A COMPARATIVE STUDY ON TRADITIONAL AND MODERN AROMATIC RICE VARIETIES IN *AMAN* SEASON

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*This is to certify that thesis entitled, "***A COMPARATIVE STUDY ON TRADITIONAL AND MODERN AROMATIC RICE VARIETIES IN** ***AMAN*** **SEASON***" 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 (MS) IN AGRICULTURAL BOTANY, embodies the result of a piece of bona-fide research work carried out by MD. RAZAUL ISLAM, Registration no. 10-03903 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 duly been acknowledged.

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ABSTRACT

A field experiment was conducted at the Research Farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, from July to December, 2018 (*Aman* season) with six traditional (Chinigura, Dulabhog, Chiniatop, Begun Bichi, Badshabhog and Kalizira) and four modern rice varieties (BRRIdhan34, BRRI dhan37, BRRI dhan38 and BRRIdhan50) with a view to assessing their performances. The experiment was laid out in Randomized Complete Block Design with three replications. Significant variation was found among the selected traditional and modern rice varieties in respect of their different growth and yield contributing characters. Among the ten rice varieties, traditional Begun Bichi was found inferior in case of grain yield. All the modern aromatic varieties contained higher amount of chlorophyll in their flag leaf at flowering to maturity compared to the traditional one. BRRI dhan50 exhibited superiority over the rest modern and traditional aromatic varieties in different growth parameters like leaf area index, tillers and leaves hill^{-1} at reproductive stages. BRRI dhan50 also showed superiority in case of yield parameters such as effective tillers hill^{-1} (23.53), panicle length (25 cm), filled grains panicle^{-1} (108), 1000-grain weight (23.57 g), biological yield (10.26 tha^{-1}) and grain yield (5.99 tha^{-1}). Rest of the modern varieties *viz.* BRRI dhan38 (3.85 tha^{-1}), BRRI dhan37 and BRRI dhan34 (3.62 tha^{-1}) also provided higher grain yield compared to traditional Badshabhog (2.13 tha^{-1}), Dulabhog (1.75 tha^{-1}), Chinigura (1.69 tha^{-1}), Kalizira (1.56 tha^{-1}), Chiniatop (1.49 tha^{-1}), and Begun Bichi (1.11 tha^{-1}). Effective tillers hill^{-1}, filled grains panicle^{-1} and 1000-grain weight mainly contributed to the higher grain yield of the modern aromatic rice varieties over the traditional varieties.

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

CHAPTER 1

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the most important crops in tropical and subtropical country in world. It is the major sources of food for approximately half of the world population and hence the most important crop on the earth. Asia is the prominent producer of rice and about 60% of the Asian gets their calorie from rice. Rice provides 20-80% dietary energy and near about 12-17% of dietary protein for Asians (FAOSTAT, 2017). In worldwide, 483.3 million metric tons of rice was produced from 159.64 million hectares of land during the year of 2016-17 which is 4.5 million metric tons higher than last season (USDA, 2016). FAO estimates Bangladesh to produce around 34.578 million tons of rice in 2016-17, in an area about 11.78 million hectare. During the year 2016-17, 13.4 million metric tons of *Aman* rice was produced from 5.9 million hectares of land with an average yield of 2.27 t ha^{-1} in Bangladesh (BBS, 2018). Rice is the main crop in Bangladesh and its production need to be increased to fulfill the food necessity of an over populated country where the volume of the population is increasing rapidly.

Rice can also be classified as aromatic and fine (non- aromatic) rice on the basis of aroma. In Bangladesh northern region such as Rangpur, Dinajpur and Panchagarh district are famous for the production of aromatic rice. In Bangladesh, aromatic rice is cultivated during ‘*Aman*’ season in June and July.

The cultivation of aromatic fine rice is given the priority along with coarse rice to meet up the food demands (Bhuiyan *et al.*, 2014). Generally, the price of the aromatic rice is three to four times greater than that of the non-aromatic or ordinary rice varieties in national and international markets. Dutta *et al.* (2016) reported that production of aromatic rice in Bangladesh is becoming popular due to its high prices and export potentiality. The modern and traditional aromatic rice has greater demand in national level and international market. The aromatic rice has a wider acceptance in the market due to their test and aroma content. Most of the well-off the people preferred long, slender fine grain rice. In addition, fine aromatic rice can be grown under wide range of environmental condition (Begum *et al*., 2010).

According to Nasiruddin (1993) annual per capita consumption of rice in Bangladesh is the highest in the world. Rice provides about 70% of an average citizen's total calorie intake in Bangladesh (BRRI, 2010).Also rice accounts for about 18% of the national GDP (BRRI, 2010). During 1970-1975, the snack of amount of rice was below 455g per head per day but in 2016-2017, the snack of rice per head per day increased more than 490 g although the rice land per capita per year decreased anxiously. This scenario indicates that the country needs to produce extra amount of rice to feed its increased population. This becomes possible because of the cultivation of modern rice varieties in 67% rice land (BBS, 2017). Modern varieties of transplanted *Aman* cover 80% of rice land area and also reported that rice produce in *Aman* season has the highest Benefit Cost Ratio (BCR) (1.63) as it does not need costly irrigation(USDA, 2018).

There are three seasons of rice cultivation in Bangladesh named as *Aus*, *Aman* and *Boro*, which are belongs April to July, August to December and January to May months of a year respectively. About two-thirds of the cultivated land area of Bangladesh is occupied by rice. *Aman* is second main rice growing season in Bangladesh. The traditional varieties of rice in Bangladesh are comparatively lower-yield and it is impossible to change this yield with reachable resources under the prevailing situation. IRRI (1993) proposed that higher yield can be achieved by two processes, firstly through the cultivation of modern varieties and secondly by following developed management practices. For fulfilling the demand of rice for Bangladesh needs to cultivate the modern varieties of rice. Baqui *et al*.

(1997) revealed that among the aromatic rice cultivars, Chinigura was the predominant one that covered more than 70% farms in the northern districts of Naogaon and Dinajpur. In these districts, 30% of the rice lands were covered by aromatic rice cultivars during *Aman* season. The rapid rate of extinction of indigenous cultivars of local rice points to the danger of narrowing genetic base. Around 67 percent of the country's cultivated land area is used for rice production. Bangladesh Rice Research Institute (BRRI) reported that in the period 1990-91 to 2016-17, adoption of modern varieties (MV) increased area by 11% in *Boro*, 246% in *Aus* and 135% in *Aman* season rice. Additionally, *Aman* rice accounts for 50% of rice land, but due to the planting of lower yield varieties, its yield increase is lowest (39%) (USDA, Foreign Agricultural Service, 2018). Moreover, Aromatic rice is a good source of different phytochemical such as phenolic compounds, anthocyanin, flavonoids etc. These components are most likely involved in the reduction of degenerative human diseases due to their anti-oxidative and free radical scavenging properties (Basu *et al*., 2012).

Consumption of un-husked rice is diversified, for both human and animal use. A bag of 40 kg paddy (un-husked rice) in an automatic rice mill produces four types of product and by-products which includes 26 kg of husked rice (62-65%), 8.7 kg of rice husk (8.7-9.3%), 3.3 kg of rice bran (3.3-3.5%) and 2 kg of broken rice (2-2.2%). Rice husk is converted to briquettes for use as bio-fuel and fuel for steaming the rice in the mill. Rice bran is used in feed processing and producing rice bran oil, while broken rice is also used for human consumption and feed processing. The proportion of un-husked rice used in the livestock and aquaculture feed sectors is significant as the country has a well-established poultry sector and the world's fifth largest inland aquaculture sector. Developing those above sectors modern varieties is mandatory. Modern varieties of rice can break the yield ceiling of traditional varieties. Farmers are gradually replacing the low yielding traditional varieties by high yielding modern varieties.

Especially the traditional fine rice variety has more adaptability in adverse condition than the modern aromatic variety but most of the traditional aromatic rice varieties are photosensitive and suitable for growing in *Aman* season. Grain yield of modern aromatic rice is higher than the traditional one. To meet up the increasing demand of the scented rice, its cultivation is expanded in *Aman* season using production cost saving technology and also will be search out suitable aromatic rice varieties. Research work limited on aromatic rice in Bangladesh. For expanding its cultivation, suitable varieties and proper technology is to be developed or found. Considering this situation, the study was undertaken to compare the performance of previously mentioned traditional and modern rice varieties in *Aman* season.

Observing the foregoing problems in view, this study was commenced with the following objectives-

1. To observe tiller and leaf characteristics of traditional and modern aromatic rice varieties in *Aman* season.

2. To compare yield and yield attributes of traditional and modern aromatic rice varieties in *Aman* season.

CHAPTER 2

REVIEW OF LITERATURE

Rice (*Oryza sativa* L.) is the staple food of more than half of the world's population is more than 3.5 billion people depend on rice for more than 20% of their daily calories. Rice provided 19% of global human per capita energy and 13% of per capita protein in 2009. Asia accounts for 90% of global rice consumption, and total rice demand there continues to rise. In 2015/16 growing season total milled rice production in Asia is 118.2 million tons where 47.0 million hectares of land which approximately 45 percent or 21.0 million hectares are irrigated were harvested in Southeast Asia alone (approximately 87% of total world rice production) (USDA, 2016). In Bangladesh, there are thousands of local landraces of rice (Kaul *et al.*, 1982), many of which are either fine grain or aromatic types. The breeding of high yielding modern aromatic varieties is an essential component of the strategy to fulfill the demand in national and international market.

Yield is the product of yield components such as panicle number, grain number, and grain weight in rice (Yoshida, 1981). Yield potentiality also depends on physiological parameters like leaf area index, dry matter accumulation, translocation of assimilate etc. The available literatures under the heads of the objectives of the study were also reviewed in the following paragraphs.

2.1 Morpho-Physiological parameters

2.1.1 Plant height

The rice breeders are interested in developing cultivars with improved yield and other desirable agronomic characters to overcome the global problem of hunger and starvation. Different morphological traits play an important role for increased rice production with new plant type characteristics associated with the yield. Among different morpho-physiological characteristics plant height is the most important. Days to flowering affects on the plant height. Effect of DF on PH was highest when DF was the shortest.

Midget may be one of the most important physical characters of rice, because it is often associated by lodging resistance and there by adapts well to heavy fertilizer application. Plant height is negatively correlated with lodging resistance; higher plant height in modern aromatic is not desirable, particularly with high nitrogen fertilizer (Futsuhara and Kikuchi, 1984). Higher plant height is a common character of traditional fine grain rice varieties which increases lodging of plant. For this reasons production decrease drastically. But modern variety has lower plant height which helpful for higher production. Mandavi *et al*. (2004) found in his an experiment that plant height was negatively correlated with grain yield. Thus, in modern aromatic varieties, plant height was not a limiting factor for grain yield because of reduced lodging and conducted better translocation of assimilates.

Sarkar (2014) found that height varies from one variety to another. In his experiment he found that Tia (78.46 cm) was the tallest plant which gave the lower yield and shortest was recorded in Aloron (63.88 cm) which gave the highest yield. Dutta *et al*. (2016) found that traditional aromatic rice varieties in *Aman* season gave higher plant height about 145 cm. Samsuzzamn (2007) also reported that plant height of the modern aromatic and hybrids ranged from 82.46 to 90 cm.

