GROWTH, YIELD AND GRAIN QUALITY OF TRADITIONAL AROMATIC RICE CULTIVARS IN *BORO* SEASON

A THESIS

BY

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CERTIFICATE

*This is to certify that the thesis entitled '***GROWTH, YIELD AND GRAIN QUALITY OF TRADITIONAL AROMATIC RICE CULTIVARS IN *BORO* SEASON***' submitted to the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE in AGRICULTURAL BOTANY****, embodies the results of a piece of bona-fide research work carried out by* ***SHIKHA AKTER****, Registration No.***12-04757*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2018
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TO

MY BELOVED PARENTS

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GROWTH, YIELD AND GRAIN QUALITY OF TRADITIONAL AROMATIC RICE CULTIVARS IN *BORO* SEASON

ABSTRACT

An experiment was conducted at Agronomy Field, Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207 during the period from November 2017 to May 2018 to evaluate growth, yield and grain quality of traditional aromatic rice cultivars in *Boro* season. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Eleven aromatic rice genotypes viz. T_1 = Kataribhog-1, T_2 = Kataribhog-2 (awned), T_3 = BRRI dhan34, T_4 = Badshabhog, T_5 = BRRI dhan38, T_6 = Chinigura, T_7 =Madhumala, T_8 = BRRI dhan50, T_9 = Zirabhog, T_{10} = Chiniatap-1 and T_{11}= Chiniatap-2. attributes, yield and harvest index. Chinigura was produced the tallest plant (151.23 cm), higher number of tillers hill^{-1} (25.66), and leaves hill^{-1} (65.00). The maximum leaf area index (5.5) was obtained from Chinigura (T_6) which was statistically differed from all other varieties. Days to 50% flowering (92.66 days) was more for Chinigura (T_6) which was statistically similar with all varieties except BRRI dhan38 (T_5) and Madhumala (T_7). BRRI dhan34 (T_3) produced the highest chlorophyll content in leaves which was statistically identical with BRRI dhan38 (T_5), Chinigura (T_6) and Chiniatap-2 (T_{11}). Grain length and breadth ratio is the lowest (2.26 : 1) in Kataribhog-1.Chinigura provided the highest grain yield (3.46 t ha^{-1}) followed by Kataribhog-1 (3.32 t ha^{-1}), Badshabhog (3.20 t ha^{-1}), BRRI dhan38 and BRRI dhan50 (2.65 t ha^{-1}). Chinigura also provided the highest straw yield (8.11 t ha^{-1}) and biological yield (11.10 t ha^{-1}). So, Chinigura exhibited higher adaptability in *Boro* season compared to rest of the cultivars.

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LIST OF ABBREVIATIONS

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

CHAPTER 1

INTRODUCTION

Aromatic rice is known for its characteristic fragrance when cooked. It fetches higher price in market than non-aromatic ones. In fact aromatic rice is very popular in the national and in the international markets (Yoshihito, 2005). Cultivation of aromatic rice has been gaining popularity in Bangladesh on the recent years, because of its huge demand both for internal consumption and export (Das and Baqui, 2000; Dutta *et al.,* 2002). However, the choice of grain quality depends of the consumers' income. The demand for scented fine grain rice has been increased due to economic development of the people of Bangladesh (Ali *et al.,* 2016). Most of the well-off people preferred long, slender scented fine grain rice (Mannan *et al.*, 2012; Sarkar *et al.,* 2014). Despite the generally favourable agro-climatic conditions, area of aromatic rice cultivation is less than 2% of the national rice acreage of Bangladesh (Singh *et al.*, 2004; Ashrafuzzaman *et al.,* 2009).

To feed the fast increasing global population, the world's annual rice production must be increased to 760 million tons by the year 2020 (Kundu and Ladha, 1995). It plays a vital role in the economy of Bangladesh providing significant contribution to the GDP, employment generation and food availability. In Bangladesh, rice is the most extensively cultivated cereal crop. It provides about 75% of the calories and 55% of the protein in the average daily diet of the people of our country (Bhuiyan *et al*., 2002).

The traditional fine-grained aromatic rice genotypes are comparatively taller than modern ones and more suitable for low-lying areas. But most of the traditional fine-grained rice genotypes are photoperiod-sensitive, well adopted to the local environment and suitable for in growing in the *Boro* season (Hossain, 2008). However, aromatic rice varieties have occupied about 12.5% of the total transplant *Boro* rice cultivation (Islam *et al.,* 2015). Most of the high quality rice cultivars are low yielding. Due to low yield, farmers have little interest to growing these aromatic rice cultivars.

Most of the aromatic rice varieties in Bangladesh are of traditional type, photoperiod sensitive and are grown during *Aman* season in the rain fed low land ecosystem (Baqui *et al.*, 2000). In Northern districts of Bangladesh, 30% of the rice lands were covered by aromatic rice cultivars during *Aman* season (Islam *et al*., 2012). Among the aromatic rice cultivars, Chinigura was the predominant one that covered more than 70% farms in the northern districts of Naogaon and Dinajpur (Baqui *et. al.,* 1997). The average area devoted to aromatic rice production in the T. *Aman* season was 12.5%, with an average yield of 2.0 t ha^{-1} and the resultant total production of 1.42 million metric tons.

Worldwide, rice provides 27% of dietary energy supply and 20% dietary protein (Kueneman, 2006). It constitutes 95% of the cereal consumed and supplies more than 80% of the calories and about 50% of the protein in the diet of the general people of Bangladesh (Yusuf, 1997). Being the 4th largest rice producer of the world, Bangladesh comprises an area of about 11.10 million hectares for rice production (FAO, 2015) of which around 27 % is occupied by fine rice varieties (BBS, 2016). Consumer demand for the fine rice varieties is higher due to its good nutrition quality, palatability, taste, cooking quality and fragrance (Kaul *et al.,* 2008). Most of the consumers prefer fine rice varieties with good cooking quality that have aroma. Due to special flavor and taste, aromatic rice is highly favored. This quality of rice receives a premium price in the market and has export potential (Arumugachamy *et al.,* 2002). An aromatic rice variety may grow and yield satisfactorily in a wide area but its quality traits are expressed in its native area of cultivation (Singh *et al*., 2000). Bangladesh produces several fine aromatic rice varieties with excellent eating quality for regular consumption as steamed rice as well as for polao, biriani, jarda, firni type preparations which are served on special occasions. Yield and quality of rice depends on the genetic potential of cultivars, it surrounding environment and management practices. Selection of right type of variety is most important factors for maximizing rice production. Yield of rice changes due to growing environment, such as different locations, seasonal fluctuations, different dates of planting etc. (Sarker, 2002).

A comprehensive survey conducted by the Department of the Agriculture Extension (DAE) in all the districts revealed that total area devoted to aromatic rice production in *Ama*n and *Boro* seasons of 2003-04 was 118 thousand hectares, with a total production of 173 thousand metric tons of rice only (DAE, 2016). In respect of production of aromatic rice, Dinajpur, Naogaon, Chittagong and Sherpur had 1st, 2nd, 3rd and 4th position respectively in 2002-03 (Talukder *et. al.,* 2004). Aromatic rice varieties are rated best in quality and fetch much higher price in international market. Aromatic rice plays a vital role in international rice trading. Bangladesh has a bright prospect for export of fine rice thereby earning foreign exchange (Islam *et al.,* 2012). The demand of aromatic rice in this country is increasing due to its special appeal for aroma and acceptability although grain yield is low. Aromatic rice is the most highly valued rice commodity in Bangladesh agricultural trade markets having small grain and pleasant aroma with soft texture upon cooking (Dutta *et al*., 1998). However, the price of fine rice, especially the aromatic rice is 2-3 times higher than that of coarse rice (*Biswas et al.*, 1992). In spite of low yielding of aromatic rice, it requires less input compared to coarse rice. Aromatic rice is rated best in quality and fetches much higher price than high quality non-aromatic rice in the domestic and international market. The demand of aromatic rice for internal consumption and also for export is increasing day by day (Das and Baqui, 2000). Due to low yield and limited market facilities farmers seem to have little interest to continue growing these aromatic rice cultivars. This will ultimately economize fertilizer use and maintain soil productivity and yield.

For improving present situation, higher yielding aromatic rice varieties have to be developed through characters selection in breeding program or yield level of existing cultivars have to be improved through manipulation of agronomic cultural management practices. Detail information on morpho-physiological characters and their relation with grain yield of aromatic rice genotypes are needed to serve the above purposes. But research work regarding aromatic rice cultivar is limited in Bangladesh.

Based on the above proposition, the present research programme has been undertaken to investigate the variations in morpho-physiological characters in aromatic rice cultivars and their relation with grain yield of the same. With this background the present experiment was taken up with the following objectives.

Objectives

i) To investigate the growth behaviour, grain quality and yield of the aromatic rice cultivars in *Boro* season.

ii) To evaluate the adaptability of the traditional aromatic rice cultivars in *Boro* season.

CHAPTER II

REVIEW OF LITERATURE

Extensive work had carried out to evaluate the growth and yield in traditional aromatic rice cultivars. The yield of short grain aromatic rice varieties is comparatively less than high yielding non scented varieties. The farmers have switched to high yielding aromatic rice because the higher yield from aromatic varieties compensates for the premium price of scented rice.

Morpho-physiological traits and yield

An experiment was conducted by (Talukdat *et al.*, 2004) at RDRS Bangladesh farm, Monthana, Rangpur, Bangladesh during July to December 2016 to evaluate the yield performance of seven aromatic rice varieties of Bangladesh viz. Jirakatari, Chiniatab, Chinigura, Kataribhog, Kalizara, Badshabhog and BRRI dhan34. The experiment was laid out in a randomized complete block design with three replications. The entire yield contributing attributes and quality parameters varied significantly among the aromatic rice varieties. The highest plant height (167.0 cm) was found in the variety Chinigura and the lowest (120.1 cm) in the variety Chiniatab. In the variety Kataribhog number of filled grains panicle^{-1} was found highest (255.6) and the lowest (130.7) was recorded in the variety Badshabhog. Badshabhog produced the highest 1000-grain weight (18.3 g) and the lowest (11.4 g) was recorded from the variety Kataribhog. The highest grain yield (2.54 t ha^{-1}) was obtained from Kataribhog and the lowest grain yield (1.83 t ha^{-1}) was obtained from Kalizara. Among the seven aromatic rice varieties under North-west condition Kataribhog and BRRI dhan34 are suitable in respect of yield.

Akther *et al*. (2009) was conducted an experiment at the Hajee Mohammad Danesh Science and Technology University Farm, Dinajpur, Bangladesh during July to December of 2009 to study the feasibility of using poultry litter as a source of plant nutrient for aromatic rice cultivation compared to cow dung and NPKSZn fertilizers in respect of yield of local aromatic rice varieties. The experiment was laid out in a randomized complete block design with three replications. The experiment comprised of four treatments *viz*., control (no fertilizer), cow-dung @ 5 t ha^{-1}, poultry litter @ 3t ha^{-1}, recommended dose of NPKSZn fertilizer and five local aromatic rice varieties namely, Kataribhog, Badshabhog, Radhunipagal, Kalizera and Shakhorkora. All the fertilizer treatments produced significantly higher grain yield than control. Growth attributes of aromatic rice such as plant height, total tillers hill^{-1}, fertile tillers hill^{-1}, spikelets panicle^{-1}, grains panicle^{-1} and 1000 grain weight showed higher value with the incorporation of poultry litter @ 3 t ha^{-1}. Poultry litter @ 3 t ha^{-1} produced the highest grain yield that was statistically similar to cow-dung @ 5 t ha^{-1} and recommended NPKSZn chemical fertilizers. Grain yield differed significantly among the varieties. Therefore, it is suggested that poultry litter @ 3 t ha^{-1} may be used to get higher yield of local aromatic rice.

