# MORPHO-PHYSIOLOGICAL ATTRIBUTES AND YIELD PERFORMANCE OF DIFFERENT AROMATIC RICE GENOTYPES

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## *CERTIFICATE*

*This is to certify that thesis entitled, "MORPHO-PHYSIOLOGICAL ATTRIBUTES AND YIELD PERFORMANCE OF DIFFERENT AROMATIC RICE GENOTYPES" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in AGRICULTURAL BOTANY, embodies the result of a piece of bona fide research work carried out by REZUANA PERVIN, Registration No. 12-04815 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

*I further certify that such help or source of information, as has been availed of during the course of this investigation has been duly acknowledged.*

**Dated: December, 2017**
**Place: Dhaka, Bangladesh**

**Prof. Dr. Md. Ashabul Hoque**
**Supervisor**

**DEDICATED**

**TO**

**MY BELOVED PARENTS**

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**ABSTRACT**

An experiment was carried out at the research field of Sher-e-Bangla Agricultural University, Dhaka during the period from July 2017 -December 2017, to study the morpho-physiological attributes and yield performance of different aromatic rice genotypes and to identify the important morpho-physiological and yield contributing characteristics which might contribute in higher yield. Twelve rice varieties were used as treatments. The experiment was laid out in a Randomized complete Block Design (RCBD) with three replications. Data on different morpho-physiological parameters and yield with yield contributing characters were recorded. The collected data were statistically analyzed for evaluation of the treatment effect. Results signified that the highest number of total tillers hill$^{-1}$, dry weight hill$^{-1}$, crop growth rate , absolute growth rate, flag leaf area, SPAD value of flag leaf , number of effective tiller plant$^{-1}$, number of ineffective tiller$^{-1}$, panicle length, number of filled grains panicle$^{-1}$, number of unfilled grains panicle$^{-1}$, grain yield (3.30 ton ha$^{-1}$), straw yield (6.10 ton ha$^{-1}$), biological yield (9.4 ton ha$^{-1}$) and harvest index (35.11%) were recorded from the variety, $V_{11}$ (BRRI dhan37). The 2$^{nd}$ highest grain yield (2.81 ton ha$^{-1}$), straw yield (5.48 ton ha$^{-1}$), biological yield (8.29 ton ha$^{-1}$) and harvest index (33.90%) were recorded from the variety, $V_{12}$ (BRRI dhan38). The lowest number of effective tiller, number of filled grains panicle$^{-1}$, number of grains panicle$^{-1}$, grain yield (1.42 ton ha$^{-1}$), straw yield (3.92 ton ha$^{-1}$), biological yield (5.34 ton ha$^{-1}$) and lowest harvest index (26.59%) were observed from the variety, V6 (Modhumala).

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## ABBREVIATIONS AND ACRONYMS

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

# CHAPTER I

# INTRODUCTION

Rice is the second most staple food of the world after wheat. It is widely consumed by the large part of the world's population, especially in Asia. Ninety percent global rice production occurs in tropical land subtropical Asian countries (Mejia, 2006). Worldwide, rice provides 27% of dietary energy supply and 20% dietary protein (Kueneman, 2006). Being the 4$^{th}$ largest rice producer of the world, Bangladesh comprises an area of about 11.10 million hectares for rice production (FAO, 2003) of which around 27% is occupied by fine rice genotypes (BBS, 2003).

Rice is extensively grown in Bangladesh in the three seasons namely, Aus, Aman and Boro which covers total 80% of the total cultivable area of the country (AIS, 2011). Among these cropping seasons transplanted aman is most important and occupied about 46% of the rice cultivated land in 2009-10. The rest 41, 9 and 4 percent of the land is occupied by Boro, Aus and sown Aman respectively. Area covered by Aus is 10.50 lac hectare and production 23 lac 2 metric ton, area covered by Aman is 56 lac hectare and production 131 lac metric ton, lastly area covered by Boro is 48 lac hectare and production 192 lac matric ton (BBS, 2016). Aromatic rice varieties hasoccupied about 12.5% of the total aman rice cultivation (BBS, 2005). Further,the productivity of aromatic rice is even lower than HYV coarse varieties (BBS, 2005).

There are thousands of local land races in this country, many of which some good qualities i.e, fitness, taste, aroma and protein content (Kaul *et al*., 1982). Consumer demand for the fine rice genotypes is higher due to its good nutrition quality, palatability, taste, cooking quality and fragrance (Kaul *et al*., 1982). Most of the consumers prefer fine rice genotypes 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*., 1992).

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.

Aromatic rice has more demand both in external and internal trade markets. Moreover, the price of aromatic fine milled rice is much higher than modern rice. Therefore, the cultivation of aromatic rice in our country is becoming popular due to it's prices and export potentiality (Dutta *et al*., 2002).

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).

Growth is directly related to various morpho-physiological processes such as photosynthesis, respiration, enzyme activity etc. The growth analysis means the calculation of the components viz. CGR, RGR, AGR, etc. These components are widely used by plant physiologists and provide same indices of the plant responses to its environment. The yield of rice depends on its different growth parameters i.e. leaf area index, dry matter production and its partitioning, tillering, etc (Idris and Matin, 1990). Again the yield of rice also depends on high dry matter production, leaf area index, leaf area duration (LAD), crop growth rate (Yusuf, 1997).

It is, therefore, to evaluate the performance of aromatic rice genotypes through appropriate cultural practices to get maximum yield. But research works on local aromatic rice genotypes is limited in Bangladesh in relation to their morpho-physiological characteristics.

With conceiving the above scheme in mind, the present research work has been undertaken in order to fulfilling the following objectives:

1. To study the morpho-physiological attributes of different local aromatic rice genotypes.

2. To evaluate the yield performance of different local aromatic rice genotypes.

# CHAPTER II

# REVIEW OF LITERATURE

Rice yield varies due to varietal differences of yield attributes. So, varieties are the most important factor needed to be considered in rice cultivation. Some of the important and informative works and research findings related to different aromatic rice varieties done at home and abroad have been reviewed under the following headings:

## 2.1 Morpho-physiological parameters

### 2.1.1 Plant Height

Mohammad *et al. (*2002) reported that plant height is mostly governed by the genetic makeup of the cultivar, but the environmental factors also influence it.

Enamul *et al.* (2004) found that plant height did not vary significantly among the varieties at 35 and 50 days after transplanting (DAT) but during harvest significant variations in plant height were found among the varieties tested.

Ashrafuzzaman *et al.* (2009) reported that plant height varied significantly among the entries from 107.90 cm to 93.40 cm. Kalizira was the tallest (107.90 cm) of all the varieties. It had shown no significant difference with BR38 (107.80 cm) and BR34 (106.70 cm). Chiniatop was the shortest and was insignificant to Kataribhog (95.30 cm).The shorter plant height in Chiniatop (93.40 cm) was due to shorter internode length. Taller plants produced longest internodes than shorter ones that confirms the findings of Guevarra and Chang (1965) and they reported that the height of the plant was found to be dependent on the number of internodes and their individual lengths.

Satish *et al.* (2009) found that plant height registered significant positive association with number of productive tillers per plant, panicle length and number of grains per panicle indicating that the increase in panicle length and number of grains per panicle could be positive with increase in plant height.

Sinha *et al.* (2009) studied the performance of aromatic rice varieties and found that plant height varied significantly among the varieties up to 60 days after transplanting which increased up to maturity. The maximum plant height was recorded in Taroari Bas, followed by Bas 386 and Tulsi Bhog, however the minimum plant height was observed with CRM2007-1 at 90 days after transplanting.

### 2.1.2 Leaf number plant$^{-1}$

Yin and Kropff (1998) showed that final leaf number (FLN) varied among seven rice cultivars and in different sowing dates. Temperature, photoperiod and genetic characteristics are major factors that determine the final leaf number in rice (Yin and Kropff, 1998; Streck *et al*., 2008 and Sie *et al*., 1998)

Jaffuel and Duazat (2005) worked on the synchronism of leaf and tiller emergence relative to the position and main stem development stage in rice and concluded that the number of leaf in rice is related to the timing of several plant developmental stages such as tillering.

Aye and Oscar (2009) observed that the number of leaves on the main culm in PSB, Rc72H, PSB Rc18 and Dinorado rice varieties were higher with consequently high photosynthetic productivity.

### 2.1.3 Tiller number plant$^{-1}$

Yoshida *et al*. (1972) studied the physiological aspect of high yields in rice and reported that number of panicles per unit area is the most important component of rice yield. It accounts for 89% of the variation in grain yield. Similarly, Gallagher and Biscoe (1978) and Miller *et al.* (1991) also found that tiller number directly affects the number of panicle and as a consequence affects the total yield Zahid *et al.* (2005) also reported a highly significant variation for different traits including the number of productive tillers per plant which was correlated with total yield.

Peng *et al.* (1994) showed that a low tillering new plant type bears the advantage of higher nitrogen use efficiency compared to a high-tillering rice cultivar, when both of them are grown with high N supply.

Enamul *et al.* (2004) studied the yield performance of three aromatic fine rice genotypes in costal low land and found that the number of tiller per hill was significantly influenced by the variety at three different stages (35 and 50 DAT and at harvest). The highest number of tillers was found in Chinigura-1 (8.00) at 35 DAT, in Kalijira (10.50) at 50 DAT and lowest in Begunbitchi (7.25) at 50 DAT. At harvest Kalijira produced the maximum effective tillers (8.50) among the varieties.

Ahmad *et al*. (2005) reported that excessive tillering leads to high tiller abortion, poor grain setting, small panicle size and reduction in grain yield. Excessive branching is often considered expensive, as formation of low productive tillers becomes investment loss for a plant (Dun *et al*., 2006).

Wiangsamut *et al*. (2006) studied the tiller formation in five rice genotypes and found that tiller number per square meter increased up to 40 DAT and after 40 DAT, the tiller number among the five genotypes started to decrease.

Hossain *et al.* (2008) conducted a study to estimate the relationship between grain yield and morphological parameters in five local and three modern aromatic rice genotypes and found that the highest number of fertile tillers per hill was obtained in BRRI dhan37 (11.7) which was identically followed by Radhunipagal, Badshabhog and lowest fertile tillers per hill was obtained from Kalizera (9.8) and concluded that grain yield is directly associated with number of fertile tillers.

Jamal *et al*. (2009) evaluated five exotic rice genotypes along with a local check for yield and yield contributing traits and found that tillers per plant among rice genotypes ranged from 10 to 13. Maximum number of 13 tillers per hill was recored in variety IRI 384 and minimum number of 10 was recorded in variety PR 26881-JP 16-4B-78-5-1. They further concluded that grain yield was directly associated with number of effective tillers.

Satish *et al*. (2009) studied correlation and path analysis for yield and yield components in rice and revealed that grain yield is positively associated with number of productive tillers per plant.

Shahidullah *et al.* (2009) conducted an experiment with thirty aromatic rice genotypes to evaluate the tillering patterns and to explore its relationship with grain yield. Much variation was observed in tillering dynamics among the genotypes. They found that the number of panicles was positively correlated with maximum number of tillers and grain yield. Total number of tillers at harvest had the direct effect on grain yield.

Sinha *et al*. (2009) found that the number of tillers increased continuously and attained maximum values at 60 day after transplanting. Among the varieties Taroari Bas produced the highest number of tillers at all stages of development followed by Bas 386 and CRM-2203-4 whereas Tulsi Bhog recorded lowest number of tiller per square meter.

**2.1.4 Leaf area index**

Norbakhshian and Rezai (1999) reported that relative growth rate (RGR) and CGR at flowering had positive correlation with grain yield in rice and also stated that LAI was correlated negatively with grain yield at flowering. While Pinheiro and Guimaraes (1990) reported that in the absence of environmental stress, yield increased with increase in LAI.

Chandra and Das (2000) found that leaf area index was significantly and positively associated with grain yield; leaf area index showed significant positive association with dry matter of clums and dry matter of panicles. Miah *et al.* (1996) showed that LAI of 7.3 is the maximum that is necessary to give high grain yield. Yield increasing with increasing LAI and maximum yield at LAI 7.

Sharma and Haloi (2001) conducted an experiment on scented rice and found that there was remarkable variation in all the crop growth variables viz, seedling behavior, root volume, culm diameter, loding behavior,leaf area index ,net assimilation rate,flag leaf area, specific leaf weight (SLW) and rate of dry matter production.Yang *et al.* (2001) studied that grain yield and yield component of two rice cultivar (IND 3 and JND13).The variety IND 13 exhibited leaf area index after heading compare with NDS 3.

### 2.1.5 Flag leaf area

Sheela *et al.* (1990) studied the role of flag leaf on grain yield and spikelet sterility in rice cultivars and concluded that the grain yield and yield related traits were positively related to flag leaf area. Flag leaf plays an important role in grain yield, spikelet fertility, panicle size, grain size and weight.

Positive correlation between flag leaf area and grain yield and yield components was reported by Rao (1992).

Mohtashami (1998) studied the genotypic and phenotypic correlation between quantitative and qualitative traits and grain yield in rice and found that flag leaf angle had negative and significant correlation with grain yield, 1000-grain weight and filled grain number in rice.

Dutta *et al.* (2002) studied the plant architecture and growth characteristics of fine grain and aromatic rice and concluded that flag leaf area and flag leaf angle may be more related to current photosynthate synthesis and translocation for grain filling and higher grain fertility in local rice genotypes.

### 2.1.6 SPAD value of flag leaf

Kariya *et al.* (1982) reported that the chlorophyll meter quantifies the greenness or relative chlorophyll content of leaves thus the critical or threshold SPAD value is important and that indicates the leaf area based critical nitrogen concentration in rice leaves. Thus the chlorophyll meter or SPAD (Soil plant analysis development) offers a new strategy for synchronizing N application with actual crop demand in rice (Peng *et al.*, 1996).

Miah *et al.* (1997) reported that Chlorophyll pigments play an important role in the photosynthetic process as well as biomass production. Genotypes maintaining higher leaf chlorophyll-a and chlorophyll-b during growth period may be considered potential donors for the ability of producing higher biomass and photosynthetic capacity. Higher photosynthetic rate is supported by leaf chlorophyll content in leaf blades.

Hussain *et al.* (2000) studied the use of chlorophyll meter efficiency indices for nitrogen management of irrigated rice and reported that the chlorophyll meter indicates the need of a nitrogen top dressing that would result in greater agronomic efficiency of nitrogen fertilizer than common pre-application of nitrogen.

Munshi (2005) reported that grain yield in rice was positively correlated with chlorophyll content and showed that high yielding genotypes also showed higher chlorophyll content. Similarly, Swain *et al.* (2006) also found highly significant and positive relation between total chlorophyll content at all the growth stages and grain number/$m^2$. The increase in the yield was attributed to the chlorophyll content in sink development and grain filling.

Hossain *et al*. (2007) reported that the biological yield had significant correlation to chlorophyll of leaves. When chlorophyll of leaves increase, the amount of photosynthetic assimilates increase and is stored in shoot of plant. But, when chlorophyll content of flag leaf is high, the photosynthetic assimilates transported to kernel and flag leaf role in production of biological yield is lower than other leaves.

Mian *et al.* (2009) reported a linear and positive relationship of SPAD values with total chlorophyll, chlorophyll-a and leaf nitrogen % indicating the dependence of SPAD values with chlorophyll and nitrogen content of leaf at flowering.

### 2.1.7 Dry weight hill$^{-1}$

Tanaka *et al.* (1964) reported that higher dry weight need not necessarily be correlated with higher grain yield. The increase in total dry weight was slow initially, became rapid at flowering stage.

Sahu and Murthy (1975) reported the accumulation of 30, 65 and 85 percent of total dry weight at panicle initiation, flowering and mid harvest stage, respectively. They also stated that the accumulation was comparatively low up to panicle initiation stage (10%).

Venkateshwarlu and Prasad (1982) reported that greater dry weight accumulation per hill resulted in more seed yield per hill. Similarly Weng(1984) have also reported that the yield increases in Japanese varieties were mainly due to high dry weight production after heading.