2.1.2 Tillering properties

Rice tillering is a major determinant for panicle production (Miller *et al.*, 1991) and as a consequence affects total yield (Gallagher and Biscoe, 1978). The number of tillers has been reported to have a supreme association with plant biomass and economic yields in rice (Deng *et al.* 2015). Rice is one of the most important agricultural commodities in the world. From 1980 to 2016, dedicated rice planting areas were increased by only 12 % worldwide, while total rice production increased by 78 % (USDA 2016). Tillering is an important agronomic criterion for rice population quality and grain production (Ling, 2000). This is because excess tiller production results in a dense canopy, which provides a moist micro-environment favorable for diseases and pests, whereas too few tillers results in insufficient numbers of panicles (Cu *et al.* 1996). Typically, late emerging tillers do not contribute significantly to the grain yield of rice (Wang *et al.* 2007).

Sarkar (2014) expressed that number of total tiller per hill increased with the advancement of vegetative growth stages. He also observed that hybrid produced a significantly higher number of tillers per hill. Shahidullah *et al.* (2009) reported that tiller number of aromatic traditional rice variety is higher at earlier stage but mortality is higher before panicle initiation stage. Song *et al*. (2004) observed that modern varieties produced a significantly higher number of effective tillers. Cu *et al* (1996) observed that excess tiller production results in a dense canopy, which provides a moist micro-environment favorable for diseases and pests, whereas too few tillers results in insufficient numbers of panicles.

The number of panicles is positively correlated with maximum number of tillers. Total number of tillers at harvest has the biggest direct effect on grain yield. Number of panicles has insignificant direct effect on yield.

2.1.3 Days to maturity

Mohapatra and Kariali (2008) indicated that short growth duration was the principal reason for poor grain production by late emerging rice tillers. Ma *et al.* (2001) found that a comparative performance of 8 modern rice varieties. All varieties showed shorter growth duration (97- 107 days).

Bangladesh rice research institute reported that modern aromatic rice varieties need 130-150 days for maturity and traditional varieties need longer duration more than 145 days. Longer crop duration increase the cost of production than shorter duration variety. Oad *et al.* (2006) observed that traditional aromatic varieties and their crosses initiated flowering between 73 and 105 days.

Dutta *et al.* (2016) also found that crop duration was higher in traditional aromatic rice varieties (more than 144 days) than modern aromatic rice varieties. Ashrafuzzaman *et al.* (2009) observed that Basmati required shorter days to maturity and Kalizira taken the longest days to maturity.

2.1.4 Leaves per hill

Sarkar (2014) observed that a significant difference on total number of leaves per hill from vegetative to reproductive stage. Hassan (2001) represented that photo synthetically active leaves per hill of all varieties (modern and traditional) increased with the growth period up to booting stage except in Binasail. He also observed that maximum number of leaves were produced at the tillering stage and then declined slowly. The rate of declination was acute in local varieties.

Hosen (2015) also indicated that number of leaves increase up to certain growth stage till the end of the vegetative stage and then declined.

2.1.5 Leaf area index (LAI)

Chandra and Das (2007) observed that LAI was significantly and directly correlated with grain yield. The reduction of LAI is greater in traditional aromatic rice than that of modern.

Dutta*et al.* (2016) found that Binasail, Chinigura, Masuri, Basmati, Kaskhani, Balagura, Mugy, Chiniatab, Bhogbalam, Kalajira have lower LAR and Kataribogh, Badshabhog, Zabsiri, Ragusail, Binni, Birai, Ukunimadhu, Zingasail, Balam representing higher LAR.

Rao (1997) observed that flag leaf area could be choosing as a factor for increasing rice grain yield. Leaf area increase contributes for canopy development. As the leaf area increases, a higher photo synthetically active surface area becomes available and it would therefore be expected that the production rate would be greater the higher the leaf area.

Kyzlasov (1987) reported that leaf area is indictor of potential grain yield and broader and long leaves give higher grain yield. Mahdevi *et al.* (2004) recorded that all genotypes gained maximum LAI at pre-flowering but Dash and Taron gained LAI at flowering. Wada *et al*. (2002) observed that greater crop growth rate after anthesis on account of the higher mean LAI during ripening period.

Sharma and Haloi (2001) showed a remarkable variation of leaf area in an experiment on scented rice. They mentioned that Leaf area ratio of different varieties differed significantly throughout the growth stages and declined from tillering to flowering stage. They found that at tillering, modern BRRI dhan32 possessed the highest LAR and traditional Kataribhog showed the lowest LAR.

Hybrid rice variety produce the higher leaf area than the check variety and the variation in leaf area might occur due to the variation in number of leaves (Sarkar, 2014). Islam (2006) observed that the leaf area per hill varied significantly due to genotype at all growth stages.

Mahdavi *et al*. (2004) also indicated that improved genotypes were with greater leaf area than traditional genotypes. He found that flag leaf area had positively correlated with grain yield.

Yuan (2001) showed that LAI is about 6 in top three leaves and Mia (2001) found that about 7.3 LAI is the maximum that is necessary for giving high grain yield. Lu *et al.* (2000) described that higher yield of rice was on account of the better distribution of LAI after heading.

2.1.6 Total dry matter weight per hill

Sharma and Haloi (2001) guided a study in Assam during the kharif season with 12 varieties of scented rice cultivars and observed that among them all varieties *cv*. Kunkuni Joha gradually maintained a greater rate of dry matter production at all growth stages and the highest dry matter accumulation at the panicle initiation stage.

Attaining higher yield depends on increasing total crop biomass, because there is little scope to further increase the proportion of that biomass allocated to grain Reddy *et al*. (1994) observed that dry matter production and grain yield were positively and significantly connected with each other and also with Net Assimilation Rate (NAR) and Harvest Index (HI).

Dry matter (DM) accumulation over time varied considerably due to variety. Among different days after transplanting (DAT), Kachra produced the highest dry matter (1420.7 g m^{-2}) and Kalizira produced the lowest dry matter (1105.7 g m^{-2}) at 92 DAT (Islam *et al.*, 2013). Vergera *et al*. (1974) reported that dry matter accumulation increased with time and the initial increase was slow then it was accelerated.

2.1.7 Flag leaf chlorophyll content

Flag leaf has an important role in rice yield by increasing grain weight in amount of 41 to 43 percent. Flag leaf area increase contributing by increasing chlorophyll content and fresh weight of flag leaf (Santosh, 2011).

Chlorophyll content in flag leaf and chlorophyll a: chlorophyll b ratio gradually decreased in the traditional and modern varieties with advancement of maturity. Reduction of chlorophyll content at 23 days after flowering compared to 2 days after flowering was 33 and 36% in modern and traditional, respectively. Planting dates had little influence on flag leaf chlorophyll content. Faisal (2014) found that grain yield significantly and positively correlated with flag leaf area, fresh weight of flag leaf and total chlorophyll content. However, environmental influence on total chlorophyll content of flag leaf was relatively small.

Salem *et al.* (2011) observed that chlorophyll content was significantly increased for the 20 days seedling and 40 days seedling gave the lowest value of chlorophyll.

2.2 Yield parameters

2.2.1 Effective tillers hill^{-1}

Saha *et al*. (2015) found that minimum and maximum number of tillers was observed in Begun Bichi and Tilkapur, respectively. The highest number of fertile tillers hill^{-1} was observed in BRRI dhan37 and it was identically followed by Radhunipagal, Badshabhog, Chinigura, BRRI dhan38 and the lowest fertile tillers hill^{-1} was obtained from Kalizira which was statistically similar to Kataribhog (Hossain *et al*., 2005).

Shahidullah *et al.*, (2009) showed that maximum number of tillers varied from 136 (Khazar) to 455 m^{-2} (Chinigura) and the highest rate of tiller mortality was found 49.29% in Chinigura and lowest in Jessobalam (10.10%). Dutta *et al*. (2016) observed that Kalizira gave the lower sterile tillers and Badshabhog gave the higher sterile tillers.

The highest number of effective tillers hill-^{1} (13.0) was produced by Kalizira and the lowest number of effective tillers hill^{-1} (7.13) was observed in Morichasail (Islam *et al.*, 2013). Nehru *et al*. (2000) observed that the number of fertile tillers directly correlated with yield of rice. Ganapathy *et al*. (1994) and Mishra *et al.* (1996) also concluded that number of tillers per hill and number of grains per panicle exhibited positive significant correlation with yield.

2.2.2 Panicle length

The minimum panicle length was recorded in Begun Bichi while maximum panicle length in BR5 (Dulabhog) (Saha *et al.*, 2015). He also found that panicle length of Badshabhog, Chinigura, Kalizira was 25.33cm, 23.67cm, 24.67cm respectively. Ifftikhar *et al.* (2009) studied genetic variability for different traits and found that this trait is belongs to the genetic control and could be used in the selection process of some desirable traits. Ramalingam *et al*. (1994) observed that varieties with long panicles, a higher number of filled grains and more primary rachis would be suitable for selection because these characters have high positive fraternity with grain yield and are correlated among themselves.

Laza, *et al*. (2004) showed that panicle size had the most consistent and closest positive correlation with grain yield. According to Islam *et al.* (2013) panicle length was the highest (23.25 cm) in the variety Morichsail and the variety Kalizira produced lowest panicle length (20.03 cm). Anonymous reported that panicle length influenced by variety.

Increasing panicle length and plant height might have increased grain yield of rice indirectly by increasing the number of spikelet's per panicle and panicle length, respectively (Behera, 1998). Islam *et al.* (2013) reported that the highest panicle length (21.62 cm) was recorded in the variety Bapoy which was followed by the variety Kajollata and Bereratna. They also reported that the lowest panicle length (15.13 cm) was found with the variety Sylhety boro which was preceded by Nayonmoni, GS one, Kaliboro and Choiteboro.

2.2.3 Filled grains per panicle

Anonymous (1994) reported that the number of filled grains panicle^{-1} influenced significantly due to variety. Saha *et al.* (2015) in an experiment found that number of filled grains per panicle ranged from 88 to 219. They also showed that the least numbers of filled grains per panicle was observed in the genotype Kalizira (Late), while the maximum was in Chinikanai-1.

Dutta *et al*. (2016) mentioned modern varieties in *Aman* season such as BR 11, BR 22 produced higher filled grain than traditional varieties such as Badshabhog, Kalazira, Chiniatab. Liu and Yuan (2002) studied that the relationships between high- yielding potential and yielding traits. They found that the filled grains per panicle was positively correlated with biomass, harvest index and grain weight per plant. Chaudhary and Motiramani (2003) also showed that the filled grain per panicle significantly correlated with effective tillers per plant.

2.2.4 Unfilled grains panicle^{-1}

Number of unfilled grains panicle^{-1} was important one and played a vital role in yield reduction. Effect of variety on the number of unfilled grains per panicle was highly significant. This variation in number of unfilled grains per panicle might be due to genetic characteristics of the varieties (Chowdhury *et al*., 1993). Morichsail produced the lowest number of unfilled grains per panicle (11.17) which contributed highest grain yield of that variety and Khaskani, Badshabhog and Kalizira produced the highest number of unfilled grains per panicle 38.88, 32.93 and 21.17 respectively (Islam et al., 2013).