A field experiment was conducted at the Bangladesh Institute of Nuclear Agriculture (BINA) farm Mymensingh, Bangladesh during the irrigated ecosystem in December, 2009 to May 2010, with a view to study the performance of aromatic fine rice under different date of transplanting. The experiment was carried out with four aromatic fine rice (V_1 = Chinisagar, V_2 = Chiniatab, V_3 = Basmati, V_4 =Awnless Minicat) and three different date of transplanting (D_1 =20 January, D_2 =5 February, D_3 =20 February). The experiment was laid out in split-plot design with three replications assigning four varieties in the main plot and the three different transplanting dates in the sub plot. Aromatic fine rice and dates of transplanting individually showed significant effect on the agronomic parameters. Among the aromatic fine rice Awnless Minicat gave the highest yield (3.10 t ha^{-1}) but that was at par with those of Basmati (1.77 t ha^{-1}). Transplantation on 20 January gave the highest grain yield (2.41 t ha^{-1}) which was at par with the transplantation on 5 February (1.99 t ha^{-1}). The result revealed that 20 January and 5 February produced highest grain yield by all the variety. In later date of transplanting 20 February produced lower grain yield (Islam *et al*., 2015).

The experiment was carried out by Islam *et al.* (2015) at Mymensingh, Bangladesh with four aromatic fine rice viz. ‘Chinisagar’, ‘Chiniatab’, ‘Basmati’ and ‘Awnless Minicat’ with three different date of transplanting 20 January, 5 February and 20 February. Among the aromatic fine rice ‘awnless Minicat’ gave the highest yield (3.10 t ha^{-1}) but that was at par with those of Basmati (1.77 t ha^{-1}) Netam *et al.*,(2008) reported that variety ‘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

A study was conducted 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 variety. 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. (Saha *et al*., 2015)

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 1000 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 4000-2400 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.

A study was conducted at the Hajee Mohammad Danesh Science and Technology University Farm, Dinajpur, Bangladesh in *Aman* season (July-December) of 2007 to observe the yield and quality of ten popular aromatic rice varieties of Bangladesh. The varieties were Kataribhog (Philippines), Kataribhog (Deshi), Badshabhog, Chinigura, Radhunipagal, Kalizera, Zirabhog, Madhumala, Chiniatab and Shakhorkora. The experiment was laid out in a randomized complete block design with four replications. All the yield contributing attributes and quality parameters varied significantly among the aromatic rice varieties. The highest grain yield was obtained from Kataribhog (Philippines) which identically followed by Badshabhog. In respect of quality, Zirabhog gave the highest head rice outturn that was statistically similar to Badshabhog and Chiniatab. All the tested varieties had bold type shape. Grain protein content ranged from 6.6-7.0 % in brown rice. The cooking time of tested varieties varied from 12 to 16 minutes. Aroma intensity differed due to variety. Kalizera, Badshabhog, Chiniatab contained high level of aroma while, rests of the varieties had moderate type aroma. (Hossain *et al.,* 2006)

Dahiphale *et al.* (2004) worked at Akola, found that quality parameters viz. kernel length (cm), kernel breadth (cm), kernel L/B ratio, kernel length after cooking, elongation ratio and amylose content (%) were not influenced significantly among Basmati genotypes.

Kader *et al.* (2018) was observed that BRRI dhan70 is a new aromatic, high yielding and extra-long slender grain containing transplanted *Aman* rice variety which is an improvement over existing premium quality rice BRRI dhan37. BRRI dhan70 has pleasingly passed in the proposed variety trial conducted in the farmers' field. As a result National Seed Board (NSB) approved this variety 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 variety 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 variety 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 variety for cultivating in the wet (T. *Aman*) season and farmers can be benefited by the cultivation of BRRI dhan70.

An experiment was conducted at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, to study the yield and quality of aromatic fine rice as affected by variety and nutrient management during the period from June to December 2013. The experiment comprised three aromatic fine rice varieties 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% cow-dung (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 (Sarkar *et al*., 2016).

A field experiment was carried out by Jisan *et al.* (2016) at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during transplant *Aman* season from July to December 2008 to evaluate the yield performance of some local and HYV aromatic rice varieties. The experiment was laid out in a randomized complete block design with four replications. The basal dose of fertilizers applied into the soil were one third of urea @ 120 Kg ha^{-1}, TSP @ 60 Kg ha^{-1} , MP @ 35 kg ha^{-1}, Gypsum @ 10 kg ha-1 and Zink sulphate @ 5 kg ha^{-1}. Nitrogen was also applied in two splits at 20 and 40 days after transplanting. Fertilizers significantly affect on the number of effective tillers $hill^{-1}$, number of non-effective tillers $hill^{-1}$, number of grains $panicle^{-1}$, unfilled spikelets $panicle^{-1}$, 1000-grain weight, grain yield, straw yield, biological yield and harvest index of aromatic rice varieties. The highest grain yield (5.00 t ha^{-1}), straw yield (6.40 t ha^{-1}), number of effective tillers $hill^{-1}$ (11.81) and total number of grains $panicle^{-1}$ (166.75) were found in V6 (BRRI dhan30) treatment and the lowest grain yield (2.69 t ha^{-1}), straw yield (4.53 t ha^{-1}), number of effective tillers $hill^{-1}$ (9.67) and total number of grains $panicle^{-1}$ (134.00) were recorded from V3 (Badshabhog), V8 (BRRI dhan38) and V1 (Kalojira) treatment, respectively. From the findings of the present study, it may be concluded that aromatic rice cv. BRRI dhan30 appears to be better than other varieties. Key words: Transplant *Aman*, performance, aromatic rice and yield.

Rice is one of the very few crop species endowed with rich genetic diversity which is embodied in the traditional rice landraces or folk varieties. It is one of the most researched crops. Rice genetic resources and human welfare are intricately interlinked. Rice has shaped the history, culture, diet and economy of billions of people of Asia. The diversity data generated in time and space have been valuable to communities, scientists and policy managers to formulate and implement conservation strategies of in situ, on-farm as well as ex situ conservation and management of genetic resources. West Bengal has rich rice genetic wealth. But this genetic wealth is being silently depleted due to the onslaught of the high-yielding varieties (HYVs) and neglect. Descriptor codes were used for the qualitative evaluation of genetic diversity among the 20 rice genotypes collected from different parts of West Bengal, following the Standard Evaluation System (SES) for rice developed by the International Rice Research Institute (IRRI). There is an urgent need to document, characterize and conserve these varieties (Ray *et al.*, 2015).

There are so many rice landraces were cultivated in this district in near past. But in present situation rice cultivation is restricted to 5-10 high yielding variety and few landraces varieties. In this study characterization of twenty landraces of rice presently available in this district was performed using DUS testing protocol. Agro-morphic characterization of these twenty landraces was done during 2011-12 & 2012-13 kharif session at the Village of Ranbahal, PO-Amarkanan of this District. In this study we observed that out of the 20 investigated varieties 11 varieties are distinctive according to the five essential and the eighteen additional characters proposed by the DUS guideline. The present work is so much important in respect to the present scenario of agro-biodiversity of this region as well as identification, conservation and documentation of landraces variety for future crop improvement. Rice is staple food grain of India and is cultivated on 36.95 million hector of land almost throughout the year. Annually approximate 120.6 million tons of rice is being produced and on the basis of production it occupies second position in the world (Food and Agriculture Statistics, 2010). India is centre of origin and as per rice is concerned all together this country proudly possess 88681 different variety of rice, out of that 55615 are landraces, 1171 are wild races and 32895 are other varieties. Green revolution is considerably held to improve production of food grains in our country and its role in achieving status of self sufficiency in food grain is beyond any doubt. But high yielding varieties, which are the back bone of green revolution have indirectly stimulated erosion of landraces and wild varieties of rice. Presently more than 90% of rice cultivation is being done using high yielding varieties only. The situation is fast eroding indigenous cultivars of rice. Another serious factor is changing climatic condition of this region. The climatic condition adversely affects maturation and reproductive cycle of plants. Keeping the severity of situation an attempt is being made to collect, document and conserve indigenous varieties of rice which are fast. (Sinha *et al.,* 2013)

Das *et al*. (2012) suggested that the aromatic rice is one of the most widely accepted rice due its pleasant aroma. Traditionally, many varieties 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.

A field experiment was conducted at the Hajee Mohammad Danesh Science and Technology University Farm, Dinajpur, Bangladesh during transplant *Aman* season of 2004 to determine the influence of transplanting date on the physical and chemical properties of grain of five local and three modern aromatic rice varieties of Bangladesh. The varieties Kataribhog, Radhunipagal, Chinigura, Badshabhog, Kalizera, BRRI dhan34, BRRI dhan37 and BRRI dhan38 were transplanted during the period 15 July to 3 September at 10 day intervals. The physical and chemical characteristics measured in the study were milling outturn, head rice outturn, 1000-grain weight, grain length, length breadth ratio, grain elongation ratio, volume expansion ratio, protein content, amylose content and cooking time. The transplanting date, variety and transplanting datexvariety interaction effect had significant effect on all the characteristics studied except on cooking time where only the variety was found to be significant and on length breadth ratio where only the transplant date was found to be not significant. Chemical and physical properties except cooking time were found to be influenced by transplanting date in T. *Aman* season. Suitable transplanting date was found to be between 4 to 14 August in T. *Aman* season in order to improve physical and chemical properties of aromatic rice. However, the best compromise between physical and chemical properties, particularly the protein content, may be achieved by transplanting around 24 August. In case of all planting dates, weight of 1000 grains, grain length, length breadth ratio and, volume expansion ratio were highest in BRRI dhan38 while the highest protein and amylose contents were found in Kalizira and BRRI dhan34, respectively (Hossain *et al.,* 2011)

An experiment was conducted by Halder *et al*. (2018) at the Agronomy Field of Patuakhali Science and Technology University, Dumki, Patuakhali from June to

December, 2013 to find out the effect of variety 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 varieties (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 variety 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.

Samal *et al.* (2014) was found that the genus *Oryza* has 21 species of which *Oryza sativa* and *Oryza glaberrima* are the only cultivated species derived respectively from their perennial wild progenitors *Oryza rufipogan* and *Oryza longistaminata*. 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 varieties, 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 intra-population diversity among 78 rice genotypes with a view to assess the potentials and consequences of on farm management of rice landraces in traditional farming.

The grain elongation on cooking is dependent on genetic factors as well as the degree of milling (Mohapatra and Bal, 2006) Samal *et al.* (2014) found grain length ranged from 4.90 to 12.41 mm and grain width was 1.80 to 3.50 mm in indigenous aromatic rice. Wide variation in L/B ratio from 2.21 to 4.12 (Itani *et al.*, 2002), 2.62 to 4.55 (Singh *et al.*, 2005), 1.95 to 3.85 (Vanaja and Babu, 2006), 1.5 to 3.5 (Bhonsle and Sellappan, 2010), 2.02 to 4.22 (Meena *et al.*, 2010), from 3.55 to 4.24 (Verma *et al.*, 2013) and from 1.69 to 5.86 (Samal *et al.*, 2014), have been reported. Thomas *et al.* (2013) was reported highest l/b ratio (3.75) for the local white rice, whereas, the lowest ratio was recorded for brown rice (2.09) in locally grown and imported rice varieties marketed (Lipika and Bhaben, 2017).

Islam *et al.* (2018) was reported that the pleasant scent of aromatic rice is making it more popular, with demand for aromatic rice expected to rise in future, varieties 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 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.

Hien *et al.* (2007) was conducted an experiment to evaluate phenotypic and genotypic traits of aromatic rice and the pattern influence on rice grain yield were investigated among 18 rice varieties. This evaluation is vital to know the effects of various characters on yield for selection criteria for high yielding genotype. Experiment was carried out in randomized complete block design (RCBD) with three replications. Yield and yield related traits were studied. Statistical analysis exhibited that rice varieties differed significantly for days to 50% heading (DH), number of primary (PB) and secondary branches per panicle (SPB), spikelets per panicle (SP), days to maturity (DM), thousand grain weight (TGW), and grain yield (GY). Moreover, significantly positive genotypic correlations of grain yield with PB, SPB, SP and TGW were observed. Principal component analysis also classified superior varieties. Swat-1, IR-8, DR-82 and Fakhr-e-Malakand showed superiority for yield and yield related traits. These four varieties can be used as commercial cultivars in Peshawar area after multi-location yield test trials. Genotypic evaluation of different rice varieties for yield and yield related traits.