WuWen *et al.* (2008) found that the grain yield had no significant correlation with dry weight accumulation before the elongation stage while had a significantly positive correlation from the elongation to maturity stages in super hybrid rice. There was more dry weight in vegetative organs at the heading stage in the super hybrid rice but its contribution to yield was 4.3 percent lower than that in the check.

Sinha *et al.* (2009) observed that dry weight accumulation in the root and shoot increased with the increase in crop age and there was significant difference among the varieties.

WuGuicheng*et al*. (2010) showed that yield was significantly correlated with dry weight at maturity and the dry weight accumulation from heading to maturity. Dry weight production from jointing to heading was significantly positively correlated with yield.

### 2.1.8 Crop growth rate

Mia *et al*. (1994) reported that yield was associated with higher pre-flowering CGR in short duration rice varieties and with higher post-flowering CGR in long duration rice varieties and suggested that rice yield improvements may be possible by enhancing the photosynthetic rate before anthesis.

Montomatsu *et al*. (1988) reported that the semidwarf cultivars had higher yields, longer panicles, and larger dry matter accumulation in grains due to higher CGR and higher photosynthetic rates after panicle formation than Japanese cultivars. Karimi and Siddique (1991) also reported that CGR at anthesis was greater for modern than old cultivars.

Horie (2003) reported that in early maturity lines, the CGR increase before flowering had significant correlation with grain yield, while in the late maturity lines CGR increase after flowering had significant correlation with yield.

Farrel *et al.* (2003) indicated that grain yield had positive correlation with LAI, CGR and NAR and found that there is also a correlation between tiller initiation and leaf initiation. Increase in tiller number and length of leaves were the reason for LAI increase in high and low tiller varieties.

WuWen *et al.* (2008) reported that the high yield of super hybrid rice mostly was due to the products of photosynthesis after heading, which is shown by the increased CGR at middle and later stages. It was also suggested that LAD might be used to better explain the advantage in the dry matter production of super hybrid rice than LAI.

Shahidullah *et al.* (2009) reported that different aromatic rice genotypes exhibited enormous variations for leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), grain yield, total dry matter, harvest index and photosynthetic efficiency or energy use efficiency (Eμ) at panicle initiation and heading stages.

### 2.1.9 Relative growth rate

Norbakhshian and Rezai (1999) reported that relative growth rate (RGR) and CGR at flowering had positive correlation with grain yield in rice and also stated that LAI was correlated negatively with grain yield at flowering. While Pinheiro and Guimaraes (1990) reported that in the absence of environmental stress, yield increased with increase in LAI.

Chandrasekhar *et al. (*2001) reported that CGR, LAI, LAD and SLW had direct effect on dry matter production and yield whereas RGR had negative and significant correlation with grain yield (Kulmi, 1992).

Shahidullah *et al*. (2009) reported that different aromatic rice genotypes exhibited enormous variations for leaf area index (LAI), crop growth rate (CGR), relative growth rate (RGR), net assimilation rate (NAR), grain yield, total dry matter, harvest index and photosynthetic efficiency or energy use efficiency (Eμ) at panicle initiation and heading stages.

### 2.1.10 Absolute growth rate

Mondal *et al.* (2010) reported that the physiological and yield parameters differed significantly among the genotypes. The mutant RM 100-24 performed well with respect to physiological parameters like AGR, RGR and NAR. Moreover, RM 100-24 also manifested superiority in yield contributing characters over the other genotypes and resulted in higher grain yield.

## 2.2 Yield and yield contributing parameters

### 2.2.1 Number of effective and ineffective tiller plant$^{-1}$

Yoshida *et al.* (1999) reported that the plant length and the specific leaf area showed strong negative and positive significant correlation, respectively, with the maximum tiller number.

Nuruzzaman *et al.* (2000) conducted an experiment to find out the relationship between the tillering ability and morphological character among 14 rice varieties. They observed that tiller number varied widely among the varieties and the number of tillers per plant at the maximum tiller number stage between 14.3 and 39.5 in 1995 and 12.2 and 34.6 in 1996. Among all the varieties IR 36 produced the highest tiller number followed by suweon 258 Dawn which produced the lowest tiller number.

Yang *et al.* (2001) studied the grain yield and yield components of two rice cultivars (JND3 and JND13). They observed that JND3 exhibited a higher tillering capacity than JND13.

Siddique *et al*. (2002) studied some rice varieties which include JPS, SWAT-1, SWIT-11, DILROSH-9, PARC-3, IETI 13711, IRRI-4, GOLAM-6, GOLAM-7. The analysis of data revealed that statistically significant differences were registered for all the parameters studied except number of tillers plant$^{-1}$ number of panicle plant $^{-1}$.

### 2.2.2 Number of filled grains panicle$^{-1}$

Kusutani *et al.* (2000) reported that the variety which produced highest number of effective tillers per hill and highest number of grains per panicle also showed highest grain yield in rice. Similarly Fageria and Baligar (2001) reported that grain number per panicle had a positive and significant correlation with grain yield.

Krishna *et al.* (2010) reported that filled grains and spikelet fertility were significantly correlated with grain yield similarly Samonte *et al.* (1998) also found that number of filled grains per panicle had significant positive effect on rice grain yield whereas Rasheed *et al.* (2002) reported that fertility percentage showed positive but non-significant correlation with grain yield per plant.

### 2.2.3 Number of unfilled grains panicle$^{-1}$

Chowdhury *et al.* (1993) reported that the cultivar BR23 showed superior performance over pajam in respect of number of tiller hill$^{-1}$, length of panicle, 1000 grain weight, grain yield and straw yield. On the other hand, the cultivar pajam produced significantly taller plant, higher number of total spikelet panicle$^{-1}$ and unfilled spikelet panicle$^{-1}$.

Evaluation of performance of four rice genotypes viz, IRATOM 24, BR 14, BINA 13and BINA 19 showed that cultivars / advanced lines differed significantly for the plant height, number of total effective and non- effective tillers hill$^{-1}$ , panicle length, sterile spikelet panicle$^{-1}$ but grain yield did not differ significantly (BINA, 1993).

### 2.2.4 Spikelet fertility

Tahir *et al.* (2002) reported significant variation among the different genotypes for number of spikelets per panicle.

Patel *et al.* (2010) found that among the yield components assessed, sink size (spikelets per panicle) contributed more to the yield and is considered to be most important factor responsible for yield gap between aerobic and flooded rice.

Krishna *et al.* (2010) reported that filled grains and spikelet fertility were significantly correlated with grain yield similarly Samonte *et al.* (1998) also found that number of filled grains per panicle had significant positive effect on rice grain yield whereas Rasheed *et al.* (2002) reported that fertility percentage showed positive but non-significant correlation with grain yield per plant.

### 2.2.5 Panicle length

Fageria and Baligar (2001) reported that panicle length and spikelet number had the highest correlation with grain yield. Panicle length had the high positive and significant correlation to number of grains per panicle and significant and negative correlation to grain yield.

Sharma (2002) reported that there had been significant variation in panicle length in aromatic rice varieties

Ashrafuzzaman *et al*. (2009) working on yield and yield contributing characters in aromatic rice reported that BR34 possessed the longest panicle (19.73 cm) and Kataribhog had the shortest panicle (16.20 cm).

### 2.2.6 Weight of 1000 grain

Cheema *et al*. (1998) found positive and significant correlation between 1000-grain weight and grain yield per plant. Similar results were also reported by Mirza *et al*. (1992). Mondal *et al*. (2005) reported the significant difference among the cultivars studied for 1000- grain weight.

Sidhu *et al.* (1992) recorded 1000 grain weight of 15.80 g with Basmati 385 variety, 15.70 g with Basmati 370 and 16.50 g with Pusa Basmati-1 and Jamal *et al.* (2009) reported minimum 1000-grain weight in IRI384, while maximum 1000-grain weight with variety ILLABONG.

### 2.2.7 Grain yield

Miah *et al.* (1996) reported that high yield is determined by physiological process leading to a high net accumulation of photosynthates and their partitioning to sink whereas Biswas *et al.* (1998) reported varietal differences in grain yield in rice.

Chandrasekhar *et al.* (2001) reported that the yield differences were due to the significant difference in their yield components and similarly Ashrafuzzaman *et al.* (2009) presented the relationship between morphological and yield contributing characters with grain yield.

Sharma (2002) found that between physiological characters with the grain yield of 22 rice varieties and seed yield was significantly and positively correlated with net assimilation rate,leaf area index, photosynthetic rate, total dry matter and photosynthetic rate had very high direct and indirect effects on grain yield.

Rajesh *et al*. (2008) carried out morpho-physiological analysis of yield in different rice genotypes under lowland situation and found that genotype PHB-71 recorded highest grain yield and was significantly superior to all the genotypes studied which was due to higher number of total tiller, effective tiller and number of filled grains per panicle.

### 2.2.8 Straw yield

Chowdhury *et al*, (1995) showed that both grain and straw yield were higher in the improved varieties (BR3, BR11, Pajam, Mala) than the native (Mulati, nazirshail and Chandrashail) varieties.

### 2.2.9 Biological yield

Chowdhury *et al.* (1995) showed that grain yield was positively correlated with biological yield in rice. Hoque (2004) worked with four fine grain rice and observed that high yielding cultivars had grater biological yield than low yielding ones. Similar result was reported but most of the researchers (Singh and Gangwer, 1989; Sharma and Haloi, 2001; Yang *et al*, 2001; Akter, 2005; Munshi 2005).

### 2.2.10 Harvest index

Kusutani *et al*. (2000) conducted the studies on the varietal differences in harvest index and morphological characteristics of rice and highlighted the contribution of high harvest index to yields.

Ashrafuzzaman *et al.* (2009) found that the highest harvest index of 34.94% was recorded in BR34 and the lowest harvest index of 31.51% was obtained from Basmati and stated that harvest index is a vital character having physiological importance. It reflects the ability of a variety to translocate photosynthates to the economic parts.

# CHAPTER III

# MATERIALS AND METHODS

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka during the period from July 2017 to December 2017. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations, data recording and their analysis.

## 3.1 Site description

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

## 3.2 Climate

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

## 3.3 Soil

The farm belongs to the general soil type, shallow red brown terrace soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. The experimental area was flat having available irrigation and drainage system. The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done by Soil Resources and Development Institute (SRDI), Dhaka. The physicochemical properties of the soil are presented in Appendix III.

### 3.4 Treatments

Single factor experiment was conducted and 12 aromatic rice varieties were considered as the treatment for the present study. The respected varieties were as follows:

$V_1$ = Kalijira

$V_2$ = Chiniatap1

$V_3$ = BRRI dhan50

$V_4$ = Kataribhog 1

$V_5$ = Badshabhog

$V_6$ = Modhumala

$V_7$ = Zirabhog

$V_8$ = Shakkhorkhora

$V_9$ = Chiniatap 2

$V_{10}$= Kataribhog 2

$V_{11}$= BRRI dhan37

$V_{12}$ = BRRI dhan38

### 3.5 Plant materials and collection of seeds

Twelve local aromatic rice varieties *viz*. Kalijira, Chiniatap 1, BRRI dhan50, Kataribhog 1, Badshabhog, Modhumala, Zirabhog, Shakkhorkhora, Chiniatap 2, Kataribhog 2, BRRI dhan37 and BRRI dhan38 were used as plant materials for the present study. The seedsof local varieties was collected from BRRI, Joydebpur, Gazipur, Bangladesh.

### 3.6 Seed sprouting

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

### 3.7 Preparation of nursery bed and seed sowing

As per BRRI recommendation, seedbed was prepared with 1m wide adding nutrients as per the requirements of soil. Seeds were sown in the seed bed on July, 2017 in order to transplant the seedlings in the main field.

### 3.8 Preparation of experimental field

The plot selected for the experiment was opened in the first week of July 2017 with a power tiller, and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed, and finally obtained a desirable field for transplanting of the seedlings.

### 3.9 Fertilizer application

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

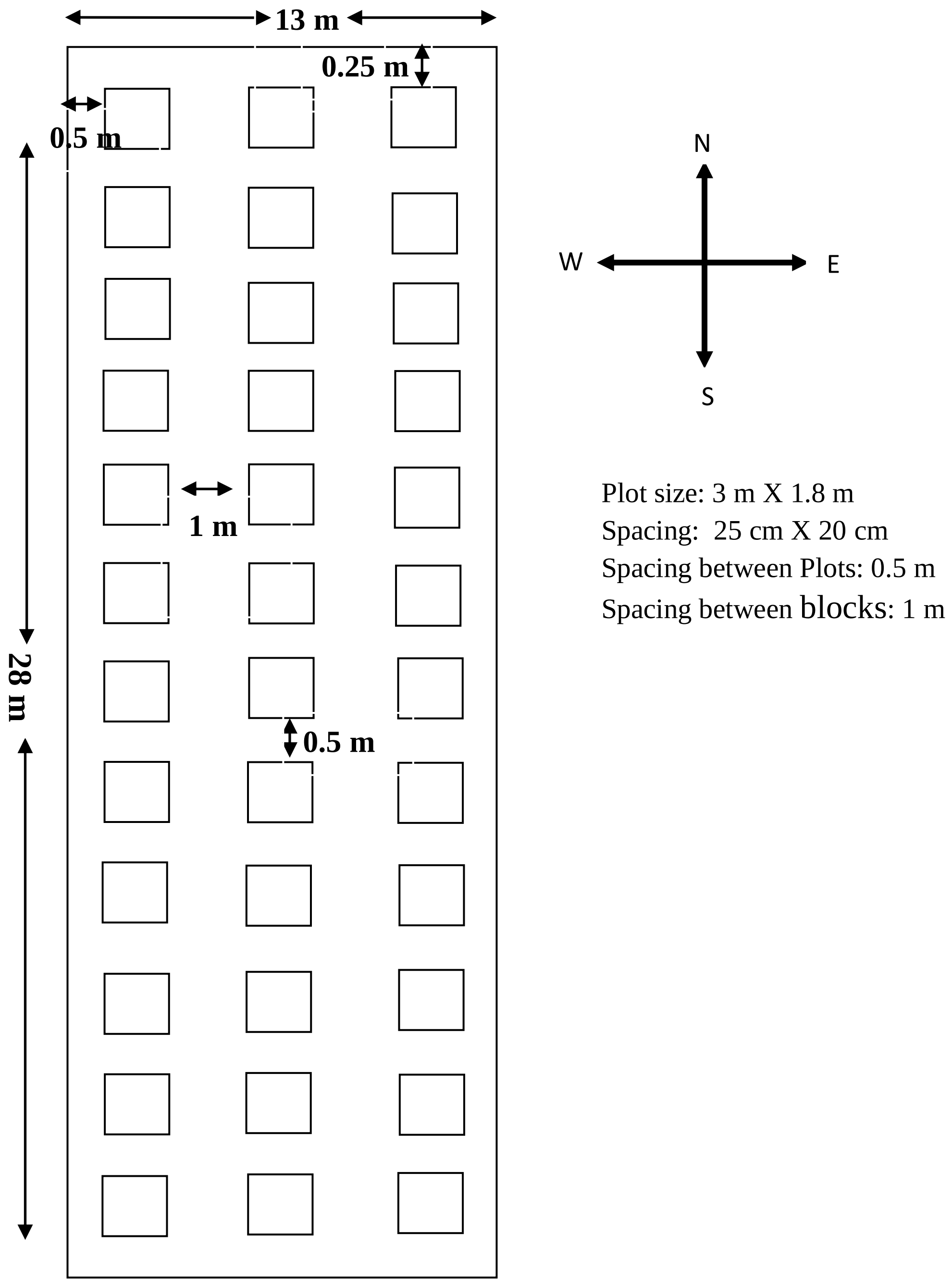
| Fertilizer | Recommended doses (kg $ha^{-1}$) |
|---|---|
| Urea | 150 |
| TSP | 100 |
| MP | 100 |
| Zinc sulphate | 10 |
| Gypsum | 60 |
| Borax | 10 |

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

### 3.10 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications (block). Each block was first divided into 12 sub plots where varieties of rice were assigned. Thus the total number of unit plots was 12×3=36. The size of the unit plot was 3m × 1.8m. The distance maintained between the row was

0.5m and between column was 1m. The treatments (varieties) were randomly assigned to the plots within each block.