2.2.5 Thousand grain weight

Kumar *et al*. (1994) mentioned that grain weight was highly correlated to grain size. Among 30 genotype Saha *et al*. (2015) found that the Kalizira (Normal) gave the minimum thousand grain weight, while maximum in Kaloshailla. Islam *et al*. (2013) lowest 1000-grain weight (13.32 g) was recorded from the variety Kalizira for its smaller grain size. Sarkar (2003) also mentioned the variety Kalizira was giving lowest 1000-grain weight.

Sarkar *et al*. (2005) showed that the highest heritability value was registered for 1000-grain weight, followed by brown kernel length and grain length. Saha *et al*. (2015) evaluated that minimum spikelet length was recorded in Kalizira (White type), while maximum was observed in Kaloshailla. They also evaluated that minimum and maximum spikelet breadth was observed in Chinigura PL-2 and Sakkorkhora, respectively.

Dutta *et al.* (2016) observed that the rates of grain growth for all coarse grain varieties (BR3, BR11 and BR22) were higher than those for the fine grain varieties (Nizersail, Pajam and Badshabhog). Where BR3 with the largest grain, had the highest rate of grain development and Badshabhog with the smallest grain, had the lowest.

2.2.6 Grain yield

BRRI published that BRRI dhan34, BRRI dhan37, BRRI dhan38 gave 3.5ton grain yield per hectare and BRRI dhan50 gave up to 6 ton grain yield per hectare. Chaudhary and Motiramani, N.K. (2003) reported that grain yield per plant significantly correlated with effective tillers per hill, spikelets density and filled grain per panicle.

Islam *et al*. (2013) found that the variety Morichsail produced the highest grain yield (2.53 t ha^{-1}) followed by Kachra (2.41 t ha^{-1}), Raniselute (2.13 t ha^{-1}) and Badshabhog (2.09 t ha^{-1}) and the lowest grain yield (1.80 t ha^{-1}) was obtained from Kalizira. Saha *et al*. (2015) also explained that the highest grain yield per plant was observed in Chinikanai-1, which was followed by Kalizira PL-9, Kalizira PL-3 and Badshabhog. Chinikanai-1 had the highest number of grains per panicle.

Shahidullah *et al.* (2009) in their experiment found that among the aromatic rice genotypes, Elai produced highest grain yield (3.35 t/ha) and the lowest yield was harvested 1.42 t/ha from Khazar. Ashrafuzzaman *et al.* (2009) found that thousand grain weight and grain yield both were highest in BR38 among the six aromatic rice varieties BR34, BR38, Kalizira, Chiniatop, Kataribhog and Basmati.

2.2.7 Straw yield

Among the five local and three modern aromatic rice varieties namely, Kataribhog, Radhunipagal , Chinigura , Badshabhog , Kalizira, BRRI dhan34, BRRI dhan37 and BRRI dhan38, Kataribhog gave the highest straw yield (8.9 t ha^{-1}) and the lowest straw yield (5.8 t ha^{-1}) was obtained from Kalizera identically followed by BRRI dhan37 and BRRI dhan38 (Hossain *et al.*, 2005).

2.2.8 Biological yield

Among the local aromatic rice cultivars viz. Kalizira, Khaskani, Kachra, Raniselute, Morichsail and Badshabhog the highest biological yield (9.46 t ha^{-1}) was obtained from the variety Kachra and the lowest biological yield (3.87 t ha^{-1}) was recorded from the variety Kalizira (Islam *et al.*, 2013).

2.2.9 Harvest index

It was found that harvest index do not follow any regular aptitude and was not significant due to variety. Numerically the highest harvest index (36.06%) was recorded from the variety Khaskani and the lowest (25.48%) was calculated from the variety Kachra that means the variety Kachra is less efficient to translocate the assimilation towards the grain (Islam *et al.*, 2013). Shah *et al*. (1997) reported that the variety had a great influence on harvest index. Kalizira gave the higher harvest index than Bashabhog (Dutta *et al.*, 2016).

Harvest index is an essential character having physiological importance. It reflects translocation on alternatively dry matter partitioning of a given genotype to the economic parts of plants. The highest harvest index was recorded from BR34 (34.94%) and the lowest harvest index was obtained from Basmati (31.51%) (Ashrafuzzaman *et al.*, 2009).

CHAPTER 3

MATERIALS AND METHODS

This chapter describes a short description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design and layout, crop growing procedure, fertilizer application, uprooting of seedlings, intercultural operations, data collection and statistical analysis.

3.1 Description of the experimental site

3.1.1 Location

The experiment was conducted at the Experimental shed of the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka during the period from July-December, 2017. The experimental site was located at 8.45m elevation above sea level with latitude of 23º74´N and longitude of 90º33´E. For better understanding about the experimental site has been shown in Appendix I.

3.1.2 Soil

The experiment was carried out in a typical rice growing soil belongs to the Modhupur tract. The soil of the experimental area belonged to the Madhupur tract (AEZ No. 28). It was a medium high land with non-calcarious dark grey soil. The pH value of the soil was 5.7. The physical and chemical properties of the experimental soil have been shown in Appendix II.

3.1.3 Climate

The experimental area was present under the subtropical climate and characterized by high temperature, high humidity and heavy precipitation with occasional a blast of winds during the period from July to September. The detailed meteorological data in respect of air temperature, relative humidity, rainfall and sunshine hour recorded by the meteorology center, Dhaka for the period of experimentation have been presented in Appendix III.

3.2 Plant materials

Six traditional aromatic rice varieties and four modern high yielding aromatic varieties from Bangladesh Rice Research Institute were used in this experiment.

Varieties are:

1. Chinigura (V_1)
2. Dulabhog (V_2)
3. Chiniatop (V_3)
4. Begun Bichi (V_4)
5. Badshabhog (V_5)
6. Kalizira (V_6)
7. BRRI dhan34 (V_7)
8. BRRI dhan37 (V_8)
9. BRRI dhan38 (V_9)
10. BRRI dhan50 (V_{10})

3.3 Details of the experiment

3.3.1 Experimental treatments

One factor experiment was conducted to assess the performance of modern aromatic rice varieties comparing to the traditional aromatic rice varieties in *Aman* season.

3.3.2 Layout of the experimental design

The experiment was conducted in Randomized Complete Block Design (RCBD) with three replications, where the experimental area was divided into three blocks representing the replications helps to reduce soil hetero-genetic effects. The total number of unit plots was 30. The size of unit plot is 4m x 2.5m. The distances between plot to plot and block to block were 0.6m and 1m respectively.

The layout is given below:

Layout of the experimental design

R1	R2	R3
V_1	V_3	V_5
V_8	V_{10}	V_7
V_3	V_5	V_6
V_5	V_1	V_8
V_4	V_7	V_3
V_6	V_8	V_{10}
V_9	V_9	V_1
V_2	V_4	V_2
V_7	V_6	V_9
V_{10}	V_2	V_4

3.3.3 Seed sprouting

Healthy seeds were collected. Seeds were immersed in fresh water for 24 hours. Then seeds were capped in tightly and shady areas. The seeds started sprouting after 48 hours, which were suitable for sowing in 72 hours.

3.3.4 Raising of seedling

A common procedure was followed raising seedlings in the seedbeds. The nursery bed was prepared through pudding with repeated ploughing followed by laddering. Then sprouted seeds were sown as uniformly as possible. Irrigation was gently provided to the bed when needed.

3.3.5 Land preparation

The experimental plot was prepared by three successive ploughing and cross ploughing. Each ploughing was followed by laddering to have a good puddle field. All kinds of weeds and residues of previous crop were removed at final ploughing. Making individual plots for transplanting and finally leveled all the plots.

3.3.6 Fertilizer Management

Cow-dung at the rate of 10 t ha^{-1} was applied at the time of first ploughing. The experimental land was fertilized with 125, 55, 80, and 60kg of Urea, TSP, MP and Gypsum per hectare respectively. The whole amount of fertilizer for per plot were calculated, measured by balance and applied separately each plot. One third urea and all other fertilizer were applied and incorporated into the soil at the time of final land preparation. The rest amount of urea was top dressed in two equal splits, one at 25 days after transplanting (DAT) and other at 45 DAT.

3.3.7 Uprooting of seedling

The seedbed was made wet by application of water both in the morning and evening on the previous day before uprooting to reduce the seedling injury. The seedlings were uprooted carefully so that the mechanical injury in the roots and seedlings was less as possible then kept in soft mud under shade.

3.3.8 Transplantation

Seedlings of 25 days old were uprooted carefully from the seedbed and transplanted in the respective plots at the rate of single seedling hill^{-1} maintaining 25cm x 15cm spacing.

3.4 Intercultural operation

3.4.1 Irrigation and Drainage

The experimental field was irrigated completely and adequate water was ensured throughout the entire crop growth period. A good drainage facility was also maintained for immediate release of excess rainwater from the field.

3.4.2 Gap filling

Gap filling was done at 7-8 days after transplanting (DAT) with same aged seedlings from the same source.

3.4.3 Weeding

First weeding was done at 25 days after seedling transplanting followed by second weeding at 20 days after first weeding.

3.4.4 Application of irrigation water

Irrigation water was added to each plot according to their demands. All the plots were kept irrigated as per requirement. Before ripening stage, the field was kept dry for all the plots. Irrigation was given at a regular interval to maintain 3-4 cm water depth up to hard dough stage of rice.

3.4.5 Plant protection measures

Plants were infested by the leaf roller insects were observed in the crop and they were successfully controlled by applying Durshban two times on 35 DAT and 50 DAT at 20ml/10L of water. Rice bug also attacked at milking stage of grain and it was controlled by the application of Cypermathrin at 8 ml/10 L water. Rice stem borer, leafhopper attacked some extent, which was successfully controlled by application of Diazinon and Ripcord @ 10 ml/ 10 liter of water. Crop was protected from birds and rats during the grain-filling period. Protection from the birds long net was spread over the whole field and for rats aluminum-phosphate tablet was used.

3.5 Procedure of sampling for growth study during the crop growth period

3.5.1 Plant height

The height of the rice plants was recorded from 30 days after transplanting (DAT) at 15 days interval up to 75 DAT and at harvesting, randomly selected five hills from each plot, beginning from the ground level up to tip of the leaf was counted as height of the plant.

3.5.2 Tillers hill^{-1}

Total tiller number was taken from 30 DAT at 15 days interval up to 75 DAT randomly selected five hills from each plot and at harvesting.

3.5.3 Leaves per hill

Total leaves number was taken from 30 DAT at 15 days interval up to 75 DAT randomly selected five hills from each plot and at harvesting.

3.5.4 Leaf area index

Leaf area index (LAI) was measured manually from 30 DAT at 15 days interval up to 75 DAT randomly selected five hills from each plot and at harvesting. The final data was calculated multiplying by a correction factor 0.75 as per Yoshida (1981).