Roy *et al.* (2009) from a field experiment on clay loam soils of North-eastern (NE) India, comprising of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura, possess diverse array of locally adapted non-Basmati aromatic germplasm. The germplasm collections from this region could serve as valuable resources in breeding for abiotic stress tolerance, grain yield and cooking/eating quality. To utilize such collections, however, breeders need information about the extent and distribution of genetic diversity present within collections. In this study, we report the result of population genetic analysis of 107 aromatic and quality rice accessions collected from different parts of NE India, as well as classified these accessions in the context of a set of structured global rice cultivars. A total of 322 alleles were amplified by 40 simple sequence repeat (SSR) markers with an average of 8.03 alleles per locus. Average gene diversity was 0.67. Population structure analysis revealed that NE Indian aromatic rice can be subdivided into three genetically distinct population clusters: P1, *joha* rice accessions from Assam, *tai* rice from Mizoram and those from Sikkim; P2, *chakhao* rice germplasm from Manipur; and P3, aromatic rice accessions from Nagaland. Pair-wise F_{ST} between three groups varied from 0.223 (P1 vs P2) to 0.453 (P2 vs P3). With reference to the global classification of rice cultivars, two major groups (*Indica* and *Japonica*) were identified in NE Indian germplasm. The aromatic accessions from Assam, Manipur and Sikkim were assigned to the *Indica* group, while the accessions from Nagaland exhibited close association with *Japonica*. The *tai* accessions of Mizoram along with few *chakhao* accessions collected from the hill districts of Manipur were identified as admixed. The results highlight the importance of regional genetic studies for understanding diversification of aromatic rice in India. The data also suggest that there is scope for exploiting the genetic diversity of aromatic and quality rice germplasm of NE India for rice improvement.

Singh *et al*. (2004) reported that 'Pusa Rice Hybrid 10'recorded significantly higher values for the yield attributes (panicles $hill^{-1}$, panicle weight, spikeletspanicle1, grains $panicle^{-1}$ and 1000-grain weight), yield and nutrient accumulation than the non-hybrid 'Pusa Basmati-1'.

An experiment was conducted 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 variety Morichsail and the lowest in the variety Khaskani. Number of filled grains panicle-1 was found highest (100) with the variety Khaskani and the lowest was recorded in the variety Raniselute. Raniselute produced the highest 1000-grain weight (32.09 g) and the lowest (13.32 g) was recorded from the variety Kalijira. The variety Morichsail produced the highest grain yield (2.53 tha^{-1}) followed by Kachra (2.41tha^{-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 (Bony *et al*., 2015)

Aroma volatiles in Basmati-370, Ambemohar-157 (non-basmati scented), and IR-64 (non-scented) rice cultivars were qualitatively and quantitatively analyzed at vegetative and maturity stages to study their differential accumulation using headspace solid-phase micro-extraction, followed by gas chromatography mass spectrometry (HS-SPME-GCMS) with selected ion monitoring (SIM) approach. In addition, expression analysis of major aroma volatile 2-acetyl-1-pyrroline (2AP)-related genes, betaine aldehyde dehydrogenase 2 (badh2) and (1)-pyrolline-5-carboxylic acid synthetase (P5CS), were studied by real-time PCR. Maximum number of volatiles recorded at vegetative (72-58) than at mature stage (54-39). Twenty new compounds (12 in scented and 8 in both) were reported in rice. N-containing aromatic compounds were major distinguishing class separating scented from non-scented. Among quantified 26 volatiles, 14 odor-active compounds distinguished vegetative and mature stage. Limit of detection (LOD) and limit of quantification (LOQ) for 2AP was 0.001 mg/kg of 2AP and 0.01 g of rice, respectively. 2AP accumulation in mature grains was found three times more than in leaves of scented rice. Positive correlation of 2AP with 2-pentylfuran, 6-methyl-5-hepten-2-one, and (E)-2-nonenal suggests their major role as aroma contributors. The badh2 expression was inversely and P5CS expression was positively correlated with 2AP accumulation in scented over non-scented cultivar (Deb *et al*., 2000)

The purposes of this study were 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 varieties. Selection for long grain with slender shape will simultaneously increase amylose content and alkali spreading value or gelatinization temperature. Aroma score categorized rice varieties as mild and strongly aromatic, which also was similar to aroma genotyping with genebased marker for *betaine aldehyde dehydrogenase 2* (BADH2). Sequence analysis of BADH2 revealed that all strongly aromatic and two mild aromatic rice varieties 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 (Samwal *et al.,* 2014)

Rahman *et al.* (2008) conducted an experiment at Dinajpur to investigate the influence of spacing on the yield and yield attributes of some varieties of aromatic rice. The experiment comprised of three varieties namely, 'Kalizira', 'Badshabhog' and 'Tulshimala'and four different spacing viz.8 cm x 25 cm, 12 cm x 25 cm, 16 cm x 25 cm and 20 cm x 25 cm. 'Badshahbhog' produced the highest grain yield (2.90 t ha^{-1}) which was consequence of the highest number of effective tiller $hill^{-1}$,number of grains panicle-1and 1000-grain weight.

Dutta *et al.* (1998) stated that aromatic rice accounts for about 10% of total rice cultivated area, and 30% of total rice production. Furthermore, the competitiveness of non-aromatic rice has worsened recently. By observing this trend, this study aims to grasp the differences in characteristics and profitability between non-aromatic and aromatic rice production, and to discuss the factors affecting the variety selection from farmers' viewpoint. This study is based on the survey conducted in Voatkor commune, Battambang province in 2017, one of the biggest rice producing areas in Cambodia. In the survey, random sampling method was applied, and 82 rice farmers were interviewed. Among the sample, 59 farmers adopted non-aromatic rice, and 61 farmers adopted aromatic rice, including farmers adopted both aromatic and non-aromatic. Study farmers generally cultivated only once a year, mainly in wet season. The result of the study showed that aromatic rice was not commonly used for home consumption, and that more than 80% of the production was for sale, considering greater demand from international market. On the other hand, the non-aromatic rice was mainly used for home consumption and domestic market. The costs of aromatic rice production were higher on material and labor costs, but farmers were able obtain higher yield in comparison with the non-aromatic rice. Despite higher production costs, aromatic rice was found to be more profitable in gross value added, gross margin and net profit, thanks to higher yield and favorable paddy price. In addition, this study also identified non-economic factors affecting the farmers' decision-making on varieties. Finally, some recommendations are offered.

Low yield is a common phenomenon of aromatic rice and consequently rice breeders are trying to develop the agronomic characters to gain a better grain yield. In this study, a total of 53 rice genotypes including 12 globally popular aromatic rice cultivars and 39 advanced breeding lines were evaluated for yield and yield contributing characters in Malaysian tropical environment. Two local varieties MRQ 50 and MRQ 72 were used as check varieties. Correlation analysis revealed that the number of fertile tillers ($r = 0.69$), grain/panicle ($r = 0.86$) and fertile grain per panicle ($r = 0.65$) have the positive contribution to grain yield. Highest grain yield was observed in E36, followed by KhauDau Mali, E26 and E13. E36 appeared with lowest plant height and it also produced highest number of fertile tillers. After evaluation of yield components four genotypes namely E36, KhauDau Mali, E26 and E13 were selected as outstanding genotypes, which can be used as potential breeding materials for Malaysian tropical environment (Faruk *et al*., 2011).

A study was undertaken by Rahman *et al.* (2010) to evaluate the growth performance and grain quality of six aromatic rice varieties BR34, BR38, Kalizira, Chiniatop, Kataribhog and Basmati grown under rainfed conditions. The rice varieties differed significantly ($P<0.05$) with respect to leaf chlorophyll content, plant height, internode length, thousand grain weight and grain and straw yields. Varieties differed in morphological and yield and yield contributing traits. Thousand grain weight and grain yield both were highest in BR38. Basmati required shorter days to maturity and Kalizira longest days to maturity.

In evaluation of six aromatic rice varieties for yield and yield contributing characters, two varieties of aromatic rice (*Oryza sativa* L.) BRRI Dhan50 (Bangla Moti) and BRRI Dhan 34 (Khaskhani) were used to establish a suitable system for callus initiation and regeneration. MS (Murashige and Skoog, 1962) media supplemented with different concentrations i.e. (1.0, 2.0, 3.0, 4.0 mg/L of 2,4-D (2,4-dichlorophenoxyacetic acid) and combination with BAP (6-benzylaminopurine), (2.0 mg/L) were used for callus induction from mature dehusked rice seeds. MS medium supplemented with only 3.0 mg/L of 2, 4-D, produced maximum percentage of callus that is 90% for BRRI Dhan 50 and 80% for BRRI Dhan34. On the other hand, MS media with 3.0 and 4.0 mg/L of 2,4-D in combination with 2.0 mg/L BAP produced highest percentage of callus (80 %) for BRRI Dhan 50 and 70 % for BRRI Dhan 34. For plantlet regeneration, MS media with 1.0 mg/L NAA (1-Napthaleneacetic acid), 2.0 mg/L BA (6-benzyladenine) and various concentrations of Kinetin (0.0, 1.0, 2.0, 3.0, 4.0 mg/L) were employed. The maximum percentage of shoot regeneration was recorded at MS media supplemented with 4.0 mg/L of Kinetin +1.0 mg/L NAA and 2.0 mg/L BA for both varieties. These results will be very helpful to improve rice quality through somaclonal variation and genetic transformation.

A field experiment was conducted by Rao *et al.* (1993) at Cuttack reported that Badshahbhog, the local scented rice variety gave the highest grain yield (3.21 t ha^{-1}), among the long slender Basmati grain type varieties, Kasturi, Rambir Basmati, IET-8579 were promising with mean yield of 2.22 -2.58 t ha^{-1}. The varieties gave significantly higher yield than Basmati 370 and Pakistan Basmati in dry session.

Brahmachari *et al.* (2005) from West Bengal reported that the maximum grain yield was recorded in 'Kataribhog' than other local scented rice varieties. The performance of 'Batraj' was poor because of its total lodging during the later part of its growth stages.

Hussain *et al.* (2008) worked at Mymensingh, Bangladesh, to evaluate the effect of different nitrogen levels on the performance of four rice varieties in transplanted *Aman* (monsoon) season. Aromatic rice varieties included 'BRRI dhan38','Kalizira', Badshabhog'and 'Tulsimala', while nitrogen was applied at 30, 60, 90 and 120 kg ha^{-1}. Performance of different varieties was different. 'Kalizira' produced the maximum number of grains per panicle (135.90). Among the varieties, 'BRRI dhan 38' gave the maximum grain yield (4.00 t ha^{-1}).

A experiment comprised at Mymensingh, Bangladesh of three varieties viz., 'Kalizira', 'Badshabhog' and 'Tulshimala' and three levels of nitrogen viz., 40, 60 and 80 $kgha^{-1}$. 'Kalizira' was found significantly superior to 'Tulshimala' and 'Badshabhog' with respect to quality of grain and soil fertility of the post harvest soil (Sikdar *et al.*, 2010).

Bhowmick *et al*. (2011) emphasized that among the different aromatic rice varieties tested at West Bengal variety, Kalijira produced significantly higher grain yield.

CHAPTER III

MATERIALS AND METHODS

A field experiment entitled "Growth, yield and grain quality of traditional aromatic rice cultivars in *Boro* season" was carried out under field conditions during *Boro* season 2017-18 at the Agronomy Field of Sher-e-Bangla Agricultural University, Dhaka - 1207. The details of the research work carried out, materials used and methodologies adopted in this study are described here under.

3.1 Experimental site

The farm is geographically located at $23^{0}77^{'}$ N latitude and $90^{0}35'$ E longitude at an altitude of 8.6 m above mean sea level under the Agro-ecological Zone of Modhupur Tract, AEZ-28.