**Layout of the experimental plot**

### 3.11 Uprooting of seedlings

The nursery bed was made wet by application of water one day before uprooting the seedlings. The seedlings were uprooted on August 5, 2017 without causing much mechanical injury to the roots.

### 3.12 Transplanting of seedlings in the field

The seedlings were transplanted in the main field on August 5, 2017 with a spacing 20 cm from hill to hill and 25 cm from row to row.

### 3.13 Intercultural operations

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

#### 3.13.1 Irrigation and drainage

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

#### 3.13.2 Gap filling

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

#### 3.13.3 Weeding

The crop was infested with some common weeds, which were controlled by uprooting and remove them three times from the field during the period of experiment. Weeding was done after 15, 32 and 52 days of transplanting.

### 3.14 Plant protection

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

### 3.15 Harvesting, threshing and cleaning

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

### 3.16 General observation of the experimental field

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

### 3.17 Recording of data

The following data were recorded during the study period:

#### 3.17.1 Morpho-physiological parameters

1. Plant height (cm)
2. Number of leaves $plant^{-1}$
3. Number of total tillers $plant^{-1}$

4. Leaf area index
5. Flag leaf length (cm)
6. Flag leaf beadth (cm)
7. Flag leaf area ($cm^2$)
8. SPAD value of flag leaf
9. Dry weight $hill^{-1}$
10. Crop growth rate ($mgcm^{-2}day^{-1}$)
11. Relative growth rate ($mgg^{-1}day^{-1}$)
12. Absolute growth rate ($cmday^{-1}$)

### 3.17.2 Yield and Yield contributing parameters

1. Number of effective tillers $plant^{-1}$
2. Number of in-effective tillers $plant^{-1}$
3. Number of total grains $panicle^{-1}$
4. Number of filled grains $panicle^{-1}$
5. Number of unfilled grains $panicle^{-1}$
6. Panicle length (cm)
7. Spikelet fertility ( % )
8. Weight of 1000 grain (g)
9. Grain yield (ton $ha^{-1}$)
10. Straw yield (ton $ha^{-1}$)
11. Biological yield (ton $ha^{-1}$)
12. Harvest index (%)

### 3.18 Procedures of recording data

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

### 3.18.1 Plant height

The height of plant was recorded in centimeter (cm) at the time of 30, 55, 80 DAT and at harvest. Data were recorded as the average of same 5 plants pre-selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the plant.

### 3.18.2 Number of leaves plant$^{-1}$

Number of leaves plant$^{-1}$ was counted from the average of same 5 plants pre-selected at random from the inner rows of each plot.

### 3.18.3 Number of total tillers plant$^{-1}$

Total tillers which had at least one leaf visible were counted. It includes both productive and unproductive tillers. It was counted from the average of same 5 plants pre-selected at random from the inner rows of each plot.

### 3.18.4 Leaf area index

LAI =Leaf area / Ground area

### 3.18.5 Flag leaf length (cm)

Flag leaf length was measured with a meter scale from 5 pre-selected plants from the inner rows of each plot.

### 3.18.6 Flag leaf breadth (cm)

Flag leaf breadth was measured with a meter scale from 5 pre-selected plants from the inner rows of each plot.

### 3.18.7 Flag leaf area ($cm^2$)

Flag leaf area was calculated by multiplying length and breadth of the leaf from 10 selected plants and the mean values were recorded.

### 3.18.8 SPAD value of flag leaf

Flag leaf SPAD value was recorded at growth stage.

### 3.18.9 Dry weight hill$^{-1}$

Randomly selected 5 hills were cut at the ground level from each line and leaves were separated from clum. Then the sample were dried in an electrical oven for 72 hours.after drying weight of each sample was taken and convert to g/hill.

### 3.18.10 Crop growth rate ($gcm^{-2}day^{-1}$)

CGR is the rate of dry matter production per unit of ground area per unit of and was worked out by the following formula,

$$CGR = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{1}{A} \text{ g cm}^{-2} \text{ day}^{-1}$$

Where,

$W_1$ = dry weight of the plant at time $t_1$

$W_2$ = dry weight of the plant at time $t_2$

A = land area covered by the plant in $cm^2$

$t_2$ and $t_1$ = time interval in days

### 3.18.11 Relative growth rate ($mgg^{-1}day^{-1}$)

$RGR = (LogeW_2 - LogeW_1) / (t_2 - t_1)$

Where, $LogeW_1$ and $LogeW_2$ are the natural logs of total dry weights at time $t_1$ and $t_2$

### 3.18.12 Absolute growth rate (cm day$^{-1}$)

$AGR = (h_2 – h_1) / (t_2 – t_1)$

Where, $h_1$ and $h_2$ are the plant height at time $t_1$ and $t_2$

### 3.18.13 Number of effective tillers plant$^{-1}$

The total number of effective tillers plant$^{-1}$ was counted from 5 selected plants at harvest and average value was recorded.

### 3.18.14 Number of in-effective tillers plant$^{-1}$

The total number of effective tillers plant$^{-1}$ was counted from 5 selected plants at harvest and average value was recorded.

### 3.18.15 Number of total grains panicle$^{-1}$

The total number of filled and unfilled grains were counted together randomly from selected 5 plants of a plot and then average number of total grains panicle$^{-1}$ was recorded.

### 3.18.16 Number of filled grains panicle$^{-1}$

The total number of filled grains was collected randomly from selected 5 plants of a plot and then average number of filled grains panicle$^{-1}$ was recorded.

### 3.18.17 Number of unfilled grains panicle$^{-1}$

The total number of unfilled grains was collected randomly from selected 5 plants of a plot and then average number of unfilled grains panicle$^{-1}$ was recorded.

### 3.18.18 Spikelet fertility(%)

The filled grains present on panicles were counted and spikelet fterility percentage was calculated with the help of following formula

Spikelet fertility % = number of filled grains/total number of grains x 100

### 3.18.19 Panicle length (cm)

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

### 3.18.20 Weight of 1000 grain (g)

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

### 3.18.21 Grain yield (ton $ha^{-1}$)

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

### 3.18.22 Straw yield (ton $ha^{-1}$)

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

### 3.18.23 Biological yield (ton $ha^{-1}$)

Biological yield was determined using the following formula

Biological yield = Grain yield + Straw yield

### 3.18.24 Harvest index (%)

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

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

### 3.19 Statistical analysis

The data were analyzed in Randomized Complete Block Design and the means were separated by DMRT at 5% level of significance using the statistical computer package program MSTAT-C (Russell, 1986).

# CHAPTER IV

# RESULT AND DISCUSSION

The experiment was conducted to study morpho-physiological attributes and yield performance of different aromatic rice genotypes. The results obtained from the study have been presented, discussed and compared in this chapter through different tables, figures and appendices. The results have been presented and discussed and possible interpretation has been given under the following headings.

## 4.1 Morpho-physiological parameters

### 4.1.1 Plant height

Plant height of different aromatic rice varieties of different days after transplanting are showed statistically significant difference presented in the Fig 1 and Appendix IV. Plant height increased progressively with the advancement of time and growth stages.

At 30 DAT, among the varieties the highest (62.97) plant height was observed in the variety $V_6$ (Modhumala) which was followed by the variety $V_1$, $V_2$, $V_{11}$, $V_{12}$, $V_7$ and $V_{10}$ and they were statistically similar. On the other hand, the lowest (45.15) plant height was observed in $V_8$ (Shakkhorkhora) which was statistically similar to the variety $V_3$ and $V_9$.

At 55 DAT, among the varieties the highest (112.8) plant height was observed in $V_6$ (Modhumala) which was followed by the variety $V_1$, $V_8$,$V_9$,$V_{10}$ and $V_{11}$and they were statistically similar. On the other hand, the lowest (85.86) plant height was observed in the variety $V_3$ (BRRI dhan50) which was statistically similar to the variety $V_4$ and $V_7$.

At 80 DAT, among the varieties the highest (145.1) plant height was observed in the variety $V_6$ (Modhumala) which was followed by the variety $V_9$ and $V_{10}$ and they were statistically similar. On the other hand, the lowest (113.2) plant height was observed in $V_3$ (BRRI dhan50) which was statistically similar to the variety $V_5$.

At harvest, among the varieties the highest (165.7) plant height was observed in the variety $V_6$ (Modhumala) which was followed by the variety $V_5$ and $V_8$ and they were statistically similar. On the other hand, the lowest (130.3) plant height was observed in the variety $V_3$ (BRRI dhan 50). Simillar result also reported by Sinha *et al.* (2009).Which is supported the present study. They studied the performance of aromatic rice varieties and found that plant height varied significantly among the varieties after transplanting which increased up to maturity, justifying the present experiment.

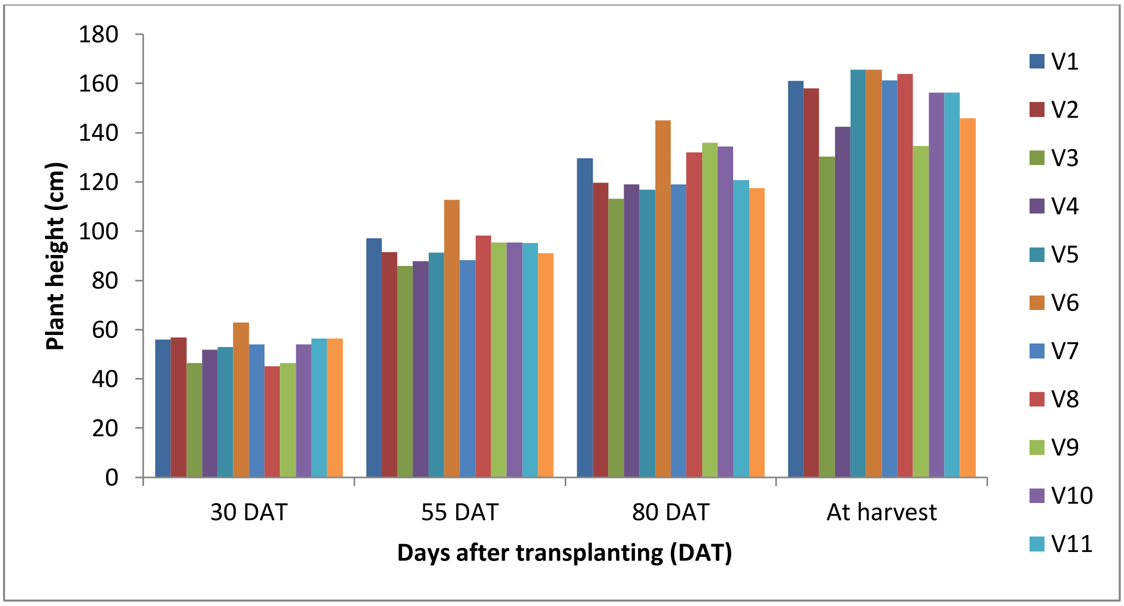



**Fig. 1. Plant height of different aromatic rice varietiesat various days after transplanting (DAT) and at final harvest. Values followed by same letter(s) did not differ significantly at 5% level of probability.**

$V_1$ = Kalijira, $V_2$ = Chiniatap 1, $V_3$ = BRRI dhan 50, $V_4$ = Kataribhog 1, $V_5$ = Badshabhog, $V_6$ = Modhumala, $V_7$ = Zirabhog, $V_8$ = Shakkhorkhora, $V_9$ = Chiniatap 2, $V_{10}$ = Kataribhog 2, $V_{11}$ = BRRI dhan37, $V_{12}$ = BRRI dhan38

### 4.2.2 Number of leaves plant$^{-1}$

Number of leaves plant$^{-1}$ of different aromatic rice varieties of different days after transplanting are showed different significant difference presented in the Table 1 and Appendix V and the total number of leaves was continued to increase up to 80 DAT and thereafter declined.

At 30 DAT, among the varieties the highest (31.67) number of leaves plant$^{-1}$ was observed in the variety $V_9$ (Chiniatap 2) which was followed by the variety $V_7$, $V_{12}$ and they were statistically similar. On the other hand, the lowest (21.50) number of leaves plant$^{-1}$was observed in the variety $V_3$ (BRRI dhan50) which was statistically similar to the variety $V_{5.}$

At 55 DAT, among the varieties the highest (75.25) number of leaves plant$^{-1}$ was observed in the variety $V_9$ (Chiniatap 2) which was followed by the variety $V_4$ andthey were statistically similar. On the other hand, the lowest (51.75) number of leaves plant$^{-1}$ was observed in the variety $V_3$ (BRRI dhan50) which was statistically similar to the variety $V_{5.}$

At 80 DAT, among the varieties the highest (71.33) number of leaves plant$^{-1}$ was observed in the variety $V_9$ (Chiniatap 2) which was followed by the variety $V_{1,}$ $V_4$, $V_{12}$ but they are statistically similar. On the other hand, the lowest (41.17) number of leaves plant$^{-1}$was observed in the variety $V_3$ (BRRI dhan50) which was statistically similar to the variety $V_{6.}$

At harvest, among the varieties the highest (68.50) number of leaves plant$^{-1}$ was observed in the variety $V_9$ (Chiniatap 2) which was followed by the variety $V_{1,}$ $V_4$, $V_{12}$ but they are statistically similar. On the other hand, the lowest (39.33) number of leaves plant$^{-1}$was observed in the variety $V_3$ (BRRI dhan50). Simillar result also reported by Yin and Kropff (1998) and they showed that leaf number varied among seven rice cultivars.Temperature, photoperiod and genetic characteristics are major factors that determine the leaf number in rice (Yin and Kropff, 1998; Streck *et al.*, 2008 and Sie *et al.*, 1998).

**Table 1. Number of leaves plant$^{-1}$ of different aromatic rice varieties at various days after transplanting and at final harvest.**

| Variety | Number of leaves plant$^{-1}$ at different DAT | | | |
|---|---|---|---|---|
| | 30 DAT | 55 DAT | 80 DAT | At harvest |
| $V_1$ | 24.25 e | 57.25 e | 64.17 b | 62.83 b |
| $V_2$ | 24.25 e | 55.75 e | 57.58 cd | 55.92 c |
| $V_3$ | 21.50 f | 51.75 g | 41.17 f | 39.33 g |
| $V_4$ | 24.83 de | 72.00 b | 64.33 b | 62.42 b |
| $V_5$ | 23.00 ef | 52.25 fg | 53.00 e | 50.17 f |
| $V_6$ | 28.50 bc | 55.00 ef | 43.00 f | 40.25 g |
| $V_7$ | 31.00 a | 62.75 d | 53.08 e | 50.42 ef |
| $V_8$ | 26.75 cd | 60.75 d | 55.58 de | 52.83 de |
| $V_9$ | 31.67 a | 75.25 a | 71.33 a | 68.50 a |
| $V_{10}$ | 25.00 de | 63.75 d | 58.00 cd | 55.17 cd |
| $V_{11}$ | 24.00 e | 67.50 c | 59.58 c | 56.67 c |
| $V_{12}$ | 30.25 ab | 67.00 c | 63.25 b | 60.50 b |
| LSD0.05 | 2.232 | 2.945 | 3.606 | 2.437 |
| CV(%) | 8.06 | 9.99 | 11.97 | 12.96 |

Values followed by same letter(s) did not differ significantly at 5% level of probability.

$V_1$ = Kalijira, $V_2$ = Chiniatap 1, $V_3$ = BRRI dhan 50, $V_4$ = Kataribhog 1, $V_5$ = Badshabhog, $V_6$ = Modhumala, $V_7$ = Zirabhog, $V_8$ = Shakkhorkhora, $V_9$ = Chiniatap 2, $V_{10}$ = Kataribhog 2, $V_{11}$ = BRRI dhan37, $V_{12}$ = BRRI dhan38

### 4.1.3 Number of tillers plant$^{-1}$

Number of tillers plant$^{-1}$ of different aromatic rice varieties of different days after transplanting are showed different significant difference presented in the Fig. 2 and Appendix VI.

