GROWTH, YIELD AND QUALITY PERFORMANCE OF TRASPLANTED AROMATIC AMAN RICE GENOTYPES

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TO

MY PARENTS &

GRANDMOTHER

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CERTIFICATE

This is to certify that the thesis entitled " ***GROWTH, YIELD AND QUALITY PERFORMANCE OF TRANSPLANTED AROMATIC AMAN 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 (MS)*** *in* ***AGRONOMY,*** *embodies the results of a piece of bona fide research work carried out by* ***SUCHANA PAUL*** *Registration. No.* ***11-04327*** *under my supervision and guidance. No part of this 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.

Dated:

Dhaka, Bangladesh

(Prof. Dr. Parimal Kanti Biswas)
Supervisor

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ABSTRACT

A field experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka during the period from July 2016 to December 2016 to study the growth, yield and quality of different Aman rice genotypes comparing with Kataribhog and BRRI dhan66 as check varieties in Aman season. The experiment comprised of 14 rice genotypes *viz.,* (i) SAU ADL1, (ii) SAU ADL2, (iii) SAU ADL3, (iv) SAU ADL4, (v) SAU ADL5, (vi) SAU ADL6, (vii) SAU ADL7, (viii) SAU ADL8, (ix) SAU ADL9, (x) SAU ADL10, (xi) SAU ADL11, (xii) SAU ADL12, (xiii) Kataribhog, (xiv) BRRI dhan66. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications of each treatment. All the genotypes varied significantly for all parameters. At harvest, the highest plant height (219.08 cm), tillers hill^{-1} (18.73), LAI (2.45) were recorded in SAU ADL10. The lowest plant height (101.00 cm) was in modern variety BRRI dhan66. The lowest number of tillers hill^{-1} (6.53) was from SAU ADL12 and the lowest LAI (1.34) was found in SAU ADL7. Maximum SPAD value (47.29) was recorded from SAU ADL8 and minimum value (38.49) was in SAU ADL10. The highest effective tillers m^{-2} (446.72) was in SAU ADL10 and the lowest (142.24) in SAU ADL12. The highest panicle length (32.63 cm) was recorded in SAU ADL10 and the lowest (24.74) in BRRI dhan66. Again, SAU ADL12 needed the longest time for flowering (104.33 days) and maturity (139.67 days). On the other hand, BRRI dhan66 needed the shortest time (71.33 days) for flowering and maturity (106.67 days). Maximum filled grain (198.33 no.) was counted in SAU ADL2 and minimum (50.33 no.) was in SAU ADL7. SAU ADL7 showed the highest sterility percentage (72.56%) and the lowest grain yield (2.28 t ha^{-1}) with the lowest harvest index (HI) (17.31%) where SAU ADL2 showed the highest Harvest Index (HI) (47.63%). Sterility percentage was the lowest (7.03%) in BRRI dhan66 with the highest grain yield (5.24 t ha^{-1}). SAU ADL5, SAU ADL2, SAU ADL9, SAU ADL3 provided maximum grain yield which was statistically similar to modern variety BRRI dhan66 and almost 69% higher than Kataribhog. SAU ADL10 and SAU ADL11 also gave almost 19 to 28% higher yield than Kataribhog. The highest hulling percentage and milling percentage was in Kataribhog. The highest Head Rice Recovery (HRR) was recorded from BRRI dhan66. Presence of aroma was recorded in SAU ADL3, SAU ADL5, SAU ADL7, SAU ADL9, SAU ADL10, SAU ADL11 and SAU ADL12 with grain length>6.50 mm, L/B ratio >2.7, higher protein% (8.4%-10.6%), higher Kernel Length After Cooking (KLAC) (8-9.98 mm), elongation ratio (1.29-1.47) over Kataribhog. Kataribhog needed the lowest time for cooking (14.75 min) over local aromatic genotypes. As such, short stature aromatic genotype SAU ADL11, high yielding aromatic genotype SAU ADL5, SAU ADL9, SAU ADL3, SAU ADL10, highest protein containing SAU ADL7 were found promising.

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LIST OF ACRONYMS

AEZ	=	Agro-Ecological Zone
As	=	Arsenic
et al.	=	And others
@	=	At the rate of
BRRI	=	Bangladesh Rice Research Institute
BBS	=	Bangladesh Bureau of Statistics
cm	=	Centimeter
Cd	=	Cadmium
cv.	=	Cultivar
CV%	=	Percentage of coefficient of variance
^{0}C	=	Degree Celsius
DAT	=	Days After Transplanting
ER	=	Elongation Ratio
g	=	Gram (g)
HI	=	Harvest Index
HRR	=	Head Rice Recovery
IRRI	=	International Rice Research Institute
kg	=	Kilogram
KLAC	=	Kernel Length After Cooking
LSD	=	Least Significant Difference
mm	=	Millimeter
MP	=	Muriate of Potash
N	=	Nitrogen
NPK	=	Nitrogen, Phosphorus and Potassium
NS	=	Non-significant
No.	=	Number
Pb	=	Lead
ppb	=	Parts per billion
ha^{-1}	=	Per hectare
%	=	Percent
q	=	Quintal
SAU	=	Sher-e-Bangla Agricultural University
SCMR	=	SPAD chlorophyll meter reading
Se	=	Selenium
SRDI	=	Soil Resources Development Institute

SPAD	=	Soil Plant Analytical Development
i.e.	=	That is
t ha^{-1}	=	Ton per hectare
TSP	=	Triple Super Phosphate
Zn	=	Zinc
viz.	=	Videlicet (namely)
Wt.	=	Weight

CHAPTER 1

INTRODUCTION

Bangladesh has an agrarian economy in which rice (*Oryza sativa* L.) is the dominant crop. Rice is the staple food of more than half of the world's population. Most of the world's rice is produced and consumed in Asia which constitutes more than half of the global population (Chakravarthi and Naravaneni, 2006). Rice crop is interwoven in the cultural, social and economic lives of millions of Bangladeshis and it holds the key for food and nutritional security of the country. It is consumed as the staple food and has been given the highest priority in meeting the demands of its ever-increasing population in Bangladesh. Being the 4th largest rice producer of the world, Bangladesh comprises an area of about 11.45 million hectares for rice production and produces 34.5 m. MT rice of which Aman rice was 13.19 m. MT (Baral, 2016). Local variety including aromatic rice genotypes occupied about 12.16% of the rice growing areas in Bangladesh (BBS, 2011).

Aromatic rice is that rice which has nut-like aroma and taste. Aromatic rice constitutes a special group of rice genotypes well known in many countries across the world for their aroma and/or super fine grain quality (Sing *et al.*, 2000a). Aromatic rice generally contains lower concentrations of toxic elements (As, Cd, Pb) and higher concentrations of essential elements (Se, Zn) compared to non-aromatic rice. This type of rice could also be used in infant foods instead of non-aromatic rice with higher As (Arsenic) concentration. This is very good news for millions of Bangladeshis who are exposed to high concentration of arsenic through drinking water and rice and are also deficient in zinc and selenium (Al-Rmalli *et al.*, 2012).

Aromatic rice varieties are popular throughout Asia, and have also gained wider acceptance in Europe, Middle East, Australia and the United States of America (Sakthivel *et al.*, 2009). The consumers demand has increased markedly to pay a premium price for fragrant rice (Louis *et al.*, 2005) because it is used for special purposes like feasts and religious occasions, like Eid, Puja, wedding ceremony, and so on. With proper promotion and marketing support, Bangladeshi fine quality and aromatic rice could find significant markets both at home and abroad. Bangladesh has a bright prospect for export of fine rice thereby earning foreign exchange. Islam *et al.* (1996) observed that the yield of aromatic rice was lower (1.5-2.0 t ha^{-1}) but its higher price and low cost of cultivation generated higher profit margins compared to other varieties grown in the area.

It is estimated that about 1,20,000 distinct rice varieties exist in the world (Khush, 1997). Bangladesh has a stock of above 8,000 rice germplasms of which nearly 100 are aromatic (Hamid *et al.*, 1982 and Khalequzzaman *et al.*, 2012). This time, farmers have cultivated Badshabhog, Nonia, Zirakatari, Basmati, Radhunipagol, Uknimadhu, Zirashail, Begunbichi, Tilkapur, Bhogzira, Dulabhog, Khirshabhog, Bawaibhog, BRRI dhan34 and some other varieties aromatic rice. Like other parts of the world, Bangladesh has already lost a large number of aromatic rice genotypes and many at the verge of extinction (Singh *et al.*, 2000b). Rapid adoption of modern varieties is a serious threat for the existence of fine quality aromatic rice genotypes for their low yield.

The Himalayan foothill including parts of Bangladesh is considered to be the secondary center of diversity of the genus *Oryza* (Morishima, 1984) but information about the characterization or genetic diversity of aromatic rice is very limited. The improvement of aromatic rice genotypes requires its collection and evaluation of existing cultivars of Bangladesh. Systematic study and characterization of such germplasm is not only important for utilizing the appropriate attribute based donors, but also essential in the present era for protecting the unique rice. Thus, there is a need to collect, exploit and evaluate the untapped germplasm (Parikh *et al.*, 2012).

Most of the aromatic rice varieties in Bangladesh are of traditional type, photoperiod-sensitive and are grown during Aman season in the rainfed lowland ecosystem, although quite a few are also grown in the Boro season. Aromatic rice varieties have low yield compared to non-aromatic rice varieties (Fitzgerald *et al.*, 2008). Most of the traditional aromatic rice cultivars are of tall stature and very much susceptible to lodging which reduces the ultimate yield markedly. Lack of high-yielding varieties is also associated with the low yield of aromatic rice that is mainly traditional and local land-races (Mia *et al.*, 2012).

Aromatic and fine rice germplasm native to Bangladesh generally have short bold and medium bold grain type with mild to strong aroma (Shahidullah *et al.*, 2009b and Islam *et al.*, 2013a). But international trade market is covered by long slender Basmati, Jasmine rices. Therefore, various efforts should be conducted to achieve long slender high yielding aromatic rice genotypes. But in most cases, the outcomes are limited because the improvement of aromatic rice varieties is often challenged by the environment and genotype interactions for aromatic quality (Gay *et al.*, 2010).

In recent decades as living conditions are being steadily improved, human demand for high quality rice is continuously on increase, which entailed in incorporation of preferred grain quality features as the most important objective next to enhancement in yield. The rice grain quality traits generally include milling quality, appearance quality, and nutritional quality in terms of cooking and eating quality which are most important for the consumers. Physical quality properties such as size, shape, uniformity and general appearance (Cruz and Khush, 2000; Sellappan *et al.*, 2009); Kernel shape and L/B ratio are important features while assessing grain quality (Rita and Sarawgi, 2008). Starch (amylose and amylopectin) and protein composition are equally important in determining the cooking quality of rice (Lisle *et al.*, 2000; Ahmed *et al.*, 2007).

Only a few studies are found in literature evaluating the quality characteristics of traditional rice (Wickramasinghe and Noda, 2008; Abesekara *et al.*, 2013). However, the available information is not sufficient enough to gain an overall idea on the quality characteristics of the grain and their potential in international rice markets and their potential applications in future varietal improvement program. This demands more elaborated studies to identify the diversity of grain quality characteristics of traditional rice varieties.

Due to the lack of short stature, long slender grain aromatic rice in Bangladesh this study has been undertaken

- to explore local aromatic rice germplasm
- to evaluate local aromatic rice germplasm based on physico-chemical quality
- to find out non-lodging short stature, long slender / medium slender grain aromatic rice germplasm

CHAPTER 2

REVIEW OF LITERATURE

The Himalayan foothill including parts of Bangladesh is considered to be the secondary center of diversity of the genus *Oryza* (Morishima, 1984) but information about the characterization or genetic diversity of aromatic rice is very limited. Aromatic rice varieties are reputed for their grain quality and pleasant aroma. Traditional scented rice varieties are tall, lodging susceptible, photosensitive with low yield potential. The improvement of aromatic rice genotypes requires its collection and evaluation of existing cultivars of Bangladesh. The literature on some of the local aromatic genotypes and their performance are reviewed hereunder.

2.1 Growth parameters

2.1.1 Plant height

Hoque *et al.* (2013) investigated the performance of aromatic varieties on the growth and yield of aromatic rice and found that the differences among the varieties in respect of panicle length were statistically significant where plant height varied significantly among the studied entries from 121.3 cm to 76.30 cm. Variety had significant influence on plant height of aromatic rice. The highest plant height of 121.3 cm was observed in variety Kowla which was followed by Chandramukhi (116.3 cm) and the lowest was observed in BRRI dhan50 (76.30 cm). Plant height is mostly governed by the genetic makeup of the cultivar, but the environmental factors also influence it. Alam *et al.* (2009) reported similar effects of variety on the plant height of rice.

Islam *et al.* (2013a) evaluated the performance of local aromatic rice cultivars viz. Kalijira, Khaskani, Kachra, Raniselute, Morichsail and Badshabhog and showed that plant height increased progressively reaching a maximum or peak at 78 days after transplanting (DAT) and the highest plant height (116.00 cm) was found in the variety Morichsail and the lowest (63.70 cm) in Khaskani.

Jewel *et al.* (2011) evaluated, twenty-six (26) aromatic rice genotypes for agronomic characteristics and aroma detection. They reported that plant height, IR 50 had the minimum and Basmoti370 had the maximum height and ranged from 71.0 to 121.6 cm and the mean value for this trait was 93.00 cm.

Hossain *et al.* (2008a) evaluated the effect of different nitrogen levels on the performance of four aromatic rice varieties in transplanted Aman (monsoon) season as BRRI dhan38, Kalizira, Badshabhog and Tulsimala. Results revealed that maximum plant height was found from the variety Tulsimala (153.00 cm), which was significantly differed from the other varieties. While lowest plant height was observed in the variety BRRI dhan38.

Hossain *et al.* (2008b) evaluated the yield and quality performance of some aromatic rice varieties of Bangladesh and showed that Plant heights at maturity of the tested varieties showed significant variation. Highest plant height (165.8cm) was observed in Chinigura and the lowest (137.1cm) in Chiniatab. They also added that lodging of local aromatic rice varieties at maturity stage was observed due to higher plant height. These may be due to genetic characteristics of the varieties.

Sikdar *et al.* (2006) conducted an experiment to examine yield performance and protein content of some varieties of aromatic rice Plant height at harvest was significantly influenced by variety and they observed Tulshimala to produce the tallest plant (151.02 cm), which was followed by Kalizira (148.96 cm) and Badshabhog(141.33 cm). It was evident that plant height significantly differed from variety to variety (BlNA, 1993).

Hossain *et al.* (2005) conducted an experiment in order to investigate the relationship between grain yield with the morphological parameters of five local and three modern aromatic rice varieties. The varieties Kataribhog, Radhunipagal, Chinigura, Badshabhog, Kalizera, BRRI dhan34, BRRI dhan dhan37 and BRRI dhan38 were transplanted. The highest plant height was observed in Chinigura (162.8 cm) which statistically similar to Kataribhog (158.8cm). 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.

In Bangladesh. BRRI (2000a) reported that from different varieties Basmati 406 (4508, Katarihhog, BRRI dhan34 and Basmati) plant height differed significantly among the varieties. Result revealed that the tallest plant (126 cm) was recorded from Basmati 406 and the shortest one (115 cm) was observed due to Katarihhog. Anonymous (1998) reported that highest plant height was obtained from katarivog (153 cm) followed by Khaskani (143 cm)

BRRI (1998a) reported that highest plant height was obtained from Kataribhog (153 cm) followed by Khaskani (143 cm), BR4384-213-2-24 (130 cm), 13114384-28-2-2-6 (125 cm) and BR4384-2B-2-2-211R3 (125 cm) lines. Reddy and Redd (1997) reported that plant height is one of the important growth parameters of any crop as it determines or modifies yield contributing characteristics and finally shapes the grain yield.

Alam *et al.* (1996) conducted an experiment to evaluate the performance of different rice varieties. Among the varieties. Kalijira produced the tallest plant. which was followed by Pajam. Padmavathi *et al.* (1996) said that high positive direct effects of plant height, number of panicles/plant and panicle length on grain yield.

Anonymous (1993) evaluated the performance of four varieties / advanced lines, IRATOM, BR14, BINA 13 and BINA 19 and noticed that varieties / advanced lines differed significantly for plant height. Anonymous (1991) reported that height differed among the varieties.

Sawant *et al.* (1986) conducted an experiment with the new rice cv. R-73-1-1, R-711 and the traditional cv. Ratna and reported that Ratna was the shortest. Shamsuddin *et al.* (1988), Hossain *et al.* (1991) and Khatun (2001) also observed variable plant heights among the varieties and reported that variation in plant height might be due to the differences in their genetic make-up.