3.1.1 Weather during the crop growth period

The climate of the experimental site is subtropical. It receives rainfall mainly from South West monsoon (May-October) and winter season from November to February. The weather data during experimental period was collected from the Meteorological Station of Bangladesh, Sher-e Bangla Nagar, presented in Appendix II.

The maximum temperature during the crop growth period ranged from 15^{0}C to 35^{0} C with an average of 28.5^{0} C during 2018, while the minimum temperature 10^{0} C to 24^{0} C with an average 17.33^{0} C. The mean relative humidity ranged from 57 percent to 74 percent. The total rainfall received during the crop growth period was 302 mm received in 27 rainy days.

3.1.2 Soil

The soil of the research field belongs to "The Modhupur Tract", AEZ – 28 is slightly acidic in reaction with low organic matter content. The experimental area was above flood level and sufficient sunshine with having available irrigation and drainage system during the experimental period. Soil sample from 0-15 cm depth were collected from experimental field and the soil analysis were done from Soil Resources Development Institute (SRDI), Dhaka. The experimental plot was high land having pH 5.6. The physical properties and nutritional status of soil of the experimental plot are given in Appendix III.

3.2 Test crops

Eleven aromatic rice genotypes namely- Kataribhog-1, Kataribhog-2 (awned), BRRI dhan34, Badshabhog, BRRI dhan38, Chinigura, Madhumala, BRRI dhan50, Zirabhog, Chiniatap-1 and Chiniatap-2 were used for this experiment. Seeds were collected from Bangladesh Rice Research Institute (BRRI) Joydebpur, Gazipur, Bangladesh. The collected wheat genotypes were free from any visible defects, disease symptoms and insect infestation.

3.3 Experimental details

3.3.1 Treatments:

One set of treatments included in the experiment were as follows:

i) T_1 = Kataribhog-1

ii) T_2= Kataribhog-2 (awned)

iii) T_3= BRRI dhan34

iv) T_4 = Badshabhog

v) T_5 = BRRI dhan38

vi) T_6 = Chinigura

vii) T_7 = Madhumala

viii)T_8 = BRRI dhan50

ix) T_9 = Zirabhog

x) T_{10} = Chiniatap-1

xi) T_{11} = Chiniatap-2

3.3.2 Experimental design

The experiment was laid out in Randomized Completely Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the variety. There were 33 plots of size 2 m × 1.5 m in each of 3 replications. The treatments of the experiment were assigned at random into each replication following the experimental design. There were 0.75 m width and 10 cm depth for drains between the blocks. Each treatment was again separated by drainage channel of 0.5 m width and

10 cm depth. Two seedlings hill^{-1} were used during transplanting. The layout of the experimental field has been shown in Appendix IV.

3.4 Cultivation details

Details of cultivation practices are presented here under.

3.4.1 Seed sprouting

Healthy seeds were selected by specific gravity method and then immersed 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 in nursery bed after 72 hours.

3.4.2 Nursery

The field selected for nursery was thoroughly ploughed. Seed rate was calculated based on test weight and germination percentage. Sprouted seed was sown uniformly in the nursery bed on 23-11-2017. All the three test varieties were sown in an area of 1 m^2each on the same day i.e. 23-11-2017. Later, the seed was covered immediately and then a light irrigation was given. The nursery of 3m^2 was fertilized with a basal dose of 65g urea, 95g of single super phosphate and 25g of muriate of potash. Weeding and plant protection measures were taken up as and when necessary. Top dressing of urea @ 25g 3m^2 was given 10 days after sowing.

3.4.3 Main Field Preparation

The experimental field was ploughed twice with a tractor drawn puddler to obtain the required puddle after impounding 5 cm of standing water in the field. After thorough puddling, leveling was done. Water was drained out of the field in order to layout the plan of the experiment as shown in appendix 4.

3.4.4 Manures

A well decomposed farmyard manure as per the treatments was used in the present study applied at the time of final land preparation just 3 days prior to zinc application.

3.4.5 Fertilizer Application

A recommended dose of 180 kg urea, 165 kg TSP, and 180 kg MP ha^{-1} and 90 kg gypsum was applied as N, P_2O_5, K_2O and S respectively. Entire quantity of phosphorus and half of potassium and one third of the N were applied at the time of final land preparation just before transplanting. The remaining one third of the N and half of K were applied at two installment

3.4.6 Transplanting

Rice seedlings of 40 days old were transplanted in experimental plots keeping two seedlings hill^{-1}for inbred by adopting a spacing of 25 cm × 15 cm and one seedling hill-1 for hybrid spacing as 20 cm× 15 cm on 02-01-2017.

3.5 Intercultural operation

3.5.1 Gap Filling

Some seedlings from the nursery were transplanted alongside of the irrigation channels at the time of transplanting for the purpose of gap filling. Gap filling was done at the tenth day by using seedlings planted alongside the channels which were also lifted along with the intact soil in order to maintain uniform population.

3.5.2 Irrigation

A thin film of water was maintained at the time of transplanting for better establishment of the seedlings. From the third day onwards, 2 to 3 cm depth of water was maintained up to the panicle initiation stage except at the time of top dressing of nitrogen, where the water was drained out and re-flooded after 48 hours to maintain 5 cm depth of water up to physiological maturity. After dough stage, water was gradually drained out to facilitate easy harvesting of the crop.

3.5.3 Weeding

Weeds were removed from the plots by manual labour from four weeks after transplanting and the plots were kept weed free as and when necessary. Second weeding was taken up at Panicle Initiation (PI) stage (60 DAT).

3.5.4 Plant Protection

No major incidence of pests and diseases was observed except minor incidence of leaf folder, observed at 35 days after planting, which was controlled by spraying curbofuran 3G @ kg *a.i.* ha^{-1} of water.

3.5.5 Harvesting and Threshing

At maturity, border rows were harvested first in all the plots and separated. Then the net plots were harvested and left in the field for 3 days for sun drying. Before harvesting net plots, the plants selected for recording post observations were harvested separately. Threshing was done by manual labour and the grain was cleaned and sun dried. Grain and straw yields were recorded plot wise after drying to constant weight. The grain weights from sample plants were also added to the net plot yields.

3.6 Sampling

For sampling, 5 representative hills were selected randomly and tagged in each plot second rows from each side of the plot. The biometric data and post-harvest observations were recorded on the tagged hills.

3.7 Data recording

The following data were collected during the study period:

A. Crop growth characters

i. Plant height (cm) at 40, 55, 70, 85 DAT and at harvest

ii. Number of tillers hill^{-1}at 40, 55, 70, 85 DAT and at harvest

i**ii**. Leaves hill^{-1}

iv. Leaf area index

v. SPAD value

vi. 50% flowering

B. Yield attributes

i. Number of effective tillers hill^{-1}

ii. Number ofnon-effective tillers hill^{-1}

iii. Length of panicle

iv. Number of filled grains panicle^{-1}

v. Number of unfilled grains panicle^{-1}

vi. Grain length

vii. Grain breadth

vii. Weight of 1000 grains

C. Yield and harvest index

viii. Grain yield

ix. Straw yield

x. Biological yield

xi. Harvest index (%)

3.8 Procedure data collection

3.8.1 Crop growth characters

3.8.1.1 Plant height

Plant height was recorded for the five randomly tagged hills in each treatment in all the three replications. Plant height was measured from the base of the plant to tip of the top most leaf of every labeled hill at each sampling at 40, 55, 70, 85 DAT and at harvest. The plant height was expressed in centimeters (cm).

3.8.1.2 Number of tillers hill^{-1}

Total number of tillers hill^{-1} from the labeled plants at 40, 55, 70, 85 DAT and at harvest was counted and expressed as total number of tillers hill^{-1}.

3.8.1.3 Leaves hill^{-1}

The leaves hill^{-1}was recorded at harvest by counting total leaves as the average of same 5 hills pre-selected at random from the inner rows of each plot.

3.8.1.4 Leaf area index

Leaf area index (LAI) was estimated manually at the time of harvest. Data were collected as the average of 5 plants selected from middle of each row. Final data were calculated multiplying by a correction factor 0.75.

3.8.1.5 Chlorophyll content

Flag leaves were sampled at 6 days after flowering and a segment of 20 mg from middle portion of leaf was used for chlorophyll analysis. Chlorophyll content was measured on fresh weight basis extracting with 80 % acetone and used doubled beam spectrophotometer (Model: U-2001, Hitachi, Japan) according to Witham *et al.* (1986). Amount of chlorophyll was calculated using following formulae.

$$\text{Chlorophyll a (mg g}^{-1}\text{)} = [12.7\ (OD_{663}) - 2.69\ (OD_{645})] \times \frac{V}{100W}$$

$$\text{Chlorophyll b (mg g}^{-1}\text{)} = [12.9\ (OD_{663}) - 4.68\ (OD_{645})] \times \frac{V}{100W}$$

Where,
OD = Optical density of the chlorophyll extract at the specific wave length.

V = Final volume of the 80% acetone chlorophyll extract (ml)

W = Fresh weight in gram of the tissues extracted.

The total chlorophyll content was estimated by adding chlorophyll a and chlorophyll b.

3.8.1.6 Days to 50% flowering

Number of days taken from the sowing to when 50% of plants in the plot reached to flowering was taken as days to 50% flowering.

3.8.2 Yield attributes

3.8.2.1 Number of effective tillers hill^{-1}

Number of ear bearing tillers from the labeled plants at harvest were counted and expressed as effective tillers hill^{-1}.

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

Number of without ear bearing tillers from the labeled plants at harvest were counted and expressed as non-effective tillers hill^{-1}.

3.8.2.3 Panicle length

Measurement of panicle length was taken from basal node of the rachis to apex of each panicle. Each observation was an average total panicles of two hill.

3.8.2.4 Filled grains panicle^{-1}

Grain was considered to be filled if any kernel was present there in. The number of total filled grains present total panicles of two hills were recorded and finally averaged.

3.8.2.5 Unfilled grains panicle^{-1}

Unfilled grains means the absence of any kernel inside in and such grains total panicles of two hills were counted and finally averaged.

3.8.2.6 Grain length

Grain length was estimated manually at the time of harvest. Data were collected as the average of randomly selected 5 grain and expressed as millimeter (mm)

3.8.2.7 Grain breadth

Grain breadth was estimated manually of middle of grain at the time of harvest. Data were collected as the average of randomly selected 5 grain sand expressed as millimeter (mm)

3.8.2.8 1000 seed weight

One thousand grains were counted from a random sample for each treatment from a composite sample drawn from the net plot yield, weighed and expressed as 1000 seed weight (g).

3.8.3 Yield and harvest index

3.8.3.1 Grains yield

The crop harvested from 1m^2 each treatment was bundled separately and sun dried and later threshed individually plot-wise by manual labour. Cleaning of the grain was done after threshing followed by sun drying to a constant weight to record the final yield and expressed the final grain yield in t ha^{-1}.

3.8.3.2 Straw yield

Straw from 1m^2 each of each plot was dried in sun to a constant weight. Straw yield finally express as t ha^{-1}.

3.8.3.3 Biological yield

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

Biological yield (t ha^{-1}) = Grain yield (t ha^{-1}) + Straw yield (t ha^{-1})

3.8.3.4 Harvest index

Harvest index is the ratio of grain yield to the total biological yield (grain + straw) and expressed in percent. It was calculated using the formula given hereunder as suggested by Yoshida (1981).

$$\text{Harvest index (\%)} = \frac{\text{Grain yield (t ha}^{-1}\text{)}}{\text{Biological yield (t ha}^{-1}\text{)}} \times 100$$

3.9 Statistical analysis

All the data recorded are subjected to statistical analysis using analytical computer software program Statistix-10. Standard error at 0.05 level was worked out for the effects, which were significant. The results were presented in tables and depicted graphically wherever necessary.

CHAPTER IV

RESULTS AND DISCUSSION

A field experiment was conducted to study the "Growth, yield and grain quality of traditional aromatic rice cultivars in *Boro* season". The results of the experiment analyzed statistically are discussed in this chapter with cause, effects and collaborative research findings of the scientists.