At 30 DAT, among the varieties the highest (11.68) number of tillers plant$^{-1}$ was observed in $V_{11}$ (BRRI dhan37) which was followed by the variety $V_7$ and $V_{12}$ and they were statistically similar. On the other hand, the lowest (7.167) number of tillers plant$^{-1}$was observed in the variety $V_6$ (Modhumala) which was statistically similar to the variety $V_{3.}$

At 55 DAT, among the varieties the highest (17.83) number of tillers plant$^{-1}$ was observed in the variety $V_{11}$ (BRRI dhan37) which was followed by the variety $V_9$ but it was statistically similar. On the other hand, the lowest (9.853) number of tillers plant$^{-1}$ was observed in the variety $V_6$ (Modhumala).

At 80 DAT, among the varieties the highest (25.08) number of tillers plant$^{-1}$ was observed in the variet $V_{11}$ (BRRI dhan37) which was followed by the variety, $V_{12}$ but it was statistically similar. On the other hand, the lowest (17.42) number of tillers plant$^{-1}$ observed in the variety $V_6$ (Modhumala) which was statistically similar to the variety, $V_1$ and $V_{3.}$

At harvest, among the varieties the highest (21.25) number of tillers plant$^{-1}$ was observed in the variety $V_{11}$ (BRRI dhan37) which was followed by the variety $V_2$ and $V_{12}$ but they were statistically similar. On the other hand, the lowest (10.92) number of tillers plant$^{-1}$ was observed in $V_6$ (Modhumala). This result was also supported by Zahid *et al.* (2005) and they reported that a highly significant variation for different traits including the number of productive tillers per plant which was correlated with total yield.This result also supported by Hossain *et al*. (2008) and they conducted a study to estimate the relationship between grain yield and morphological parameters in five local and three modern aromatic rice genotypes and found that the highest number of fertile tillers per hill was obtained in BRRI dhan37.This result again also supported by Enamul *et al.* (2004).

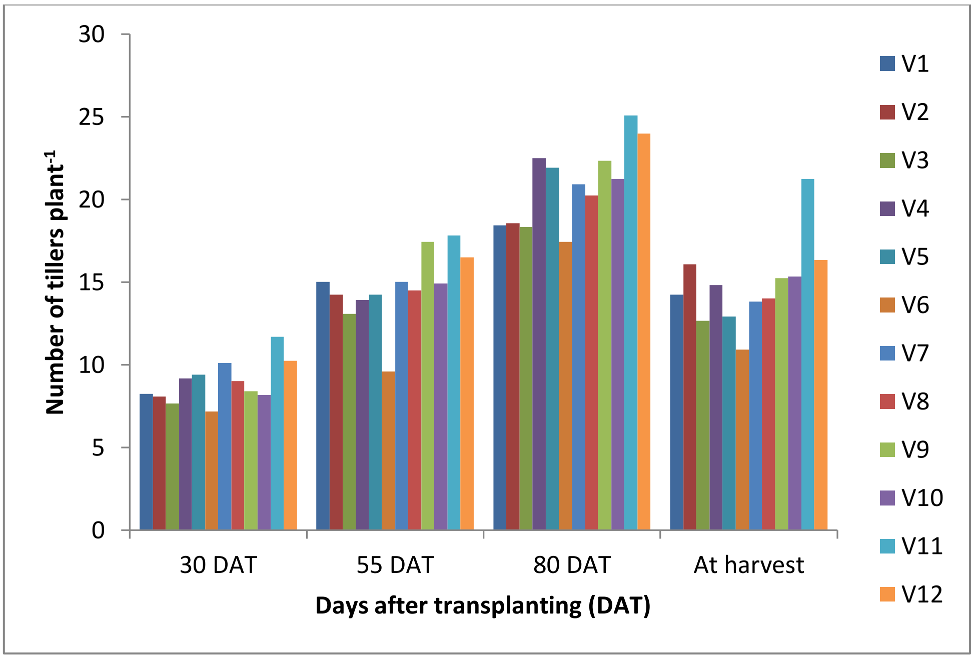



**Fig. 2. Number of tillers plant$^{-1}$ of different aromatic rice varieties at various days after transplanting (DAT) and at final harvest. Values followed by same letter(s) did not differ significantly at 5% level of probability.**

$V_1$ = Kalijira, $V_2$ = Chiniatap 1, $V_3$ = BRRI dhan 50, $V_4$ = Kataribhog 1, $V_5$ = Badshabhog, $V_6$ = Modhumala, $V_7$ = Zirabhog, $V_8$ = Shakkhorkhora, $V_9$ = Chiniatap 2, $V_{10}$ = Kataribhog 2, $V_{11}$ = BRRI dhan37, $V_{12}$ = BRRI dhan38

### 4.1.4 Leaf area index

Leaf area index of different aromatic rice varieties of different days after transplanting are showed different significant difference presented in the Table 2 and Appendix VII and significant variation was observed in LAI among the aromatic rice genotypes studied from 55 DAT to 80 DAT.

At 30 DAT, all the twelve aromatic rice varieties showed non-significant difference among them in case of leaf area index.

At 55 DAT, among the varieties the highest (5.92) leaf area index was observed in the variety $V_{11}$ (BRRI dhan37) which was followed by the variety $V_{12}$ and they were statistically similar. On the other hand, the lowest (3.26) leaf area index was observed in the variety $V_6$ (Modhumala) which was statistically similar to the variety $V_{3.}$

At 80 DAT, among the varieties the highest (5.64) leaf area index was observed in the variety $V_{11}$ (BRRI dhan37) which was followed by the variety $V_{12}$ and they were statistically similar. On the other hand, the lowest (3.05) leaf area index was observed in the variety $V_6$ (Modhumala) which was statistically similar to the variety $V_{3.}$ These variations could be described to genetic, climatic, and nutritional factors as supported byChandra and Das (2000) and this study also confirms the results of Shahidullah *et al.* (2009) who stated that different aromatic rice genotypes exhibited significant variations for leaf area index (LAI).

**Table 2. Leaf area index of different aromatic rice varieties at various days after transplanting.**

| Variety | Leaf area index at different DAT | | |
|---|---|---|---|
| | 30 DAT | 55 DAT | 80 DAT |
| $V_1$ | 1.06 | 5.32 b | 5.05 b |
| $V_2$ | 0.88 | 4.73 c | 4.46 d |
| $V_3$ | 0.52 | 3.34 g | 3.12 g |
| $V_4$ | 0.67 | 3.80 f | 3.57 f |
| $V_5$ | 0.98 | 5.19 b | 4.88 bc |
| $V_6$ | 0.49 | 3.26 g | 3.05 g |
| $V_7$ | 0.91 | 4.90 c | 4.69 c |
| $V_8$ | 0.74 | 4.10 e | 3.86 e |
| $V_9$ | 0.84 | 4.46 d | 4.23 d |
| $V_{10}$ | 0.60 | 3.70 f | 3.48 f |
| $V_{11}$ | 1.14 | 5.92 a | 5.64 a |
| $V_{12}$ | 1.08 | 5.81 a | 5.49 a |
| LSD0.05 | NS | 0.214 | 0.227 |
| CV(%) | 3.15 | 5.48 | 5.31 |

Values followed by same letter(s) did not differ significantly at 5% level of probability.

$V_1$ = Kalijira, $V_2$ = Chiniatap 1, $V_3$ = BRRI dhan 50, $V_4$ = Katari bhog 1, $V_5$ = Badshabhog, $V_6$ = Modhumala, $V_7$ = Zirabhog, $V_8$ = Shakkhorkhora, $V_9$ = Chiniatap 2, $V_{10}$ = Katari bhog 2, $V_{11}$ = BRRI dhan 37, $V_{12}$ = BRRI dhan 38

### 4.1.5 Flag leaf length

Flag leaf length of different aromatic rice varieties showed significant difference presented in the Table 3 and Appendix VIII.Among the varieties the highest (37.72) flag leaf length was observed in the variety $V_{11}$ (BRRI dhan37) which was followed by the variety $V_9$ and the lowest (29.05) flag leaf length was observed in the variety $V_6$ (Modhumala).

### 4.1.6 Flag leaf breadth

Flaf leaf breadth of different aromatic rice varietie showed different significant difference presented in the Table 3 and Appendix VIII. Among the varieties the highest (1.98) flag leaf breadth was observed in the variety $V_8$ (Shakkhorkhora) which was followed by the variety $V_3$ and $V_{11}$ and the lowest (0.58) flag leaf breadth was observed in the variety $V_6$ (Modhumala ).

### 4.1.7 Flag leaf area ($cm^2$)

Flag leaf area plant$^{-1}$ of different aromatic rice varieties showed significant difference presented in the Table 3 and Appendix VIII. Among the varieties the highest (60.39) flag leaf area was observed in the variety $V_8$ (Shakkhorkhora) which was followed by the variety $V_{11}$ and the lowest (16.85) flag leaf area was observed in the variety $V_6$ (Modhumala). Simillar result was reported by Sheela *et al.* (1990) and they studied the role of flag leaf on grain yield and spikelet sterility in rice cultivars and concluded that the grain yield and yield related traits were positively related to flag leaf area. Flag leaf plays an important role in grain yield, spikelet fertility, panicle size, grain size and weight.Simillar result was also reported by Rao (1992), Mohtashami (1998) and Dutta *et al.* (2002). They studied the plant architecture and growth characteristics of fine grain and aromatic rice and concluded that flag leaf area and flag leaf angle may be more related to current photosynthate synthesis and translocation for grain filling and higher grain fertility in local rice genotypes.

### 4.1.8 SPAD value of flag leaf

SPAD value of flag leaf (Chlorophyll content) of different aromatic rice varieties showed significant difference presented in the Table 3 and Appendix VIII. Among the varieties, the highest SPAD value (44.95) of flag leaf was observed in the variety $V_{11}$ (BRRI dhan37) which was followed by the variety $V_{12}$ and the lowest SPAD value (31.27) of flag leaf was observed in the variety $V_6$ (Modhumala).Similar result was reported by Munshi (2005) and he reported that grain yield in rice was positively correlated with chlorophyll content and showed that high yielding genotypes also showed higher chlorophyll content. Similarly, Swain *et al.* (2006) also found highly significant and positive relation between total chlorophyll content at all the growth stages and grain number/$m^2$. The increase in the yield was attributed to the chlorophyll content in sink development and grain filling.

**Table 3. Flag leaf length, breadth, area and SPAD value of flag leaf of different aromatic rice varieties.**

| Variety | Morpho-physiological parameters | | | |
|---|---|---|---|---|
| | Length of flag leaf (cm) | Breadth of flag leaf (cm) | Flag leaf area ($cm^2$) | SPAD value of flag leaf |
| $V_1$ | 32.97 c | 0.97 d | 31.98 c | 42.42 b |
| $V_2$ | 32.04 d | 0.69 fg | 22.11 f | 42.04 b |
| $V_3$ | 31.97 d | 1.23 b | 39.32 b | 39.69 c |
| $V_4$ | 32.50cd | 1.27 b | 41.28 b | 42.10 b |
| $V_5$ | 30.99 e | 0.76 ef | 23.55 ef | 38.83 c |
| $V_6$ | 29.05f | 0.58 g | 16.85 g | 31.27 e |
| $V_7$ | 30.38 e | 0.90 de | 27.34 de | 42.61 b |
| $V_8$ | 30.50 e | 1.98 a | 60.39 a | 39.23 c |
| $V_9$ | 35.08 b | 0.90 de | 31.57 cd | 38.03 cd |
| $V_{10}$ | 30.94 e | 0.75 ef | 23.21 ef | 36.20 d |
| $V_{11}$ | 37.72 a | 1.15 bc | 43.38 b | 44.95 a |
| $V_{12}$ | 32.60 cd | 1.04 cd | 33.90 c | 43.17 ab |
| LSD0.05 | 0.6580 | 0.1417 | 4.324 | 1.892 |
| CV(%) | 8.30 | 4.12 | 6.58 | 10.84 |

Values followed by same letter(s) did not differ significantly at 5% level of probability.

$V_1$ = Kalijira , $V_2$ = Chiniatap 1, $V_3$ = BRRI dhan 50, $V_4$ = Kataribhog 1, $V_5$ = Badshabhog, $V_6$ = Modhumala, $V_7$ = Zirabhog, $V_8$ = Shakkhorkhora, $V_9$ = Chiniatap 2, $V_{10}$ = Kataribhog 2, $V_{11}$ = BRRI dhan37, $V_{12}$ = BRRI dhan38

### 4.1.9 Dry weight hill$^{-1}$

Dry weight hill$^{-1}$ of different aromatic rice varieties showed significant difference presented in the Fig. 3 and appendix IX. Among the varieties, it was noted that the highest dry weight hill$^{-1}$ was observed in the variety $V_{11}$ (BRRI dhan37) at 55, 80 DAT and at harvest which was followed by variety $V_{12}$. On the other hand the lowest dry weight hill$^{-1}$ was observed in the variety $V_6$ (Modhumala) 55, 80 DAT and at harvest which was followed by variety $V_3$. Dry weight hill$^{-1}$ was recorded higher in varieties, this might be due to higher tiller number and grain yield in the varieties. Venkateshwarlu and Prasad (1982), Weng. (1984) and WuGuichang*et al.*(2010) found similar result justify the present study.

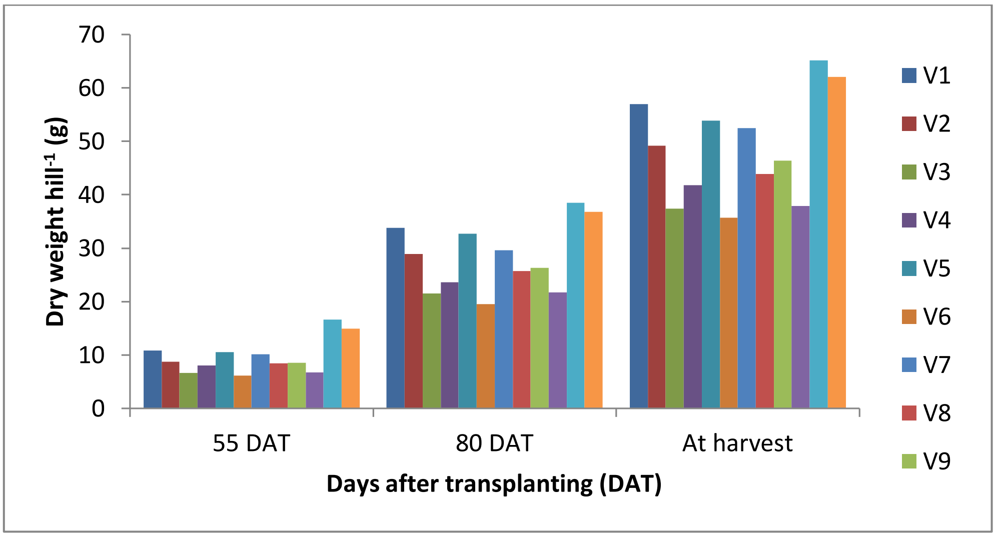



**Fig. 3. Dry weight hill$^{-1}$of different aromatic rice varieties at various days after transplanting (DAT) and at final harvest. Values followed by same letter(s) did not differ significantly at 5% level of probability.**

$V_1$ = Kalijira, $V_2$ = Chiniatap 1, $V_3$ = BRRI dhan 50, $V_4$ = Kataribhog 1, $V_5$ = Badshabhog, $V_6$ = Modhumala, $V_7$ = Zirabhog, $V_8$ = Shakkhorkhora, $V_9$ = Chiniatap 2, $V_{10}$ = Kataribhog 2, $V_{11}$ = BRRI dhan37, $V_{12}$ = BRRI dhan 38

### 4.1.10 Crop growth rate (mg cm$^{-2}$ day$^{-1}$)

Crop growth rate of different aromatic rice varieties showed significant difference presented in the Table 4 and Appendix X and the increase in CGR is due to increased leaf area index values and light interception thereby increased photosynthetic rate and dry matter production. Among the varieties, it was noted that the highest (2.29) crop growth rate was observed in the variety $V_1$ (Kalijira) at 55-80 DAT, which was followed by the variety $V_{5,}$ $V_{11}$ and $V_{12}$ and at 80 to harvest highest (2.67) crop growth rate was observed in the variety $V_{11}$ (BRRI dhan37) which was followed by the variety, $V_{12}$. On the other hand, the lowest crop growth rate was observed in the variety $V_6$ (Modhumala) at 55-80 DAT and 80 to harvest which was followed by variety $V_3$. These results are consistent with the result of Miah *et al.* (1994) and Shahidullah *et al. (*2009) who reported that varietal differences of CGR were significant at different growth stage.