2.1.2 Number of tillers hill^{-1}

Sumon (2015) evaluated the response of green manure and chemical fertilizer on growth, yield and quality of aromatic rice varieties in Aman season. He observed the highest number of tillers hill^{-1} (11.13, 14.43, 17.30, 16.33, 16.04 and 15.60 at 15, 30, 45, 60, 75 DAT and harvest, respectively) in BRRI dhan34 (V_3) which is statistically similar with Kataribhog (V_1) at 15, 60 DAT and harvest. Among the varieties, Raniselute (V_2) produced lowest number of tillers hill^{-1} (8.38, 9.65, 14.22, 13.28, 12.41 and 11.15 at 15, 30, 45, 60, 75 DAT and harvest, respectively).

Malik *et al.* (2014) conducted an experiment during rainy season at crop research farm Allahabad agriculture institute (Deemed university) to evaluate the effect of different levels of nitrogen on growth and yield attributes of different varieties of Basmati Rice (*Oryza sativa* L.). Number of Tillers hill^{-1} at 20 (DAT) affected non-significantly but at 40, 60 and 80 days after transplanting the numbers of tillers hill^{-1} increased slowly from 40-60 days after transplanting there after a gradual decline was observed up to 80 days after transplanting. They reported that tiller production hill^{-1} was significantly affected by the influence of levels of nitrogen at all stages. Number of tillers differ in the treatments. Maximum number of tillers was found in the variety Pusa Basmati $^{-1}$ (19.29) at level (140) followed by Haryana Basmati^{-1} (18.60) at level (140). Tillering is an important trait for grain production and is therefore an important aspect in rice yield.

Roy *et al.* (2014) conducted an experiment to evaluate the growth, yield and yield attributing characteristics of 12 indigenous Boro rice varieties collected from South-Western regions of Bangladesh namely; Nayon moni, Tere bale, Bere ratna, Ashan boro, Kajol lata, Koijore, Kali boro, Bapoy, Latai balam, Choite boro, GS one and Sylhety boro. They reported that tiller numbers in most of the treatments increased exponentially up to harvest.

Islam *et al.* (2013a) evaluated the performance of local aromatic rice cultivars viz. Kalijira, Khaskani, Kachra, Raniselute, Morichsail and Badshabhog and showed that tiller number in most of the treatments increased almost exponentially upto 78 DAT and after that a gradual decline in tiller number was noticed and before harvesting it reached a plateau. The maximum number of tillers m-2 (404.20) was observed in the variety Kalijira and the minimum (108.90) was recorded in the variety Khaskani. Variation in tiller number might be due to the differences in their genetic make-up.

Metwally *et al.* (2012). reported that aromatic rice varieties significantly varied in tillers numbers m-2 in the two seasons. Plants of IR77510 variety produced the greatest tillers numbers m-2 at harvest in the two seasons. Plants of IR 65610 and IR 71137 varieties produced the lowest tillers numbers m-2 in the first and second seasons, respectively.

Mia and Shamsuddin (2011) reported that there was significant difference in the number of tillers among the cultivars throughout growth stages. Binasail and BRRI dhan32 produced the highest number of tillers at tillering stage thereafter declined gradually till maturity. And other varieties Ukunmadhu and Kataribhough produced the greatest number of tiller at panicle initiation stage and declined gradually up to maturity.

Shahidullah *et al.* (2009a) evaluated thirty aromatic rice genotypes to observe the tillering patterns and to explore its relationship with grain yield. They found much variation in tillering dynamics among the genotypes and added that nineteen genotypes reached to peak population around 40 days after transplantation (DAT), when after tiller numbers started to reduce; 10 of them showed tillering climax at 50 DAT and only Kalijira Tapl-73 at 60 DAT. Maximum number of tillers varied from 136 (Khazar) to 455m^{-2} (Chinigura). The highest rate of tiller mortality was found 49.29% in Chinigura and lowest in Jesso balam (10.10%).

Hossain *et al.* (2008a) revealed that significant differences were observed for producing total tiller, panicle bearing tillers and non-bearing tillers. Maximum number of total tillers was observed in BRRI dhan38, however Tulsimala produced the lowest numbers of tiller.

Hossain *et al.* (2008b) reported that the total number of tillers hill-1 ranged from 8.8 to 12.5. Maximum number tillers $hill^{-1}$ (12.5) was obtained from Chinigura and it was similarly followed by Radliunupagal. The highest number of fertile tillers hill $^{-1}$ (10.5) was found in Badshabhog, which was statistically similar to Kataribhog (Philippines), Chinigura and Radhunipagal.

Hossain *et al.* (2005) observed highest number of total tillers hill^{-1} in Chinigura (12.5) which was similar followed by Radunipagal, Badshabhog, BRRI dhan dhan37 and BRRI dhan38. The lowest number of total tillers hill^{-1} was obtained from Kalizira (9.8) which was statistically similar to Katarivbhog.

Padmavathi *et al.* (1996) observed the importance of number of tillers plant^{-1} which influenced yield. Ganapathy *et al.*, (1994) studied that the number of productive tillers hill^{-1}, panicle length and grains panicle^{-1} had a significant and positive association with grain yield.

Peng *et al.* (1994) revealed that tillering ability plays a vital role in determining rice grain yield. Too few tillers result fewer panicle, but excessive tillers enhance high tiller mortality, small panicle, poor grain filling and consequent reduction in grain yield. Ghose and Ghatge (1960) stated that tiller number, panicle length contributed to yield.

Hossain *et al.* (1989) who reported that number of total tillers hill^{-1} differed among varieties. Ramasamy *et al.* (1987) reported that number of tillers m^{-2} differed due to varietal variation.

2.1.3 Leaf area index

Mante (2016) observed that crop establishment and variety significantly affected the leaf area index. Varieties exhibited significant variations. Kalinayan obtained the biggest leaf area index while kasturi, the smallest. Basmati 385 and 370 did not differ with 1.55 and 1.46 leaf area index. The index difference among varieties can be attributed to the respective inherent trait.

Mia and Shamsuddin (2011) showed that modern varieties produced higher TDM than the aromatic varieties. These were because of the better photosynthetic capacity due to higher leaf area index and net assimilation rate. In modern varieties, the leaves are oriented vertically thereby harvesting more photos for synthesis of plant biomass. This variety also showed higher crop growth rate because of higher values of LAI. They also reported that the significant difference of LAI was observed among the varieties which increased progressively from tillering to panicle initiation stage and thereafter declined after flowering. The higher dry matter production was attributed due to higher LAI. The highest LAI was recorded in Binasail at panicle initiation followed by BRRI dhan32 and the lowest was found in Kataribhough.

Metwally *et al.* (2012) explained that aromatic rice varieties exhibited significant differences in leaf area index in the two seasons. The rice variety Egyptian Yasmin and IR77510 were among those which having the highest leaf area index. The variety IR65610 produced the lowest leaf area index in both seasons. The superiority of Egyptian Yasmin and IR77510 varieties in leaf area index could be attributed to high number of tillers and leaves. They also reported that the genotype differences in leaf area index, as here obtained, reflect different genetic make-up or genetic constitution.

Ghosh *et al.* (2004) reported varietal differences of leaf area index. Weng *et al.* (1982) and Tanaka (1983) reported that the increase of TDM was dependent on the leaf area production. Chandra and Das (2000) reported that Leaf area index was also significantly and positively associated with grain yield. Takeda *et al.* (1983) observed that high-yielding rice varieties had higher LAI.

2.1.4 SPAD readings

Gholizadeh *et al.* (2017) made regression analysis between SPAD readings and leaf N content. Positive significant linear relationships were observed between attributes. They also examined the correlation between the two stages of SPAD readings and grain yield (kg ha^{-1}) to verify their relationship. The test illustrated that SPAD values were positively and significantly correlated with rice grain yield at both growth stages.

Ashrafuzzaman *et al.* (2009) investigated and noticed that high yielding genotypes also showed higher chlorophyll content in rice cultivars. Hassan *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.

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. Similarly, Swain *et al.* (2006) also found highly significant and positive relation between total chlorophyll content at all the growth stages and grain number/m2

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. Maiti *et al.* (2004) reported that the significant positive correlations of the measured attributes (SPAD readings, N status, and grain yield) indicated that the top dressing of N can be practiced based on SPAD readings to obtain optimum grain yield.

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.

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.

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).

2.1.5 Days to flowering and maturity

Mante (2016) reported that the number of days from seeding to 50% heading was significantly affected by both crop establishment and variety. However, no interaction effect between the factors was observed. Significant differences among varieties were also observed. Basmati 385 flowered earlier (68.83 DAS) followed by Basmati 370 and kasturi with 72.49 and 75.49 DAS respectively. On the other hand, kalinayan flowered late with 91.58 days. This finding is consistent with that of Salas (1999) claiming that Basmati 370 flowered in 62 DAT and 72 DAT for kasturi. The difference in days to flower can be attributed to the genetic make-up of the varieties tested.

Jewel *et al.* (2011) evaluated, twenty-six (26) aromatic rice genotypes for agronomic characteristics and aroma detection. Reported that days to 50% flowering, the period ranged from 90 days to 145 days. PSB RC18 (IR51672-62-2-1-1-2-3) was found to be required more days whereas Basmati 370 took fewer days and the mean value was 127.07. The period of maturity of 26 germplasm ranged from 127 to 167 days. Basmati 370 was found to be the earliest maturing, whereas, YN96-5021 took maximum time to mature and the mean value for this trait was 155 days.

Ashrafuzzaman *et al.* (2009) evaluated the growth performance and grain quality of six aromatic rice varieties BR34, BR38, Kalizira, Chiniatop, Kataribhog and Basmati grown under rainfed conditions and reported that number of days required to 50% flowering differed significantly among the studied varieties. The lowest number of days required to 50% flowering was observed in Chiniatop (81.33 days), which is statistically indifferent from Kataribhog (82.33 days). The maximum number of days required to 50% flowering was for Kalizira (86.67 days).

Jamal *et al.* (2009) reported highly significant genetic variations among genotype for days to 50 percent flowering. This might be due to the genetic makeup of exotic lines and genotypic environmental interaction. Oad *et al.* (2006) evaluated the growth and yield performance of various aromatic strains. The results of the research revealed that aromatic varieties and their crosses initiated flowering between 73 and 105 days. Among the screened varieties, Lateefy, Bas-370xJajai and IR-8xJajai-77 exhibited minimum (73-77) days to flowering, followed by D. Basmati x Lateefy which recorded 80 days to flowering. The aromatic rice variety Jajai-77 took maximum (105) days to flowering and statistically was different to other tested varieties.

Zaman *et al.* (2005) reported that the duration to 50 percent flowering showed largest contribution to the total divergence in rice. Iftekharuddaula *et al.,* (2001) reported that days to flowering, days to maturity, plant height and spikelets/panicle had positive and higher indirect effect on grain yield through grains/panicle.

Sathya *et al.,* (1999) studied of eight quantitative traits in rice (*Oryza sativa*). Days to 50% flowering was the principal character responsible for grain yield per plant followed by 1000-grain weight, plant height and harvest index as they had positive and significant association with yield.

Padmavathi *et al.* (1996) suggested that days to 50% flowering had high positive direct effects of number of panicles/plant and panicle length on grain yield. 1000-grain weight, dry matter production, spikelets sterility, days to 50% flowering, number of grains/panicle and plant height had positive direct effects on grain yield. BINA (1993) reported that varieties differed significantly due to number of unproductive tillers hill^{-1}.

Ganesan and Subramaniam (1990) said that days to flowering, plant height, number of tillers/plant, and productive tillers/plant had both positive and negative indirect effects on yield. De Datta (1981) revealed that flowering begins with protrusions of the first dehiscing anthers in the terminal spikelets. At the time anthesis is occurring, the panicle is erect in shape.

Sharma (1981) revealed that the number of days required for scented rice to reach to flowering stage vary from variety to variety and the location. The duration is influenced by climatic factors and also reported that scented rice variety Kadamphool flowered in 70 days while BDT 1010 flowered in 77 days. Again, Fernandez *et al.* (1979) explained that the panicle flower beginning at the top, middle and lower thirds, occurring in the 1, 2 and 3rd day after panicle exertion (heading) in a tropical environment.

2.2 Yield and yield contributing characters

2.2.1 Number of effective tillers m^{-2}

Islam *et al.* (2016a) evaluated the effect of integrated nutrient management on the performance of three transplant Aman rice varieties. Resuslts revealed that the highest number of effective tillers hill^{-1} (8.62) was found in BRRI dhan31 variety and the lowest one (7.81) was found in BRRI dhan39 variety. The results are in agreement with those reported by Chowdhury *et al.* (1993) who stated that effective tillers hill-1 is the genetic makeup of the variety which is primarily influenced by heredity.

Mante (2016) reported that non-productive tiller was significantly influenced by crop establishment and varieties tested. Interactions among treatments were highly significant. Basmati 385 and kasturi transplanted in both cultivations obtained the highest number of non -productive tillers followed by Basmati 370 with 2.7, 2.63, 2.60, 2.40 and 2.37.

Sarkar *et al.* (2014) evaluated yield and quality of aromatic fine rice as affected by variety and nutrient management and revealed that the variation in plant height, number of effective tillers hill^{-1} and number of grains panicle^{-1} among the varieties were probably due to heredity or varietal characters.

Islam *et al.* (2013a) observed that the highest number of effective tillers hill^{-1} (13.0) was produced by Kalijira and the lowest number of effective tillers hill^{-1} (7.13) was observed in Morichasail. The reason of difference in effective tillers hill^{-1} is the genetic makeup of the variety, which is primarily influenced by heredity.

Metwally *et al.* (2012) reported that aromatic rice varieties significantly varied in panicle number m^{-2} in the two seasons. Plants of IR77510 variety markedly produced the highest panicle number m^{-2} at harvest in the two seasons. Plants of IR 65610 and IR 71137 varieties produced the lowest panicle number m^{-2} in the first and second seasons, respectively. The increase in panicle number m^{-2} may be due to increase in tillers number m^{-2}.

Jewel *et al.* (2011) evaluated twenty-six (26) aromatic rice genotypes for agronomic characteristics and aroma detection. Reported that number of effective tillers per plant ranged from 9 to 20 and significant variation was observed among the genotypes. IR71144-393-2-2-3-1 had the maximum number of effective tillers and Binadhan7 had the lowest.

Hossain *et al.,* (2008b) reported that number of panicles was the result of the number of tillers produced and the proportion of effective tillers, which survived to produce panicle.

Hossain *et al.* (2008a) evaluated the effect of different nitrogen levels on the performance of four aromatic rice varieties in transplanted Aman (monsoon) season as BRRI dhan38, Kalizira, Badshabhog and Tulsimala. Bearing tillers was found to be highest from the variety Kalizira, which was statistically similar with Badshabhog. The highest number of non- bearing tillers was produced by Badshabhog, which was followed by Tulsimala whereas Kalizira produced the lowest number of non-bearing tillers. The reduction of number of tillers was due to tiller mortality in the vegetative stages.

Sikdar *et al.* (2006) reported that variety had significant effect on effective tillers $hill^{-1}$. The results indicated that Badshabhog and Tulshimala the highest number of effective tillers $hill^{-1}$ (6.38). Kalizira produced the lowest number of effective tillers $hill^{-1}$ (6.20). The reasons for difference in producing effective tillers $hill^{-1}$ might be due to the variation in genetic make-up of the variety that might be influenced by heredity. This was confirmed by BRRI (1991) who stated that effective tillers $hill^{-1}$ varied with variety.

Hossain *et al.* (2005) observed the highest number of fertile tillers $hill^{-1}$was observed in BRRI dhan37 (11.4) and it was similarly followed by Radhunipagal, Badshabhog, Chinigura, BRRI dhan38 and the lowest fertile tillers $hill^{-1}$was obtained from Kalizera (8.7) which was statistically similar to Kataribhog. Kusutani *et al.* (2000) and Dutta *et al.* (2002) reported that the genotypes, which produced higher number of effective tillers per hill and higher number of grains per panicle also showed higher grain yield in rice.

BRRI (1997) stated that in local varieties namely. llaloi. Titockachari. Nizersail and Eatishail. the number of effective tillers hill^{-1}were 9.7, 9.3. 10.8 and 9.0, respectively. Again, Chowdhury *et al.* (1993) reported that effective tillers hill^{-1} varied with the variety. This result was supported by anonymous (1991).

Geetha (1993) indicated that number of ear-bearing tillers, filled grain/per panicle, percentage filled grain, and test weight, straw yield and harvest index were all correlated positively with grain yield. However, BRRI (1991) reported that the number of effective tillers hill^{-1} was produced by transplant Amon rice varieties which ranged from 7-14. Number of effective tillers hill^{-1} significantly differed among the varieties.

Sawant *et al.* (1986) reported that the maximum effective tillers hill^{-1} (12.4) and minimum non-effective tillers hill^{-1} (2.7) were found from V_4 (ACI hybrid dhan 2) which was statistically similar (12.9) with V_3 (BRRI hybrid dhan 2) and closely followed (11.0) by V_2 (BRRI dhan29). The minimum effective tillers hill^{-1} (9.6) and maximum non-effective tillers hill^{-1} (3.5) were found from V_1 (BRRI dhan28) and V_2 (BRRI dhan29). The previous findings reported that variable effect of variety on the effective and non-effective tillers hill^{-1}.

