. Layout of the experimental plot

Appendix 5. Plant height of 10 aromatic rice as influenced by different cultivars in *Aman* season

Sources of variation	Degrees of freedom	Plant height (cm)			
		30 DAT	60 DAT	90 DAT	At harvest
Replication	2	3.014	2.453	5.717	4.289
Variety	9	101.46**	142.75*	307.86*	419.35*
Error	18	1.322	3.941	5.711	6.304

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix 6. Number of leaves hill^{-1} of 10 aromatic rice as influenced by different cultivars in *Aman* season

Sources of variation	Degrees of freedom	Number of leaves hill^{-1}			
		30 DAT	60 DAT	90 DAT	At harvest
Replication	2	1.056	2.452	4.115	3.289
Variety	9	48.941*	204.33*	373.96*	298.48*
Error	18	0.912	1.712	3.297	2.522

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix 7. Number of tillers hill^{-1} of 10 aromatic rice as influenced by different cultivars in *Aman* season

Sources of variation	Degrees of freedom	Number of tillers hill^{-1}			
		30 DAT	60 DAT	90 DAT	At harvest
Replication	2	1.053	0.798	1.633	2.071
Variety	9	22.47**	67.488*	201.71*	146.38*
Error	18	2.371	3.645	2.912	3.266

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix 8. Leaf area index of 10 aromatic rice as influenced by different cultivars in *Aman* season

Sources of variation	Degrees of freedom	Leaf area index		
		30 DAT	60 DAT	90 DAT
Replication	2	0.012	0.436	0.487
Variety	9	NS	6.514**	7.163**
Error	18	0.041	0.271	0.314

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix 9. Length and breadth of flag leaf as influenced by different aromatic rice cultivars in *Aman* season

Sources of variation	Degrees of freedom	Length of flag leaf	breadth of flag leaf
Replication	2	1.103	0.045
Variety	9	12.482**	3.671**
Error	18	0.717	0.173

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix 10 Number of tillers hill^{-1} (effective and non-effective) of 10 aromatic rice as influenced by different cultivars in *Aman* season

Sources of variation	Degrees of freedom	Yield contributing parameters		
		Total number of tillers hill^{-1}	Number of non effective tillers hill^{-1}	Number of effective tillers hill^{-1}
Replication	2	0.714	0.671	0.277
Variety	9	42.93**	16.39**	9.512**
Error	18	0.852	1.013	0.817

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix 11. Yield contributing parameters of 10 aromatic rice as influenced by different cultivars in *Aman* season

Sources of variation	Degrees of freedom	Yield contributing parameters				
		Panicle length (cm)	Number of total grains panicle^{-1}	Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}	Sterility percentage
Replication	2	1.052	5.377	2.114	0.965	0.911
Variety	9	18.177**	212.37*	378.363*	9.167**	17.308**
Error	18	0.864	5.793	6.294	1.052	1.004

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Appendix 8. Yield parameters of 10 aromatic rice as influenced by different cultivars in *Aman* season

Sources of variation	Degrees of freedom	Yield parameters				
		1000 grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	0.117	0.115	0.078	0.203	1.134
Variety	9	13.364**	8.307**	11.73**	16.376*	14.71*
Error	18	0.796	0.248	0.314	0.577	1.078

NS = Non-significant * = Significant at 5% level ** = Significant at 1% level

Plate 1: Seedling stage

Plate 2: Growing stage

Plate 3: Flowering stage

Plate 4: Grain maturation

Plate 5: Harvesting

Plate 6: Data Collection