4.1 Crop growth characters

4.1.1 Plant height

The data pertaining to plant height of rice at different days after transplantation presented in Table 1. It was inferred that irrespective of varieties of plant height increased gradually up to at harvest. But the rate of increase was much higher up to 85 DAT. After that it reduced slightly. Among the varieties, Chinigura (T_6) showed tallest plant than other tested varieties for all sampling dates. At 40 DAT, the tallest plant (36.81 cm) was observe in Chinigura (T_6) which was statistically identical with Kataribhog-1 (T_1), BRRIdhan34 (T_3) and similar with Badshabhog (T_4). The shortest plant found (25.96 cm) in BRRI dhan50 (T_8) which was statistically similar with Kataribhog-2 ((T_2), BRRI dhan38 (T_5), Madhumala (T_7), Zirabhog (T_9) Chiniatap-1 (T_{10}) and Chiniatap-2 (T_{11}). At 55 DAT, The tallest plant (61.14 cm) was recorded in Chinigura ((T_6) which was statistically similar with all varieties except BRRI dhan50 (T_8) and the shortest plant (51.87 cm) in BRRIdhan50 ((T_8) which was statistically similar with all varieties except Chinigura (T_6). At 70 DAT, The tallest plant (100.00 cm) was recorded in Chinigura (T_6) which was statistically similar with BRRI dhan34 ((T_3), Badshabhog (T_4) and BRRI dhan38 (T_5). The shortest plant (67.42 cm) was in BRRI dhan50 ((T_8). At 85 DAT, the tallest plant (137.30 cm) was found in Chinigura (T_6) which was statistically identical with Kataribhog-1 (T_1) and similar with Chiniatap-1 (T_{10}). The shortest plant (82.03cm) was in BRRI dhan50 (T_8). At harvest, the tallest plant (151.23 cm) was exerted in Chinigura (T_6) which was statistically differed from all other varieties. The shortest plant (86.87 cm) was found in BRRIdhan50 (T_8). The difference in plant height of varieties might be due to difference in their genetic makeup. Difference in plant height with different varieties was also observed by Priyadarsini (2001).

Table 1. Effect of variety on plant height at different days after transplanting of traditional aromatic rice in *Boro* season

Treatments	Different Days After Transplanting (DAT)				
	40	**55**	**70**	**85**	**At harvest**
T_1	36.2 a	55.62 ab	98.67 a	133.45 a	138.53 b
T_2	29.54 bc	58.55 ab	87.83 b-d	116.07 bc	131.43 bc
T_3	37.17 a	57.96 ab	94.08 a-c	114.00 bc	130.40 bc
T_4	32.04 ab	53.62 ab	96.42 ab	118.42 bc	123.80 c
T_5	30.38 bc	54.27 ab	94.58 a-c	115.33 bc	130.07 bc
T_6	36.81 a	61.14 a	100.00 a	137.30 a	151.23 a
T_7	31.12 bc	56.99 ab	83.50 d	96.65 d	112.00 d
T_8	25.96 c	51.87 b	67.42 e	82.03 e	86.87 e
T_9	26.48 bc	53.73 ab	79.08 d	97.00 d	122.30 cd
T_{10}	30.43 bc	57.78 ab	81.33 d	126.83 ab	132.73 bc
T_{11}	29.02 bc	54.0 ab	85.42 cd	109.03 cd	122.30 cd
LSD $_{(O.O5)}$	**5.60**	**7.60**	**10.40**	**13.7**	**11.40**
CV(%)	**10.33**	**7.97**	**6.93**	**7.12**	**5.35**

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. **T_1** = Kataribhog-1, **T_2**= Kataribhog-2 (awned), **T_3**= BRRI dhan34, **T_4** = Badshabhog, **T_5** = BRRI dhan38, **T_6** = Chinigura, **T_7** = Madhumala, **T_8** = BRRI dhan50, **T_9** = Zirabhog, **T_{10}** = Chiniatap-1 and **T_{11}** = Chiniatap-2

4.1.2 Number of tillers hill^{-1}

The number of plant tillers hill^{-1} of rice at different days after transplanting as influenced by the varieties are presented in Table 2. It is noticed that the number of tillers hill^{-1} was increased rapidly at 40 DAT to 70 DAT and it reached the highest at 90 DAT. Than number of tillers ware reduced due to dry and rotten some non-effective tillers. Among the tested varieties, the maximum tillers (7.66, 14.50, 24.33, 27.66 and 25.66 at 40, 55, 70, 85 DAT and at harvest at sampling dates, respectively) was found in Chinigura (T_6) which was statistically similar with Kataribhog-2 ((T_2), Badshabhog (T_4), BRRI dhan50 (T_8) at 40 DAT; Kataribhog-1 (T_1), Kataribhog-2 ((T_2), BRRI dhan34 (T_3), BRRI dhan38 (T_5), BRRI dhan50 (T_8), Chiniatap-2 ((T_{11}) at 55 DAT;

Kataribhog-1 (T_1), Kataribhog-2 ((T_2), Chiniatap-2 ((T_{11}) at 70 DAT; Kataribhog-1 (T_1) Kataribhog-2 (T_2), Chiniatap-2 ((T_{11}) at 85 DAT and statistically similar with all varieties except Badshabhog (T_4) and BRRI dhan50 (T_8) at harvest which might be due to its higher tillering ability compared to other varieties. The lowest tiller (8.33, 13.75, 17.66 and 13.66 at 55, 70, 85 DAT and at harvest,) was observed in Badshabhog (T_4). At 40 DAT, the minimum tiller (4.08) was observed Zirabhog (T_9). The present findings are in accordance with those of Priyadarsini (2001) who reported that different varieties produced different tillers hill^{-1}.

Table 2. Effect of variety on tillers hill^{-1} at different days after transplanting of traditional aromatic rice in *Boro* season

Treatments	Different Days After Transplanting (DAT)				
	40	55	70	85	At harvest
T_1	4.75 cd	12.50 a-d	22.57 a-c	24.08 ab	22.33 a-c
T_2	6.16 a-c	13.16 a-c	20.33 a-d	23.16 a-c	21.33 a-c
T_3	4.08 d	13.83 -ac	16.08 de	20.33 bc	18.33 a-c
T_4	6.91 ab	8.33 e	13.75 e	17.66 c	13.66 c
T_5	5.41 b-d	12.16 a-d	19.16 b-d	20.91 bc	17.00 a-c
T_6	7.66 a	14.50 a	24.33 a	27.66 a	25.66 a
T_7	4.83 cd	10.50 c-e	16.33 de	20.83 bc	18.33 a-c
T_8	6.25 a-c	13.41 a-c	17.66 de	18.00 c	15.33 bc
T_9	4.08 d	9.41 de	18.33 cd	21.50 bc	19.33 a-c
T_{10}	5.58 b-d	10.66 b-e	19.33 b-d	22.16 a-c	20.33 a-c
T_{11}	5.83 bc	14.16 ab	22.66 ab	27.83 a	24.00 ab
LSD (O.O5)	**1.63**	**3.64**	**4.28**	**5.84**	**9.03**
CV(%)	**10.10**	**13.74**	**7.59**	**8.92**	**15.62**

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. **T_1** = Kataribhog-1, **T_2**= Kataribhog-2 (awned), **T_3**= BRRI dhan34, **T_4** = Badshabhog, **T_5** = BRRI dhan38, **T_6** = Chinigura, **T_7** = Madhumala, **T_8** = BRRI dhan50, **T_9** = Zirabhog, **T_{10}** = Chiniatap-1 and **T_{11}** = Chiniatap-2

4.1.3 Leaves hill^{-1}

The leaves hill^{-1} of aromatic rice varieties were significantly influenced by varieties at harvest (Table 3). The results revealed that at harvest, the highest leaves hill^{-1} (65.00) were recorded from Chinigura (T_6) which was statistically similar with Madhumala (T_7) and Chiniatap-1 ((T_{10}) whereas; the lowest leaves hill-1 (38.33) were recorded from Kataribhog-2 (T_2) which was statistically similar with Kataribhog-1 (T_1), Kataribhog-2 ((T_2), BRRI dhan38 (T_5), BRRI dhan38 (T_5) and Chiniatap-2 (T_{11}). The results substantiate with the findings of Luh (1991) who observed that might be due to cause of genotypic characters of varieties and proper nutrient availability.

4.1.4 Leaf area index

The data leaf area index at harvest was significantly affected by varieties has been shown in Table 3. The maximum leaf area index (5.5) was obtained from Chinigura (T_6) which was statistically differed from all other varieties. This might be due to cause of proper nutrient supply mechanism from soil to the plants, light intensity and light holding capacity of a variety and above all phenotypic characters of the varieties. The finding was also observed by several researchers such as Kulandaivel *et al*. (2004) and Mustafa *et al*. (2011). The minimum leaf area index (3.10) was observed in Kataribhog-2 ((T_2) which was statistically similar with Kataribhog-1 (T_1), Kataribhog-2 (T_2), BRRI dhan34 (T_3), Badshabhog (T_4), BRRIdhan38 (T_5), Zirabhog (T_9), Chiniatap-1 (T_{10}) and Chiniatap-2 (T_{11}).

Table 3. Effect of variety on leaves hill^{-1} and leaf area index (LAI) of traditional aromatic rice in *Boro* season

Treatment	Leaves hill^{-1}	Leaf area index
T_1	44.91ef	3.32 cd
T_2	38.33 f	3.10 d
T_3	48.00 de	3.50 cd
T_4	51.00 c-e	3.64 b-d
T_5	43.00 ef	3.21 cd
T_6	65.00 a	5.50 a
T_7	57.00 a-c	4.50 b
T_8	55.00 b-d	4.14 bc
T_9	43.00 ef	3.43 cd
T_{10}	62.00 ab	3.87 b-d
T_{11}	46.00 ef	3.43 cd
LSD (O.O5)	**8.62**	**0.94**
CV(%)	**5.81**	**8.43**

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. **T_1** = Kataribhog-1, **T_2**= Kataribhog-2 (awned), **T_3**= BRRI dhan34, **T_4** = Badshabhog, **T_5** = BRRI dhan38, **T_6** = Chinigura, **T_7** = Madhumala, **T_8** = BRRI dhan50, **T_9** = Zirabhog, **T_{10}** = Chiniatap-1 and **T_{11}** = Chiniatap-2

4.1.5 SPAD value

The chlorophyll content of aromatic rice varieties were significantly influenced by varieties (Figure 1). The results revealed that BRRI dhan34 (T_3) produced the highest chlorophyll content which was statistically identical with BRRI dhan38 (T_5), Chinigura (T_6) and Chiniatap-2 (T_{11}) and similar with Kataribhog-1 (T_1), Madhumala (T_7), BRRI dhan50 (T_8), Zirabhog (T_9) and Chiniatap-1 (T_{10}). Kataribhog-2 (T_2) produced the lowest chlorophyll content (39.38 mg g^{-1}) which was statistically similar with Kataribhog-1 (T_1), Badshabhog (T_4), Madhumala (T_7) BRRI dhan50 (T_8) and Chiniatap-1 (T_{10}).