2.2.2 Number of ineffective tillers m^{-2}

Islam (1995) in a study with the cultivars *viz.* BR10. BR11. BR22 and BR23 found that the highest number of nonbearing tillers hill^{-1} was produced by cultivar BRl1 and the lowest number was produced by the cultivar BR10.

Islam *et al.* (2016a) revealed that the highest number of noneffective tillers hill^{-1} (6.44) was found in BRRI dhan39 rice variety and the lowest one (4.26) was found in BRRI dhan31 variety.

2.2.3 Panicle length

Islam *et al.* (2016a) found the longest panicle (25.17 cm) in BRRI dhan41 and the shortest one (23.72 cm) was obtained from BRRI dhan39 variety. This variation as assessed might be mainly due to genetic characteristics which are influenced by heredity.

Malik *et al.* (2014) evaluated the effect of different levels of nitrogen on growth and yield attributes of different varieties of Basmati Rice (*Oryza sativa L.*). They reported that length of Panicle also differs in different varieties. The maximum panicle length of 31.73 cm in case of Pusa Basmati -1 at an optimal dose of Nitrogen - 120.

Hoque *et al.* (2013) investigated the performance of aromatic varieties on the growth and yield of aromatic rice and found that the differences among the varieties in respect of panicle length were statistically significant. The longest panicle of aromatic rice varieties was found in Chinigura (22.53 cm), Rata (22.50 cm) and Chandramukhi (22.43 cm). The shortest panicle was observed in Kalizira (17.00 cm).

Islam *et al.* (2013a) observed that panicle length recorded was the highest (23.25 cm) in the variety Morichsail and the variety Kalijira produced lowest panicle length (20.03 cm). They showed a simple linear regression using panicle length as independent variable and yield as dependent variable showed a positive but non-significant relationship. The value of R^2 (0.59) indicates that about 60% variation in yield could be explained by the variation in panicle length.

Mia and Shamsuddin (2011) determined the physio-morphological attributes in relation to yield potential of modern and aromatic rice varieties and reported that the variety Binasail recorded the longest panicle and BRRIdhan 32 showed the lowest. The result also showed that there was no significant difference in Binasail, Ukunmadhu and Kataribhough but BRRI dhan32 showed significantly the shorter panicle compared to others.

Hossain *et al.* (2008a) evaluated the effect of different nitrogen levels on the performance of four aromatic rice varieties in transplanted Aman (monsoon) season as BRRI dhan38, Kalizira, Badshabhog and Tulsimala. The length of panicle was significantly affected by variety. Longest panicles (25.84 cm) were observed in BRRI dhan38. Whilst shortest panicles (20.95 cm) were recorded in Tulsimala.

Hossain *et al.* (2005) investigated the relationship between grain yield with the morphological parameters of five local and three modern aromatic rice varieties. Panicle length differed significantly in aromatic rice varieties. Maximum panicle length was found by BRRI dhan38 (24.14 cm) and minimum panicle length by Radhunipagal (20.65 cm).

Laza *et al.* (2004) study was measured with yield-related traits, panicle size had the most consistent and closest positive correlation with grain yield. Shrirame and Muley (2003) observed that panicle length had no significant difference among the genotypes studied.

Sharma (2002) worked with fine grain rice and reported that there had been significant variation in panicle length. Behera (1998) reported that increasing panicle length and plant height might have increased grain yield of rice indirectly by increasing the number of spikelets per panicle and panicle length, respectively.

Sawant *et al.* (1995) concluded that panicle length was negatively correlated with flowering time and positively correlated with tiller height. Ganapathy *et al.* (1994) reported that panicle length, the number of productive tillers per hill, and grains/panicle had a significant and positive association with grain yield.

Anonymous (1993) reported that panicle length influenced by variety. Junco *et al.* (1992) reported positive linear relationship of panicle length with number of spikelets panicle^{-1}. Idris and Matin (1990) also found that panicle length differed among the varieties and it was greater in IR 20 than that of any of the indigenous and high yielding varieties.

2.2.4 Primary branches panicle^{-1}

Mia *et al.* (2012) evaluated biochemical traits and physico-chemical attributes of aromatic-fine rice in relation to yield potential and reported that Ukonmodhu showed the greatest number whereas Binasail recorded the lowest number of primary branches. The remaining varieties showed the intermediate status.

Mia and Shamsuddin (2011) determined the physio-morphological attributes in relation to yield potential of modern and aromatic rice varieties and reported that number of primary branches revealed significant difference among the varieties. The highest number of primary branches showed in Ukunmadhu followed by BRRIdhan32 and Kataribhough.

Yamagishi *et al.* (2003) reported that rachis-branching system in a panicle is an important factor determining the yield. They found high yielding variety to have a relatively large number of primary rachis-branches as compared with the secondary rachis-branches.

Ramalingam *et al.,* (1994) observed that varieties with long panicles, a greater number of filled grains and more primary rachis would be suitable for selection because these characters have high positive association with grain yield and are correlated among themselves.

2.2.5 Flag leaf length

Ashrafuzzaman *et al.* (2009) found the longest flag leaf (34.45 cm) in Basmati, while Kalizira produced the shortest (25.28 cm) flag leaf. Raj and Tripathi (2000) evaluated the relationship between flag leaf area and yield-related traits and reported that grain yield and yield-related traits were positively related to flag leaf area.

2.2.6 Filled grains panicle^{-1}

Malik *et al.* (2014) conducted an experiment during rainy season at crop research farm Allahabad agriculture institute (Deemed university) to evaluate the effect of different levels of nitrogen on growth and yield attributes of different varieties of Basmati Rice (*Oryza sativa L*.). Number of filled grains were also influenced in different varieties. The maximum number of filled grains were found in Pusa Basmati -1106.10 at the nitrogen dose of -120. Number of filled grains were also influenced in different varieties. The maximum number of filled grains were found in Pusa Basmati -1 at the nitrogen dose of -120. The rice yield revealed that the crop responded significantly with the varieties and Nitrogen application.

Islam *et al.* (2013a) evaluate the performance of local aromatic rice cultivars viz. Kalijira, Khaskani, Kachra, Raniselute, Morichsail and Badshabhog and showed that number of filled grains panicle^{-1} was found highest (100) with the variety Khaskani and the lowest was recorded with the variety Raniselute.

Jewel *et al.* (2011) evaluated, twenty-six (26) aromatic rice genotypes for agronomic characteristics and aroma detection. Reported that number of filled grains per plant ranged from 750 to 1217. IR73887-1-8-1-4 had the highest number of filled grains per plant, whereas IR72869-52-1-1-1 had the minimum number of grains per plant.

Hossain *et al.* (2008b) evaluated the yield and quality performance of some aromatic rice varieties of Bangladesh and showed that the maximum number of spikelets per panicle (154.5) was observed in Badshabhog and the minimum (93.3) was obtained from Madhumala. The number of grains per panicle is the most important criteria of high yield in rice cultivars (Venkateswaslu *et al.*,1986).

Padmavathi *et al.*, (1996) concluded that number of filled grains/panicle, plant height 1000-grain weight, dry matter production, spikelets sterility, days to 50% flowering had positive direct effects on grain yield.

Lin (1995) studied the relationship among filled grains panicle^{-1}, grain size, yield components and quality of grains. The percentage of filled grains/panicle was the most important factor affecting grain yield. Ganapathy *et al.* (1994) said that the number of filled grains panicle^{-1}, productive tillers per hill, panicle length had a significant and positive association with grain yield.

BRRI (1994) conducted an experiment to observe the performance of BR 14. Pujam. BR5 and Tulsimala. They observed that Tulsimala produced the highest number of spikelets panicl^{-1} and BR 14 produced the lowest number of spikelets panicle^{-1}. Anonymous (1994) reported that the number of filled grains panicle^{-1} influenced significantly due to variety. The results were also supported by Singh and Gangwer (1989).

Mahajan *et al.* (1993) indicated that filled grains panicle^{-1}, grain yield plant^{-1} was positively and significantly correlated with straw yield plant^{-1}. Chowdhury *et al.* (1993) observed that the variety Pajam produced significantly higher number of total spikelets as well as unfilled spikelets panicle^{-1} than that of BR23.

2.2.7 Unfilled grains per panicle

Mante (2016) reported that number of unfilled grains was significantly affected by crop establishment, variety and land preparation. The analysis of variance showed highly significant interaction between treatments. Transplanted Kalinayan and Kasturi in “payatak” tillage had the highest number of unfilled grains with 33.90 and 30.93, respectively. Basmati 385 direct seeded in conventional prepared areas and Basmati 370 transplanted in “payatak” tillage gave the least number of unfilled grains with 15.3 and 16.00, respectively. The difference in the number of unfilled grains of the different treatments can be due to the difference in occurrence of insect pest.

Islam *et al.* (2016b) evaluated the effect of integrated nutrient management on the performance of three transplant Aman rice varieties. Variety BRRI dhan41 produced the highest number of grains panicle^{-1} (157.06) and the lowest one (133.24) was produced by the variety BRRI dhan39.

BRRI (1994) also reported that the number of grains panicle^{-1} was influenced significantly due to variety as it is mostly governed by heredity. BRRI dhan31 variety produced the highest number of sterile spikelets panicle^{-1} (19.25) and the lowest one (13.54) was found in BRRI dhan39. BINA (1993) reported differences in number of sterile spikelets panicle^{-1} due to varietal differences. This variation might be due to genetic characteristics of the varieties.

Murthy *et al.* (2004) recorded variation of filled and unfilled grains panicle^{-1} for different variety. Islam *et al.* (2013a) observed that the undesirable traits, 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 panicle^{-1} was highly significant. Morichsail produced the lowest number of unfilled grains panicle^{-1} (11.17) which contributed highest grain yield of that variety.

Hoque *et al.* (2013) reported that, Kataribhogh and Rata varieties produced the maximum number of unfilled grains (19.09% and 18.40%, respectively) whereas the lowest number of unfilled grains was recorded in Kowla. BRRI dhan50 produced 15.63% unfilled grain. BRRI (1994) also reported that the number of grains panicle^{-1} was influenced significantly due to variety as it is mostly governed by heredity. BRRI dhan31 variety produced the highest number of sterile spikelets panicle^{-1} (19.25) and the lowest one (13.54) was found in BRRI dhan39.

Paul and Sarmah (1997) reported that yield was negatively correlated with false grains/panicle days to maturity, plant height and filled grains/panicle. BINA (1993) reported differences in number of sterile spikelets panicle^{-1} due to varietal differences. Similarly, Chowdhury *et al.* (1993) reported that the variation in number of unfilled grains panicle^{-1} might be due to genetic characteristics of the varieties.

2.2.8 Total number of grains panicle^{-1}

Hoque *et al.* (2013) investigated the performance of aromatic varieties on the growth and yield of aromatic rice. The experiment consisted of eight varieties viz. BRRI dhan50, Kataribhogh, Rata (local), Kowla (local), Kalizira, Chandramukhi (local), Chinigura and Tulsimala. They revealed that number of spikelets panicle^{-1} was the highest in Chinigura (155.70) which was followed by Tulsimala (128.60). On the other hand, Kowla produced the lowest number of spikelets panicle^{-1}(94.22).

Hossain *et al.* (2008b) evaluated the yield and quality performance of some aromatic rice varieties of Bangladesh and showed that the maximum number of spikelets panicle^{-1}

(154.5) was observed in Badshabhog and the minimum (93.3) was obtained from Madhumala.

Kusutani *et al.* (2000) reported that the variety which produced highest number of effective tillers per hill and highest number of grains panicle^{-1} also showed highest grain yield in rice. Similarly, Fageria and Baligar (2001) reported that grain number panicle^{-1} had a positive and significant correlation with grain yield.

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.

2.2.9 Weight of 1000-grains

Mante, (2016) reported that similar to filled grains, the 1000 grains weight was significantly affected by land preparation, crop establishment and varieties tested. There was interaction between treatments still the significant differences possibly were due to the genetic characteristics of the varieties.

Islam *et al.* (2013) evaluated the performance of local aromatic rice cultivars viz. Kalijira, Khaskani, Kachra, Raniselute, Morichsail and Badshabhog and reported that it was observed that grain yield has significant positive relationship with 1000-grain weight.

Hoque *et al.* (2013) reported that the 1000-grain weight among the varieties differed significantly. The largest grain size was produced in cultivar Rata which has highest 1000-grain weight (18.80 g). Kowla also produced more or less similar size seed with a 1000-grain weight of 18.43 g. Chinigura produced the smallest sized grain weight (9.47g 1000-grain weight) followed by Tulsimala (11.37 g).

Metwally *et al.* (2012) reported that aromatic rice varieties exhibited significant differences in 1000-grain weight in the two seasons. The relative ranking of varieties with respect to

1000-grain weight was inconsistent in the two seasons. The Egyptian Yasmin variety and IR 65610 and IR 78530 varieties were among those having the heaviest 1000-grain weight in both seasons.

Mondal *et al.* (2005) studied 17 modern cultivars of transplant aman rice and reported that 1000-grain weight differed significantly among the cultivars studied. On the other hand, Sathya *et al.* (1999) reported that 1000-grain weight, days to 50% flowering, plant height and harvest index had positive and significant association with yield. Ashraf *et al.* (1999) also reported that 1000-grain weight, an important yield-determining component, is a genetic character least influenced by environment.

BRRI (1998a) reported that the 1000- grain weight of Kuieha Binni, Leda Binni. Chanda Binni, Dudh Methi, Maraka Binni, Nizcrshail and one high yielding variety BR 25 were 24. 22, 25, 20. 23, 18 and 17g. respectively. BRRI (1998b) found that 1000-grain weight of some aromatic rice varieties ranged from 12 to 20 g and it difl'ered significantly from variety to variety.

Ashvani *et al.* (1997) stated that 1000 grain weight and total biological yield plant^{-1} may be considered for further improvement of rice. In an annual report, BRRI (1997) scientists reported that 1000-grain weight differed among the cultivars.

Kim and Rutger (1988) observed positive yield predominantly in 1000-grain weight and no. of spikelets per plant. They also observed high correlation between 1000-grain weight and grain yield.

Shamsuddin *et al.* (1988) and Chowdhury *et al.* (1993) who reported that weight of 1000-grain differed among the varieties. Yoshida (1981) reported that under most conditions, 1000 grains of filled crop is a very stable character.

2.2.10 Grain yield

Islam *et al.* (2016a) evaluated the effect of integrated nutrient management on the performance of three transplant Aman rice varieties. Results revealed that the highest grain yield was found in BRRI dhan31 (5.64 tha-1) followed by BRRI dhan41 and BRRI dhan39.

Islam *et al.* (2016b) investigated genetic variability among 113 aromatic and fine local rice genotypes of which five were exotic in origin and reported that plants with high panicles have high number of filled grains thereby increasing rice yield.

Mante (2016) reported that significant differences were observed in the different varieties tested. Basmati 370 obtained the highest yield of 4.51 ton/ha followed by Kasturi, 3.21 ton/ha. Kalinayan and Basmati 385, on the other hand, produced the low yield of 2.78 and 2.77 t ha^{-1}, respectively. The high yield of the transplanted Basmati 370 can be due to its high produced tiller count, relatively high filled grains and heavier grain weight.

Hoque *et al.* (2013) investigated the performance of aromatic varieties on the growth and yield of aromatic rice. BRRI dhan50 produced the highest grain yield (4.43 t ha-1) followed by Kataribhogh (2.63t ha-1) and Rata (2.50 t ha-1). On the other hand, the lowest grain yield was recorded from Kalizira (2.16 t ha-1). They included that there was significant difference in grain yield among the aromatic rice varieties.

Islam *et al.* (2013a) showed that grain yield of rice mainly depends on the number of effective tillers per unit area, panicle length, filled grains panicle-1 and 1000-grain weight. Grain yield differed significantly among the varieties. The variety Morichsail produced the highest grain yield (2.53 t ha-1) and the lowest yield (1.38 t ha-1) was obtained from Kalijira. Tyeb *et al.* (2013) and Islam *et al.* (2012) reported that variety exerted variable effect on yield and yield contributing characters of rice.

Metwally *at al.* (2012) reported that aromatic rice varieties exerted a significant effect on grain yield in the two seasons. Plants of Egyptian Yasmin in the two seasons and IR 77510 in the first season significantly produced the greatest grain yield. Plants of IR 65610 variety produced the lowest grain yield in the two seasons. The superiority of Egyptian Yasmin and IR 77510 variety might be resulted from its better growth, i.e. leaf area index, dry matter accumulation and yield attributes, i.e. number of panicles m-2 and number of filled grain panicle^{-1}.