### 4.1.11 Relative growth rate (mg g$^{-1}$ day$^{-1}$)

Relative growth rate of different aromatic rice varieties showed significant difference presented in the Table 4 and Appendix X. Among the varieties,it was noted that the highest (20.72) relative growth rate was observed in the variety $V_2$ (Chiniatap 1) at 55-80 DAT, which was followed by the variety $V_3$ and at 80 to harvest highest (10.5) relative growth rate was observed in the variety $V_6$ (Modhumala). On the other hand, the lowest (14.5) relative growth rate was observed in the variety $V_{11}$ (BRRI dhan37) at 55-80 DAT and at 80 to harvest the lowest (8.69) relative growth rate was observed in the variety $V_5$ (Badshavog) which was followed by variety $V_{11}$ and$V_{12}$. Relative growth rate (RGR) decreased with the age of crop. Similar decrease of RGR with the age of crop was reported by Chandrasekhar *et al.* (2001). The reason of this decrease with the age of plant was due to senescence of leaves and decrease in metabolic activities (Norbakhshian and Rezai, 1999).

### 4.1.12 Absolute growth rate (cm $day^{-1}$)

Absolute growth rate of different aromatic rice varieties showed significant difference presented in the Table 4 and Appendix Xand showed that there was a gradual increase in absolute growth rate up to 30-55 DAT in all genotypes studied. AGR values decreased from 55-80 DAT to harvest, among the genotypes. Among the varieties, it was noted that the highest (2.28) absolute growth rate was observed in the variety $V_6$ (Modhumala) at 30-55 DAT, which was followed by the variety $V_8$ and at 55-80 highest (1.62) absolute growth rate was observed in the variety $V_9$ (Chiniatap 2) .On the other hand, the lowest (1.36) absolute growth rate was observed in the variety $V_1$ (Kalijira) at 30-55 DAT which was followed by the variety $V_2$ and at 55-80 the lowest (1.03) absolute growth rate was observed in the variety $V_{11}$ (BRRI dhan37) which was followed by variety $V_{12.}$Similar variation in the AGR values in aromatic rice mutants was also reported by Mondal *et al*. (2010).

**Table 4. Crop growth rate, relative growth rate and absolute growth rate of different aromatic rice varieties.**

| Variety | Crop growth rate (CGR) (mg $cm^{-2}$ $day^{-1}$) | | Relative growth rate (RGR) (mg $g^{-1}$ $day^{-1}$) | | Absolute growth rate (AGR) (cm $hill^{-1}$ $day^{-1}$) | |
|---|---|---|---|---|---|---|
| | 55 – 80 DAT | 80 DAT – At harvest | 55 – 80 DAT | 80 DAT – At harvest | 30 – 55 DAT | 55 - 80 DAT |
| $V_1$ | 2.29 a | 2.32 bc | 19.75 cd | 9.08 de | 1.36 c | 1.31 b |
| $V_2$ | 2.01 ab | 2.03 cd | 20.72 a | 9.23 cd | 1.39 c | 1.13 cd |
| $V_3$ | 1.48 cd | 1.60 e | 20.39 ab | 9.65 bc | 1.58 bc | 1.09 d |
| $V_4$ | 1.55 cd | 1.82 de | 18.62 e | 9.94 b | 1.44 c | 1.24 bc |
| $V_5$ | 2.21 a | 2.12 cd | 19.58 d | 8.69 e | 1.54 bc | 1.02 d |
| $V_6$ | 1.34 d | 1.62 e | 20.09 bc | 10.5 a | 2.28 a | 1.29 b |
| $V_7$ | 1.94 ab | 2.29 bc | 18.62 e | 9.97 b | 1.37 c | 1.24 bc |
| $V_8$ | 1.73 bc | 1.82 de | 19.40 d | 9.29 cd | 2.12 a | 1.36 b |
| $V_9$ | 1.78 bc | 2.01 cd | 19.49 d | 9.83 b | 1.96 ab | 1.62 a |
| $V_{10}$ | 1.50 cd | 1.62 e | 20.28 b | 9.66 bc | 1.65 bc | 1.56 a |
| $V_{11}$ | 2.19 a | 2.67 a | 14.56 g | 9.14 de | 1.55 bc | 1.03 d |
| $V_{12}$ | 2.19 a | 2.53 ab | 15.68 f | 9.09 de | 1.38 c | 1.06 d |
| LSD0.05 | 0.3213 | 0.3076 | 0.3935 | 0.4544 | 0.435 | 0.1312 |
| CV(%) | 4.864 | 5.233 | 7.217 | 6.899 | 7.62 | 5.38 |

Values followed by same letter(s) did not differ significantly at 5% level of probability.

$V_1$ = Kalijira , $V_2$ = Chiniatap 1, $V_3$ = BRRI dhan 50, $V_4$ = Kataribhog 1, $V_5$ = Badshabhog, $V_6$ = Modhumala, $V_7$ = Zirabhog, $V_8$ = Shakkhorkhora, $V_9$ = Chiniatap 2, $V_{10}$ = Kataribhog 2, $V_{11}$ = BRRI dhan37, $V_{12}$ = BRRI dhan38

## 4.2 Yield and yield contributing parameters

### 4.2.1 Number of effective tiller plant$^{-1}$

Number of effective tiller plant$^{-1}$of different aromatic rice varieties showed significant difference presented in the Fig. 4 and Appendix XI. Among the varieties, the highest (20.50) number of effective tiller found in the variety $V_{11}$ (BRRI dhan37) which was followed by the variety $V_2$ and $V_{12}$. On the other hand the lowest (7.917) number of effective tiller found in the variety $V_6$ (Modhumala). Similar results were also reported by Yang *et al* (2001).

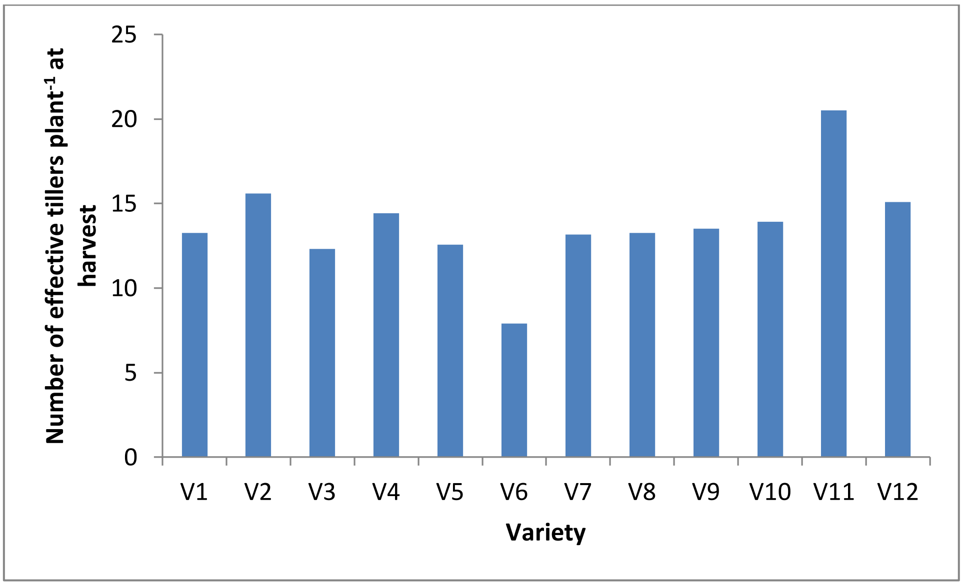



**Fig. 4. Number of effective tillers plant$^{-1}$of different aromatic rice varieties. Values followed by same letter(s) did not differ significantly at 5% level of probability.**

$V_1$ = Kalijira, $V_2$ = Chiniatap 1, $V_3$ = BRRI dhan50, $V_4$ = Kataribhog 1, $V_5$ = Badshabhog, $V_6$ = Modhumala, $V_7$ = Zirabhog, $V_8$ = Shakkhorkhora, $V_9$ = Chiniatap 2, $V_{10}$ = Kataribhog 2, $V_{11}$ = BRRI dhan37, $V_{12}$ = BRRI dhan38.

### 4.2.2 Number of ineffective tiller plant$^{-1}$

Number of ineffective tiller plant$^{-1}$of different aromatic rice varieties showed significant difference presented in the Fig. 5 and Appendix XI. Among the varieties, the highest (3.00) number of ineffective tiller found in the variety $V_6$ (Modhumala) which was followed by the variety $V_9$. On the other hand, the lowest (0.42) number of ineffective tiller was found in the variety $V_3$ (BRRI dhan50) which was followed by the variety $V_2$, $V_4$ and $V_5$.Similar results were also observed by Yang *et al.* (2001), Siddique *et al.* (2002) etc.

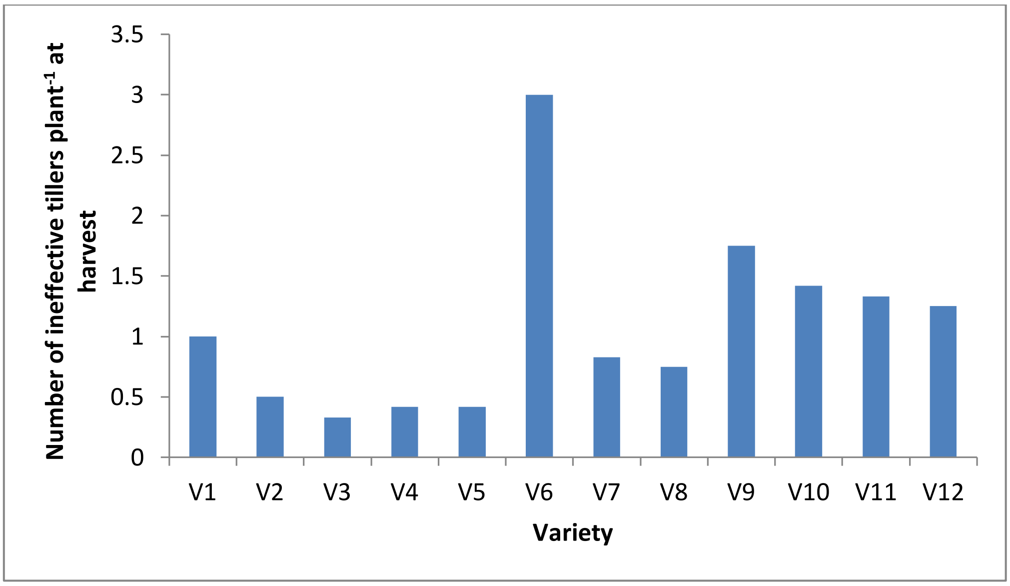



**Fig. 5. Number of ineffective tillers plant$^{-1}$of different aromatic rice varieties. Values followed by same letter(s) did not differ significantly at 5% level of probability.**

$V_1$ = Kalijira, $V_2$ = Chiniatap 1, $V_3$ = BRRI dhan50, $V_4$ = Katari bhog 1, $V_5$ = Badshabhog, $V_6$ = Modhumala, $V_7$ = Zirabhog, $V_8$ = Shakkhorkhora, $V_9$ = Chiniatap 2, $V_{10}$ = Katari bhog 2, $V_{11}$ = BRRI dhan37, $V_{12}$ = BRRI dhan38

### 4.2.3 Number of total grains panicle$^{-1}$

Number of total grains panicle$^{-1}$of different aromatic rice varieties showed significant difference presented in the Table 5 and Appendix XII. Among the varieties, the highest (222.1) number of grains panicle$^{-1}$found in the variety $V_{11}$ (BRRI dhan37) which was followed by the variety $V_{12}$. On the other hand, the lowest (100.6) number of grains panicle$^{-1}$found in the variety $V_6$ (Modhumala) which was followed by the variety $V_{10}$.

### 4.2.4 Number of filled grains panicle$^{-1}$

Number of filled grains panicle$^{-1}$ of different aromatic rice varieties showed significant difference presented in the Fig. 6 and Appendix XII. Among the varieties, the highest (208.0) number of filled grains panicle$^{-1}$ found in the variety $V_{11}$ (BRRI dhan37) which was followed by the variety $V_{12}$. On the other hand, the lowest (72.67) number of filled grains panicle$^{-1}$found in the variety $V_{10}$ (kataribhog 2) which was followed by the variety $V_{6.}$ Similar result were also observed by Kusutani *et al.* (2000) and Fageria and Baligar (2001).

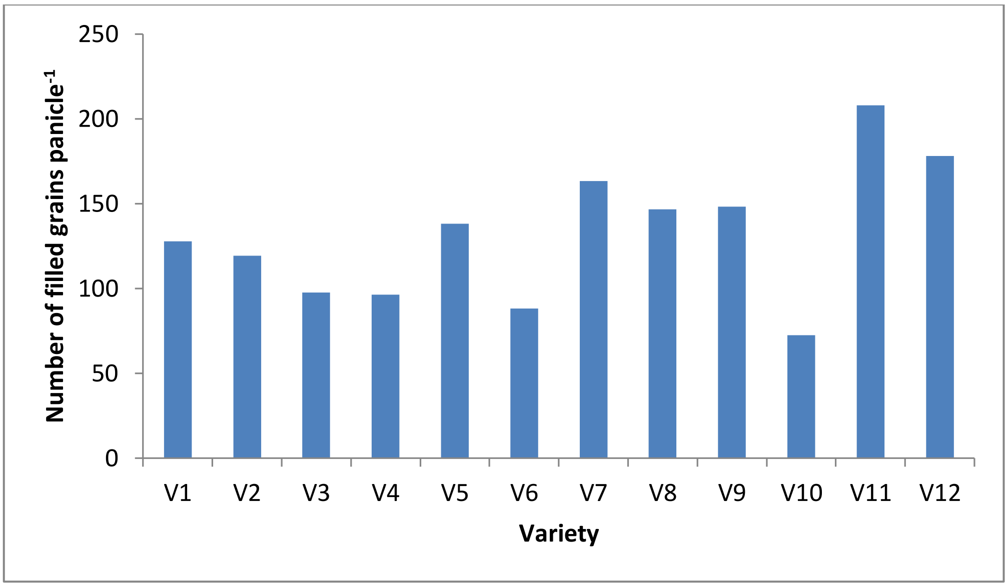



**Fig. 6. Number of filled grains panicle$^{-1}$of different aromatic rice varieties. Values followed by same letter(s) did not differ significantly at 5% level of probability.**

$V_1$ = Kalijira, $V_2$ = Chiniatap 1, $V_3$ = BRRI dhan50, $V_4$ = Kataribhog 1, $V_5$ = Badshabhog, $V_6$ = Modhumala, $V_7$ = Zirabhog, $V_8$ = Shakkhorkhora, $V_9$ = Chiniatap 2, $V_{10}$ = Kataribhog 2, $V_{11}$ = BRRI dhan37, $V_{12}$ = BRRI dhan38

### 4.2.5 Number of unfilled grains panicle$^{-1}$

Number of unfilled grains panicle$^{-1}$of different aromatic rice varieties showed significant difference presented in the Fig. 7 and Appendix XII. Among the varieties, the highest (42.92) number of unfilled grains panicle$^{-1}$ found in the variety $V_{12}$ (BRRI dhan38) which was followed by the variety $V_4$ and $V_{10}$. On the other hand, the lowest (6.42) number of unfilled grains panicle$^{-1}$ found in the variety $V_1$ (Kalijira). Similar result was also observed by Chowdhury *et al.* (1993).