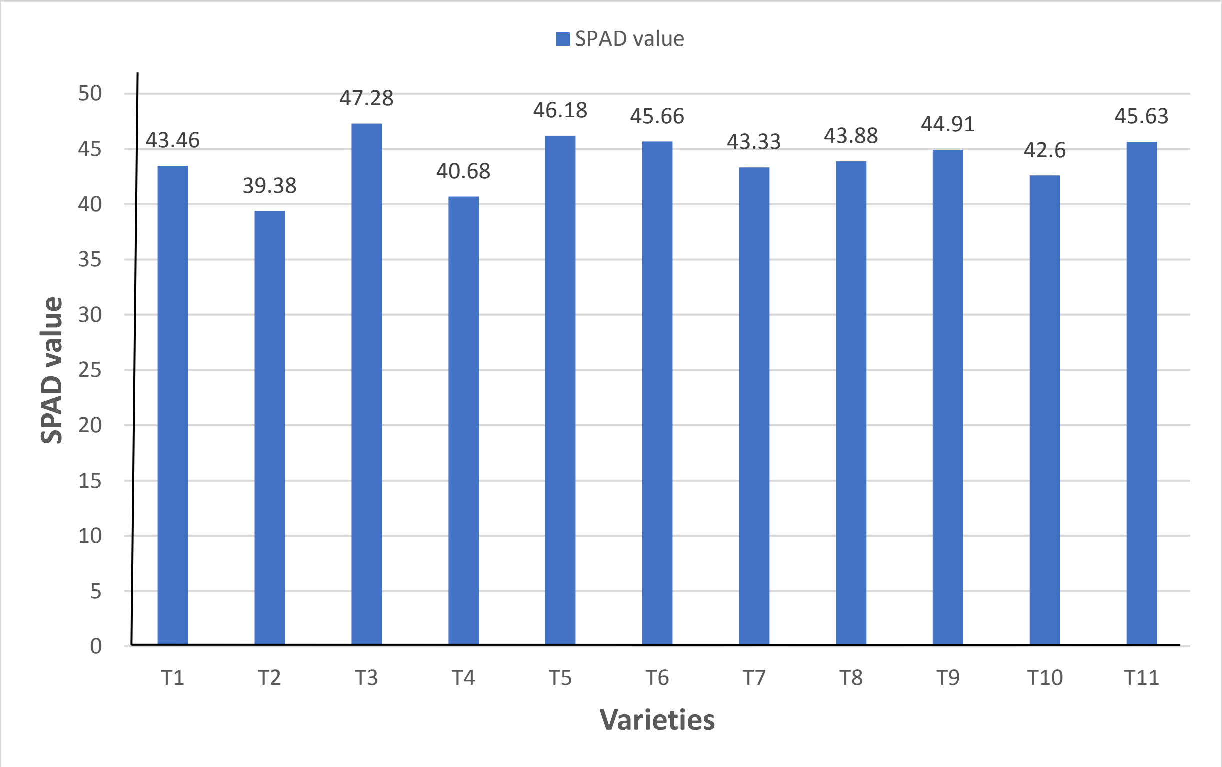

Figure 1. Effect of varieties on SPAD value of traditional aromatic rice in *Boro* season (LSD=4.9416 at 5% level of significance)

4.1.650% flowering

Data presented on days to 50% flowering revealed significant variations due to varieties (Figure 2). A considerable variation in days to 50% flowering was observed among the cultivars due to variation in the duration of cultivars. Days to 50% flowering (92.66

days) was more for Chinigura (T_6) which was statistically similar with all varieties except BRRI dhan38 (T_5) and Madhumala (T_7). On the other hand the variety, BRRI dhan38 ((T_5) was the earlier to reach to 50% flowering (72.30 days) which was statistically similar with (Madhumala (T_7). BRRI dhan38 (T_5) was being a short duration (135 to 145 days) variety, reached 50% flowering earlier compared to that of other cultivars. Chinigura (T_6) has the maximum duration (145 days) and hence, it took more number of days to attain 50% flowering. Attainment of 50% flowering as per the duration of cultivars was also reported by (Sinha *et al.*, 1999) who observed considerable variation in days to 50% flowering in rice. Similar results were observed by Raju *et al.* (1992) and Shehu *et al.* (2011).

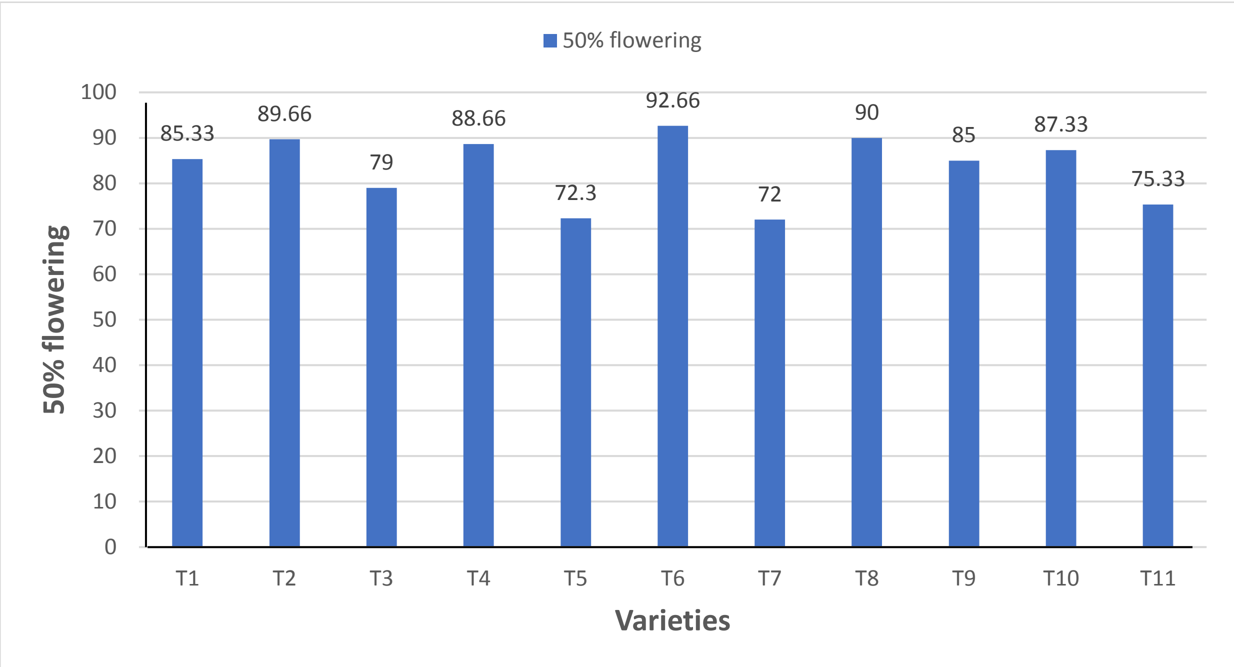

Figure 2. Effect of varieties on 50% flowering of traditional aromatic rice in *Boro* Season (LSD=18.376 at 5% level of significance)

4.2 Yield attributes

4.2.1 Number of effective tillers hill^{-1}

The data regarding the number of effective tillers hill^{-1} exerted significant influence due to varieties used in the present study (Table 4). The highest effective tillers hill^{-1} (18.23) was observed in Chinigura (T_6) which was statistically differed from all other varieties. The lowest (11.12) effective tillers hill^{-1} was recorded in Badshabhog (T_4) which was statistically similar with BRRI dhan50(T_8).This might be due to its high tillering ability and conversion of total number of tillers into more effective tillers. The results were in conformity with the findings of Sharma *et al*., (1999).

4.2.2 Number of Non effective tiller hill^{-1}

The number of non-effective tiller hill^{-1} was significantly influenced due to different varieties (Table 4). Result revealed that the maximum non effective tillers hill^{-1} (10.90) was observed in Chiniatap-2 (T_{11}) which was statistically differed from all other varieties. Lowest non effective tillers hill^{-1} (2.33) was obtained from Badshabhog (T_4) which was statistically identical with BRRIdhan38 (T_5)

4.2.3 Panicle length

Panicle length was significantly affected by rice varieties (Table 4). The longest panicle (25.43 cm) was obtained from Chinigura (T_6) which was statistically similar with all varieties except BRRI dhan50 (T_8). The shortest panicle was found in BRRI dhan50 (T_8) which was statistically similar with all varieties except Kataribhog-2 (T_2). This may due to the genetic makeup of varieties that panicle length varied with variety to variety among the varieties.

4.2.4 **Filled grains panicle^{-1}**

Number of filled grain panicle^{-1} differed significantly due to varieties (Table 4). Significantly highest number of filled grains (137.00) was recorded in Chinigura (T_6) which was statistically identical with Badshabhog (T_4). Variation in grains panicle^{-1} might be due to difference in panicle size of the varieties, which is a genetic character and specific to each variety. Similar relation with different varieties on total grains panicle^{-1} were reported by Sharma *et al.*, (1999). The lowest number of filled grains (78.00) was recorded with Madhumala (T_7).

4.2.5 Unfilled grains panicle^{-1}

The data pertaining to number of unfilled grains panicle^{-1} as influenced by varieties has been presented in the Table 4. Significantly highest number of unfilled grains panicle^{-1} (35.00) was recorded in BRRI dhan34 (T_3) which was statistically identical with Badshabhog (T_4) and the lowest (8.00) was obtained from Madhumala (T_7) followed by BRRI dhan38 (T_5) and Chiniatap-1 (T_{10}).

4.2.6 Weight of 1000 grain

1000-seed weight of rice was significantly affected due to varieties difference (Table 4). The highest 1000-seed weight (19.30 g) was found with Chinigura (T_6) followed by Kataribhog-1 (T_1) and BRRI dhan50 (T_8). This might be due to the bold size of the grain. Sharma *et al*. (1999) also reported variation in grain weight among the varieties. The lowest test weight (8.10 g) was observed with Badshabhog (T_4) which was statistically similar with Chinigura (T_6), Madhumala (T_7), Zirabhog (T_9), Chiniatap-1 (T_{10}) and Chiniatap-2 (T_{11}). This might be due to the fact that Badshabhog (T_4) being a fine quality rice grain recorded the lower 1000-grain weight.

Table 4. Effect of varieties on yield attributes of traditional aromatic rice in *Boro* season

Treatments	Effective tillers hill^{-1}	Non-effective tillers hill^{-1}	Panicle length (cm)	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	Weight of 1000 grain (g)
T1	16.89 b	5.44 d	25.09 ab	104.50 d	23.00 b	14.84 ab
T2	16.10 b	5.23 d	22.20 ab	90.65 e	17.00 cd	13.98 b
T3	14.67 c	6.32 c	23.21 ab	124.00 b	35.00 a	13.55 b
T4	11.12 g	2.54 g	21.86 ab	135.00 a	30.00 a	8.10 c
T5	14.67 c	2.33 g	24.21 ab	78.00 f	10.00 ef	11.23 bc
T6	18.23 a	7.43 b	25.43 a	137.00 a	21.00 bc	19.30 a
T7	14.05 cd	4.28 e	23.21 ab	85.40 ef	8.00 f	11.87 bc
T8	12.12 fg	3.21 f	18.76 b	116.00 bc	22.00 bc	15.00 ab
T9	12.81 ef	6.52 c	23.70 ab	110.00 cd	14.00 de	10.87 bc
T10	13.76 c-e	6.57 c	25.12 ab	112.00 cd	12.00 d-f	10.92 bc
T11	13.10 d-f	10.90 a	24.32 ab	109.00 cd	21.00 bc	9.80 bc
LSD (O.O5)	**1.2319**	**0.5838**	**6.5586**	**10.899**	**5.4075**	**5.3164**
CV(%)	**2.92**	**3.58**	**9.52**	**3.38**	**9.47**	**14.22**

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. **T1** = Kataribhog-1, **T2**= Kataribhog-2 (awned), **T3**= BRRI dhan34, **T4** = Badshabhog, **T5** = BRRI dhan38, **T6** = Chinigura, **T7** = Madhumala, **T8** = BRRI dhan50, **T9** = Zirabhog, **T10** = Chiniatap-1 and **T11** = Chiniatap-2

4.2.7 Grain length

Grain length was significantly influenced due to different varieties (Figure 3). Result revealed that the tallest grain (5.50 mm) was observed in Kataribhog-1 (T_1) which was statistically similar withKataribhog-2 (T_2). The shortest grain (3.60 mm) was obtained from BRRI dhan34 (T_3) which was statistically identical with BRRI dhan38 (T_5), Chinigura (T_6) Madhumala (T_7) BRRI dhan50 (T_8), Chiniatap-2 (T_{11}) and similar with Badshabhog (T_4), Zirabhog (T_9), Chiniatap-1 (T_{10}). This might be due to cause of genotypic characters of varieties and proper nutrient availability from soil.