Ashrafuzzaman *et al.* (2009) evaluated the growth performance and grain quality of six aromatic rice varieties and reported that different varieties exhibited significant differences in grain yield. BR34 produced the maximum grain yield and Basmati produced the lowest. Varietal differences of grain yield were also reported by Biswas *et al.* (1998). Hossain (2008a) also reported that Kataribhog and Badshabhog produced yield of 2.30 and 2.12-ton ha $^{-1}$, respectively.

Kibria *et al.* (2008) investigeted the yield potential of local aromatic variety Kalizira, a segregating population (developed from a cross between Y-1281 and Kalizira) and reported that correlation studies between aroma and grain yield revealed that aroma is negatively correlated with grain yield.

Hossain *et al.* (2005) reported that the highest grain yield (3.5 t ha^{-1}) was obtained from BRRI dhan34 which was similarly followed by Kataribhog. The lowest grain yield (2.5 t ha^{-1}) was obtained from Kalizera which was statistically similar to Chinigura, BRRI dhan37 and BRRI dhan38.

Islam and Islam (2004) reported that grain yield of aromatic rice vaetics was low but its high price and low cost of cultivation generates high profit compared to other varieties grown in the Northern region of Bangladesh.

Somnath and Ghosh (2004) reported that the association of yield and yield related traits with the number of effective tillers and had negative association with yield and yield components. Hassan *et al.* (2003) reported that grain yield is a function of interplay of various yield components such as number of productive tillers, spikelets panicle^{-1} and 1000-grain weight.

Kusutani *et al.* (2000); and Dutta *et al.* (2002) reported that the genotypes, which produced higher number of effective tillers per hill and higher number of grains per panicle also showed higher grain yield in rice. Chauhan *et al.,* (1999) grain yield was positively associated with dry matter at 50% flowering, biological yield and harvest index. Leaf area index, dry matter accumulation of 50% flowering, biological yield and harvest index seemed to be important in improving grain yield.

Chabder and Jitendra (1996) conducted an experiment and reported that the average productivity of aromatic rice is very low. Marekar and Siddiqui (1996) concluded that positive and significant correlations were observed between yield per plot and plant height, length of panicle, days to maturity, 1000-grain weight, length of grain and L/B ratio.

BRRI (1994) found that BR I4 produced the highest yield (3.75 t ha') followed by Pajarn and Tuishimala while BR5 produced the lowest yield (2.61 t ha). Rao *et al.* (1993) found that the highest grain yield was obtained in the wet seasons by local variety Badshabhog (3.21 t ha^{-1}) than the other ones (cv. Kastui. Ranbir. Basmati and lET 8579) and mean yields varied from 2.22 -2.58 t ha^{-1}.

AIim *et al.* (1962) tested five fine rice cultivars namely. Badshahhog. Basmati. Ilatishail. Gohindhahhog and Radhunipagal for five years and found that Basmati showed the best performance showed by Gohindhabhog and Radshabhog. They also reported that Radshahhog and Hatishail yielded 2.6 and 2.69 t ha^{-1}, respectively.

2.2.11 Straw yield

Islam *et al.* (2016a) evaluated the effect of integrated nutrient management on the performance of three transplant Aman rice varieties. The highest straw yield (6.85 t ha^{-1}) was produced in BRRI dhan31variety and the lowest one (5.69 t ha^{-1}) was produced by the variety BRRI dhan39.

Hoque *et al.* (2013) reported that BRRI dhan50 produced the highest straw yield (10.17t ha^{-1}) and the lowest straw was recorded in Tulsimala (7.03 t ha^{-1}) which was similr to Kowla (7.23 t ha^{-1}) and kalizira (7.53 t ha^{-1}).

Mia and Shamsuddin (2011) reported highest straw yield in BRRI dhan32 and lowest in Ukunmadhu. Metwally *et al.* (2012) reported that aromatic rice varieties exerted a significant effect on straw yield in the two seasons. Plants of Egyptian Yasmin and IR 77510 in markedly produced the highest straw yield in the two seasons. Plants of IR65610 variety produced the lowest straw yield in the two seasons. The superiority of Egyptian Yasmin and IR 77510 variety might have resulted from its better growth.

Ashrafuzzaman *et al.* (2009) evaluated the growth performance and grain quality of six aromatic rice varieties BR34, BR38, Kalizira, Chiniatop, Kataribhog and Basmati grown under rainfed conditions and reported that indicated that six aromatic rice varieties differed significantly to straw yield.

Hossain *et al.* (2005) investigated the relationship between grain yield with the morphological parameters of five local and three modern aromatic rice varieties. Kataribhog gave the highest straw yield (8.9 t ha^{-1}) and the lowest straw yield was obtained from Kalizera similarly followed by BRRI dhan37 and BRRI dhan38.

2.2.12 Biological yield

Islam *et al.* (2016a) reported that the highest biological yield (12.49 t ha^{-1}) was recorded from the BRRI dhan31 and the lowest one (10.25 t ha^{-1}) was obtained from BRRI dhan39 rice variety.

Islam *et al.* (2013a) observed that 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 Kalijira. From the result, it was observed that biological yield differed due to combined effect of grain yield and straw yield. Plotting grain yield against biological yield gave a significant positive linear relationship which indicates that as biological yield increased, grain yield also increased.

2.2.13 Harvest index

Islam *et al.* (2016a) reported that the highest harvest index (45.76%) was recorded from the BRRI dhan41 and the lowest harvest index was (44.29%) obtained from BRRI dhan39 rice variety.

Hoque *et al.* (2013) reported that harvest index is a vital character having physiological importance. They observed that BRRI dhan50 produced the highest harvest index (0.44%) which was followed by Kataribhogh (0.34%). The lowest harvest index was found in Chandramukhi and Chinigura (0.30 %).

Mia and Shamsuddin (2011) reported that the highest grain yield in BRRI dhan32 may be due to higher harvest index. All other cultivars vis-a-vis Ukunmadhu recorded lower yields which might be assigned to lower harvest index

Ashrafuzzaman *et al.* (2009) reported that variety had significant differences in harvest indices. The highest harvest index was recorded from BR34 (34.94%) and the lowest harvest index was obtained from Basmati (31.51%). Harvest index is a vital character having physiological importance. It reflects translocation on alternatively dry matter partitioning of a given genotype to the economic parts.

Cui-Jing *et al.* (2000) and Reddy *et al.* (1994) also observed higher grain yield with the significant increase of harvest index. The shortest stature of the high yielding variety had the highest harvest index.

Kusutani *et al.* (2000) highlighted the contribution of high harvest index to yields. High yield is determined by physiological process leading to a high net accumulation of photosynthates and their partitioning (Miah *et al.*, 1996).

Lim *et al.* (1993) reported that there were direct relations between plant height and harvest index which is supported by Shah *et al.* (1991) reported that variety had a great influence on harvest index. Youshida (1981) explained that harvest index of traditional tall varieties is about 0.3 and 0.5 for improved short varieties.

2.3 Milling characteristics

2.3.1 Hulling percentage

Kambe (2016) reported that the genetic variability for hulling (%) was high ranging from 45.74% (NK-3325) to 89.00% (SGRH-101) with the mean value of 65.13%. Genotypic and phenotypic coefficients of variation were 18.9037 and 18.9659% respectively.

Rebeira *et al.* (2014) reported that brown rice percentage varied from 77-80% while the percentage of husk varied between 20-23% which was within the range acceptable for commercial production. Again, Kumar *et al.* (2010) reported that the characters like HP, MP and HRR showed a significant positive association at phenotypic and genotypic level.

Rita and Sarawgi (2008) reported that the more than 80 value of hulling percentage is preferred and if the hulling percentage increases the head rice recovery also increased. Igbeka *et al.* (2008) observed that high hulling percentage resulted in higher head rice yield of 93.3% in parboiled rice with the higher (5.5 x 104 N/m^2) process steam pressure. Cruz and Khush (2000) recorded variation of husk 18-26% although husk contributes generally 20-22% of rough rice.

2.3.2 Milling recovery

Ratna *et al.* (2016) reported that the milling per cent ranged from 51 to 66% but Ahuja *et al.* (1995) reported a range of 67 to 71 % for milling recovery in Basmati varieties. Hossain *et al.* (2008b) evaluated the yield and quality performance of some aromatic rice varieties of Bangladesh and observed that all the grain quality parameters were significantly influenced by variety. Milling outturn ranged from 70.0- 72.1% among the tested varieties. The highest milling outturn (72.1%) was recorded in Zirabhog.

Hossain *et al.* (2007) determined the influence of transplanting date on the physical and chemical properties of grain of five local and three modern aromatic rice varieties of Bangladesh and reported that among the aromatic varieties, Badshabhog recorded the highest milling out-turn and it was similar with that of Kataribhog, Radhunipagal and BRRI dhan34. Head rice out-turn was the highest in Badshabhog.

Cruz and Khush (2000) recorded that from a given sample of rough rice about 70 per cent milled rice was obtained. Thus, if from a sample of 100 g of rough rice, 70 g of milled rice was obtained and 20 g of this was broken, head-rice recovery was 50 per cent.

Ali *et al.* (1991) observed that during wet season early or delay transplanting adversely affected milling recovery and cooking quality of scented Basmati rice.Webb (1985) stated that milling yield is one of the most important criteria of rice quality especially from a marketing standpoint. A variety should possess a high turnout of whole grain (head) rice and total milled rice

2.3.3 Head rice recovery

Rebeira *et al.* (2014) reported that although head rice percentage of many varieties ranged from 55-73%, variety Kuruluthuda gave a head rice percentage of 41%. Verma *et al.* (2013) observed in some promising basmati genotypes for hulling, milling and head rice out-turn were 72-80%, 64-7% and 52-61.9%, respectively.

Hossain *et al.* (2008b) observed that Zirabhog gave the highest head rice out turn (69.5%) and it was statistically similar to Badshabliogand Chiniatab. Head rice out turn was dependent on grain size and shape, moreover it is a varietals characteristic (Ferdous *et al.*, 2004). Dipti *et al.* (2002) reported milling out-turn (64-70%) and HRR (61-82%). Khush *et al.* (1979) reported that the head-rice recovery may vary from as low as 25 per cent to as high as 65 per cent.

2.4 Physico-chemical characteristics

2.4.1 Kernel length and breadth

Ratna *et al.* (2016) found the utmost kernel length (8.05 mm) and breadth (1.79 mm) were in line S_2 whereas, the utmost L/B ratio (4.75) was observed in S_5. On the other hand, the minimum kernel length (5.82 mm) and L/B ratio (3.51) of milled rice were found in check variety BRRI dhan29 and the minimum breadth (1.58) of milled rice was recorded in 44.

Islam (2011) reported that contribution of kernel breadth was the most responsible for primary differentiation followed by L/B ratio, time of 50% heading, amylose content, number of filled grains/panicle, thousand grain weight, number of tillers per plant, seed yield per plant and panicle length to the total divergence in rice.

Kibria *et al.* (2008) screened aromatatic rice lines and found that Kalizira had short grains of less than 5.50 mm. Rice with kernel length of 7 mm or more and breadth of less than 2 mm are highly remunerative in international trade.

Hossain *et al.* (2008b) observed that grains of short to medium length usually, but not always, break than long grains during milling. Highest grain length (5.2mm) and length breadth ratio (2.3) was obtained from Kataribhog (Philippines). Begum (2006) reported that grain length had significant and negative correlation with grain width; significant and positive correlation with length width ratio. Grain width had significant and negative correlation with length width ratio.

Shobha (2003) reported that bold grains give low head rice recovery because of high breakage. Viraktamath (1987) observed that kernel breadth enhanced the milling output and HRR was strongly associated with milling percentage. Bhattacharjee and Kulkarni (2000) analyzed some preferred brands of basmati rice and reported that the L/B ratio ranged from 4.47-4.81. Kaul (1970) reported that aromatic variety with kernel length 6.0 mm and above is considered widely acceptable size.

2.4.2 Grain size and shape

Rita and Sarawgi (2008) reported that kernel shape and L/B ratio are important features for grain quality assessment. Sharma (2002) mentioned that the aromatic cultivars possessed a slender shape compared with the medium-slender shape of non-aromatic cultivars.

Cruz and Khush, (2000) stated that preference for grain size and shape varied from one group of consumers to the other. Some ethnic groups preferred short bold grains, some had a preference for medium long grains, and long slender grains were highly prized by others. In general, long grains were preferred in the Indian subcontinent, but in Southeast Asia the demand was for medium to medium long rice. In temperate areas, short grain varieties were prevalent. There was a strong demand for long grain rice on the international market.

Tomar and Nanda (1985) did not find any association between kernel size and shape. It had significant negative association between grain width and grain length width ratio. It had significant positive correlation between grain length and grain width.

IRRI (1980) stated that the L/B ratio of above 3 is generally considered as slender. Adair *et al.* (1973) reported grain size and shape are the first criteria for the quality of rice that breeders consider in developing new varieties for commercial production.

Kaul (1970) revealed that the length:breadth ratio (L/B) falling between 2.5 and 3.0 has been considered widely acceptable as long as the length is more than 6 mm. Adair *et al.* (1966) reported that the appearance of milled rice is important to the consumer. Thus, grain size and shape are the first criteria of rice quality that breeders consider in developing new varieties for release for commercial production

2.4.3 Kernel length after cooking

Bhonsle (2010) reported that kernel length after cooking (KLAC) ranged from 2.31-3.76 mm in aromatic traditionally cultivated rice and 4.62-5.88 mm in basmati rice. Minimum KLAC was observed in ‘Kotimirsal’ and ‘Basmati local’.

In a study on 20 new plant type genotypes, Sandeep (2003) and Hossain *et al.* (2009) reported kernel length/width ratio of cooked rice ranging from 2.04 to 3.95 and 2.39 to 5.07 respectively.

Shobha (2003) reported that the kernel length after cooking of nine released hybrids of India ranged from 10.2 to 12.4 mm. Similar result also reported by Soroush *et al.* (2005).

Khush *et al.* (1986) and Sidhu (1989) reported that breadth wise splitting is not desirable whereas length wise splitting (grain elongation) on cooking without increase in girth is considered trait in high quality premium rice such as basmati, which elongate almost 100 per cent on cooking.

Khush *et al.* (1979); Sidhu (1989) and Hossain *et al.* (2009) reported that breadth wise increase is not desirable, whereas, length wise increase without increase in girth is desirable characteristics in high quality premium rice. Hogan and Plank (1958) reported that during cooking, rice kernels absorb water and increase in volume through increase in length or breadth.

2.4.4 Elongation ratio

Rebeira *et al.* (2014) reported that Volume Expansion (VE) over cooking was taken as the ratio between volume of cooked rice and initial volume of raw rice. Volume expansion values of selected varieties were varied form a maximum of 3.3 in Deveraddiri and minimum of 2.5 in Wanni Dahanala. However, a significant difference was not observed in VE values.

Bhonsle (2010) reported that the volume expansion ratio (VER) in aromatic traditional rice varieties ranged from 2.36-4.10, while in basmati varieties 2.73-3.63. He also reported that kernel elongation ratio (ER) in aromatic traditional rice ranged from 1.01-1.42 and basmati rice ranged from 1.02-1.12.

Shahidullah *et al.* (2009b) reported that lower VER is preferred by the consumers than higher VER, on the other hand, higher elongation ratio (ER) of the cooked rice is preferred than lower ER. Hossain *et al.* (2008b) observed that the grain elongation of the tested varieties varied from 1.9-2.1. Maximum volume expansion ratio (4.1) was observed in Kataribhog (Philippines).

Hossain *et al.* (2007) determined the influence of transplanting date on the physical and chemical properties of grain of five local and three modern aromatic rice varieties of Bangladesh and reported that grain elongation and volume expansion ratio were comparatively higher in BRRI dhan34 and BRRI dhan38, respectively.

Singh *et al.* (2000a) reported that lower VER is preferred than higher VER. On the other hand, higher ER is preferred than lower ER for quality of cooked rice. They also reported that volume expansion and amylose content show more genetic variation than other traits.

2.4.5 Cooking time

Danbaba (2011) reported that Ofada rice cooks in excess water after a period ranging from 17 to 24 min, and on the average 20.8 min. The lower the cooking time the better in terms of fuel and energy consumption during cooking.

Islam *et al.* (2008) investigated the influence of spacing on the qualitative characters of aromatic rice and reported that variety had no significant effect on germination, vigour index and cooking time of grain and nitrogen content of straw.

Hossain *et al.* (2008b) reported that the cooking time of the tested varieties varied from 12.0-16.0 minutes. The highest cooking time (16.0 min.) was required for cooking of Kataribhog (Philippines).

Hossain *et al.* (2007) determined the influence of transplanting date on the physical and chemical properties of grain of five local and three modern aromatic rice varieties of Bangladesh and reported that the cooking time of the varieties varied from 11.5 to 19.0

minutes. Cooking time was higher in BRRI dhan37 and BRRI dhan3. Otegbayo *et al.* (2001) reported cooking time of 52 and 56 min in two local rice varieties.