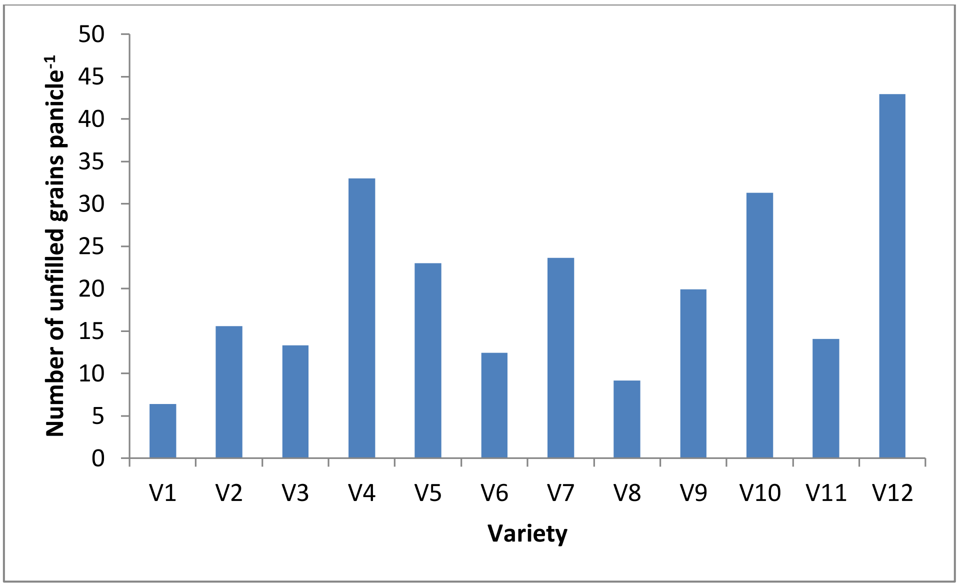



**Fig. 7. Number of unfilled grains panicle$^{-1}$ of different aromatic rice varieties. Values followed by same letter(s) did not differ significantly at 5% level of probability.**

$V_1$ = Kalijira, $V_2$ = Chiniatap 1, $V_3$ = BRRI dhan50, $V_4$ = Kataribhog 1, $V_5$ = Badshabhog, $V_6$ = Modhumala, $V_7$ = Zirabhog, $V_8$ = Shakkhorkhora, $V_9$ = Chiniatap 2, $V_{10}$ = Kataribhog 2, $V_{11}$ = BRRI dhan37, $V_{12}$ = BRRI dhan38

### 4.2.6 Spikelet fertility (%)

Spikelet fertility (%) of different aromatic rice varieties showed significant difference presented in the Table 5 and Appendix XII. Among the varieties, the highest (93.65) number of Spikelet fertility (%) found in the variety $V_{11}$ (BRRI dhan37) which was followed by the variety $V_1$ and $V_8$. On the other hand, the lowest (69.94) number of Spikelet fertility (%) found in the variety $V_{10}$ (Kataribhog 2) which was followed by the variety $V_4$. Similar result was also observed by Tahir *et al.* (2002), Krishna *et al.* (2010), Samonte *et al.* (1998) and Rasheed *et al.* (2002).

### 4.2.7Panicle length (cm)

Panicle length (cm) of different aromatic rice varieties showed statistically significant difference presented in the Table 5 and Appendix XII. Among the varieties, the highest (29.90) number of panicle length found in the variety $V_{11}$ (BRRI dhan37) which was followed by the variety $V_2$ and $V_{12}$. On the other hand, the lowest (22.55) number of panicle length found in the variety $V_6$ (Modhumala) which was followed by the variety $V_3$. Similar result was also observed by Sharma (2002) and Ashrafuzzaman *et al. (*2009). Which is supported the present study.

### 4.2.8 Weight of 1000 grains (g)

Weight of 1000 grains (g) of different aromatic rice varieties showed significant difference presented in the Table 5 and Appendix XII. Among the varieties, the highest (22.45) number of Weight of 1000 grains (g) found in the variety $V_6$ (Modhumala) which was followed by the variety $V_{3,}$ $V_4$ and $V_{12}$. On the other hand, the lowest (12.93) number of Weight of 1000 grains (g) found in the variety $V_7$ (Zirabhog) which was followed by the variety, $V_{5.}$ Similar result were also observed by Cheema *et al.* (1998), Mirza *et al.* (1992) and Mondal *et al.* (2005).

**Table 5. Yield contributing parameters of different aromatic rice varieties**

| Variety | Yield contributing parameters | | | |
|---|---|---|---|---|
| | Number of total grains $panicle^{-1}$ | Spikelet fertility (%) | Panicle length (cm) | Weight of 1000 grains (g) |
| $V_1$ | 134.4 f | 95.24 a | 27.47 cd | 15.57 c |
| $V_2$ | 134.7 f | 88.64 b | 28.89 b | 13.93 e |
| $V_3$ | 111.2 h | 87.98 b | 22.78 h | 17.33 b |
| $V_4$ | 130.0 g | 74.10 d | 26.98 de | 17.13 b |
| $V_5$ | 160.3 d | 86.28 b | 24.65 g | 13.15 f |
| $V_6$ | 100.6 i | 87.64 b | 22.55 h | 22.45 a |
| $V_7$ | 187.2 b | 87.34 b | 25.99 f | 12.93 f |
| $V_8$ | 153.9 e | 95.39 a | 26.20 ef | 14.03 e |
| $V_9$ | 168.3 c | 88.12 b | 27.87 c | 13.27 f |
| $V_{10}$ | 103.9 i | 69.94 e | 27.06 cd | 14.97 d |
| $V_{11}$ | 222.1 a | 93.65 a | 29.90 a | 15.87 c |
| $V_{12}$ | 221.2 a | 80.61 c | 29.07 b | 17.70 b |
| $LSD_{0.05}$ | 4.257 | 3.329 | 0.787 | 0.5461 |
| CV(%) | 13.56 | 8.314 | 4.78 | 11.77 |

Values followed by same letter(s) did not differ significantly at 5% level of probability.

$V_1$ = Kalijira, $V_2$ = Chiniatap 1, $V_3$ = BRRI dhan 50, $V_4$ = Kataribhog 1, $V_5$ = Badshabhog, $V_6$ = Modhumala, $V_7$ = Zirabhog, $V_8$ = Shakkhorkhora, $V_9$ = Chiniatap 2, $V_{10}$ = Kataribhog 2, $V_{11}$ = BRRI dhan37, $V_{12}$ = BRRI dhan38

### 4.2.9 Grain yield (ton ha$^{-1}$)

Grain yield of different aromatic rice varieties showed significant difference presented in the Fig. 8 and Appendix XIII. Among the varieties, the highest (3.30) number of grain yield found in the variety $V_{11}$ (BRRI dhan37) which was followed by the variety $V_{12}$. On the other hand, the lowest (1.42) number of grain yield found in the variety $V_6$ (Modhumala) which was followed by the variety, $V_3$. Similar result was also observed by Miah *et al*. (1996), Biswas *et al.* (1998), Ashrafuzzaman *et al.* (2009) and Rajesh *et al*. (2008).

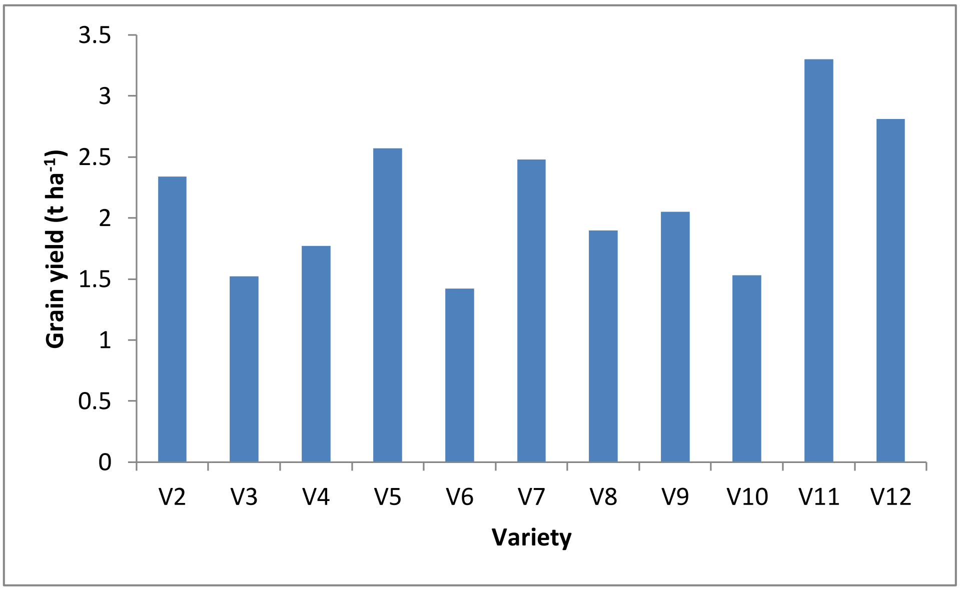



**Fig. 8. Grain yield of different aromatic rice varieties. Values followed by same letter(s) did not differ significantly at 5% level of probability.**

$V_1$ = Kalijira, $V_2$ = Chiniatap 1, $V_3$ = BRRI dhan50, $V_4$ = Kataribhog 1, $V_5$ = Badshabhog, $V_6$ = Modhumala, $V_7$ = Zirabhog, $V_8$ = Shakkhorkhora, $V_9$ = Chiniatap 2, $V_{10}$ = Kataribhog 2, $V_{11}$ = BRRI dhan37, $V_{12}$ = BRRI dhan38

### 4.2.10 Straw yield (ton ha$^{-1}$)

Straw yield of different aromatic rice varieties showed significant difference presented in the Table 6 and Appendix XIII. Among the varieties, the highest (6.10) number of straw yield found in the variety $V_{11}$ (BRRI dhan37) which was followed by the variety $V_{12}$. On the other hand, the lowest (3.92) number of straw yield found in the variety $V_6$ (Modhumala) which was followed by the variety $V_3$. Similar result was also observed by Chowdhury *et al,* (1995).

### 4.2.11 Biological yield (ton ha$^{-1}$)

Biological yield of different aromatic rice varieties showed significant difference presented in the Table 6 and Appendix XIII. Among the varieties, the highest (9.40) number of biological yield found in the variety $V_{11}$ (BRRI dhan37) which was followed by the variety $V_{12}$. On the other hand, the lowest (5.34) number of biological yield found in the variety $V_6$ (Modhumala) which was followed by the variety $V_{3.}$ Similar result were also observed by Chowdhury *et al.* (1995). They showed that grain yield was positively correlated with biological yield in rice.

### 4.2.12 Harvest index (%)

Harvest index (%) of different aromatic ricevarieties showed significant difference presented in the Table 6 and Appendix XIII. Among the varieties, the highest (35.11) number of harvest index found in the variety $V_{11}$ (BRRI dhan37) which was followed by the variety $V_{12}$. On the other hand, the lowest (26.59) number of harvest index found in the variety $V_6$ (Modhumala) which was followed by the variety, $V_{3.}$ Similarresultwere also observed by Kusutani *et al.* (2000) and Ashrafuzzaman *et al.* (2009).

**Table 6. Yield performance parameters of different aromatic rice varieties**

| Variety | Yield parameters | | |
|---|---|---|---|
| | Straw yield (t $ha^{-1}$) | Biological yield (t $ha^{-1}$) | Harvest index (%) |
| $V_1$ | 5.44 b | 8.15 bc | 33.25 bc |
| $V_2$ | 4.88 d | 7.22 de | 32.41 c |
| $V_3$ | 3.98 f | 5.50 g | 27.64 e |
| $V_4$ | 4.60 de | 6.37 f | 27.79 e |
| $V_5$ | 5.24 bc | 7.81 c | 32.91 bc |
| $V_6$ | 3.92 f | 5.34 g | 26.59 f |
| $V_7$ | 4.92 cd | 7.40 d | 33.51 b |
| $V_8$ | 4.52 e | 6.42 f | 29.60 d |
| $V_9$ | 4.78 de | 6.83 e | 30.01 d |
| $V_{10}$ | 4.18 f | 5.71 g | 26.80 ef |
| $V_{11}$ | 6.10 a | 9.40 a | 35.11 a |
| $V_{12}$ | 5.48 b | 8.29 b | 33.90 b |
| LSD0.05 | 0.321 | 0.394 | 0.9504 |
| CV(%) | 6.85 | 8.44 | 9.42 |

Values followed by same letter(s) did not differ significantly at 5% level of probability.

$V_1$ = Kalijira, $V_2$ = Chiniatap 1, $V_3$ = BRRI dhan 50, $V_4$ = Kataribhog 1, $V_5$ = Badshabhog, $V_6$ = Modhumala, $V_7$ = Zirabhog, $V_8$ = Shakkhorkhora, $V_9$ = Chiniatap 2, $V_{10}$ = Kataribhog 2, $V_{11}$ = BRRI dhan37, $V_{12}$ = BRRI dhan38

# CHAPTER V

# SUMMARY AND CONCLUSION

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka during the period from July 2017 to December, 2017 for the study of morpho-physiological attributes and yield performance of different aromatic rice genotypes. The experiment comprised of single factor (variety). Twelve aromatic rice varieties were used for the present study. The experiment was laid out in a Randomized complete Block Design (RCBD) with three replications. Data on different morpho-physiological parameters and yield with yield contributing characters were recorded. The collected data were statistically analyzed for evaluation of the treatment effect.

Aromatic rice genotypes showed significant variation in morpho-phisiological parameter for plant height, total number of tillers plant$^{-1}$, number of leaves plant$^{-1}$, dry weight hill$^{-1}$, leaf area index, crop growth rate, relative growth rate, absolute growth rate, SPAD value. Maximum plant height at final harvesting was recorded in the variety $V_6$ (Modhumala) was 165.7 cm and minimum plant height at harvesting was recorded in the variety $V_3$ (BRRI dhan50) was 130.3 cm. In all genotypes leaf number increased from 30 DAT to 80 DAT beyond which declined and maximum number of leaves per hill was recorded in $V_9$ (Chiniatap 2) 68.50 at harvest and minimum number of leaves was found in $v_1$ (Kalijira) 39.33 at harvest . There was a progressive increase for number of tiller up to 80 DAT after that declined up to maturity because of drying of unproductive tillers. Maximum number of effective tiller was produced by the variety $V_{11}$ (BRRI dhan37) 21.25 at harvest and minimum for the variety $V_6$ (Modhumala) 10.92 at harvest. Flag leaf area of aromatic rice found significantly different for all aromatic rice cultivars and maximum flag leaf area was found for the variety $V_8$ (Shakkhorkhora) 60.39 and minimum was recorded from the variety, $V_6$ (Modhumala)16.85. There was a significant increase in total dry weight in all the stages till maturity and maximum dry weight hill$^{-1}$ was found for the variety $V_{11}$ (BRRI dhan38) 65.20 during harvest and minimum was recorded from the $V_6$ (Modhumala) 35.67 during harvest. LAI increased from 30 DAT to 55 DAT and later on declined and crop growth rate (CGR) increased gradually up to 30-55 days but decreased later on. RGR decreased with the age of crop. AGR increased up to 30-55 DAT in all genotypes studied and decreased from 55-80 DAT to harvest. $V_6$ (Modhumala) has recorded maximum AGR whereas lowest was recorded with $V_5$ (Badshabogh). SPAD values differed significantly among the aromatic rice genotypes. Maximum SPAD values were recorded for variety $V_{11}$ (BRRI dhan37) 44.95 throughout the crop growth period and minimum wasfound in variety $V_6$ (Modhumala) 31.27.