4.2.8 Grain breadth

Grain breadth of aromatic rice varieties were significantly influenced by varieties (Figure 3). The results revealed that BRRI dhan38 (T_5) produced the highest grain breadth (3.10 mm) which was statistically identical with Zirabhog (T_9) and similar with BRRI dhan34 (T_3) and Madhumala (T_7). The lowest grain breadth found in BRRI dhan50 (T_8) which was statistically identical with Badshabhog (T_4), Chiniatap-1 (T_{10}) and Chiniatap-2 (T_{11}) and similar Kataribhog-1 (T_1)

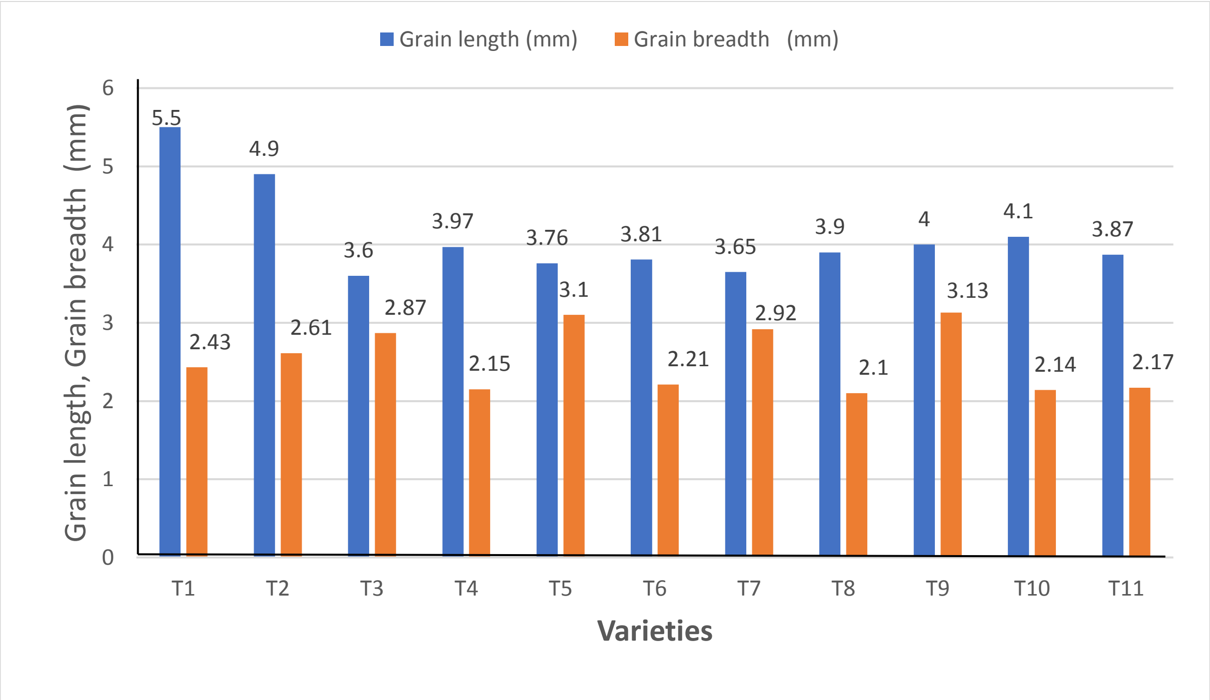

Figure 3. Effect of varieties on grain length (mm) and grain breadth of traditional aromatic rice in *Boro* season (LSD=0.9612 and 0.1243 for grain length and grain breadth, respectively at 5% level of significance)

4.3 Yield and harvest index

4.3.1 Grain yield

Grain yield of aromatic rice exerted significant variation due to varieties (Table 5 and Figure 4). Among the varieties Chinigura (T_6) out yielded over by producing 35.46% higher yield. However Chinigura (T_6) produced significantly the highest yield (3.46 t ha^{-1}) which was statistically similar with Kataribhog-1 (T_1), Kataribhog-2 (T_2), BRRI dhan34 (T_3), Badshabhog (T_4), BRRI dhan38 (T_5) and BRRI dhan50 (T_8). Lowest (2.00 t ha^{-1}) was observed from Madhumala (T_7) which was statistically identical with Chiniatap-2 (T_{11}). The higher grain yield in Chinigura (T_6) could be attributed to higher panicle length, filled grains panicle^{-1} and 1000-seed weight compared to other varieties. The result corroborates with findings of Priyadarsini (2001) and Dhaliwal *et al*. (2010) who observed yield variation among the varieties.

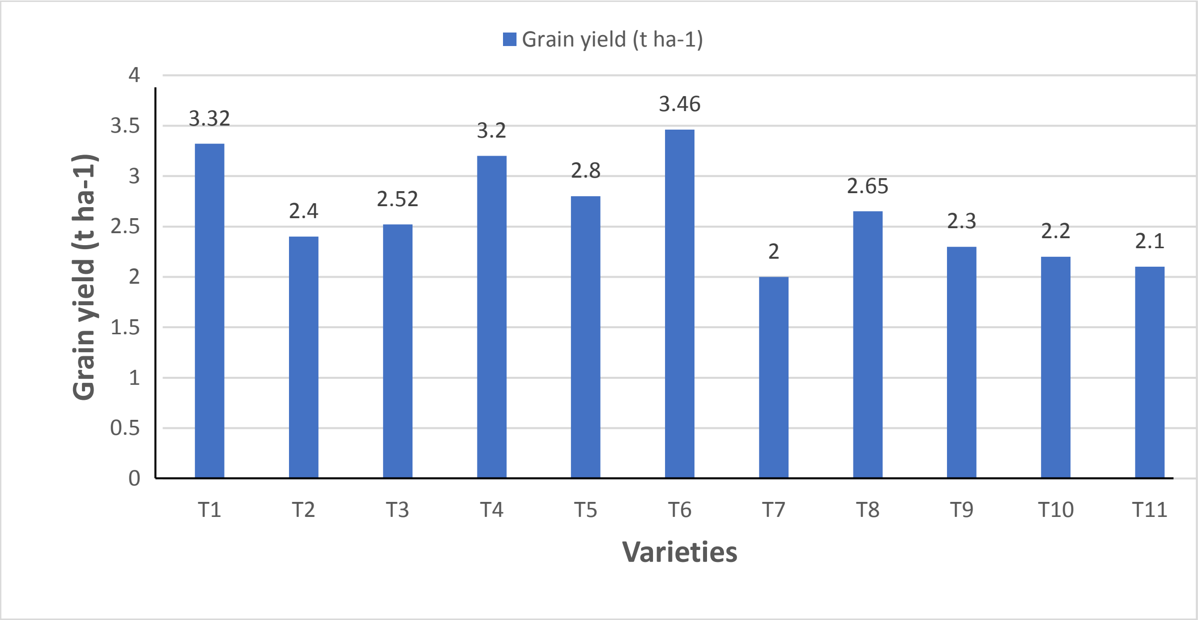

Figure 4. Effect of varieties on grain yield (t ha^{-1}) of traditional aromatic rice in *Boro* season (LSD=0.12 at 5% level significance)

4.3.2 Straw yield

Straw yield of rice differed significant due to tested varieties (Table 5). Higher straw yield of 8.11 t ha^{-1} was recorded with Chinigura (T_6) which was statistically identical with Badshabhog (T_4) and similar with Kataribhog-1 (T_1). Significant effect on straw yield of varieties might be due to their significant influence on plant height and bold tiller. The result agreed with the finding of Priyadarsini (2001) that straw yield of rice varied among the varieties.

4.3.3 Biological yield

Biological yield of rice was significantly influenced by the variety (Table 5). The highest biological yield (11.10 t ha^{-1}) was obtained from Chinigura (T_6) which was statistically identical with Kataribhog-1 (T_1) and BRRI dhan50 (T_8), Badshabhog (T_4) and similar with BRRI dhan38 (T_5) and BRRI dhan50 (T_8). The lowest (6.60 t ha^{-1}) from Chiniatap-2 (T_{11}) which was statistically identical with Kataribhog-2 (T_2), Chinigura (T_6) Madhumala (T_7), BRRI dhan50 (T_8), Zirabhog (T_9) and Chiniatap-1 (T_{10}). Rahman (2001) reported that hybrid variety produced higher biological yield compared to inbred variety due to higher grain yield and straw yield.

4.4.4 Harvest index (%)

Statistically analyzed data on harvest index are presented in Table 5. The result revealed that harvest index was significant regarding the varieties and highest harvest index (37.64) was obtained from BRRI dhan50 (T_8) followed by BRRI dhan34 (T_3). The lowest harvest index (24.62) found in Chinigura (T_6)

Table 5. Effect of variety on yield and harvest index of traditional aromatic rice in *Boro* season

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
T_1	3.32 ab	7.23 ab	10.69 a	31.74 c-e
T_2	2.40 a-d	4.33 d	6.73 c	35.65 ab
T_3	2.52 a-d	4.70 d	7.22 bc	34.92 a-c
T_4	3.20 a-c	7.90 a	10.76-a	28.80 e
T_5	2.80 a-d	6.50 bc	9.30-ab	30.08 e
T_6	3.46 a	8.11 a	11.10 a	24.62 f
T_7	2.00 d	4.80 d	6.80-c	29.34 e
T_8	2.65 a-d	5.50 cd	8.82 a-c	37.64 a
T_9	2.30b cd	4.50 d	6.80 c	33.82 b-d
T_{10}	2.20 cd	4.80 d	7.00 c	31.426 de
T_{11}	2.10 d	4.50 d	6.60 c	31.80c de
LSD (O.O5)	**1.01**	**1.21**	**2.30**	**3.50**
CV(%)	**14.17**	**7.20**	**9.33**	**3.72**

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability. **T_1** = Kataribhog-1, **T_2**= Kataribhog-2 (awned), **T_3**= BRRI dhan34, **T_4** = Badshabhog, **T_5** = BRRI dhan38, **T_6** = Chinigura, **T_7** = Madhumala, **T_8** = BRRI dhan50, **T_9** = Zirabhog, **T_{10}** = Chiniatap-1 and **T_{11}** = Chiniatap-2