Kumar (1989) reported that some varieties elongate more than others upon hydration and starch gelatinization without increase in girth, this is considered a desirable cooking quality traits in most high-quality rice of the world. Basmati rice of India and Pakistan, Bahra of Afghanistan, Domsiah of Iran, Bashful of Bangladash, and D25-4 from Myanmar are reported to elongate 100% upon cooking, and are considered high quality rice internationally.

Adeyemi *et al.* (1986) and Rhagavendra and Juliano (1970) reported that the cooking times are comparable with the control varieties and falls within the reported value of 10-25min. Juliano *et al.* (1981) reported that rice differ in optimum cooking time in excess water between15 to 25 minutes without pre-soaking.

2.4.6 Protein content

Sarkar *et al.* (2014) evaluated yield and quality of aromatic fine rice as affected by variety and nutrient management and revealed that the highest grain protein content (8.18%) was found in BRRI dhan34 followed by BRRI dhan38 (7.98%) and the lowest one (7.75 %) was observed in BRRI dhan37. Zhu *et al.* (2010) reported that the contents of amylose and protein are two major components influencing the palatability of cooked rice.

Hossain *et al.* (2008b) observed that Grain protein content ranged from 7.1 to 6.5% in brown rice among the tested varieties. Highest protein content (7.1 %) was obtained from Zirabhog that was similar to Badshabhog,Chiniatab and Chinigura.

Islam *et al.* (2008) observed that Kalizira grain contained the highest nitrogen content (1.45%) and protein (8.62%). The lowest nitrogen content (1.43%) and protein (8.50%) were recorded from Badshabhog which was statistical similar to Tulshimala. This result was consistent to Dutta *et al.* (1998), who recorded variable nitrogen content and protein percentage among varieties.

Hossain *et al.* (2007) determined the influence of transplanting date on the physical and chemical properties of grain of five local and three modern aromatic rice varieties of Bangladesh and observed that Protein content of the varieties varied from 6.1% to 7.33% in brown rice. Highest protein content and amylose content have been recorded in Kalizera and in BRRI dhan34, respectively. This result was consistent to Dutta *et al.* (1998) and Alam (2002) recorded variable protein percentage among varieties.

Sagar *et al.* (1988) studied physicochemical characteristics of some aromatic and non-aromatic rice and reported that protein content (PC) ranged from 6.5 to 8.7% and from 6.4 to 8.6% in aromatic and non-aromatic rice, respectively.

Gomez (1979) reported that the protein content from 4.3 to 18.2% in IRRI's world collection and explained that cropping season, management and cultural practices are largely responsible for variations in the level of protein content.

2.5 Organoleptic characteristic

2.5.1 Aroma

Sakthivel *et al.* (2009) reported that aroma is a much-valued quality factor for rice. Various volatile aroma compounds, with 2-acetyl 1-pyrroline being the principal aromatic compound, have been identified in cooked rice grains of varieties originated from diverse regions. Jezussek *et al.* (2002) also supported this.

Islam *et al.* (2008) investigated the influence of spacing on the qualitative characters of aromatic rice and reported that the highest aroma (3.26) was recorded from Kalizira and the lowest aroma (1.28) was recorded from Badshabhog. They explained that Varietals differences regarding aroma might be due to their difference in genetic make-up.

Hossain *et al.* (2008b) observed that the variety Kalizera, Badshabhog contained higher level of aroma among the tested varieties, while, rests of the varieties had moderate type aroma.

Bourgis *et al.* (2008); Kovach *et al.*, (2009) and Hashemi *et al.* (2013) reported that out of several volatile flavour compounds, which contribute to rice aroma, 2- acetyl-1-pyrroline (2-ACP) has been identified as the principal compound for distinctive fragrance in Basmati and Jasmine rice. Sood and Siddiq, 1978 added that the sensory or chemical methods to determine the rice fragrance involve smelling leaf tissue and grains after heating with water or reacting with KOH or I2- KI8 solutions.

Singh *et al.* (1997) reported that in addition to field factors there are other factors like storage conditions, milling and processing methods, cooking methods, parboiling etc. which might influence the aroma. These factors must be standardized to harness maximum aroma from rice.

Dutta *et al.* (1998) reported that aroma varied among the varieties. Varietal differences regarding grain protein content and aroma might be due to their difference in genetic make-up. Juliano and Duff (1991) reported that aroma development is influenced by both genetic and environmental factors

Cruz *et al.* (1989) reported that aroma is best developed when aromatic rice is grown in areas where the weather is cooler during maturity. Efferson (1985) informed that scented or aromatic rice was preferred in some areas of Asia and draws a premium price in certain specialty markets. The Middle East consumers preferred rices with strong aroma.

Buttery et al. (1982) isolated and identified 2-acetyl-l-pyrroline as an important compound contributing to the aromatic odor. They suggested that 2-acetyl-l-pyrroline was a major contributor to the popcorn-like aroma in several of the Asian aromatic rice varieties.

Buttery *et al.* (1983a) determined the concentration for 10 varieties of rices. The range of concentration was from 6 ppb to 90 ppb with the milled rice. They found that the unmilled rice (brown rice) had concentrations of 2-acetyl-pyrroline from 100 ppb to 200 ppb. They explained that the surface layer constituents of rice grain play an important role in the formation of cooked rice aroma. An odor threshold of 2-acetyl-1 pyrroline was determined using a trained panel of 16 judges. The panel could consistently detect 7 ppb. The threshold level appeared to be 0.1 ppb. It is amazing that the human nose can detect such low levels. The result would suggest that it takes very little 2-acetyl-1-pyrroline to contribute to the odor of aromatic rice.

Buttery *et al.* (1983b) analysed Pandan leaves and found that the major volatile component was 2-acetyl-1- pyrroline. They found a high correlation between the 2-acetyl-l-pyrroline in Pandan leaves and aromatic rice. The concentration of 2-acetyl-1- pyrroline in Pandan leaves was 10 times greater than aromatic rice and 100 times greater than non-aromatic rice. The concentration of 2-acetyl-1- pyrroline was lower in aged aromatic rice. Aromatic rice had 15 times more 2-acetyl-1-pyrroline than non-aromatic rice.

Kadam and Patanker (1938) reported that the scent aroma is due to presence of large number of compounds in endosperm in specific proportion. The biochemical basis of aroma was identified as 2-acetyl-1-pyrroline.

So, this research review's purpose is to help the reader understand variation growth, yield and quality parameters' pattern of different aromatic rice genotypes posed by research in rice growing countries. The study of past forty years revealed that world has been evaluating local, modern and hybrid aromatic rice germplasms. In Bangladesh, most of the research were on mostly used local aromatic rice germplasm. But our country has 8000 rice germplasm as a secondary center of diversity of the genus Oryza. So, it is important to collect the untapped germplasm and conduct more studies to explore aromatic rice germplasm.

CHAPTER 3

MATERIALS AND METHODS

The experiment was conducted at the Agronomy Field, Sher-e-Bangla Agricultural University, Dhaka-1207 during the period from July 2016 to December 2016.

3.1 Site description

3.1.1 Geographical location

The experimental area was situated at 23°77′N latitude and 90°33′E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004).

3.1.2 Agro-ecological region

The experimental field belongs to the Agro-ecological zone of “The Modhupur Tract”, AEZ-28 (Anon., 1988). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain (Anon., 1988b). The experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.1.3 Climate

The area has sub-tropical climate, characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in Kharif season (April-September) and scanty rainfall associated with moderately low temperature during the October-December.

3.1.4 Soil

The soil of the experimental site 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. Soil pH ranged from 5.6 and had organic matter 0.78% (Appendix II). The experimental area was flat having available irrigation and drainage system and above flood level.

3.2 Details of the experiment

3.2.1 Treatments

Single factor experiment was conducted to screened aromatic Aman rice genotypes.

Treatments included in the experiment were as follows:

I.	SAU ADL1	II.	SAU ADL2
III.	SAU ADL3	IV.	SAU ADL4
V.	SAU ADL5	VI.	SAU ADL6
VII.	SAU ADL7	VIII.	SAU ADL8
IX.	SAU ADL9	X.	SAU ADL10
XI.	SAU ADL11	XII.	SAU ADL12
XIII.	Katraibhog	XIV.	BRRI dhan66

3.2.2 Experimental design

The experiment was laid out in a RCB design with three replications. There were fourteen treatments. The total numbers of unit plots were 42. The size of unit plot was 3.0 m by 2.0 m. The distances between plot to plot and replication to replication were 0.50 m and 1.0 m, respectively. The layout of the experiment has been shown in Appendix III.

3.3 Planting material

Twelve local aromatic rice cultivars along with Kataribhog and BRRI dhan66 were used as planting material.

3.3.1 Description of BRRI dhan66

BRRI dhan66, a high yielding variety of Aman season was developed by the Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur, Bangladesh and was released in 2014. It takes about 110 to 115 days to mature. It attains at a plant height of 118-120 cm. 1000-grains weight of about 24 g. The cultivar gives an average grain yield of 4.5-5.0 t ha^{-1}. It is resistant to drought.

3.3.2 Description of Kataribhog

Kataribhog is a local cultivar of aromatic rice grown in Aman season. It is a tall stature, photosensitive cultivar and lodged with higher management package. It takes around 140 days to mature. It is considered as a low yield potential aromatic cultivar.

3.4 Crop management

3.4.1 Seedling raising

3.4.1.1 Seed collection

Seeds of a local aromatic Aman rice genotype was collected from an NGO named Suranjana from where other specific lines were selected from the lot through various field observation by the Agronomy department of Sher-e-Bangla Agricultural University. The selected materials were named as SAU ADL (Sher-e- Bangla Agricultural University Agronomy Department Line) having chronological numerical as SAU ADL1, SAU ADL2…. etc. Kataribhog from market and BRRI dhan66 was collected from Bangladesh Rice Research Institute, Gazipur.

3.4.1.2 Seed sprouting

Seeds were selected by following specific gravity method. Seeds were immersed into water in a bucket for 24 hours. These were then taken out of water and kept tightly in gunny bags. The seeds started sprouting after 48 hours which were suitable for sowing in 72 hours.

3.4.1.3 Preparation of seedling nursery

A common procedure was followed in raising seedlings in the seedbed. The seedbed was prepared by puddling with repeated ploughing followed by laddering. Weeds were removed and irrigation was gently provided to the bed as and when necessary. No fertilizer was used in the nursery bed.

3.4.1.4 Seed sowing

Sprouted seeds were sown on the seedbed on 11th July 2016 for raising nursery seedlings. The sprouted seeds were sown as uniformly as possible.

3.4.2 Preparation of experimental land

The experimental field was first ploughed on 26th July 2016 with the help of a tractor drawn disc plough, later on 8th August 2016 the land was irrigated and prepared by three successive ploughings and cross ploughings with a tractor drawn plough and subsequently leveled by laddering. All weeds and other plant residues of previous crop was removed from the field. Immediately after final land preparation, the field layout was made on 9th August 2016 according to experimental specification. Individual plots were cleaned and finally leveled with the help of wooden plank so that no water pocket could remain in the puddled field.

3.4.3 Fertilizer application

The experimental area was fertilized with 120, 80, 80 and 20 kg ha^{-1} of N, P_2O_5, K_2O and S applied in the form of urea, triple super phosphate (TSP), muriate of potash (MP) and gypsum respectively. The entire amounts of triple super phosphate, muriate of potash and gypsum were applied as basal dose at final land preparation. Urea was top-dressed in three equal installments, after seedling recovery, during the vegetation stage and at 7 days before panicle initiation.

3.4.4 Transplanting of seedlings

For nursery seedlings 30 days old seedlings were uprooted carefully on 9th August, 2016 and were kept in soft mud in shade**.** The seedbeds were made wet by application of water in previous day before uprooting the seedlings to minimize mechanical injury of roots. Seedlings were then transplanted with 25 cm × 15 cm spacing on the well-puddled plots. In each plot, there were 8 rows, each row contains 20 hills of rice seedlings.

3.4.5 Intercultural operations

3.4.5.1 Weeding

The crop was infested with some weeds during the early stage of crop establishment. Three hand weeding were done for every method, first weeding was done at 10 days after transplanting followed by second weeding at 15 days after first weeding. Third weeding was done 15 days after second weeding.

3.4.5.2 Application of irrigation water

Irrigation water was added to each plot as and when necessary. All the plots were kept irrigated and dried 7 days before harvesting.

3.4.5.3 Plant protection measures

Plants were infested with rice stem borer (*Scirphophaga incertolus*) and leaf hopper (*Nephotettix nigropictus*) to some extent which were successfully controlled by applying Diazinon @ 10 ml/10 liter of water for 5 decimal lands on 3rd September and by Ripcord @ 10 ml/10 liter of water on 15th September and 10th October 2016. Crop was protected from birds and rats during the grain filling period. Field trap and foxtoxin poisonous bait was used to control the rat. For controlling the birds watching was done properly, especially during morning and afternoon.

3.5 Harvesting and post-harvest operation

The rice plant was harvested depending upon the maturity of plant. Harvesting was done manually from each plot. Harvesting was started at 106 days and continued up to 138 days. Maturity of crop was determined when 80% of the grains become matured. Twelve pre-selected hills per plot from which different data were collected and 1m^2 areas from middle portion of each plot was separately harvested and bundled, properly tagged and then brought to the threshing floor for recording grain and straw yield. Threshing was done using pedal thresher. The grains were cleaned and sun dried to a moisture content of 12%. Straw was also sun dried properly. Finally grain and straw yields plot^{-1} were determined and converted to ton ha^{-1}.

3.6 Recording of data

Experimental data were determined from 25 days of growth duration and continued until harvest. The followings data were determined during the experiment.

A. Crop growth characters

i. Plant height (cm) at 25 days interval and at harvest

ii. Number of tillers hill^{-1} at 25 days interval and at harvest

iii. Leaf area index at 25 days interval and at harvest

iv. Days to 50% flowering and maturity

v. SPAD value at 50 DAT

B. Yield and other crop characters

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

ii. Number of noneffective tillers hill^{-1}

iii. Length of panicle (cm)

iv. Number of primary branches of panicle

v. Flag leaf length (cm)

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

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

viii. Number of total grains panicle^{-1}

ix. Sterility percentage

x. Weight of 1000-grains

xi. Grain yield

xii. Straw yield

xiii. Biological yield

xiv. Harvest index

C. Grain quality characteristics

xv. Hulling percentage

xvi. Milling recovery

xvii. Milling degree

xviii. Head rice recovery

xix. Broken rice

xx. Kernel length and breadth

xxi. Kernel length and breadth ratio

xxii. Kernel length after cooking

xxiii. Elongation ratio

xxiv. Protein and moisture percentage

xxv. Aroma

3.7 Detailed procedures of recording data

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

A. Crop growth characters

i. Plant height (cm)

Plant height was measured at transplanting, 25, 50, 75 DAT and at harvest. The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf height before heading, and to the tip of panicle after heading.

ii. Number of tillers hill^{-1}

Number of tillers hill^{-1} were counted at 25, 50 DAT and at harvest from ten randomly pre-selected hills and was expressed as number hill^{-1}. Only those tillers having three or more leaves were used for counting.

iii. Leaf area index (LAI)

Leaf area index were estimated measuring the length and average breadth of leaf (at 25, 50 DAT and at harvest) and multiplying by a factor of 0.75 followed by Yoshida (1981).

iv. Time of flowering

Time of flowering (days) was recorded when about 50% of the panicle within a plot emerged.

v. SPAD Chlorophyll Meter Reading at 50 DAT

The SPAD-502 chlorophyll meter (Minolta Camera Co., Japan) is a simple, portable, diagnostic and nondestructive light weight device used to estimate leaf chlorophyll content (Minolta, 1989). The computed values by this device represents the whole content of chlorophyll (a, b) in plant, (Feibo *et al.*, 1998; Ichie *et al.*, 2002; Ramesh *et al.*, 2002). Ten plants per treatment were selected randomly and SPAD values at 50 DAT were recorded from the fully matured leaves counted from the top of the plants, the youngest fully expanded leaf.