Grain yield and yield components varied significantly among the aromatic rice genotypes. Highest grain yield (3.30 t ha$^{-1}$), straw yield (6.10 t ha$^{-1}$), biological yield (9.4 t ha$^{-1)}$ and harvest index (35.11%) were recorded in variety $V_{11}$ (BRRI dhan37) and the lowest grain yield (1.42 t ha$^{-1}$), straw yield (3.92 t ha$^{-1}$), biological yield (5.34 t ha$^{-1}$), harvest index (26.59) was recorded in $V_6$ (Modhumala). The results on yield and yield attributes indicated that all the yield contributing characters viz. panicle length, total grain panicle$^{-1}$, 1000 grain weight, and filled grain percentage and harvest index are positively associated with grain yield.

Considering the above statement, it can be concluded that-

1. Different morpho-physiological characteristics of twelve aromatic rice varieties differed significantly.
2. Among all the aromatic rice varieties, the $V_{11}$ (BRRI dhan37) performed better due to its highest number of total tillers plant$^{-1}$, dry weight hill$^{-1}$, number of effective tillers plant$^{-1}$, panicle length, number of grains panicle$^{-1}$, 1000 grain weight, grain yield, biological yield , straw yield and harvest index.
3. From the above findings, it can be concluded that among the aromatic ricevarieties $V_{11}$ (BRRI dhan37) performed better considering it's morpho-physiological and yield characters, compared to other varieties.

Further extensive research with more parameters of aromatic rice plant is suggested to have more information and more experiments are required with the varieties of my experiment at different locations of Bangladesh for final recommendation.

# CHAPTER VI

## REFERENCES


Ahmad, S., Hussain, A., Ali, H. and Ahmad, A. (2005). Transplanted fine rice (*Oryza sativa L.*) productivity as affected by plant density and irrigation regimes. *Int. J. Agric*. Biol. 7: 445–447.

AIS (Agricultural Information Service).(2011). *Krishi Dairy*. Agric. Info. Service.

Khamarbari, Farmgate, Dhaka. pp. 10-15.

Akter, M.B. (2005). Morpho- physiological evaluation and characterization in four aman rice genotypes, M.S. Thesis, Dept. Crop Bot., Bangladesh Agric. Unv., Mymensingh.

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

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

Aye A.T., and Oscar Z,B. (2009). Morphological and agronomic response of hybrid, high yielding and Traditional rice (Oryza sativa L.) varieties to age of seedling and spacing.*Philippine Journal of Crop Science*. 34 (1): 38-52.

BBS (Bangladesh Bureau of Statistics) (2003).Statistical pocket book of Bangladesh.Ministry of Planning.Govt. Peoples Repub. Bangladesh.pp.72-78.

BBS (Bangladesh Bureau of Statistics) (2005). Hand Book of Agricultural Statistics, December, (2005).Ministry of planning Govt. People's Republic Bangladesh.p.14.

BBS (Bangladesh Bureau of Statistics) (2016): Statistics Pocket Book of Bangladesh (2014–15). Bangladesh Bureau of Statistics Division, Govt. of the People's Republic of Bangladesh.p. 51.

BINA, (1993). Annual Report (1992-1993). Bangladesh Inst. Nuclear Agric. P.O. Box. No. 4. Mymensingh, Bangladesh. p. 143.

Biswas, J.K., Hossain, M.A., Sarker, B.C., Hassan, M and Haque, M.Z. (1998). Yield performance of several rice varieties seeded directly as late aman crops. *BangladeshJ.Life Sci*. 10: 47–52.

Chandra, K. and Das, A. K. (2000). Correlation and inter correlation of physiological parameters in rice under rainfed transplanted condition. Crop Res. Hisar, Assam Agric Univ., 19:2.251-254.

Chandrasekhar, J., Rao, R.G., Reddy, R.B and Reddy, K.B. (2001). Physiological analysis of growth and productivity in hybrid rice.*Indian J.Plant physiol.,* vol. 6(2): 142-146.

Cheema, A.A., Ali, Y. Awan, M.A and Tahir, G.R. (1998).Path analysis of yield components of some mutants of Basmati rice. Trop. Agric. Res. and Ext. 1: 34-38.

Chowdhury, M.J.U., Sarker, M.A.R. and Kashem M.A. (1993). Dictionary of Agriculture Anmol Pub. Pvt. Ltd., New Delhi. p. 93.

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

Dun, E.A., Ferguson, B.J and Beveridge, C.A. (2006). Apical dominance and shoot branching. Divergent opinions or divergent mechanisms. Plant Physiol. 142: 812–819.

Dutta, R.K., Mia, M.A.B. and Khanum, S. (2002). Plant Architecture and growth characteristicsof fine grain and aromatic rice and their relation with grain yield.Inst. Rice Comm. Newsl. 51:51-55.

EnamuL.K.M., Harun A.R.M. and Sarvar J.M. (2004). Yield performance of three aromatic fine rices in costal low land. *Pakistan J. of Biological Science.* 7 (9): 23-24.

Fageria, N.K and Baligar, V.C. (2001). Lowland rice response to nitrogen fertilizer.Soil Scoence Plant Annual. 32(1): 1405-1429.

FAO (Food and Agriculture Organization).(2003). Production year book, Food and Agricultural Organization of the United Nations, Rome, Italy.No.57.

Farrel, T.C., Williams, R.L., Reinke, R.E and Lewin, L.G. (2003). Variation in radiation use efficiency in temperate rice. Proceeding of the Australian Agronomy.

Gallagher, J.N and Biscoe, P.V. (1978).Radiation absorption, growth and yield of cereals.*J.Agric. Sci*., 91: 47–60.

Guevarra, A.B and Chang, T.T.(1965). Internode elongation in rice varieties of reduced rice stature. Philippine Agrist. 49(1): 23–24.

Hoque, M.N. (2004). Morpho-physiological studies in aromatic and modern cultivars. M. S. Thesis, Dept. Crop Bot., Bangladesh Agric. Unv., Mymensingh.

Horie, T. (2003). Increasing yield potential in irrigated rice: Breaking the yield barrier. International Rice Research Institute Press, Manila, Philippines.

Hossain, K.P., Nasiri, H.P.M and Bahmanyar, M.A. (2007). Chlorophyll content and biological yield of modern and old rice cultivars in different urea fertilizer rate and applications.*Asian J. of Plant Science.* 6(1): 177-180.

Hossain, M.B., Islam, M.O and Hasanuzzaman, M. (2008). Influence of different nitrogen levels on the performance of four aromatic rice varieties. *Int. J. Agric. Biol.* 10: 693–696.

Hussain, F., Bronson, K.F., Singh, Y., Sing. B. and Peng, S. (2000). Use of chlorophyll meter efficiency indices for nitrogen management of irrigated rice in Asia. *Agron. J. Agril. Sci.* 92: 875- 779.

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

Jaffuel, S. and Dauzat, J. (2005). Synchronism of leaf and tiller emergence relative to position and to main stem development stage in rice cultivar.Annals of Botany.V.95, p.401412.

Jamal, I.H., Khalil, A.B., Sajid K. and Islam Z. (2009). Genetic variation for yield and yield components in rice.*ARPN Journal of Agricultural and Biological Science*.4(6), ISSN 1990-6145.

Karimi, M.M and Seddique, K.H. (1991). Crop growth and relative growth rates of old and modern wheat cultivars. *Aust. J.Agric.Res.42:13*-20.

Kariya, K.A., Matsuzaki and Machida, H. (1982). Distribution of chlorophyll content in leaf blade in rice plant.*Jap. J. Crop Sc*. 51: 134-135.

Kaul, A.K., Khan, M.R.I. and Monir, K.M. (1982). Rice Quality: A survey of Bangladesh Germplasm. Bangladesh Rice Res. Inst. Gazipur, Bangladesh. pp. 1-178

Krishna T., Rastogi, N.K., Pushpa T. and Sahu, L. (2010). Correlation and path analysis of yield and its component in rice germplasm accessions.Plant Archives. 8: 887-889.

Kueneman, F.A. (2006). Improved rice production in a changing environment: From concept to practice. Intl. Rice Comm. Newsl, 55:1-20.

Kulmi, G.S. (1992). Analysis of growth and productivity of transplanted rice in relation to methods of weeding.*Indian J. Agron*.37:312-316.

Kusutani, A., Tovata, M., Asanuma, K and Cui, J. (2000). Studies on the varietal differences of harvest index and morphological characteristics of rice.*Japanese J. Crop Sci*. 69: 359–364.

Mejia, D.L. (2006). Using whole grain to promote small and medium enterprises (SMEs).Intl. Rice Comm. Newsl. 55:128-139.

Mia, M.A.B., Salam, M.A., Chowdhury, S.I., Islam, A.F.M.S and Dutta, R.K. (1994). Morpho physiological studies in relation to yield potential in rice. *Bangladesh J. Nuclear Agric*. 10: 45–50.

Miah, M.N.H., Yoshida, T and Yomamoto, Y. (1997). Effect of nitrogen application during ripening period on photosynthesis and dry matter production and its impact on yield and yield components of semi dwarf indica rice varieties under water culture conditions. Soil Sci. and Plant Nut. 43(1): 205-217.

Miah, M.N.H., Yoshida, T. Yamamoto, Y and Nitta, Y. (1996). Characteristics of dry matter production and partitioning of dry matter to panicles in high yielding semi dwarf indica and japonica indica hybrid rice varieties. *Japanese J. Crop Sci.,* 65: 672–685.

Mian, S.H., Khair, A.M., Haque, M., Azadand, A.K. and Hamid. A. (2009). Genotypic variation in traditional rice varieties for chlorophyll content, spad value and nitrogen use efficiency. *Bangladesh J. Agril.* 34(3): 505-515.

Miller, B.C., Hill, J.E and Roberts, S.R. (1991). Plant population effects on growth and tied in water-seeded rice. *Agron. J. Agril. Sci.* 83: 291–297.

Mirza, M.J., Faiz, F.A and Mazid, A. (1992). Correlation studies and path analysis of plant height yield and yield components in rice (*Oryza sativa L.*).*Sarhad. J. Agric*. 8: 647-653.

Mohammad, T., Deva, W and Ahmad, Z. (2002). Genetic variability of different plant and yield characters in rice.*Sarhad J. Agric.* 18: 207–210.

Mohtashami, R. (1998). Study of genotypic and phonotypical correlation between quantitative and qualitative traits and grain yield in rice (*Oryza sativa*) using path analysis.MS thesis.Sari Agriculture College, Mazandaran University. Pp: 217.

Mondal, M.M.A., Islam, A.F.M and Siddique, M.A. (2005). Performance of 17 modern transplant aman cultivar in the northern region of Bangladesh. *Bangladesh J. Crop Sci*. 16: 23–29.

Mondal, N.N., Islam, M.M., Hasan, M.S., Rahman, Q.A and Ali, M.M. (2010). Physiological and biochemical evaluation of fine grain aromatic rice genotypes for higher yield.*International Journal of Sustainable Agricultural Technology*. 6(1): 12-18.

Montomatsu, T., Takebe, M and Yoneyama, T. (1988). Physiological characteristics of highyielding rice varieties: dry matter production and nutrient uptake. Bulletin of the National Agricultural Research Center, Japan. 1988. 12, 1-11.

Munshi, R.U. (2005). A comparative morpho-physiological study between two local and two modern rice cultivars.M.S. Thesis, Department of Crop Botany, Bangladesh Agriculture University, Mymensingh.

Norbakhshian, J and Rezai, A. (1999). Study of correlation between some traits and grain yield in rice cultivars using path analysis.*Iranian Journal of Crop Science*. 1(4): 55-65.

Nuruzzaman, M., Yamamoto, Y., Nitta, Y., Yoshida, T., and Miyazaki, A. (2000). Varietal difference in tillering ability of fourteen Japonica and Indica rice varieties. Soil Sci. Plant nutria., 46(2):381-391.

Patel, D.P., Anuo das, Munda, G.C., Ghosh, P.K., Brdoloj, J.S and Manoj Kumae.(2010). Evaluation of yield and physiological attributes of highyielding rice varieties under aerobic and flood-irrigated management practices in mid-hills ecosystem.Agricultural Water Management. 97(9): 1269-1276.

Peng, S., Garcia, P. V., Laza, R. C., Sanico, A. L., Visperas, R.M. and Cassman, K. G. (1996). Increasd N-use efficiency using a chlorophyll metter on high-yielding irrigated rice. Field crop Res. 47: 243-252.

Peng, S., Khush G.S and Cassman, K.G. (1994). Evolution of the new plant ideotype for increased yield potential. Breaking the Yield Barrier: Proc. a Workshop on Rice Yield Potential in Favourable Environ, pp: 5–20.

Pinheiro, B. da S and Guimaraes, E.P. (1990). Leaf area index and productivity in upland rice. I. Limiting levels. Pesquisa Agropecuaria Brasileira. 25(6): 863-872.

Rajesh, K., Veram, A.K., Kamleshwar, K. and Kumar.R. (2008). Morpho-physiological analysis of yield in different rice genotype.*Journal of Research* (BAU). 20(1): 37-43.

Rao, S.D. (1992). Flag leaf: a selection criterion for exploiting potential yields in rice. *Indian J.Plant Physio*. 35(3): 265-268.

Rasheed, M.S., Sadaqat, H.A and Babar, M. (2002). Correlation and path coefficient analysis for yield and its components in rice (Oryza sativa L.). *Asian J. Pl. Sci. 3*: 241-244.

Russell, D.F. (1986).MSTAT-C Pakage Programme.Crop and Soil Science, Department, Michigan University, USA.

Sahu, G and Murthy, K. S. (1975). Influence of nitrogen rate on dry matter production, nitrogen uptake and yield in high yielding cultivars of rice. *Indian journal of plant physiology*. 18 (2): 115-120.

Samonte, S.O.P.B., Wilson, L.T and McClung, A.M. (1998). Path analysis of yield and yield related traits of fifteen diverse rice genotypes. Crop Sci. 38: 1130-1136.

Sarker, U. (2002). Stability for grain yield under difference planting times in rice. *Bangladesh J. Agric.* Res. 27:425-430.

Satish C.B., Dayakar R.T., Ansari, N.A and Sudheer K.S. (2009). Correlation and path analysis for yield and yield components in rice (*Oryza sativa L.).* Agric. Sci. Digest. 29 (1): 45-47.

Shahidullah, S.M., Hanafi, M.M., Ashrafuzzaman, M., Razi Ismail, M and Salam, M.A. (2009). Phenological characters and genetic divergence in aromatic rice.*African Journal of Biotechnology*.8(14): 3199-3207.

Sharma, N. (2002). Quality characteristics of non-aromatic and aromatic rice *(Oryza sativa L.)* varieties of Punjab.*Indian J. Agric. Sci.* 72: 408–410.

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

Sheela, G., Shai, V.N and Saran. (1990). Role of flag leaf on grain yield and spikelet sterility in rice cultivars. *Oryza,* 27: 87–88.

Siddique, S., Hasan, G., Ahmed, S. Q. and Farhad, A. (2002). Genotypic performance of rice in pakhal plains of Mansehra, *Sarhad J. Agric*., 18(1):44449-52.

Sidhu, G.S., Gill, S.S., Malhi, S.S and Bharaj, T.S. (1992). Basmati 385 approved for cultivation in Punjab, India. International rice research news letter.17:5.

Sie, M., Dingkuhn, M., Wopereis, M.C.S and Miezan, K.M. (1998). Rice crop duration and leaf appearance rate in a variable thermal environment.Field Crop Research. 58: 129-140.

Singh , S. and Gangwer, B. (1989). Comparative studies on potentials in traditional tall and improved rice cultivars. *J. Andaman Sci*, Assoc . 5:81-82.

Singh, R.K., Khush, U.S., Khush, G.S. and Rohilla, R. (2000). Genetics and biotechnology of quality traits in aromatic rice's. In: Aromatic Rice's. Oxford & IBH Publishing Co. Pvt. Ltd. New Delhi. India. pp. 47-69.