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment entitled “Growth, yield and grain quality of traditional aromatic rice cultivars in *Boro* season” was carried out under field conditions during November, 2017 to December, 2018 at the Agronomy Field of Sher-e-Bangla Agricultural University, Dhaka -1207 to evaluate their growth and yield parameters. The experiment consisted of one factor – variety (eleven in number) viz; i) T_1 = Kataribhog-1, ii) T_2 = Kataribhog-2 (awned), iii) T_3 = BRRI dhan34, iv) T_4 = Badshabhog, v) T_5 = BRRI dhan38, iv) T_6 = Chinigura, vii) T_7 =Madhumala, viii) T_8 = BRRI dhan50, ix) T_9 = Zirabhog, x) T_{10} = Chiniatap-1 and xi) T_{11} = Chiniatap-2. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The total numbers of unit plots were 36. All the data recorded are subjected to statistical analysis using analytical computer software program Statistix-10. The mean differences among the treatments were compared by least significant Difference test at 5% level of significance. The weather during the crop growing period did not exhibit any major fluctuations and was congenial for crop growth. A total rainfall of 302 mm was received in 27 rainy days during the investigation period, which was insufficient for rice crop. Hence, need based irrigations were given to avoid moisture stress. The observations were recorded on plant height (cm), number of tillers hill^{-1} (no), Leaves hill$^{-1,}$ Leaf area index, SPAD value, 50% flowering, panicle length (cm), effective tillers hill^{-1}, non-effective tillers hill^{-1}, filled grains panicle^{-1} , unfilled grains panicle^{-1}, Grain length (mm), Grain breadth (mm), weight of 1000 seed (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index(%).The effect of variety on plant height showed dissimilar at different growth stage. Chinigura (T_6) showed the tallest plant (36.81, 61.14, 100.00 137.30 and 151.23 cm at 40, 55, 70, 85 DAT and at harvest, respectively) where BRRI dhan50 (T_8) showed the shortest plant (25.96, 51.87, 67.42, 82.03 and 86.87 cm at 40, 55, 70, 85 DAT and at harvest, respectively). But in terms of other growth parameters, the highest tillers hill^{-1}(7.66, 14.50, 24.33, 27.66 and 25.66 at 40, 55, 70, 85 DAT and at harvest, respectively), Leaves hill^{-1}(65.00),Leaf area index (5.50), SPAD value (47.28) and 50% flowering (90.00)were achieved by Chinigura (T_6) where the minimum tillers hill^{-1} (8.33, 13.75 , 17.66 and 13.66 at 55, 70, 85 DAT and at harvest, respectively) were gained by Badshabhog (T_4) and the lowest leaves hill^{-1} (38.33) and leaf area index (3.10), SPAD value (39.38) were gained by Kataribhog-2 (awned) (T_2) and 50% flowering (72.00) observed at Madhumala (T_7). Again, for yield and yield contributing characters viz. the highest effective tillers hill^{-1} (18.23) panicle length (25.43 cm), number of filled grains panicle^{-1} (137), 1000 seed weight (19.30 g), grain yield (3.46 t ha^{-1}), straw yield (8.11 t ha^{-1}) and biological yield (11.10 t ha^{-1}) were obtained by Chinigura (T_6) where the lowest value of effective tiller hill^{-1} (11.12) and 1000 seed weight (8.10 g) was obtained from Badshabhog (T_4); panicle length (18.76 cm) at BRRI dhan50 (T_8); number of filled grains panicle^{-1} (78.00) at BRRI dhan38 (T_5); grain yield (2.00 t ha^{-1}) at Madhumala (T_7), straw yield (4.33 t ha^{-1}) and biological yield (6.73 t ha^{-1}) were obtained by Kataribhog-2 (awned) (T_2). On the other hand, the highest grain length (5.50 mm) was obtained from Kataribhog-1 (T_1) and lowest grain length (3.60) at BRRI dhan34 (T_3); the highest grain breadth (3.10) was obtained from BRRI dhan38 (T_5) and lowest grain breadth (2.14) at Chiniatap-1 (T_{10}); the highest non-effective tillers hill^{-1} (10.90) was obtained from Chiniatap-2 (T_{11}) and lowest non-effective tillers hill^{-1} (2.33) at BRRI dhan38 (T_5); the highest unfilled grains panicle^{-1} (35.00) was obtained from BRRI dhan34 (T_3) and lowest unfilled grains panicle^{-1}

Conclusion:

- Among the test aromatic rice varieties Chinigura exhibited higher values for growth parameters (height, leaf numbers and tillers and LAI) compared to others.
- Chinigura provided the highest grain yield (3.46 t ha^{-1}) followed by Kataribhog-1 (3.32 t ha^{-1}), Badshabhog (3.20 t ha^{-1}), BRRI dhan38 and BRRI dhan50 (2.65 tha^{-1})
- Grain length and breadth ratio is the lowest (2.26 : 1) in Kataribhog-1.

Recommendation:

- Aromatic rice variety, Chinigura, Badshabhog, Kataribhog-1 and BRRI dhan38 should be cultivated for getting higher grain yield.
- For wider acceptability, the same experiment should be repeated at different Agro-ecological zones of the Bangladesh.

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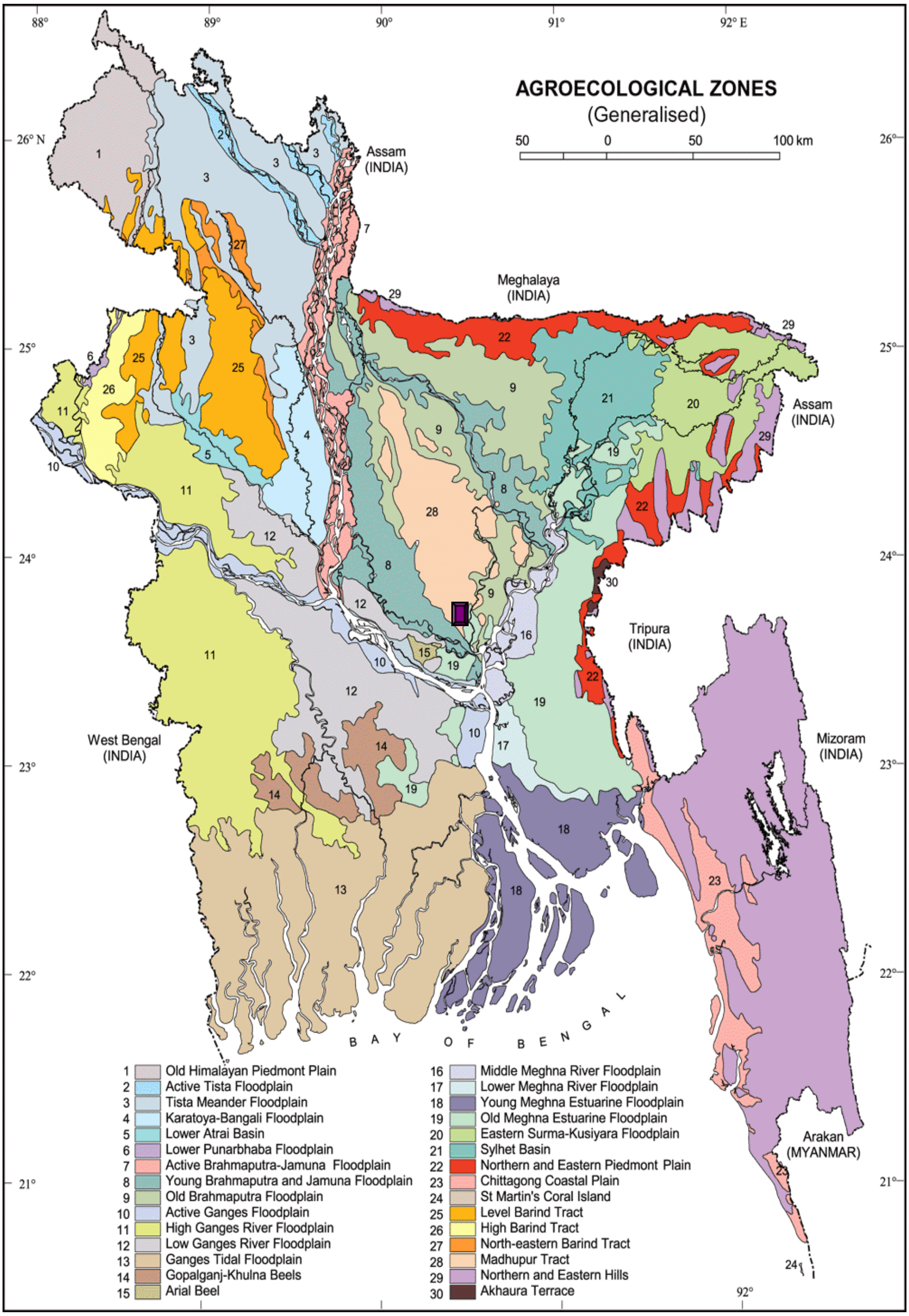
APPENDICES

Appendix I. The Map of the experimental site



Appendix II. Monthly records of air temperature, relative humidity, rainfall And sunshine during the period from November 2017 to February, 2018

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)	Sunshine (Hours)
		Max.	Min.	Avg.			
2017	December	28.2	13.5	20.9	79	8	3.8
2018	January	24.5	11.5	18.0	72	6	5.7
2018	February	33.1	12.9	23.0	55	10	8.1
2018	March	33.6	15.3	24.5	63	43	7.5
2018	April	36.0	21.20	28.6	65	86	9.5
2018	May	35.8	24.6	30.2	72	92	9.6

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

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

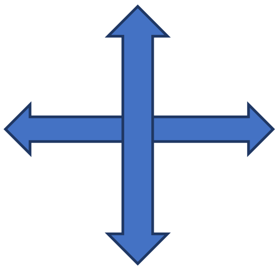
A. Morphological characteristics of the experimentalfield

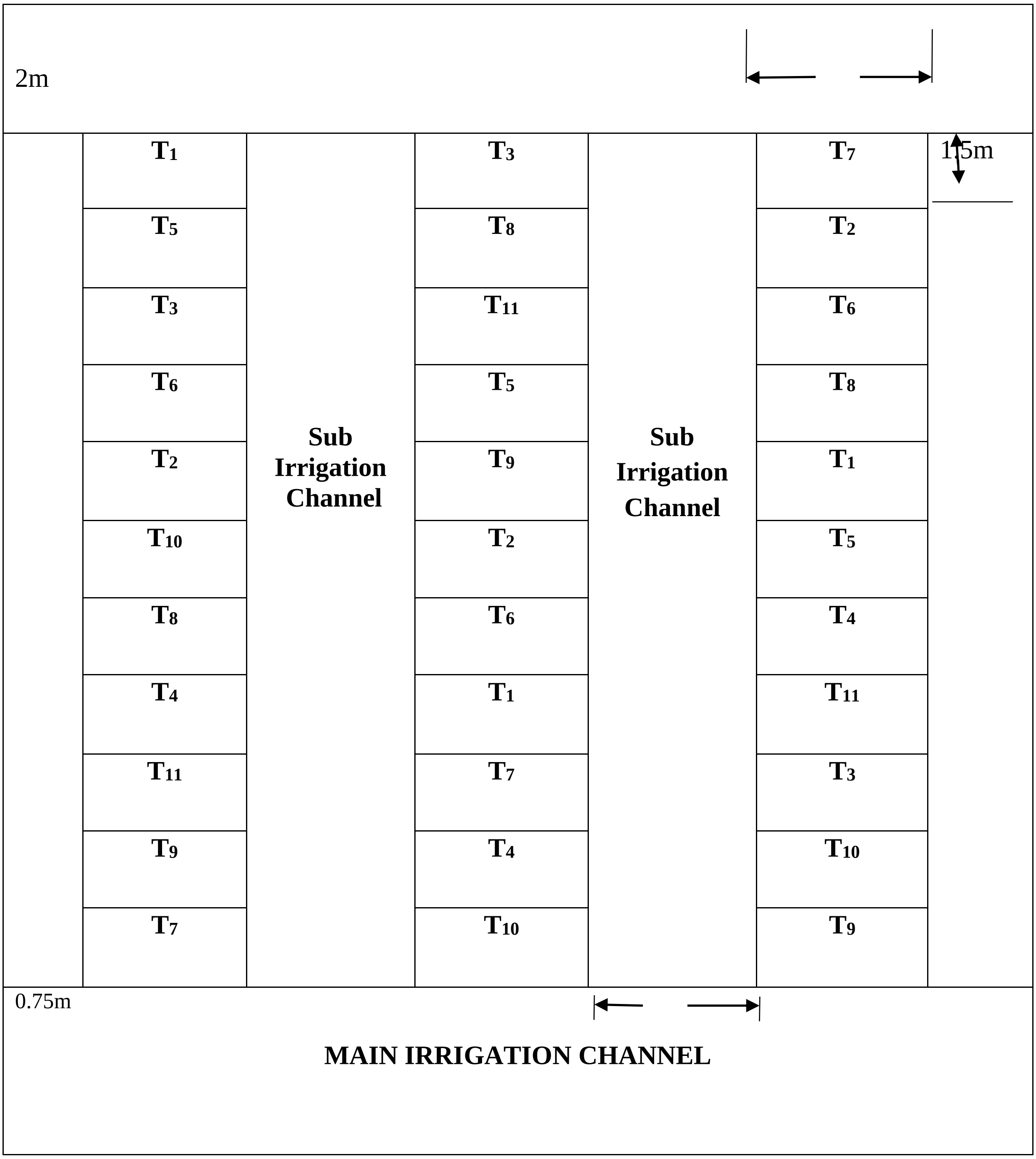
Morphological features	Characteristics
Location	Experimental field, SAU, Dhaka
AEZ	Madhupur Tract(28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initialsoil

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

N





Appendix IV. Experimental layout (RCBD)