B. Yield and other crop characters

i. Effective tillers m^{-2}

The panicles which had at least one grain was considered as effective tillers. The number of effective tillers of 10 hills was recorded and expressed as effective tillers number m^{-2}.

ii. Ineffective tiller m^{-2}

The tillers having no panicle was regarded as ineffective tillers. The number of ineffective tillers of 10 hills was recorded and was expressed as ineffective tiller number m^{-2}.

iii. Panicle length

Measurement of panicle length was taken from basal node of the rachis to apex of each panicle. Each observation was an average of 10 panicles.

iv. Primary branches of panicle

Primary branches of 10 panicles were recorded and averaged for per treatment.

v. Flag leaf length

Flag leaf length was measured at harvest from 12 hills and averaged for per treatment.

vi. Filled grains panicle^{-1}

Grain was considered to be filled if any kernel was present there in. The number of total filled grain present on 10 panicles were recorded and finally averaged.

vii. Unfilled grains panicle^{-1}

Unfilled grain means the absence of any kernel inside in and such grain present on each of 10 panicles were counted and finally averaged.

viii. Total grains panicle^{-1}

The number of filled panicle^{-1} plus the number of unfilled grains panicle^{-1} gave the total number of grains panicle^{-1}.

ix. Sterility percentage

At the harvesting, 10 panicles were harvested at maturity from five randomly chosen plants in each of the hybrids and the no. of filled, unfilled and total grain was counted. Spikelets fertility percentage was then computed as

$$\text{Sterility percentage} = \frac{\text{No.of unfilled grains in the panicle}}{\text{Total no.of grains in the panicle}} \times 100$$

x. Weight of 1000-grains

One thousand cleaned dried seeds were counted randomly from each sample and weighed by using a digital electric balance at the stage the grain retained 14% moisture and the mean weight were expressed in gram.

xi. Grain yield

Grain yield was determined from the central 1 m^2 area of each plot and expressed as t ha^{-1} and adjusted with 12% moisture basis. Grain moisture content was measured by using a digital moisture tester.

xii. straw yield

Straw yield was determined from the central 1 m^2 area of each plot. After separating of grains, the sub-samples were sun dried to a constant weight and finally converted to t ha^{-1}.

xiii. Biological yield

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

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

xiv. Harvest index

It denotes the ratio of economic yield (grain yield) to biological yield and was calculated with following formula (Donald, 1963; Gardner *et al.*, 1985).

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

C. Grain quality characteristics

i. Hulling percentage

One-hundred-gram sample of dried (12% moisture) paddy grain samples i. e. rough rices were dehulled in a Satake laboratory sheller. Moisture was determined by grain analyzer. The sample was poured into the hopper. Samples with many partially filled grains of reduced thickness, usually require two passes (Cruz and Khush, 2000) and the weight of the dehusked kernels were recorded. Hulling percentage was computed as:

$$\text{Hulling percentage (HP)} = \frac{\text{Weight of dehusked kernel}}{\text{weight of paddy}} \text{ x } 100$$

ii. Milling recovery or milling percentage or total milled rice percentage

The dehulled brown rice sample was poured into the hopper. Then the resulting brown rice was milled in McGill mill number 2 (Adair, 1952). Milling out turn was calculated with the following formula (Khush *et al.*, 1979).

Milling recovery was computd by dividing the weight of milled rice recovered by the weight of the rough rice i.e. paddy sample.

$$\text{Total milled rice (\%)} = \frac{\text{Weight of milled rice}}{\text{Weight of rough rice}} \text{ X } 100$$

iii. Milling degree

According to Rice Knowledge Bank (http://www.knowledgebank.irri.org) milling degree is computed on the basis of the amount of bran removed from the brown rice. To obtain the weight of brown rice, using laboratory huller the paddy samples were dehulled. Then using an abrasive whitener, dehulled samples were milled. The milling degree was computed using the following equation:

$$\text{Milling degree} = \frac{\text{Weight of milled rice}}{\text{Weight of brown rice}} \text{ X } 100$$

iv. Head rice recovery and percent broken rice

According to Rice Knowledge Bank (http://www.knowledgebank.irri.org) using a grain grader, separate the broken grains from the whole grains. Compute the percentage of the milling recovery component using the following equation:

$$\text{Head rice recovery} = \frac{\text{Weight of head rice}}{\text{Weight of paddy sample}} \text{ X } 100$$

$$\text{Percent broken rice} = \frac{\text{Weight of broken grains}}{\text{Weight of paddy sample}} \text{ X } 100$$

v. Grain Classification

Ten de-husked entire brown rice grains were measured using digital slide calipers and based on the L/B ratio, size and shape was classified according to the method described by Cruz and Khush (2000) and IRRI standards.

Size classification:

Scale	Size category	Length in mm
1	Very long	More than 7.50
3	Long	6.61 to 7.50
5	Medium or intermediate	5.51 to 6.60
7	Short	Less than or equal to 5.50

Shape classification:

Scale	Shape	L/B ratio
1	Slender	Over 3.0
5	Medium	2.1 to 3.0
9	Bold	2.0 or less than 2.0

vii. Elongation ratio

Each sample was cooked in a water bath at 98°C for 10 min (Azeez and Shafi, 1966). The cooked rice was then transferred to a petridish lined with filter paper. Ten cooked whole rice were measured by a digital verneer caliper.

$$ER = \frac{\text{Average length of cooked rice grains (mm)}}{\text{Average length of raw rice grains (mm)}}$$

viii. Cooking time

Cooking time was estimated in the method described by Juliano *et al.* (1969). Five grams of whole milled rice were kept in vigorously boiling water in a beaker. After 10 min of boiling, sample was tested every minute with pressing between two glass plates. The grains were considered cooked when 90% of the grains no longer had opaque or uncooked center.

ix. Kernel length after cooking

Kernel length after cooking **(**KLAC) was measured by the method of Juliano *et al.* (1966).

x. Protein and moisture content

Protein and moisture content was measured by Grain Analyzer Infratec™ 1241.

xi. Aroma

A simple laboratory technique to evaluate rices for presence of aroma was developed at IRRI (1971). One gram of freshly harvested milled rice was placed into centrifuge tube (50 ml round bottom). About 20 ml distilled water was added. The tubes are then covered with aluminum foil. The samples are placed in a boiling water bath for 10 minutes. The cooked samples were allowed to cool and the presence of aroma was determined for every sample. The samples are scored as strongly aromatic, moderately aromatic, slightly aromatic and non-aromatic. A strongly scented variety is used as check for comparison.

3.8 Statistical analysis

All the collected data were analyzed following the analysis of variance (ANOVA) technique using CROPSTAT package and the mean differences were adjudged by LSD technique (Gomez and Gomez, 1984).

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Growth parameters

4.1.1 Plant height (cm)

The plant height of aromatic rice genotypes was significantly influenced by different genotypes at transplanting, 30 and 50 days after transplanting (DAT) and at harvest (Appendix IV and Table 1).

At transplanting, the genotype SAU ADL12 produced the tallest plant (38.93 cm) which is statistically similar with SAU ADL7, SAU ADL3, SAU ADL9, SAU ADL5, SAU ADL6, SAU ADL10 (38.10cm, 37.97 cm, 37.95 cm, 37.87 cm, 37.54 cm and 36.57 cm respectively) and the modern variety BRRI dhan66 gave the shortest plant height (19.07 cm) and that was statistically similar with SAU ADL11 (19.50 cm).

At 25 DAT, SAU ADL10 produced the tallest plant (77.95 cm) and SAU ADL11 gave the shortest plant (38.02 cm) and that was statistically similar with the modern variety BRRI dhan66 (41.38 cm).

At 50 DAT, SAU ADL10 produced the tallest plant (133.63 cm). Local genotype SAU ADL7 (70.91 cm) gave the shortest plant height (38.02 cm) and that was statistically similar with SAU ADL4 (71.75 cm). Modern variety BRRI dhan66 produced the plant of 96.25 cm. At 75 DAT, similar pattern of plant height observed as 50 DAT.

At harvest, SAU ADL10 produced the tallest plant (219.08 cm) and the modern variety BRRI dhan66 gave the shortest plant height (101.00 cm) and that was statistically similar with the SAU ADL11 (107.09 cm). The second shortest plant was produced by SAU ADL4 (111.68 cm) which was statistically similar with SAU ADL5 (111.89 cm). Local aromatic germplasm SAU ADL10 found to be 116.91% taller at harvest than modern variety. Long stature of plant is responsible for lodging. Hossain *et al.* (2008a) also observed lodging of local aromatic rice varieties at maturity stage due to higher plant height during evaluation of the yield and quality performance of some aromatic rice varieties of Bangladesh. But some local genotypes showed no lodging criteria and SAU ADL11 produced short stature plant at harvest as modern variety BRRI dhan66. The aromatic rice genotype SAU ADL11 was 56.10% shorter compared to widely cultivated aromatic rice Kataribhog.

Variation in plant height might be due to the differences in their genetic make-up. Similar result was reported by Shamsuddin *et al.* (1988), Hossain *et al.* (1991) and Khatun (2001) who also observed variable plant heights among the varieties.

Table 1. Plant height of local aromatic Aman rice genotypes, Kataribhog and BRRI dhan66 at different crop growth stages

Treatments	Plant height (cm) at				
	Transplanting	25 DAT	50 DAT	75 DAT	Harvest
SAU ADL1	29.93 b	49.19 de	81.34 f	106.00 e	124.16 e
SAU ADL2	28.5 b	55.81 bc	99.29 de	126.95 d	159.57 d
SAU ADL3	37.97 a	59.82 b	103.63d	140.26 c	173.26 c
SAU ADL4	30.63 b	47.98 ef	71.75 hi	91.5 gh	111.68 fg
SAU ADL5	37.87 a	54.27 cd	81.28 f	97.45 fg	111.89 fg
SAU ADL6	37.54 a	55.45 bc	100.64 de	133.71 c	166.14 cd
SAU ADL7	38.1 a	47.70 ef	70.91 i	83.31 i	119.56 ef
SAU ADL8	28.33 b	44.30 fg	76.01 gh	86.57 h	119.73 ef
SAU ADL9	37.95a	58.78 bc	114.33 c	149.27 b	194.72 b
SAU ADL10	36.57 a	77.95 a	133.63 a	168.83 a	219.08 a
SAU ADL11	19.5 c	38.02 h	76.92 fg	96.63 fg	107.09 gh
SAU ADL12	38.93 a	59.15 b	121.00 b	165.79 a	202.25 b
Kataribhog	28.57b	41.38 b	102.36 d	129.73 d	167.17 cd
BRRI dhan66	19.07 c	58.99 gh	96.25 e	102.02 ef	101.00 h
LSD $_{(0.05)}$	4.040	4.650	4.570	7.250	8.390
CV (%)	7.49	5.18	2.87	3.61	3.37

4.1.2 Number of total tillers hill^{-1}

Rice genotypes varied for growth and number of tillers throughout the life span. Total number of tillers hill^{-1} varied significantly among local aromatic Aman rice genotypes, kataribhog and modern variety BRRI dhan66 at 25, 50 DAT and at harvest (Appendix V and Table 2). Variable effect of variety on number of total tillers hill^{-1} was also reported by Roy *et al.* (2014) and BINA (1998) who noticed that number of total tillers hill^{-1} differed among the varieties. Shahidullah *et al.* (2009a) reported that tillering patterns in aromatic rice genotypes exhibited wide range of variations without showing any major influence on grain yield.

At 25 DAT, the maximum tiller numbers hill^{-1} was observed in the local aromatic rice genotype SAU ADL4 (9.42) that was statistically similar with SAU ADL1, SAU ADL2, SAU ADL7, SAU ADL9, SAU ADL5 SAU ADL10, SAU ADL11, SAU ADL8 and SAU ADL3 and the minimum tiller numbers hill^{-1} was obtained from SAU ADL12 and that was statistically similar with SAU ADL6, BRRI dhan66 and Kataribhog.

At 50 DAT, the maximum tiller numbers hill^{-1} was observed in the local aromatic rice genotype SAU ADL10 (21.92) which was statistically similar with SAU ADL11, Kataribhog, SAU ADL7 and the minimum tiller numbers hill^{-1} was obtained from SAU ADL12 and that was statistically similar with, BRRI dhan66, SAU ADL8 and SAU ADL6.

At harvest, the maximum tiller numbers hill^{-1} was observed in the local aromatic rice genotype SAU ADL10 (18.75). The second highest tillers hill^{-1} was in SAU ADL1 (15.36) which was statistically similar with Kataribhog, SAU ADL3, SAU ADL6, SAU ADL4, BRRI dhan66, SAU ADL11, SAU ADL8 and SAU ADL7. The minimum tiller numbers hill^{-1} was obtained from SAU ADL12. This result was in consistent to Sumon (2015) who reported highest number of tillers hill^{-1} in BRRI dhan34 (16.04) at harvest and this was statistically similar with Kataribhog. But Hossain *et al.* (2005) observed the lowest number of total tillers hill^{-1} in Kalizira (9.8) which was statistically similar to Katarivbhog at harvest.

Result revealed that there was no statistical difference among local aromatic rice genotypes SAU ADL1, SAU ADL11, SAU ADL3 and check modern variety BRRI dhan66, widely cultivated aromatic rice variety Kataribhog in producing maximum tiller hill^{-1} at harvest. The variation in number of total tillers hill^{-1} as assessed might be due to varietal character. Similar result was also reported by Jisan *et al.* (2014).

Table 2. Total tillers hill^{-1} of local aromatic Aman rice genotypes, Kataribhog and BRRI dhan66 at different crop growth stages

Treatments	Total tillers hill^{-1} (no) at		
	25 DAT	**50 DAT**	**Harvest**
SAU ADL1	8.86 ab	15.83 cd	15.36 b
SAU ADL2	8.75 a-c	16.83 b-d	11.83 cd
SAU ADL3	7.25 a-d	15.00 cd	14.5 bc
SAU ADL4	9.42 a	16.67 b-d	14.00 bc
SAU ADL5	8.00 a-d	15.61 cd	10.67 d
SAU ADL6	5.75 de	14.42 de	14.50 bc
SAU ADL7	8.58 a-c	18.67 a-c	12.66 b-d
SAU ADL8	7.33 a-d	13.78 de	13.17 b-d
SAU ADL9	8.5 a-c	14.92 cd	11.83 cd
SAU ADL10	7.67 a-d	21.92 a	18.75 a
SAU ADL11	7.42 a-d	21.3 a	13.33 b-d
SAU ADL12	4.42 e	10.5 e	6.58 e
Kataribhog	6.75 b-e	20.67 ab	15.00 bc
BRRI dhan66	6.33 c-e	13.33 de	13.42 b-d
$LSD_{0.05}$	2.427	4.123	3.233
CV%	19.28	14.99	14.53

4.1.3 Leaf area index (LAI)

The leaf area of plant is one of the major determinants of its growth. It is the ratio of leaf area to its ground area (Radford, 1967) and it is the functional size of the standing crop on unit land area (Hunt, 1978). It depends on the growth, number of leaves plant^{-1}, population density and leaf senescence (Khan, 1981). The higher productivity of a crop depends on the persistence of high LAI over a greater part of its vegetative phase. The rate of crop photosynthesis depends on the LAI. After germination LAI increases and reaches the peak levels after that it declines due to increased senescence

The significant difference of LAI was observed among local aromatic Aman rice genotypes, kataribhog and modern variety BRRI dhan66 at 25, 50 DAT and at harvest (Appendix VI and Table 3). This study also confirmed by the results of Shahidullah *et al.* (2009a) who stated that different aromatic rice genotypes exhibited significant variations for leaf area index (LAI).

At 25 DAT, the highest leaf area index (LAI) was observed in the local aromatic rice genotype SAU ADL9 (1.12) and this was statistically similar with SAU ADL10, SAU ADL2, SAU ADL4, SAU ADL1, SAU ADL8 and the lowest leaf area index (LAI) was obtained from modern variety BRRI dhan66 (0.43).

At 50 DAT, the highest leaf area index (LAI) was obtained from the local aromatic rice genotype SAU ADL10 (8.30). The second highest leaf area index (LAI) was obtained from SAU ADL9 (6.57) which was statistically similar with SAU ADL2, SAU ADL1 and SAU ADL11 and the lowest leaf area index (LAI) was obtained from SAU ADL8 (3.79) and this was statistically similar with BRRI dhan66 and Kataribhog. This might be due to the production of comparatively higher tillers by local aromatic rice genotypes as modern variety. Mia and Shamsuddin (2011) also found lowest LAI in Kataribhog.

At harvest the highest leaf area index (LAI) was observed in the local aromatic rice genotype SAU ADL10 (2.45) which was statistically similar with SAU ADL11, SAU ADL9, BRRI dhan66, SAU ADL2 and SAU ADL3. The lowest leaf area index was obtained from SAU ADL12 (1.25) and this was statistically similar to Kataribhog.

Results revealed that leaf area index (LAI) increased after transplantation and it decreases at harvest due to senescence which was also reported by Katiya (1980).

Table 3. LAI of local aromatic Aman rice genotypes, Kataribhog and BRRI dhan66 at different crop growth stages

Treatments	Leaf area index at		
	25 DAT	50 DAT	Harvest
SAU ADL1	0.93 a-c	5.71 b-d	1.58 cd
SAU ADL2	0.99 a-c	6.2 bc	2.07 ab
SAU ADL3	0.62 c-e	4.65 c-f	2.02 a-c
SAU ADL4	0.94 a-c	4.90 c-f	1.74 b-d
SAU ADL5	0.83 a-d	5.10 b-f	1.80 b-d
SAU ADL6	0.53 de	4.17 d-f	1.38 d
SAU ADL7	0.72 b-e	3.90 ef	1.34 d
SAU ADL8	0.79 a-e	3.79 f	1.51 d
SAU ADL9	1.12 a	6.57 b	2.12 ab
SAU ADL10	1.04 ab	8.30 a	2.45 a
SAU ADL11	0.67 b-e	5.52 b-e	2.15 ab
SAU ADL12	0.45 de	3.96 ef	1.25 d
kataribhog	0.69 b-e	4.40 ef	1.37 d
BRRI dhan66	0.43 e	4.68 c-f	2.08 ab
$LSD_{(0.05)}$	0.330	1.650	0.460
CV (%)	25.45	19.20	15.28

4.1.4 SPAD value

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).