LAI = (Total leaf area / ground area) X 100

3.5.6 Root dry matter per hill

Root dry matter per hill was recorded from 30 DAT at 15 days interval up to 75 DAT and at harvest respectively from 10 randomly collected root per hill of each plot from inner rows leaving the border row. Collected roots were oven dried at 60ºC for 48 hours then transferred into desecrator and allowed to cool down at room temperature; final weight was taken and converted into root dry matter content per hill.

3.5.7 Stem dry matter per hill

Stem dry matter per hill was measured from 30 DAT at 15 days interval up to 75 DAT and at harvest respectively. Stem was collected randomly from 10 hills of each plot from inner rows leaving the border row. Then the collected stems were oven dried at 60ºC for 48 hours and transferred into desecrator and allowed to cool down at room temperature; final weight was taken and converted into stem dry matter content per hill.

3.5.8 Total dry matter per hill

Total dry matter per hill was recorded from 30 DAT at 15 days interval up to 75 DAT and at harvest by adding stem dry matter and leaf dry matter per hill.

3.5.9 Panicle length

Panicle length was measured with meter scale from five selected plants in each hill and the average value was recorded as per plant.

3.6 Procedure of sampling physiological parameters

3.6.1 Flag leaf chlorophyll content

Flag leaves were sampled from main tillers at 3, 8, 13, 18 and 23 days after flowering (DAF) and a segment of 20 mg from middle portion of leaf was used for chlorophyll content analysis. Flag leaf chlorophyll content was measured on fresh weight basis extracting with 80% acetone and used doubled beam spectrophotometer (Witham *et al.,* 1986). Amount of chlorophyll was calculated by using the following formulae.

Chlorophyll a (mg g^{-1}) = [12.7 (OD_{663})-2.69 (OD_{645})] x$\frac{V}{1000W}$

Chlorophyll b (mg g^{-1}) = [12.9 (OD_{663})-4.68 (OD_{645})] x $\frac{V}{1000W}$

Where,

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

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

W = Fresh weight in gram of the tissues extracted.

The total chlorophyll content was estimated by sum up chlorophyll a and chlorophyll b.

3.7 Procedure of sampling yield contributing parameter

3.7.1 Harvest and processing

Maturity of crop was ascertained when 90% of the total grains became golden yellow in color. Sample plant was separately harvested and bundled properly with tagged and then brought to the threshing floor for recording yield contributing parameter. Grain yield was determined by harvesting one square meter which was prefixed at the corner of each plot. The grains were cleaned and sun dried at14% moisture content. Straw was also sun dried properly. Finally grain and straw yield per plot were recorded and converted to ton per ha.

3.7.2 Plant height

Plant height was measured from the soil level to the apex of the leaf or panicle in randomly five hills of each plot.

3.7.3 Effective tillers plant^{-1}

The total number of tillers plant^{-1} was counted from selected samples and were grouped in effective and non-effective tillers hill^{-1} during harvesting.

3.7.4 Panicle length

Panicle length was recorded from the basal nodes of the rachis to apex of each panicle from randomly selected five hills from each plot.

3.7.5 Number of total grains panicle^{-1}

The total number grains was collected randomly from selected 5 hills of a plot on the basis of not grain in the panicle and then were grouped in filled and unfilled grains panicle^{-1}.

3.7.6 Grain yield per plot

The grains were separated by threshing per hill basis and then sun dried and weighed. The dry weight of grains of central 1m^2 area and five sample hills were added to the respective unit plot yield to record the final grain yield plot^{-1} and converted it to ton per hectare.

3.7.7 Straw yield per plot

The straw were separated by threshing per hill basis and weighed. The dry weight of straw of central 1m^2 area and five sample hills were added to the respective unit plot yield to record the final straw yield plot^{-1} and converted it to ton per hectare.

3.7.8 Biological yield

Grain yield and straw yield together were regarded as biological yield of plants. The biological yield was calculated with the following formula:

Biological yield (BY) = Grain yield + straw yield

3.7.9 1000-grain weight

One thousand clean sun dried grains (at 14% moisture content) were counted from the seed stock obtained from the sample plants and weighed by using an electronic balance.

3.7.10 Harvest index

It denotes the ratio of economic yield to biological yield and was calculated following the formula of Gardner *et al*. (1985). It was calculated by using the following formula:

$$\text{Harvest index (HI)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100$$

3.8 Statistical analysis

The data obtained for different parameters were statistically analyzed following computer based software Statistix 10.0 and mean separation was done by LSD at 5% level of significance.

CHAPTER 4

RESULTS AND DISCUSSION

This chapter constructs of the presentation and discussion of the results obtained from the present study. The results have been submitted, discussed and possible interpretations were given in tabular and graphical forms. The results obtained from the experiment have been presented under different headings and subheadings as follows:

4.1 Growth parameters

4.1.1 Plant height

There was a significant variation noticed in plant height among traditional and modern aromatic rice varieties (Table 1). At 30 DAT plant height of BRRI dhan34, BRRI dhan37, Chiniatop and BRRI dhan38 was 14.19, 15, 15.20 and 15.23 respectively which was statically similar. At 45 DAT Chiniatop, BRRI dhan37 and BRRI dhan38; at 60 DAT Dulabhog, Chiniatop, Badshabhog, BRRI dhan37 and BRRI dhan38 showed the statically similar result. At 75 DAT Badshabhog and Kalizira; BRRI dhan37 and BRRI dhan39; Chiniatop and BRRI dhan34 asserted statically similar result. At 90 DAT Chinigura, Chiniatop, Begun Bichi, BRRI dhan37 and BRRI dhan38 exibited the statically similar result. At harvest plant height of BRRI dhan37 and BRRI dhan38; Chinigura, Chiniatap and Begun Bichi showed the statically similar consequence. The highest plant height was recorded in Kalizira (20.92, 40, 63.1, 99.33, 126.3 and 146 cm at 30, 45, 60, 75, 90 days after transplanting and at harvest, respectively). Lowest plant height was recorded in BRRI dhan50 (12.30, 22.5, 48, 69.1, 76.5 and 80.03cm at30, 45, 60, 75, 90 days after transplanting and at harvest, respectively). At 90 DAT and harvest Chinigura, Chiniatap and Begun Bichi gave the statistically similar result.

Table 1. Plant height of traditional and modern aromatic rice varieties at different days after transplanting

Varieties	Plant height (cm)					
	30 DAT	**45 DAT**	**60 DAT**	**75DAT**	**90DAT**	**At Harvest**
Chinigura	18.83b	34.37b	56.40b	93.87bc	108.97d	133.73d
Dulabhog	17.00c	32.07bc	54.67bc	95.40b	113.30c	137.07c
Chiniatop	15.20d	30.37cd	53.90bc	90.40de	107.97d	134.63d
Begun Bichi	17.26c	32.23bc	52.00c	89.80e	108.33d	133.60d
Badshabhog	19.13b	34.17b	54.20bc	97.85a	119.67b	142.33b
Kalizira	20.92a	40.00a	63.10a	99.33a	126.30a	146.00a
BRRI dhan34	14.19d	29.13d	52.30c	90.33de	100.40e	114.00f
BRRI dhan37	15.00d	30.77cd	54.67bc	92.30cd	108.53d	123.17e
BRRI dhan38	15.23d	31.23cd	53.47bc	92.26cd	107.33d	121.70e
BRRI dhan50	12.30e	22.50e	48.00d	69.10f	76.50f	80.03g
$LSD_{(0.05)}$	**1.32**	**2.91**	**3.55**	**2.30**	**2.13**	**2.10**
CV (%)	**4.68**	**5.35**	**3.81**	**1.47**	**1.15**	**0.97**

Values with common letter (s) within a column do not differ significantly at 5% level of probability

4.1.2 Tiller hill^{-1}

A significant variation in the total number of tillers per hill was found among the traditional and modern aromatic rice varieties at all growth stages. At harvest significantly variation vas recorded among the varieties (Table 2). The highest tiller number was found in Chinigura rice and lowest tiller number recorded in BRRI dhan50 at 30, 45 and60 DAT. At 75 DAT Dulabhog, Chiniatop, Begun Bichi, Bashabhog and Kalizira; BRRI dhan34, BRRI dhan37 and BRRI dhan38 was gave the statically similar result. At 90 DAT and at harvest highest tiller number was recorded in BRRI dhan50 (30.03 and 25.25, respectively). Reduction of higher number of tiller was recorded in traditional varieties and lower in modern rice varieties.

Table 2. Total number of tillers per hill in traditional and modern aromatic rice varieties at different days after transplanting

Varieties	No of Tiller hill^{-1}					
	30 DAT	**45 DAT**	**60 DAT**	**75DAT**	**90DAT**	**At Harvest**
Chinigura	14.27a	16.63a	27.89a	43.33a	29.67ab	19.73g
Dulabhog	6.77de	14.02d	25.56b	37.10b	28.54abcd	20.50efg
Chiniatop	6.20e	12.87e	24.67b	37.98b	29.22abc	20.04fg
Begun Bichi	10.50b	15.52bc	24.56b	38.07b	26.62e	21.29def
Badshabhog	9.50c	14.93c	23.00c	37.60b	27.26de	21.81cde
Kalizira	7.33d	13.92d	22.56c	37.53b	28.21bcde	22.56cd
BRRI dhan34	9.53c	15.53bc	20.40d	26.11d	27.78cde	24.22ab
BRRI dhan37	9.40c	15.47bc	20.40d	26.67d	28.33bcd	24.33ab
BRRI dhan38	9.30c	15.67b	21.01d	27.63d	29.00abc	23.20bc
BRRI dhan50	10.60b	15.77b	22.83c	29.36c	30.03a	25.25a
LSD$_{(0.05)}$	**0.70**	**0.61**	**1.14**	**1.72**	**1.64**	**1.44**
CV (%)	**4.39**	**2.37**	**2.85**	**2.94**	**3.36**	**3.77**

Values with common letter (s) with in a column do not differ significantly at 5% level of probability

4.1.3 Leaves hill^{-1}

A significant variation in the total number of leaves per hill was found among the traditional and modern aromatic rice varieties at all growth stages. At harvest significantly variation vas recorded among the varieties (Table 3). The highest leaves number was found in Chinigura rice and lowest leaves number recorded in BRRI dhan50 at 30, 45 and 60 DAT. At 75 DAT Dulabhog, Chiniatop, Begun Bichi, Bashabhog and Kalizira; BRRI dhan34, BRRI dhan37 and BRRI dhan38 was gave the statically similar result. At 90 DAT and at harvest highest leaves number was recorded in BRRI dhan50 (76.87 and 58.08, respectively). Reduction of higher number of leaves was recorded in traditional varieties and lower in modern rice varieties.