Sinha, A.C., Kairi, P., Patra, P.S and De, B. (2009). Performance of aromatic rice varieties under terai region of West Bengal.*Journal of Crop Science and Weed*. 5(1): 285287.

Streck, N.A., Bosco, L.C and Lago, I. (2008). Simulating leaf appearance in rice.*Agronomy Journal*. 100: 490-501.

Swain, P., Poonam, A. and Rao, K.S. (2006). Evaluation of rice (Oryza sativa) hybrids in terms of growth and physiological parameters and their relationship with yield under transplanted condition.Indian Journal of Agricultural Sciences. 76(8): 496-499.

Tahir, M., Wadan, D and Zada, A. (2002). Genetic Variability of Different Plant Yield Characters in Rice.*Sarhad J. Agric*.18(2).

Tanaka, A., Navasero, S. A., Garcia, C. V., Parao, F. T and Raires, E. (1964). Growth habit of rice plant in the tropics and it effect on nitrogen response. International rice research institute.Technical Bulletin No.3.

Venkateshwarlu, B and Prasad, A.S.R. (1982). Nature of association among biomass, harvest index and economical yield in rice.Harvest index and biomass: Criteria for selecting plants with high yielding ability. *Indian Journal of Plant Physiology*.25: 149.

Weng, R. X. (1984). Effects of carbohydrates stored before heading stage and dry matter production on the rice grain. Agron Abroad: Rice. 2: 40–49.

Wiangsamut, B., Mendoza, C.T and Lafarge, A.T. (2006). Growth dynamics and yield of rice genotypes grown in transplanted and direct-seeded fields.*Journal of Agricultural Technology* 2(2): 299-316.

WuGuicheng., Zhang H.C., Dai Q., Huo Z.Y., Xu, E., Hui, G., Yan, W.H., Sha A., Xu Z., Hua, Q.Z., and Ying. S.J. (2010). Characteristics of dry matter production and accumulation and Super-High Yield of japonica super rice in South China. Acta Agronomica Sinica.36: 11.

WuWen, C.Z.H., YingFei, Q., Cheng Y., Cheng, W.G., ChaoQun. Z. and Dai Q. (2008). Analysis on dry matter production characteristics of super hybrid rice.Rice Science. 15(2): 110-118.

Yang, F., Wang, X. L., Ma, J.Y. and Ling, F. L., (2001). A comparative analysis of yield component factors of two rice vatieties of JND and JND 13. *J. Jilin Agril. Univ* ., 23(4): 21-24.

Yin, X and Kropff, M.J. (1998). The effect of photoperiod on interval between panicle initiation and flowering in rice.Field Crop Research. 57: 301-307.

Yoshida, S., Cock, J.H and Parao, F.T. (1972). Physiological aspect of high yield.In international rice research inst. pp455-469.Rice breeding Los Banos, Phillippines.

Yoshida, T., Miyazaki, A., Nuruzzaman, M391.., Nitta, Y. and Miyazaki, A. (1999). Varietal difference in tillering ability of fourteen Japonica and Indica rice varieties. Soil Sci. Plant nutria., 46(2):381-391.

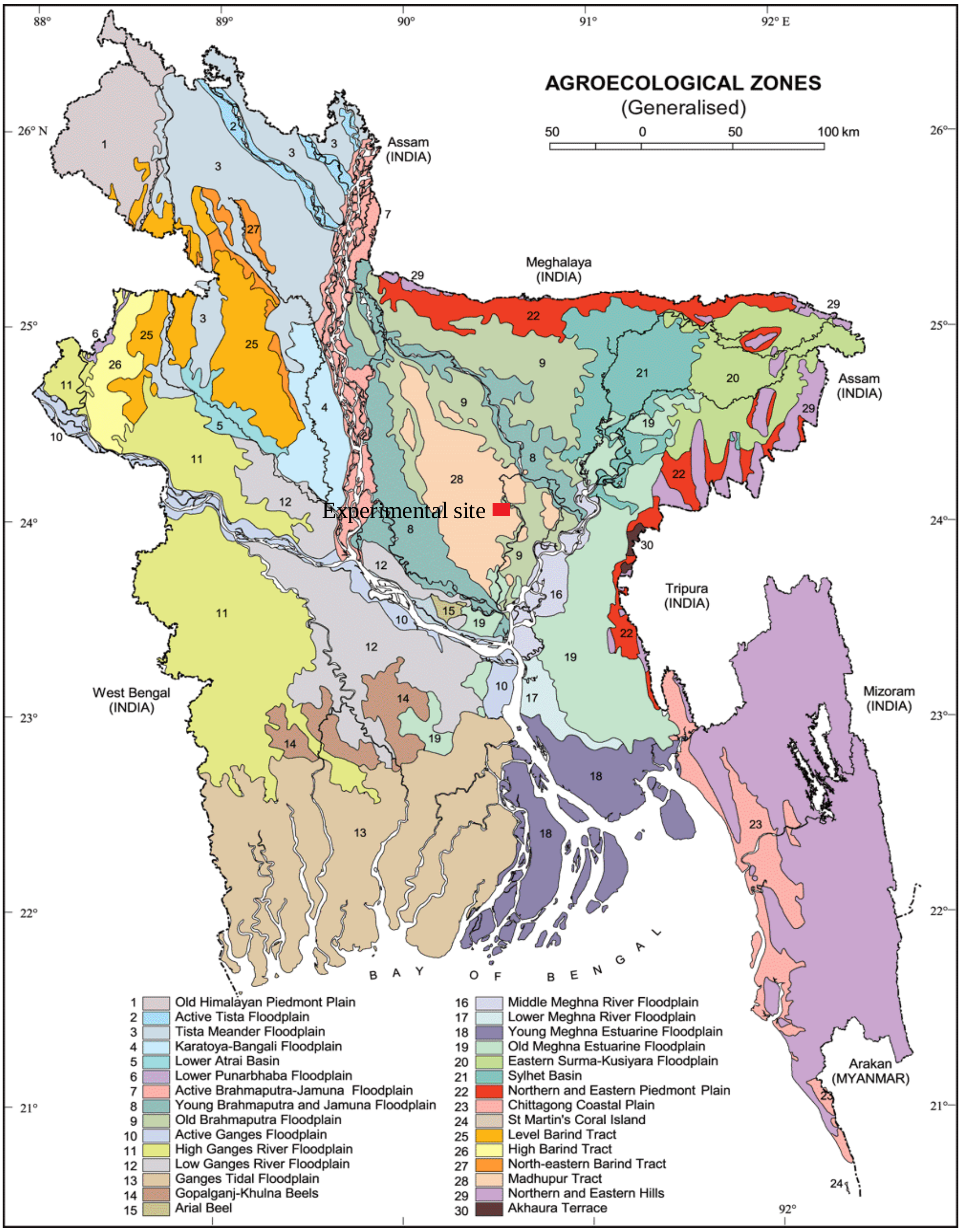
Yusuf, H.K.M. (1997). In: Report of the sustainable Food security Mission in Bangladesh (FAO, Rome), Dhaka.

Zahid A.M., Akhtar, M. Anwar, M and Adil J. (2005). Genotypic and phenotypic correlation and path analysis in coarse grain rice. Proceedings of the International Seminar on Rice Crop, October 2-3. Rice Research Institute, Kala Shah Kau, Pakistan.

# CHAPTER VII

# APPENDICES

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



**Appendix II.**Monthly records of air temperature, relative humidity, rainfall and sunshine hours during the period from July to October, 2017.

| Month | RH (%) | Air temperature (C) | | | Rainfall (mm) |
|---|---|---|---|---|---|
| | | *Max.* | *Min.* | *Mean* | |
| July | 79.60 | 33.20 | 25.74 | 29.47 | 304.0 |
| August | 76.25 | 31.66 | 24.40 | 28.03 | 152.6 |
| Septembe | 71.50 | 30.8 | 21.80 | 26.30 | 78.52 |
| October | 68.48 | 30.42 | 16.24 | 23.33 | 52.60 |

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

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

**A.** General features of characteristics of the experimental field

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

Source: Soil Resource Development Institute (SRDI)

**B.** Physical and chemical properties of the initial soil

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

Source: Soil Resource Development Institute (SRDI)

**Appendix IV**. ANOVA of plant height of different aromatic rice varieties.

| Source of variation | Degrees of freedom | Mean square of plant height (cm) at different DAT | | | |
|---|---|---|---|---|---|
| | | 30 DAT | 55 DAT | 80 DAT | At harvest |
| Replication | 2 | 3.501 | 3.430 | 2.243 | 3.016 |
| Factor A | 11 | 80.88* | 148.48* | 190.31* | 146.92* |
| Error | 22 | 4.541 | 13.781 | 9.901 | 11.727 |

**Appendix V.** ANOVA of number of leaves plant$^{-1}$of different aromatic rice varieties.

| Source of variation | Degrees of freedom | Mean square of number of leaves plant$^{-1}$ at different DAT | | | |
|---|---|---|---|---|---|
| | | 30 DAT | 55 DAT | 80 DAT | At harvest |
| Replication | 2 | 2.547 | 3.047 | 2.293 | 3.391 |
| Factor A | 11 | 33.53** | 17.18* | 28.46* | 29.77* |
| Error | 22 | 2.738 | 3.024 | 6.534 | 5.072 |

**Appendix VI.** ANOVA of number of tillers plant$^{-1}$of different aromatic rice varieties.

| Source of variation | Degrees of freedom | Mean square of number of tillers plant$^{-1}$ at different DAT | | | |
|---|---|---|---|---|---|
| | | 30 DAT | 55 DAT | 80 DAT | At harvest |
| Replication | 2 | 0.623 | 0.422 | 1.083 | 1.866 |
| Factor A | 11 | 4.832** | 17.33** | 13.77* | 19.40* |
| Error | 22 | 0.733 | 1.823 | 1.805 | 1.715 |

**Appendix VII.** ANOVA of leaf area index of different aromatic rice varieties.

| Source of variation | Degrees of freedom | Mean square of leaf area index plant$^{-1}$ at different DAT | | |
|---|---|---|---|---|
| | | 30 DAT | 55 DAT | 80 DAT |
| Replication | 2 | 0.034 | 0.099 | 0.123 |
| Factor A | 11 | 0.148$^{NS}$ | 2.520** | 2.359** |
| Error | 22 | 0.001 | 0.042 | 0.053 |

**Appendix VIII.** ANOVA of flag leaf length, breadth, area and SPAD value of flag leaf of differen taromatic rice varieties.

| Source of variation | Degrees of freedom | Mean square of morpho-physiological parameters | | | |
|---|---|---|---|---|---|
| | | Length of flag leaf (cm) | Breadth of flag leaf (cm) | Flag leaf area plant$^{-1}$ (cm$^2$) | SPAD value of flag leaf |
| Replication | 2 | 0.182 | 0.051 | 1.523 | 2.151 |
| Factor A | 11 | 16.06* | 2.42** | 42.61* | 41.56* |
| Error | 22 | 2.151 | 0.102 | 3.129 | 4.248 |

**Appendix VIX.** ANOVA of dry weight hill$^{-1}$of different aromatic rice varieties.

| Source of variation | Degrees of freedom | Mean square of dry weight hill$^{-1}$ at different DAT | | |
|---|---|---|---|---|
| | | 55 DAT | 80 DAT | At harvest |
| Replication | 2 | 1.750 | 2.451 | 3.793 |
| Factor A | 11 | 52.35** | 82.16* | 96.135* |
| Error | 22 | 0.262 | 1.644 | 3.024 |

**Appendix X.** ANOVA of crop growth rate, relative growth rate and absolute growth rate of different aromatic rice varieties.

| Source of variation | Degrees of freedom | Mean square of CGR (mg cm$^{-2}$ day$^{-1}$) | | Mean square of RGR (mg g$^{-1}$ day$^{-1}$) | | Mean square of AGR (cm hill$^{-1}$ day$^{-1}$) | |
|---|---|---|---|---|---|---|---|
| | | 55 – 80 DAT | 80 DAT – At harvest | 55 – 80 DAT | 80 DAT – At harvest | 30 – 55 DAT | 55 - 80 DAT |
| Replication | 2 | 0.163 | 0.163 | 1.426 | 0.634 | 0.026 | 0.042 |
| Factor A | 11 | 0.75** | 0.746* | 3.57** | 2.582* | 1.114** | 1.016** |
| Error | 22 | 0.004 | 0.003 | 1.654 | 0.601 | 0.012 | 0.008 |

**Appendix XI.** ANOVA of yield contributing parameters of different aromatic rice varieties.

| Source of variation | Degrees of freedom | Mean square of yield contributing parameters | | |
|---|---|---|---|---|
| | | Number of tiller plant$^{-1}$ at harvest | Number of non-effective tillers plant$^{-1}$ at harvest | Number of effective tillers plant$^{-1}$ at harvest |
| Replication | 2 | 2.866 | 0.146 | 1.313 |
| Factor A | 11 | 19.40* | 1.72** | 14.39* |
| Error | 22 | 3.715 | 0.282 | 2.811 |

**Appendix XII.** ANOVA of yield contributing parameters of different aromatic rice varieties.

| Source of variation | Degrees of freedom | Mean square of yield contributing parameters | | | | | |
|---|---|---|---|---|---|---|---|
| | | Number of grains panicle$^{-1}$ | Number of filled grains panicle$^{-1}$ | Number of unfilled grains panicle$^{-1}$ | Spikelet fertility (%) | Panicle length (cm) | Weight of 1000 grains (g) |
| Replication | 2 | 4.012 | 2.906 | 1.510 | 2.616 | 0.573 | 1.537 |
| Factor A | 11 | 176.0* | 109.4* | 35.58* | 26.95* | 16.42* | 22.05** |
| Error | 22 | 6.320 | 4.934 | 2.526 | 2.497 | 1.616 | 1.372 |

**Appendix XIII.** ANOVA of yield performance parameters of different aromatic rice varieties.

| Source of variation | Degrees of freedom | Mean square of yield parameters | | | |
|---|---|---|---|---|---|
| | | Grain yield (t ha$^{-1}$) | Straw yield (t ha$^{-1}$) | Biological yield (t ha$^{-1}$) | Harvest index (%) |
| Replication | 2 | 1.548 | 0.541 | 2.743 | 1.929 |
| Factor A | 11 | 31.14* | 41.06* | 42.13* | 47.14** |
| Error | 22 | 1.438 | 2.408 | 2.613 | 3.657 |

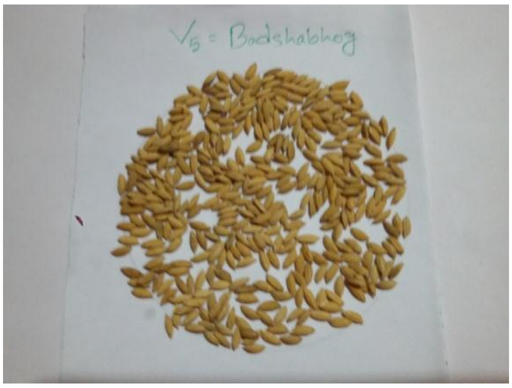
# Plates



**$V_1$= Kalijira** **$V_2$= Chiniatap 1**



**$V_3$= BRRI dhan50** **$V_4$= Kataribhog 1**





**$V_5$= Badshabhog $V_6$= Modhumala**

**Plate. 1**. Pictures of some seeds of different aromatic rice varieties.



**$V_7$= Zirabhog** **$V_8$= Shakkhorkhora**



**$V_9$ = Chiniatap 2** **$V_{10}$ = Kataribogh 2**



**$V_{11}$ = BRRI dhan37** **$V_{12}$ = BRRIdhan38**

**Plate.1.(continued).**Pictures of some seeds of different aromatic rice varieties.

**Plate. 2**. Picture of transplantation of seedlings in the main field.

**Plate. 3**. Picture of my supervisor supervising my field during the transplantation of rice seedlings in the main field.