Significant difference was observed for SPAD values at grain filling stage among local aromatic Aman rice genotypes, kataribhog and modern variety BRRI dhan66 (Appendix VII and Table 4). Maximum SPAD values were recorded for SAU ADL8 (47.29) which was statistically similar with SAU ADL1. The minimum SPAD value was obtained from SAU ADL10 (38.49) which was statistically similar with SAU ADL9, SAU ADL2, SAU ADL3, SAU ADL5 and SAU ADL7. Difference in the SPAD value in the genotypes might be due to their genetic make-up. This result was in agreement with Mian *et al.* (2009) who also found significant differences among the genotypes for SPAD values.

Munshi (2005) reported that grain yield was positively correlated with chlorophyll content and showed that high yielding genotypes also showed higher chlorophyll content in rice genotypes.

Table 4. SPAD Chlorophyll Meter Reading (SCMR) of local aromatic Aman rice genotypes, Kataribhog and BRRI dhan66 at grain filling stage

Treatments	SPAD value
SAU ADL1	45.14 ab
SAU ADL2	38.96 g
SAU ADL3	39.45 fg
SAU ADL4	44.29 bc
SAU ADL5	39.52 fg
SAU ADL6	43.52 b-d
SAU ADL7	40.77 e-g
SAU ADL8	47.29 a
SAU ADL9	38.58 g
SAU ADL10	38.49 g
SAU ADL11	44.55 bc
SAU ADL12	42.51 c-e
kataribhog	44.37 bc
BRRI dhan66	41.77 d-f
$LSD_{(0.05)}$	2.440
CV (%)	3.46

4.1.5 Days to 50% flowering and maturity

Days to flowering and maturity had positive and higher indirect effect on grain yield through grains panicle^{-1} (Iftekharuddaula *et al.,* 2001) Days to 50% flowering was the principal character responsible for grain yield plant^{-1} followed by 1000-grain weight, plant height and harvest index as they had positive and significant association with yield (Sathya *et al.*,1999).

The significant difference was observed for days to 50% flowering (Appendix VII and Table 5). The SAU ADL12 needed longest time for flowering (104.33 days) which was statistically similar with SAU ADL9 and SAU ADL1. The SAU ADL12 needed longest time for maturity (139.67 days) which was statistically similar with SAU ADL11, SAU ADL10, SAU ADL6 and SAU ADL7. On the other hand, BRRI dhan66 needed shortest time (71.33 days) for flowering and maturity (106.67 days). Widely cultivated aromatic rice Kataribhog need 97.33 days for flowering and 131.67 days for maturity. But Ashrafuzzaman *et al.* (2009) observed that Kataribhog needed (82.33 days) for 50% flowering and 105.30 days for maturity.

So, modern variety BRRI dhan66 matured 25 days earlier than Kataribhog. Kataribhog matured 6 days earlier than our local aromatic Aman rice genotypes. This variation might be due to the genotypic variation of screened genotypes. This was supported by (Karim *et al.*, 2007) who attributed this to the genetic constitution rather than environment. Whereas Shahidullah *et al.* (2009a) concluded that all phenological characters were found to vary in a wide range depending on rice genotypes as well as micro and macro environments.

Table 5. Flowering (50%) and maturity duration of local aromatic Aman rice genotypes, Kataribhog and BRRI dhan66

Treatments	Days to flowering	Days to maturity
SAU ADL1	101.00 a-c	134.67 bc
SAU ADL2	94.67 ef	125.33 d
SAU ADL3	92.337 f	126.33 d
SAU ADL4	97.67 c-e	131.33 c
SAU ADL5	98.00 c-e	131.33 c
SAU ADL6	98.33 cd	135.00 a-c
SAU ADL7	100.00 b-d	135.00 a-c
SAU ADL8	100.33 b-d	134.67 bc
SAU ADL9	102.33 ab	133.00 bc
SAU ADL10	100.00 b-d	135.33 a-c
SAU ADL11	99.33 b-d	137.00 ab
SAU ADL12	104.33 a	139.67 a
kataqribhog	97.33 de	131.67 c
BRRI dhan66	71.33 g	106.67 e
$LSD_{(0.05)}$	3.620	4.970
CV (%)	2.26	2.23

4.2 Yield and yield contributing characters

4.2.1 Number of effective and ineffective tillers m^{-2}

The number of panicles is the result of the number of tillers produced and the proportion of effective tillers, which survived to produce panicle, thereby contributing to the yield. Higher number of effective tillers per hill and higher number of grains per panicle also showed higher grain yield in rice (Kusutani *et al.*, 2000)

There was significant difference among the aromatic rice genotypes and BRRI dhan66 for number of effective tillers per square meter (Appendix VII and Table 6) and it was found that maximum effective tiller (446.72) were recorded for the genotype SAU ADL10 which was statistically similar with Kataribhog (346.71). Kataribhog also produced second highest tillers m^{-2} which was statistically similar with SAU ADL3, SAU ADL7, SAU ADL11, SAU ADL5 and BRRI dhan66. On the other hand, least effective tillers m^{-2} were recorded in SAU ADL12 (142.240) which was statistically similar with SAU ADL6 (204.487).

The reason of difference in effective tillers $hill^{-1}$ might be the genetic makeup of the variety. The results were in agreement with those reported by Chowdhury *et al.* (1993) and Islam *et al.* (2013a) who stated that effective tillers $hill^{-1}$ is the genetic makeup of the variety which is primarily influenced by heredity.

Ineffective tillers m^{-2} significantly varied among the rice genotypes (Table 6). The highest ineffective tillers m^{-2} (129.65) was found in SAU ADL1 followed by SAU ADL8 and lowest ineffective tillers m^{-2} (26.67) was recorded from SAU ADL7.

Table 6. Effective and ineffective tillers $m^{-2}$of local aromatic Aman rice, Kataribhog and BRRI dhan66

Treatment	Effective tillers (no. m^{-2})	Ineffective tillers (no. m^{-2})
SAU ADL1	320.77 bc	129.65 a
SAU ADL2	280.03 b-d	28.89 d
SAU ADL3	344.49 bc	28.89 d
SAU ADL4	335.60 bc	37.78 d
SAU ADL5	257.81 b-d	26.67 d
SAU ADL6	204.49 de	82.23 bc
SAU ADL7	311.15 bc	26.67 d
SAU ADL8	244.48 cd	106.68 ab
SAU ADL9	273.37 b-d	48.90 cd
SAU ADL10	446.72 a	53.34 cd
SAU ADL11	295.59 b-d	60.01 cd
SAU ADL12	142.24 e	33.34 d
kataqribhog	346.71 ab	46.67 cd
BRRI dhan66	275.59 b-d	82.23 bc
LSD $_{(0.05)}$	100.246	35.798
CV (%)	20.50	37.70

4.2.2 Panicle length

The panicle length had a positive effect on yield. Panicle size had the most consistent and closest positive correlation with grain yield (Laza *et al.*, 2004).

The data on the panicle length revealed that it varied significantly among the aromatic rice genotypes (Appendix VII and Table 7). Maximum panicle length of 32.63 cm was recorded in genotype SAU ADL10 and minimum panicle length of 24.74 cm of was recorded in modern variety BRRI dhan66. SAU ADL10 showed almost 32% longer panicle compared to modern variety BRRI dhan66.

Such variations might be due to the genetic make-up of the varieties. Similar result was recorded by Babiker (1986) who explained that panicle length differed due to the varietal variation. Similar results were also reported by Singh and Singh (2000), Sharma (2002) and Ashrafuzzaman *et al*. (2009).

Table 7. Panicle length. primary branches panicle^{-1} and flag leaf length of local aromatic Aman rice, Kataribhog and BRRI dhan66

Treatments	Panicle length (cm)	Primary branches panicle^{-1}	Flag leaf length (cm)
SAU ADL1	26.79 f	13.67 ab	34.49 de
SAU ADL2	26.95 f	12.47 cd	34.78 de
SAU ADL3	30.67 b	13.40 a-c	38.78 b-d
SAU ADL4	27.33 ef	13.80 ab	36.14 c-e
SAU ADL5	28.27 de	14.07 a	32.03 e
SAU ADL6	29.62 bc	11.80 d	40.29 bc
SAU ADL7	26.33 f	14.20 a	36.47 c-e
SAU ADL8	29.33 cd	13.80 ab	34.77 de
SAU ADL9	30.75 b	13.47 ab	46.82 a
SAU ADL10	32.63 a	14.00 a	43.29 ab
SAU ADL11	26.39 f	11.73 d	36.54 c-e
SAU ADL12	29.59 bc	13.87 ab	45.13 a
kataribhog	27.47 ef	10.00 e	37.98 cd
BRRI dhan66	24.74 g	13.00 e	33.33de
LSD $_{(0.05)}$	1.310	0.930	4.770
CV (%)	2.76	4.23	7.47

4.2.3 Primary branches panicle^{-1}

Rachis branching system i.e. primary and secondary branching is one of the important factors for determining yield. Yamagishi *et al*. (2003) found high yielding variety to have a relatively large number of primary rachis-branches as compared with the secondary rachis-branches.

Number of primary branches panicle^{-1} showed significant difference among the screened genotypes (Appendix VII and Table 7). The highest number of primary branches panicle^{-1} was found in SAU ADL7 (14.20) which was statistically similar with SAU ADL5, SAU ADL10, SAU ADL12, SAU ADL4, SAU ADL8, SAU ADL1, SAU ADL9, and SAU ADL3.

The lowest number of primary branches panicle^{-1} was recorded from Kataribhog (10.00). The remaining varieties showed the intermediate status of primary branches panicle^{-1}.

4.2.4 Flag leaf length

In rice, the flag leaf is metabolically active and has been a subject of study by number of investigators. It has been assigned to play an important role in terms of supply of photosynthates to the grains (Asana, 1968; Ramadas and Rajendrudu, 1977). Flag leaf appeared to play a major role in enhancing productivity (Rao, 1991). It plays an important role in grain yield (Wan and Shong, 1981 and Sheela *et al.*, 1990). Grain yield was significantly and positively correlated with leaf area (r =0.623) (Al-Tahir, 2014)

Results revealed that the significant difference was found among the aromatic rice genotypes and BRRI dhan66 for flag leaf length (Appendix VII and Table 7). Highest flag leaf length (46.82 cm) was recorded in SAU ADL9 which was statistically similar to SAU ADL12 and SAU ADL10 and the lowest leaf length (32.03 cm) was recorded from genotype SAU ADL5. Rest genotypes showed intermediate status of flag leaf length.

However, Ashrafuzzaman *et al.* (2009) recorded 27.32 cm long flag leaf and the highest flag leaf area from Kataribhog (35.42 cm^2 plant^{-1}).

4.2.5 Filled grains panicle^{-1}

Number of filled grains panicle $^{-143}$, plant height 1000-grain weight, dry matter production, spikelets sterility, days to 50% flowering had positive direct effects on grain yield (Padmavathi *et al.*, 1996).

The filled grains panicle^{-1} differed significantly for variation of the screened genotypes (Appendix VIII and Table 8). The maximum number of filled grains panicle^{-1} was found in SAU ADL2 (198.33) which was statistically similar with Kataribhog (187.20) and BRRI dhan66 (177.00). The lowest number of filled grains panicle^{-1} was obtained from the SAU ADL7 (50.33) which was statistically similar with SAU ADL1 (74.13).

This variation might be due to genetic characteristics of the varieties. These results were in consistent to those of Anonymous (1994), Singh and Gangwer (1989) who reported that the number of filled grains panicle^{-1} influenced significantly due to variety.

Table 8. Filled grains panicle^{-1}, unfilled grains panicle^{-1}, total grains panicle^{-1}and 1000 grain weight of local aromatic Aman rice, Kataribhog and BRRI dhan66

Treatments	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	Total grains panicle^{-1} (no.)	1000 grains weight (g) (no.)
SAU ADL1	74.13 gh	96.00 bc	170.13 d	31.06 a
SAU ADL2	198.33 a	18.00 f	216.33 a-c	29.96 b
SAU ADL3	108.53 ef	104.73 b	213.27 a-c	26.02 f
SAU ADL4	114.13 d-f	105.20 b	219.33 a-c	30.30 b
SAU ADL5	122.87 d-f	67.93 d	190.80 b-d	29.13 c
SAU ADL6	97.733 fg	84.80 b-d	182.53 cd	28.97 c
SAU ADL7	50.33 h	149.53 a	199.87 a-d	22.34 h
SAU ADL8	127.40 de	79.67 b-d	207.07 a-d	28.10 d
SAU ADL9	165.80 b	63.67 de	229.47 a	31.03 a
SAU ADL10	156.40 bc	71.33 cd	227.73 ab	27.22 e
SAU ADL11	137.67 cd	60.73 de	198.40 b-d	21.88 h
SAU ADL12	119.93 d-f	104.13 b	224.07 ab	27.83 de
kataribhog	187.20 a	38.07 ef	225.27 ab	15.03 i
BRRI dhan66	177.00 ab	13.40 f	190.40 b-d	23.27 g
LSD $_{(0.05)}$	25.230	27.130	37.950	0.800
CV (%)	11.45	21.41	10.94	1.78

4.2.6 Unfilled grains panicle^{-1}

Among the undesirable traits, number of unfilled grains panicle-1 was important one and played a vital role in yield reduction. Grain yield was negatively correlated with false grains/panicle (Paul and Sarmah, 1997)

The unfilled grains panicle^{-1} was significantly differed among local aromatic Aman rice genotypes, Kataribhog and BRRI dhan66 (Appendix VII and Table 8). The maximum number of unfilled grains panicle^{-1} (149.53) was counted in the SAU ADL7 and the minimum number of unfilled grains panicle^{-1} was counted in the modern variety BRRI dhan66 (13.40) which was statistically similar with SAU ADL2 and Kataribhog.

This variation in number of unfilled grains panicle-1 might be due to genetic characteristics of the varieties. This result was also supported by Chowdhury *et al.* (1993), Murthy *et al.* (2004) and BINA (1993) who reported differences in number of sterile spikelets panicle^{-1} due to varietal differences.

4.2.7 Total number of grains panicle^{-1}

The total number of grains panicle^{-1} is an important factor which contributes towards grain yield. The number of grains per panicle is the most important criteria of high yield in rice cultivars (Venkateswaslu *et al.*, 1986). Spikelets panicle^{-1} contributed more to the yield and this study confirms the views of Patel *et al.* (2010).

There was significant variation among genotypes for the number of total grains panicle^{-1} (Appendix VII and Table 8). Maximum number of grains panicle^{-1} was found in the genotype SAU ADL9 (229.47) which was statistically similar with SAU ADL10, Kataribhog, SAU ADL12, SAU ADL4, SAU ADL2, SAU ADL3, SAU ADL8, SAU ADL7 and SAU ADL11.

However minimum number of grains panicle^{-1} (170.13) was found in the genotype SAU ADL1 which was statistically similar with BRRI dhan66 (190.40). SAU ADL11 produced

198.40 grains panicle-1 which was 4% higher than modern variety BRRI dhan66 and 12% lower than kataribhog.

The variation as assessed might be mainly due to genetic background of the variety. This result was also recorded by Tahir *et al.* (2002) who reported highly significant variation for the grains panicle^{-1} for different genotypes. Spikelets panicle^{-1} contributed more to the yield and this study confirms the views of Patel *et al.* (2010) and Fageria and Baligar (2001) who reported that the sink size is the most important factor responsible for yield.

4.2.8 Sterility percentage %

Sterility percentage has direct effect on grain yield. Sterility percentage ranged from 7.03 to 72.56% (Appendix VIII and Figure 1). and the highest sterility percentage was in SAU ADL7 (72.56%) and the lowest sterility percentage was recorded in BRRI dhan66 (7.03%) followed by SAU ADL2.