Table 3. Total number of leaves per hill in traditional and modern aromatic rice varieties at different days after transplanting

Varieties	No of Leaves hill^{-1}					
	30 DAT	**45 DAT**	**60 DAT**	**75DAT**	**90DAT**	**At Harvest**
Chinigura	31.39a	43.25a	72.51a	121.33a	75.95ab	45.39g
Dulabhog	14.89de	36.44d	66.44b	103.88b	73.06abcd	47.14efg
Chiniatop	13.64e	33.45e	64.13b	106.35b	74.80abc	46.09fg
Begun Bichi	23.10b	40.34bc	63.84b	106.59b	68.14e	48.97def
Badshabhog	20.90c	38.83c	59.80c	105.28b	69.78de	50.15cde
Kalizira	16.13d	36.18d	58.64c	105.09b	72.21bcde	51.90cd
BRRI dhan34	20.97c	40.39bc	53.05d	73.11d	71.11cde	55.71ab
BRRI dhan37	20.68c	40.21bc	53.05d	74.67d	72.53bcd	55.97ab
BRRI dhan38	20.46c	40.73b	54.63d	77.38d	74.24abc	53.36bc
BRRI dhan50	23.32b	40.99b	59.35c	82.21c	76.87a	58.08a
LSD$_{(0.05)}$	**1.55**	**1.59**	**2.96**	**4.82**	**4.19**	**3.32**
CV (%)	**4.39**	**2.37**	**2.85**	**2.94**	**3.36**	**3.77**

Values with common letter (s) with in a column do not differ significantly at 5% level of probability

4.1.4 Leaf area index (LAI)

Leaf area index may be defined as the ratio of leaf area to the ground area occupied by the crop. There is significant difference of leaf area index (LAI) among the studied rice varieties from vegetative (45 DAT) to reproductive (90 DAT) stages (Table 4). At 45 DAT highest LAI (2.13) was found in BRRI dhan50. Highest LAI was recorded in BRRI dhan34 and BRRI dhan50 (2.67, 4.08, 5.63 at 60, 75 and 90 DAT, respectively). Lowest LAI was found in Begun Bichi (1.01, 1.26, 1.89, 2.67 at 45, 60, 75 and 90 DAT, respectively) and also Chinigura, Chiniatap and Kalazira gave the statically similar result. According to Ready *et al*. (1995), the high yielding varieties possessed higher LAI which led to the higher biomass production and yield. The result indicated that modern varieties showed the higher LAI than traditional varieties.

Table 4. Leaf area index of traditional and modern aromatic rice varieties at different days after transplanting

Varieties	**Leaf area index**			
	45 DAT	**60 DAT**	**75DAT**	**90DAT**
Chinigura	1.01f	1.33e	2.02e	2.79f
Dulabhog	1.25e	1.73d	2.60d	3.64e
Chiniatop	1.04f	1.30e	1.96ef	2.75f
Begun Bichi	1.01f	1.26e	1.89f	2.67g
Badshabhog	1.41d	1.76d	2.65d	3.72d
Kalizira	1.05f	1.31e	1.98e	2.77f
BRRI dhan34	2.07ab	2.67a	4.08a	5.63a
BRRI dhan37	2.00b	2.50b	3.77b	5.26b
BRRI dhan38	1.85c	2.31c	3.49c	4.85c
BRRI dhan50	2.13a	2.67a	4.08a	5.61a
$LSD_{(0.05)}$	**0.09**	**0.14**	**0.08**	**0.05**
CV (%)	**3.59**	**4.40**	**1.71**	**0.80**

Values with common letter (s) with in a column do not differ significantly at 5% level of probability

4.2 Physiological parameters

4.2.1 Flag leaf chlorophyll content

Significant variation between modern and traditional variety was recorded (Table 5).BRRI dhan50 contained the higher amount of chlorophyll (2.77, 3.04, 2.71, 2.49 and 1.96 mg g^{-1}fresh weight at 3, 8, 13, 18 and 23 DAF, respectively). Lowest flag leaf chlorophyll was recorded in Dulabhog (2.01, 2.21, 1.97, 1.88 and 1.41 mg g^{-1} fresh weight at 3, 8, 13, 18 and 23 DAF, respectively).Second highest chlorophyll was observed in BRRI dhan37. At 13, 18 and 23 DAF BRRI dhan34 and BRRI dhan37 showed the statically similar result.

Table 5. Flag leaf chlorophyll content in traditional and modern aromatic rice varieties at different days after flowering

Varieties	Flag leaf chlorophyll content (mg g^{-1} fresh weight)				
	3DAF	8DAF	13DAF	18DAF	23DAF
Chinigura	2.08g	2.29g	2.04f	1.88f	1.47f
Dulabhog	2.01h	2.21h	1.97g	1.81g	1.41g
Chiniatop	2.10g	2.30g	2.05f	1.89f	1.47f
Begun Bichi	2.17f	2.38f	2.14e	1.97e	1.54e
Badshabhog	2.55d	2.81d	2.50c	2.30c	1.79c
Kalizira	2.33e	2.57e	2.28d	2.10d	1.64d
BRRI dhan34	2.64c	2.89c	2.57b	2.36b	1.84b
BRRI dhan37	2.70b	2.97b	2.61b	2.40b	1.87b
BRRI dhan38	2.57d	2.82d	2.51c	2.30c	1.80c
BRRI dhan50	2.77a	3.04a	2.71a	2.49a	1.96a
$LSD_{(0.05)}$	**0.06**	**0.05**	**0.05**	**0.04**	**0.03**
CV (%)	**1.43**	**1.22**	**1.20**	**1.10**	**1.15**

Values with common letter (s) with in a column do not differ significantly at 5% level of probability

4. 3 Yield contributing characters

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

A significant variation in the total number of tillers hill^{-1} was found among the traditional and modern aromatic rice varieties at all growth stages (Table 6). Maximum number of effective tiller was gave BRRI dhan50 (23.53) and BRRI dhan37 gave the statically similar result. Second highest effective tiller was found in BRRI dhan34 and BRRI dhan38. Lowest effective tiller was recorded in Badshabhog (13.03). The highest no of non-effective tiller was found in Badshabhog, second highest was found in Begun Bichi and Kalizira. Lowest non-effective tiller was BRRI dhan50; BRRI dhan37 and BRRI dhan38 gave the statically similar result. Hoque (2004) observed that with the decrease of tiller per hill also decreases.

Table 6. Total number of effective and non- effective tiller hill^{-1} (no.) in traditional and modern aromatic rice varieties

Varieties	No of Effective tiller hill^{-1}	No of Non- effective tiller hill^{-1}
Chinigura	16.20cd	3.53c
Dulabhog	17.17c	3.33cd
Chiniatop	16.60cd	3.44cd
Begun Bichi	14.20e	7.09b
Badshabhog	13.03f	8.77a
Kalizira	15.63d	6.93b
BRRI dhan34	21.20b	3.02d
BRRI dhan37	22.90a	1.43e
BRRI dhan38	21.53b	1.63e
BRRI dhan50	23.53a	1.718e
LSD$_{(0.05)}$	**1.05**	**0.45**
CV (%)	**3.37**	**6.41**

Values with common letter (s) with in a column do not differ significantly at 5% level of probability

4.3.2 Panicle length

Length of panicle was varied among the different varieties of rice. A significant variation of panicle length was found among the traditional and modern aromatic rice varieties (Figure 1). BRRI dhan50 gave the highest panicle length (25 cm). Lowest panicle length was recorded in Kalizira, Chiniatop and Begun Bichi (15 cm). Panicle length is related to the higher yield in rice (Salam *et al*., 1990).

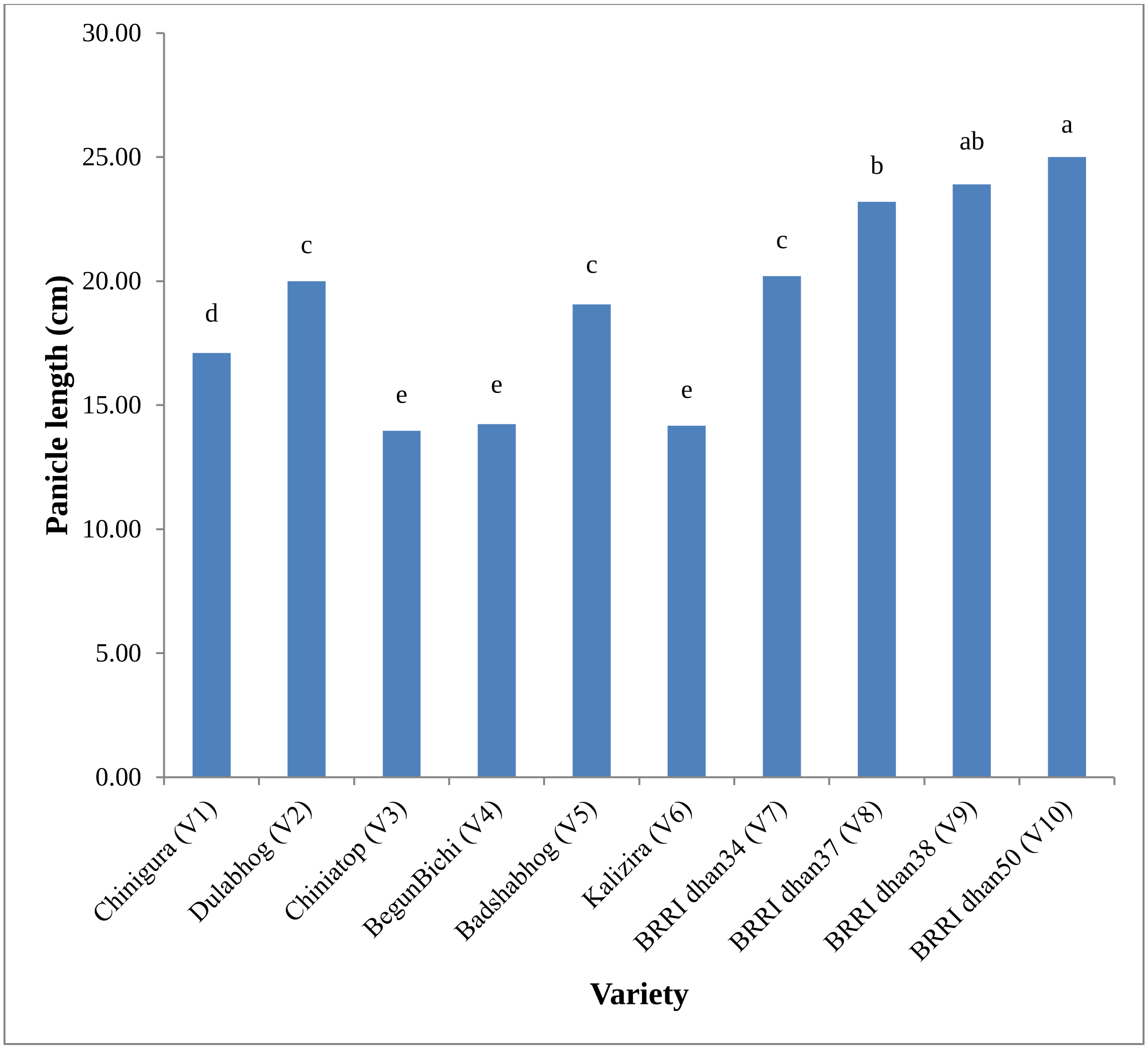

Figure 1. Panicle length of traditional and modern aromatic rice varieties in *Aman* season

4.3.3 Number of filled and unfilled grain panicle^{-1}

Filled and unfilled grain panicle^{-1} had shown a significant variation among the 10 aromatic rice varieties (Figure 2). The highest number of filled grain was recorded in BRRI dhan50 (105) and also the lowest unfilled grain was found (6.1). BRRI dhan34, BRRI dhan37 and BRRI dhan38 gave the statically similar result. Lowest no. of filled grain was occupied in Begun Bichi (54) and it produced the highest amount of unfilled grain. This result was supported by Dutta *et al*. (2016) who stated that yield was affected by the filled grain panicle^{-1} in aromatic rice varieties.

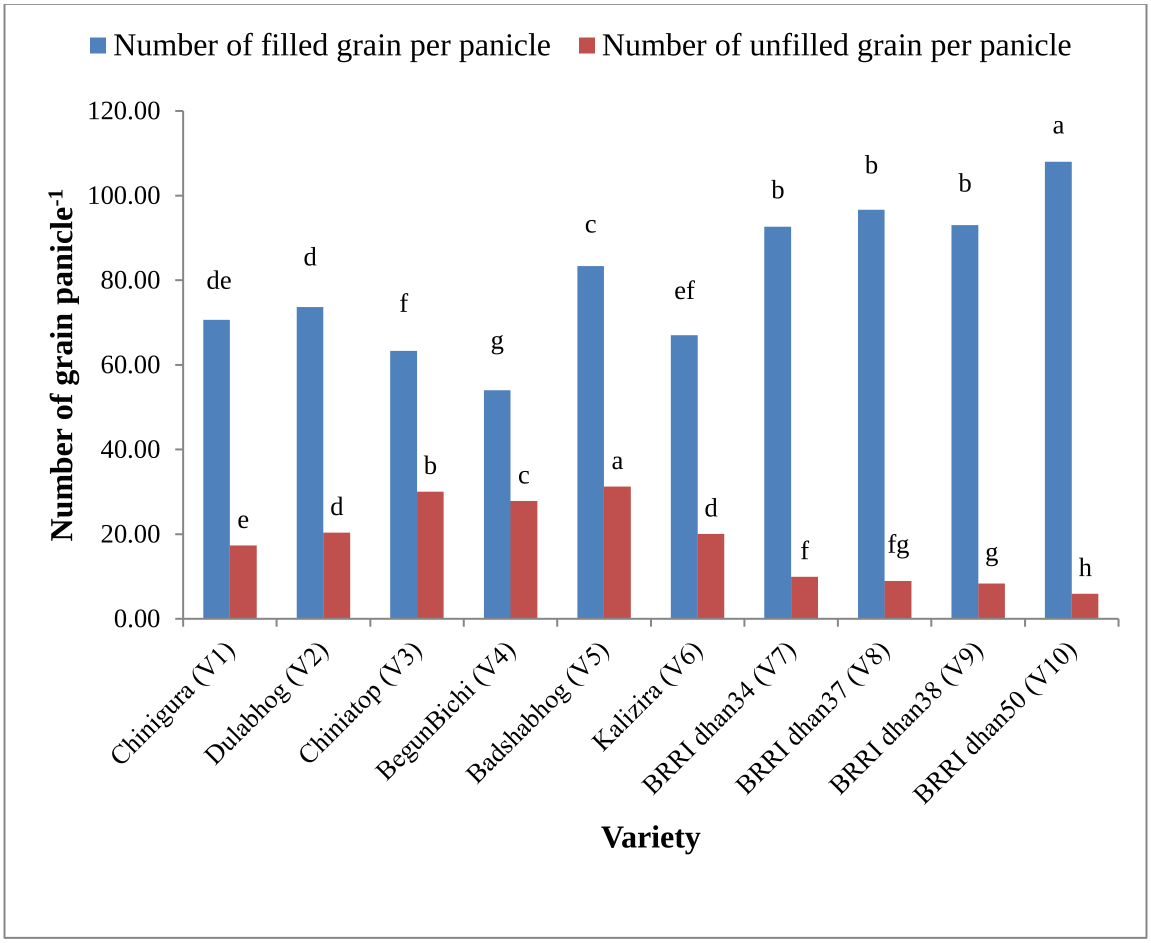

Figure 2. Number of grain panicle^{-1} of traditional and modern aromatic rice varieties in *Aman* season

4.3.4 1000-grain weight

There was a significant difference in 1000 grain weight among the traditional and modern aromatic rice varieties (Figure 3). Fujia *et al*. (1984) showed that length and thickness of rice grains were positively correlated with 1000-grain weight.

BRRI dhan50 gave the maximum weight of 1000 grain (23.57g). Dulabhog gave the lowest weight of 1000 grain (13.83g). All traditional varieties except Badshabhog gave the statically similar result. 1000 grain weight of Badshabhog was recorded 19.60g. Significant variation also was recorded among the modern varieties.

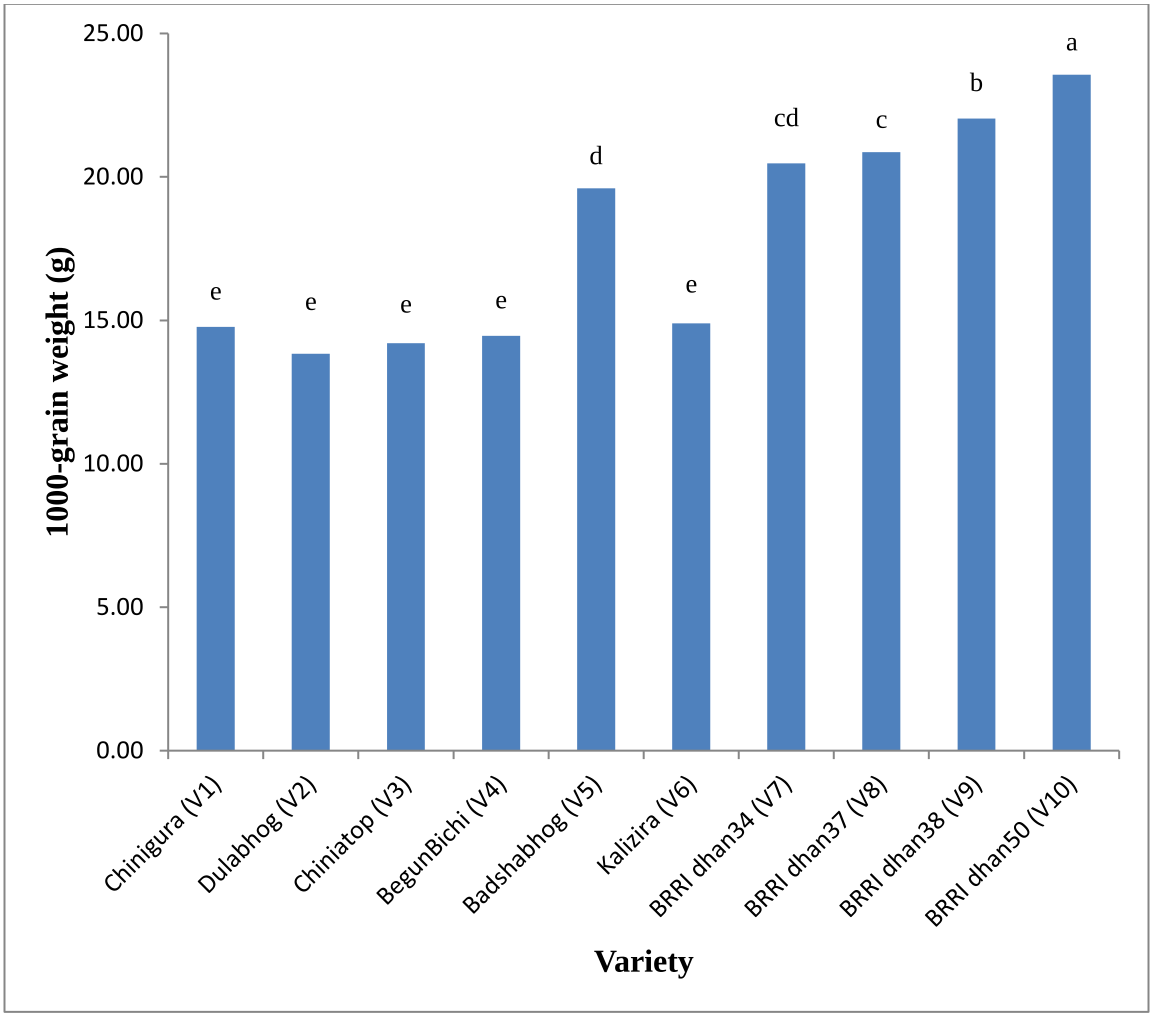

Figure 3. 1000-grain weight of traditional and modern aromatic rice varieties in *Aman* season

4.3.5 Grain yield

There had been found a significant difference among the varieties in respect of grain yield ha^{-1} (Figure 4). The highest grain yield was occupied in BRRI dhan50 (5.9t ha^{-1}). BRRI dhan34 and BRRI dhan37 gave the statically similar result (3.62t ha^{-1}). Begun Bichi gave the lowest grain yield (1.11tha^{-1}) among the traditional varieties. Among the traditional varieties Badshabhog gave the highest yield (2.13t ha^{-1}). This result indicated that the modern varieties had remarkable superiority to growth, yield attributes and grain yield over traditional rice varieties.

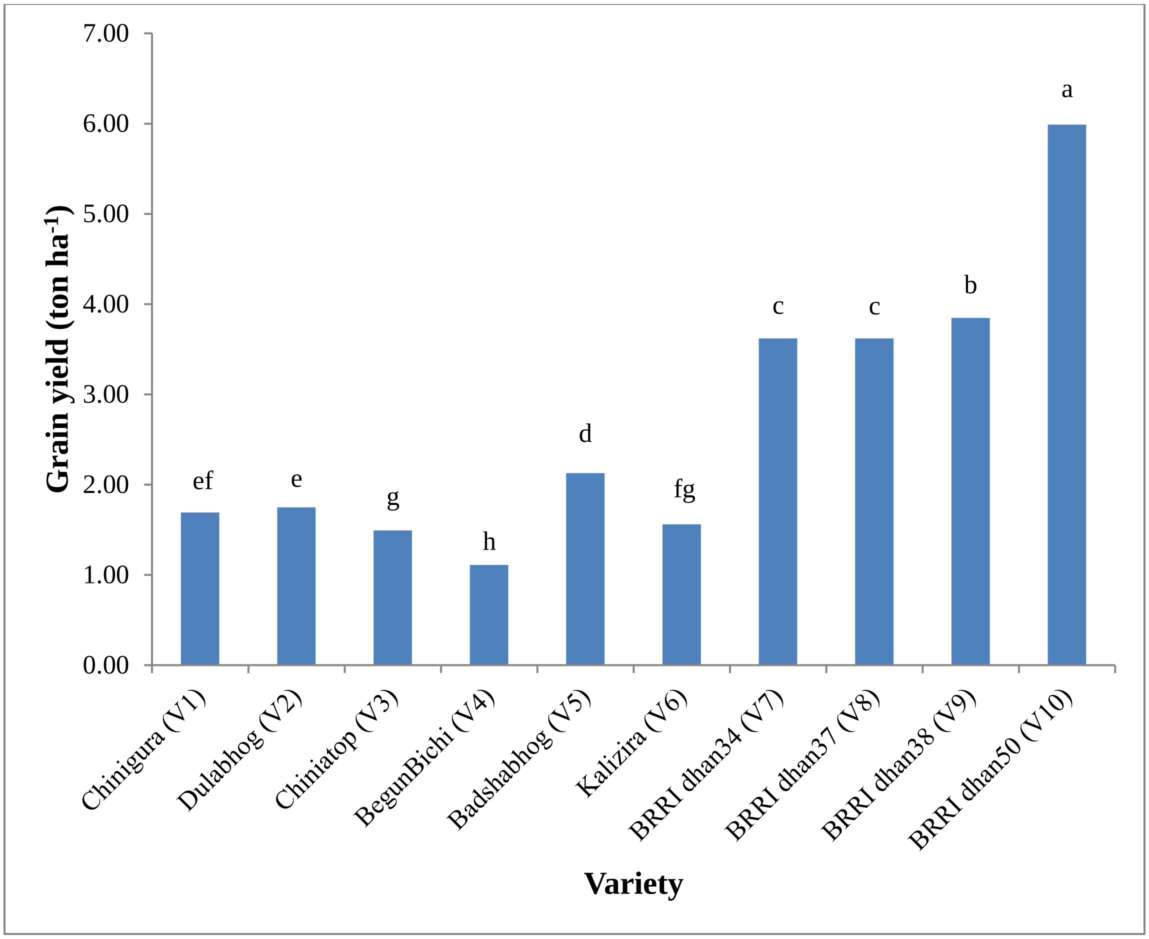

Figure 4. Grain yield of traditional and modern aromatic rice varieties in *Aman* season

4.3.6 Straw yield

The straw yield of different variety was observed differed significantly one variety to another (Figure 5). Modern varieties gave the statically similar result for straw production. Also lower straw was recorded in all modern varieties. Higher straw yield was recorded in Bdashabhog (6.74 t ha^{-1}) and Dulabhog (6.67t ha^{-1}). Kalizira gave 5.53ton straw per hectare.

4.3.7 Harvest index (%)

There was significant variation in harvest index among modern and traditional aromatic rice varieties (Figure 6). The highest harvest index was recorded in BRRI dhan50 (58.40%). Second highest harvest index was recorded in BRRI dhan38

(46.82%) followed by BRRI dhan34 (45.86%) and BRRI dhan37 (45.70%). The lowest harvest index was found in Begun Bichi (19.22%) followed by Dulabhog (20.78%). Among the traditional variety highest harvest index was occupied in Chinigura (26.28%) followed by Kalizira (25.64%) and Chiniatop (25.08%).

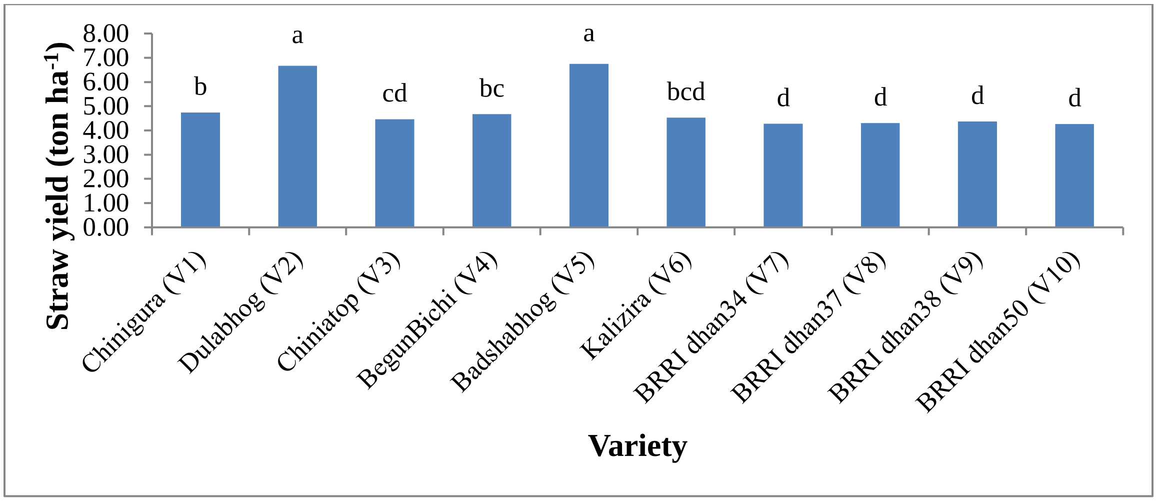

Figure 5. Straw yield of traditional and modern aromatic rice varieties in *Aman* season

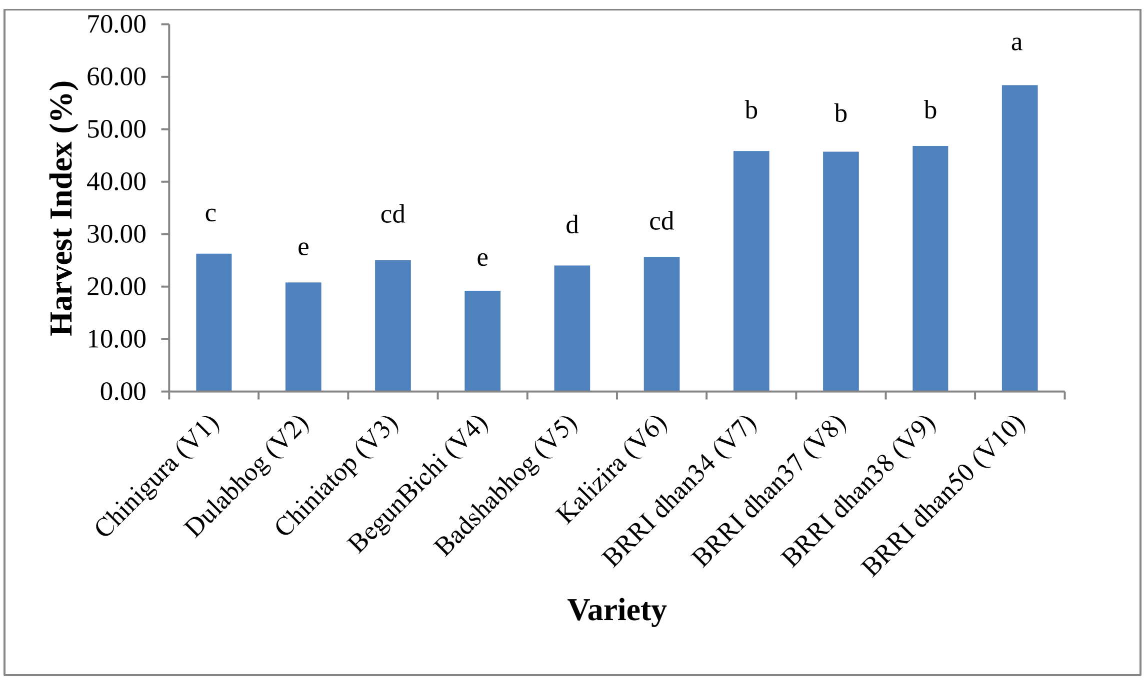

Figure 6. Harvest Index of traditional and modern aromatic rice varieties. in *Aman* season

CHAPTER 5

SUMMARY AND CONCLUSION

The experiment was conducted for studying the comparative feature of six traditional and four modern aromatic rice varieties in *Aman* season at the Experimental Farm of Sher-e-Bangla Agricultural University, Dhaka during the period from July to December. There were ten treatments which comprised six traditional and four modern aromatic rice varieties *viz*. Chinigura, Dulabhog, Chiniatop, Begun Bichi, Badshabhogan, Kalizira; BRRI dhan34, BRRI dhan37, BRRI dhan38 and BRRI dhan50. The experiment layout was Randomized Completely Block Design (RCBD) with three replications. Seedling of 25 days old was transplanted to the main field maintaining space with 25cm X 15cm. The plot size was 3.6m X 1.3 m. Seeds of all varieties were collected from Bangladesh Rice Research Institute (BRRI), Gazipur. Intercultural operations including rouging, weeding, top dressing, irrigation, pesticide application etc were done according to necessary. Collected data were analyzed with Statistix 10 software following the standard procedure and method.

There have been observed a significant variation among the selected traditional and modern aromatic rice varieties such as plant height, tillers hill^{-1}, leaves hill^{-1}, LAI and yield contributing attributes like panicle hill^{-1}, panicle length, filled and unfilled grains panicle^{-1}, 1000- grain weight, grain yield and harvest index (HI). Highest plant height was found in traditional rice Kalizira showing superiority over the rest varieties in respect (20.92cm, 40cm and 63.10cm, 99.33cm, 126.30cm and 146cm at 30, 45, 60, 75, 90 DAT and harvest respectively). Highest tillers hill^{-1}was recorded in Chinigura upto75 DAT (14.27, 16.63, 27.89 and 43.33 at different 30, 45, 60 and 75 DAT, respectively) but at 90DAT and BRRI dhan50 showed the highest tiller number (30.3 and 25.25, respectively). In case of leaves hill^{-1} Chinigura gave the higher result upto75 DAT (31.39, 43.25, 72.51and 121.33

at different 30, 45, 60 and 75 DAT, respectively) but at 90 DAT and BRRI dhan50 showed the highest leaves number (76.87 and 58.08, respectively). Higher LAI was recorded in BRRI dhan34 and BRRI dhan50 (2.67, 4.08 and 5.63 at 60, 75 and 90 DAT). BRRI dhan50 was contained maximum chlorophyll in flag leaf (2.77, 3.04, 2.71, 2.49 and 1.96 mg g^{-1} fresh weight at 3, 8, 13, 18 and 23 DAF, respectively). From the study it has been seen that number of total tillers $hill^{-1}$ gradually increase with the progress of growth and leaf number and LAI also increased up to a certain period of the vegetative phase and thereafter started to decline.

BRRI dhan50 was also found to show superiority in case of yield parameters like effective tillers $hill^{-1}$ (23.53), panicle length (25cm), filled grains $panicle^{-1}$ (108), 1000- grain weight (23.57g), grain yield (5.99t ha^{-1}) and harvest index (58.40 %). On the other hand among ten aromatic rice varieties various yield contributing character was found which reduced total grain yield of some varieties in respect of various yield parameters such as Dulabhog in lower effective tillers per hill (17.17), Bdashabhog in higher non-effective tillers $hill^{-1}$ (8.77), Chiniatap in lowest panicle length (13.97cm), Begun Bichi in lowest filled grains $panicle^{-1}$ (54), Bdashbhog in higher unfilled grain $panicle^{-1}$(31.23), Dulabhog and Chiniatop in lower 1000- grain weight (13.9 g), Begun Bichi in grain yield (1.11t ha^{-1}) and harvest index (19.22 %). Among six traditional aromatic varieties Badshabhog was found higher grain yield (2.13tha^{-1}) and Kalizira higher harvest index (25.64%).

However, modern aromatic varieties produced higher grain yield compared to the traditional. Yield components such as effective tillers $hill^{-1}$, panicle length, filled grain $panicle^{-1}$ and 1000- grain weight mainly contributed to the higher grain yield of the modern varieties over the traditional. Also higher mortality rate of tiller in traditional varieties at reproductive stages was responsible for lower yield.

In respect of biological yield, modern rice varieties such as BRRI dhan50 (10.26 t ha^{-1}), BRRI dhan38 (8.21t ha^{-1}), BRRI dhan37 (7.92 t ha^{-1}), BRRI dhan34 (7.89 t ha^{-1}) and due to higher straw yield Badshbhog showed 8.87tha^{-1} biological yield those performed better than other varieties. In case of grain yield BRRI dhan50 showed the superiority among all nine varieties (5.99 t ha^{-1}).

All studied modern rice varieties contained higher amount of chlorophyll in their flag leaf and accumulated more dry matter than the traditional varieties. Among the ten varieties the modern aromatic varieties converted more dry matter into grain compared to traditional varieties. The main determinants for the higher grain yield of the modern varieties over the traditional are effective tiller $hill^{-1}$ and 1000-grain weight.

From the above summary of the study, it can be concluded that **-**

1. BRRI dhan50 provided the highest grain yield (5.99 t ha^{-1}) contributed by effective tillers $hill^{-1}$ (23.53), filled grains $panicle^{-1}$ (108), 1000-grain weight (23.57g)
2. All the test traditional aromatic rice cultivars were found inferior to the modern one in respect of grain yield. Among the six traditional aromatic cultivars, Badshabhog gave the highest yield (2.13 t ha^{-1}**).**
3. Death rate of tillers (38% traditional and 17% modern) and leaves (55% traditional and 27% modern) were higher in traditional aromatic cultivars compared to modern one both in vegetative and reproductive stages.

Recommendation

- ❖ BRRI dhan50 may be chosen for cultivation in *Aman* season for obtaining maximum grain yield.
- ❖ For wider acceptability, the same experiment should be repeated at different Agro-ecological zones of the Bangladesh.

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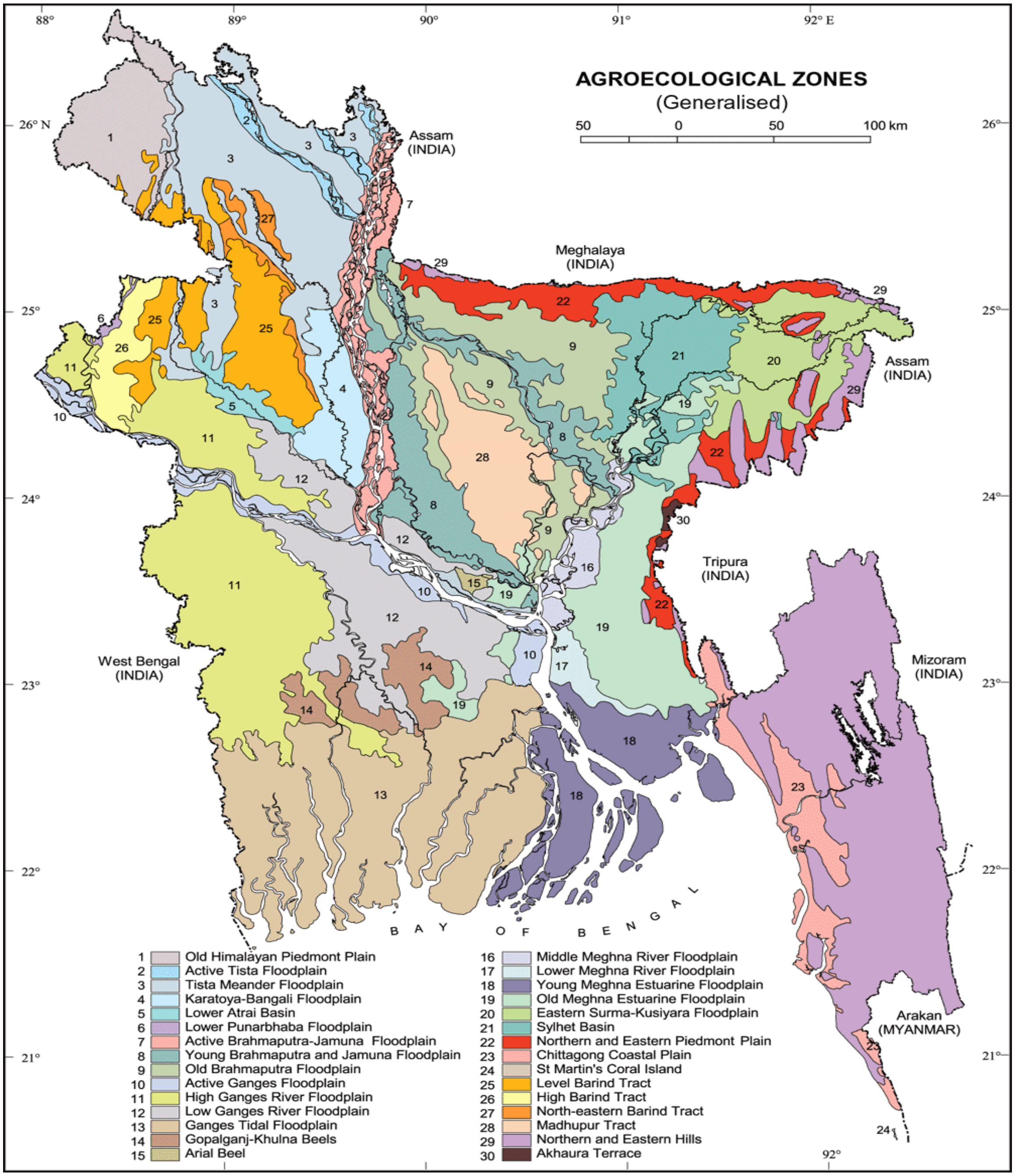
APPENDICES

Appendix I. Experiment was conducted in Sher-e-Bangla Agricultural University, Dhaka (AEZ-28) on the map of Agro-ecological Zones of Bangladesh



Appendix II. Physical and chemical properties of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka

Characteristics	Value
Particle size analysis	
% Sand	26
% Silt	41
% Clay	33
Textural class	Silty-clay
pH	5.7
Organic carbon (%)	0.45
Organic matter (%)	0.72
Total N (%)	0.04
Available P (ppm)	18.00
Exchangeable K (me/100 g soil)	0.12
Available S (ppm)	42

Appendix III. Monthly average air temperature, rainfall and relative humidity of the experimental site during the period from July to November 2017

Months	Air temperature (°C)		Relative humidity (%)	Total rainfall (mm)
	Maximum	Minimum		
July, 2017	31.6	25.9	81.5	674.86
August, 2017	32.6	26.9	79.1	352.02
September, 2017	32.6	23.1	67.5	181.06
October, 2017	34.3	24.1	61.3	67.06
November, 2017	32.3	23.1	57.3	56.06

Source: SAU Meteorological Yard , Sher-e-Bangla Nagar, Dhaka-1207.

Appendix IV. Mean square values for plant height of traditional and modern rice

Source of variation	Degrees of freedom	Mean square values for plant height at					
		30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	At harvest
Replication	2	4.04	5.24	13.48	2.075	2.299	0.96
Variety	9	20.41 *	58.86 *	43.98 **	209.70 **	516.72 **	1086.96 **
Error	18	0.60	2.87	4.28	1.79	1.55	1.50
CV (%)		4.63	5.35	3.81	1.47	1.15	0.97

*indicates significant at 5% level of probability
** indicates significant at 1% level of probability

Appendix V. Mean square values for tillers hill^{-1} of traditional and modern rice

Source of variation	Degrees of freedom	Mean square values for tillers hill^{-1}at					
		30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	At harvest
Replication	2	0.34	0.05	0.31	0.21	0.26	0.57
Treatment	9	15.93*	3.72*	17.49**	110.83**	3.39**	11.21**
Error	18	0.1678	0.12703	0.4412	1.007	0.91286	0.7064
CV (%)		4.39	2.37	2.85	2.94	3.36	3.77

*indicates significant at 5% level of probability
** indicates significant at 1% level of probability

Appendix VI. Mean square values for leaves hill^{-1} of traditional and modern rice

Source of variation	Degrees of freedom	Mean square values for leaves hill^{-1}at					
		30 DAT	45 DAT	60 DAT	75 DAT	90 DAT	At harvest
Replication	2	1.6601	0.3724	2.062	1.650	1.7196	3.0161
Treatment	9	77.09*	25.14*	118.24*	868.89*	22.24**	59.27**
Error	18	0.8122	0.8587	2.983	7.896	5.9826	3.7367
CV (%)		4.39	2.37	2.85	2.94	3.36	3.77

*indicates significant at 5% level of probability
** indicates significant at 1% level of probability

Appendix VII. Mean square values for Leaf Area Index of traditional and modern rice

Source of variation	Degrees of freedom	Mean square values			
		Leaf Area Index			
		45DAT	60DAT	75DAT	90DAT
Replication	2	0.00002	0.00197	0.00526	0.00210
Treatment	9	0.68796*	1.06325**	2.50530**	4.69241**
Error	18	0.00284	0.00688	0.00234	0.00101
CV (%)		3.59	4.40	1.70	0.80

*indicates significant at 5% level of probability
** indicates significant at 1% level of probability

Appendix VIII. Mean square values for flag leaf chlorophyll content of traditional and modern rice

Source of variation	Degrees of freedom	Mean square values				
		Flag leaf chlorophyll content				
		3DAF	8DAF	13DAF	18DAF	23DAF
Replication	2	0.00074	0.00120	0.00063	0.00071	0.00023
Treatment	9	0.24293*	0.29424**	0.22211**	0.18696**	0.11741**
Error	18	0.00116	0.00103	0.00079	0.00056	0.00037
CV (%)		1.43	1.22	1.20	1.10	1.15

*indicates significant at 5% level of probability
** indicates significant at 1% level of probability

Appendix IX. Mean square values for effective tillers and non-effective tillers hill^{-1} of traditional and modern rice

Source of variation	Degrees of freedom	Mean square values	
		Effective tillers	Non-effective tillers hill^{-1}
Replication	2	0.7410	0.0597
Treatment	9	42.5185*	20.0563*
Error	18	0.3751	0.0687
CV (%)		3.37	6.41

*indicates significant at 5% level of probability
** indicates significant at 1% level of probability

Appendix X. Mean square values for panicle length, no. of filled grains and no. of unfilled grains panicle^{-1} of traditional and modern rice

Source of variation	Degrees of freedom	Mean square values		
		Panicle length	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}
Replication	2	3.1573	3.733	1.759
Treatment	9	51.6839**	883.930*	271.109**
Error	18	0.5673	6.252	0.390
CV (%)		3.95	3.12	3.47

*indicates significant at 5% level of probability
** indicates significant at 1% level of probability

Appendix XI. Mean square values for 1000-grain weight, grain yield, straw yield and harvest index of traditional and modern rice

Source of variation	Degrees of freedom	Mean square values			
		1000-grain weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index
Replication	2	0.3036	0.02000	0.04032	0.00196
Treatment	9	42.7814**	7.11999**	2.78779*	5.79796*
Error	18	0.4304	0.00826	0.02365	0.01162
CV (%)		3.67	3.39	3.14	0.196

*indicates significant at 5% level of probability
** indicates significant at 1% level of probability