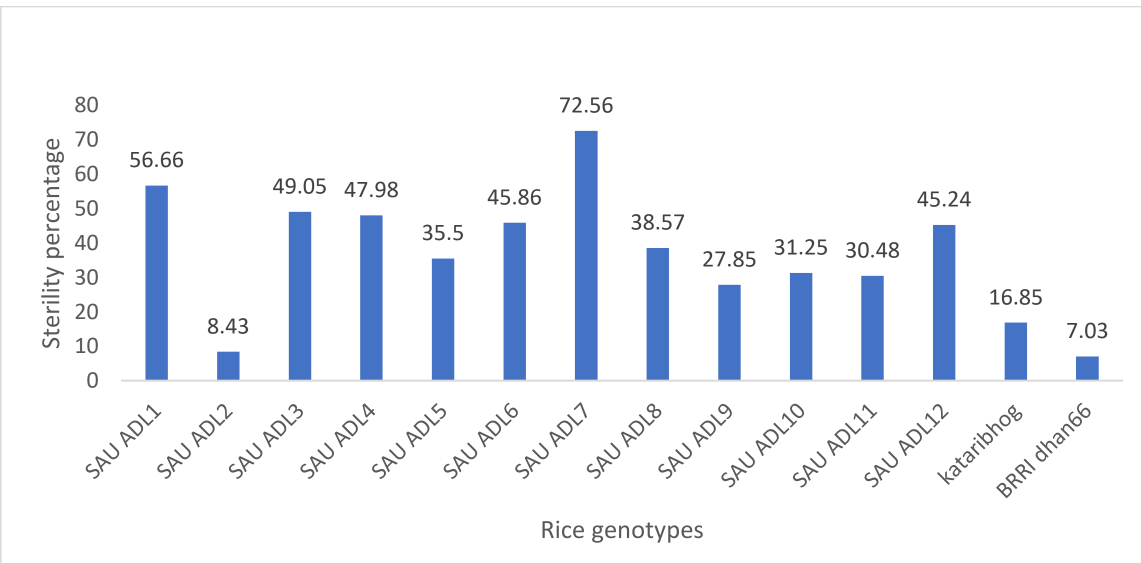

Figure 1. Sterility percentage of screened local aromatic Aman rice genotypes, Kataribhogand BRRI dhan66

4.2.9 Weight of 1000-grain

The 1000-grain weight, an important yield-determining component, is a genetic character least influenced by environment (Ashraf *et al.*,1999). Yoshida (1981) reported that under most conditions, 1000 grains of filled crop is a very stable character. Mondal *et al.* (2005) reported significant correlation between 1000-grain weight and grain yield plant^{-1}.

Screened rice genotypes differed significantly among them regarding the weight of 1000-grains (Appendix VIII and Table 8). The highest weight of 1000-grain (31.06 g) was obtained from the genotype SAU ADL1 which was statistically similar with SAU ADL9 (31.03 g). This highest yield might be due to the long slender grain.

On the other hand, the lowest weight of 1000-grain (15.03 g) was obtained from Kataribhog. This minimum weight might be due to short medium grain. Hoque *et al.* (2013) also obtained 1000-grain weight (14.83 g) of kataribhog where Hossain *et al.* (2005) found 16.47g. Second minimum 1000 grain weight was obtained from SAU ADL11 (21.88 g) which was statistically similar with SAU ADL7 (22.34 g) because these grains are of medium slender shape.

The variation of 1000-grain weight among varieties might be due to genetic constituents. This result also supported by Shamsuddin *et al.* (1988) and Chowdhury *et al.* (1993) who reported that weight of 1000-grain differed among the varieties.

4.2.10 Grain yield

Grain yield of rice mainly depends on the number of effective tillers per unit area, panicle length, filled grains panicle^{-1} and 1000-grain weight (Islam *et al.*, 2013a). Weather conditions, cultural management and nutrient supply greatly influence each yield component (Youshida, 1981). Hassan *et al.* (2003) also stated that grain yield is a function of interplay of various yield components such as number of productive tillers, spikelets panicle^{-1} and 1000-grain weight.

Grain yield was significantly influenced by the screened rice genotypes (Appendix IX and Table 9). The highest grain yield (5.24 t ha^{-1}) was obtained from the modern variety BRRI dhan66 which was statistically similar to SAU ADL5, SAU ADL2, SAU ADL9 and SAU ADL3. The highest yield attributed to highest filled grains $panicle^{-1}$ and more effective tiller.

The lowest grain yield (2.28 t ha^{-1}) was recorded from SAU ADL7 which was statistical similar to SAU ADL12, SAU ADL6, Kataribhog and SAU ADL8. The lowest yield attributed to highest unfilled grains $panicle^{-1}$, more ineffective tiller.

Local aromatic rice genotypes (except SAU ADL6, SAU ADL12 and SAU ADL7) showed almost 2% to 69% higher yield than check variety Kataribhog. Difference in grain yield among screened Aman rice genotypes might be due to their different yield potential. This result also supported by Tyeb *et al.* (2013), Islam *et al.* (2012) and Biswas *et al.* (1998) who reported that variety exerted variable effect on yield and yield contributing characters of rice.

Table 9. Grain yield, straw yield, biological yield and harvest index of local aromatic Aman rice, Kataribhog and BRRI dhan66

Treatments	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index %
SAU ADL1	3.5 de	5.74 f	9.24 ef	37.75 b
SAU ADL2	4.55 ab	5.91 f	9.55 ef	47.63 a
SAU ADL3	4.47 a-c	11.56 ab	16.03ab	27.60 de
SAU ADL4	3.46 de	6.16 f	9.62 ef	35.87 bc
SAU ADL5	5.15 a	9.36 b-d	14.50 a-c	35.58 bc
SAU ADL6	2.86 ef	11.01 a-c	13.87 a-c	20.63 g
SAU ADL7	2.28f	10.79 a-c	13.07 cd	17.31 g
SAU ADL8	3.10 d-f	5.39 f	8.49 f	36.90 b
SAU ADL9	4.48 a-c	8.90 c-e	13.37 bc	33.57 bc
SAU ADL10	3.92 b-d	12.63 a	16.55 a	23.68 e-g
SAU ADL11	3.61 c-e	7.03 ef	10.35 ef	31.97 b-d
SAU ADL12	2.81 ef	9.08 ef	11.89 c-e	25.00 ef
Kataribhog	3.04 ef	7.17 d-f	10.22 ef	29.93 c-e
BRRI dhan66	5.24 a	5.30 f	10.54 d-f	50.02 a
LSD $_{(0.05)}$	0.871	2.304	2.711	6.479
CV (%)	43.65	16.58	13.51	11.92

4.2.11 Straw yield

Straw yield was significantly affected by the screened Aman rice genotypes (Appendix VIII and Table 9). The highest straw yield (12.63 t ha^{-1}) was obtained from SAU ADL10 which was statistically similar with SAU ADL3, SAU ADL6 and SAU ADL7. The lowest straw yield (5.30 t ha^{-1}) was recorded in BRRI dhan66 which was statistically similar to

SAU ADL1, SAU ADL2, SAU ADL4, SU DL8, SAU ADL11 and Kataribhog. Local genotype SAU ADL10 gave higher straw yield (119%) than modern variety BRRI dhan66.This might be due to the higher plant height and higher number of tillers hill^{-1} of the local genotype than the modern variety.

The differences in straw yield among the varieties might be attributed to the genetic make-up of the varieties. These results uphold with the findings of Patel (2000) and Om *et al.* (1999) where they concluded that straw yield differed significantly among the varieties.

4.2.12 Biological yield

Significant variation in biological yield was observed among screened Aman rice genotypes. The biological yield of local aromatic rice genotypes ranges from 8.49-16.55 t ha^{-1} (Appendix IX and Table 9). However, Kataribhog and BRRI dhan66 gave 10.21 t ha^{-1} and 10.54 t ha^{-1} respectively. The highest and lowest biological yield were obtained from SAU ADL10 and SAU ADL8, respectively.

The biological yield of most genotypes gave higher biological yield than check variety Kataribhog except SAU ADL4, SAU ADL2, SAU ADL1 and SAU ADL8. The differences in biological yield might due to genetic make-up of screened genotypes.

4.2.13 Harvest index

Harvest index is a vital character having physiological importance. It reflects translocation on alternatively dry matter partitioning of a given genotype to the economic parts. Harvest index of traditional tall varieties is about 0.3 and 0.5 for improved short varieties (Youshida, 1981).

Significant difference was observed for harvest index (%) among screened Aman rice genotypes (Appendix VIII and Table 9). The highest harvest index was found from the genotype BRRI dhan66 (50.02%) which was statistically similar to SAU DL2 (47.63%) as the shortest stature of the high yielding variety had the highest harvest index (Cui-Jing et al. 2000). The lowest harvest index (17.31%) was found from SAU ADL7 which was statistically similar to SAU ADL6 and SAU DL10.

SAU ADL1 (37.75%), showed second highest harvest index (%) which was statistically similar to SAU ADL8 (36.75%), SAU ADL4 (35.87%), SAU ADL5 (35.58%), SAU ADL9 (33.57%), and SAU ADL11 (31.97%). They showed higher harvest index compared to check variety Kataribhog (29.93%). Sokoto and Muhammad (2014) also found the similar results in case of harvest index due to varietal variations.

4.3. Milling properties

Physical properties include kernel size, shape, milling recovery, degree of milling and grain appearance (Cruz andKhush, 2000). Physical quality has a great importance in commercial rice production as it highly influences on the final output as well as the consumer demand which directly contribute to the economic profitability of the grower and miller.

Some terms with milled rice:

- Paddy or rough rice = similar term for paddy, or rice retaining its husk after threshing
- Brown rice or husked rice = paddy from which the husk has been removed
- Milled rice = rice after milling which includes removing all or part of the bran and germ from the husked rice
- Head rice = milled rice with length greater or equal to three quarters of the average length of the whole kernel
- Large brokens = milled rice with length less than three quarters but more than one quarter of the average length of the whole kernel
- Small brokens or "brewers rice" = milled rice with length less than one quarter of the average length of the whole kernel
- Whole kernel = milled rice grain without any broken parts
- Milling recovery = percentage of milled rice (including brokens) obtained from a sample of paddy.

Head rice recovery = percentage of head rice (excluding brokens) obtained from sample of paddy.

4.3.1 Hulling percentage

Hulling percentage is the percent of brown rice i.e. dehusked kernel from rough rice. More than 80 value of hulling percentage is preferred and if the hulling percentage increases the head rice recovery also increased (Rita and Sarawgi, 2008). Generally, the hulls contribute 20 to 22 percent of the rough rice (Cruz and Khush, 2000). So, brown rice would be 80 to 78 percent of rough rice.

Hulling percentage of screened local aromatic rice genotypes, check Kataribhog and BRRI dhan66 ranged from 85.82% (Kataribhog) to 56.46% (SAU ADL7) (Figure 2). All local genotypes showed almost 9% to 34% lower hulling percentage than check Kataribhog.

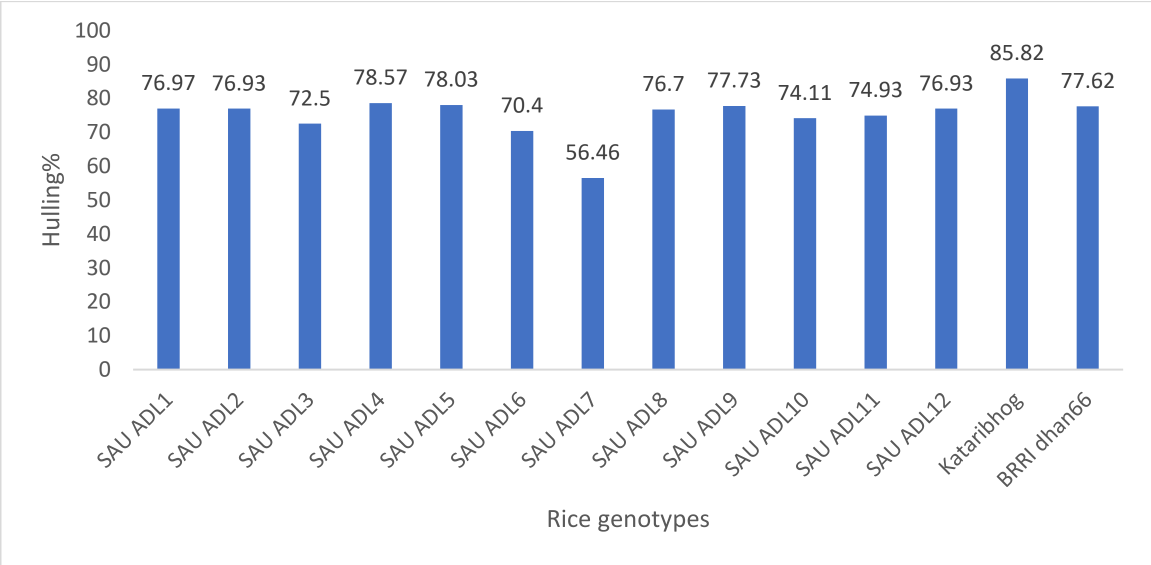

Figure 2. Hulling percentage (%) of screened local aromatic Aman rice genotypes, Kataribhog and BRRI dhan66

4.3.2 Milling recovery

Milling yield is one of the most important criteria of rice quality especially from a marketing standpoint. A variety should possess a high turnout of whole grain (head) rice and total milled rice (Webb, 1985). A good milling quality includes high whole kernel recovery and less of broken rice. For the commercial success of a rice variety it must possess high total milled rice and whole kernel (HRR) turnout. It assumes importance because it tells the actual yield of consumable product.

Milling recovery (%) of screened rice genotypes ranged from 75.92% (Kataribhog) to 49.01% (SAU ADL7) (Figure 3.). These resullts were supported by Hossain *et al.* (2007) who reported that among the aromatic varieties, Badshabhog recorded the highest milling out-turn and it was similar with that of Kataribhog, Radhunipagal and BRRI dhan34. The total number of grains panicle^{-1} is an important factor which contributes towards grain yield. This lowest milling recovery might be due to the attack of Angoumois grain moth (*Sitotroga cerealella***)** during storage.This was supported by Hardke and Siebenmorgen, (2012) who stated that disease and insects also had detrimental effects on rice quality. (http://www.deltafarmpress.com/rice/production-factors-affecting-rice-milling-quality)

Our most of the screened genotypes milling out turn was more than 68% except SAU ADL1, SAU ADL7, SAU ADL3 and SAU ADL12 where typically range of milling recovery was from 68 to 72 percent (Hardke and Siebenmorgen, 2012). Milling recovery might be affected by grain size and shape. This result was supported by Viraktamath (1987) who observed that kernel breadth enhanced the milling output and HRR was strongly associated with milling percentage.

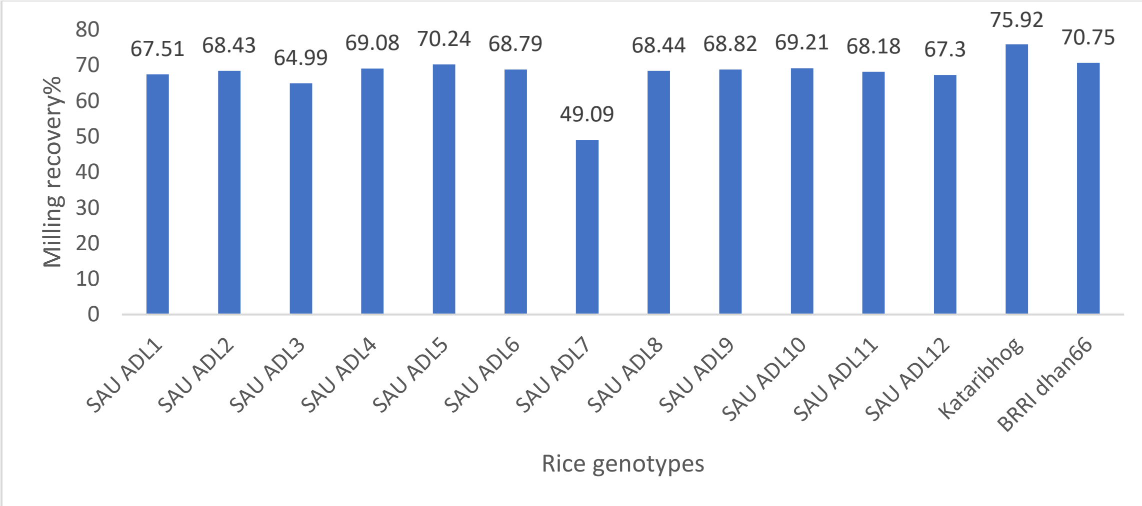

Figure 3. Milling recovery (%) of screened local aromatic Aman rice genotypes, Kataribhog and BRRI dhan66

4.3.3 Milling degree

The degree of milling or the percentage of brown rice removed as bran affects the level of white rice recovery and influences consumer acceptance. Grades range from under-milled, well-milled to extra well-milled. Well-milled rice has normally 10% of rice removed during whitening. Milling degree influences the color and also the cooking behavior of rice as under-milled rice absorbs water slowly and does not cook well. During milling bran and embryos are removed from brown rice and this removal amount is 8 to 10 per cent (Cruz and Khush, 2000).

Results revealed that milling degree (%) of local aromatic Aman rice genotypes ranged from the highest 93.39% (SAU ADL10) to lowest 86.96% (SAU ADL7) i. e. 6.61 to 13.04 % had been removed during milling (Figure 4).

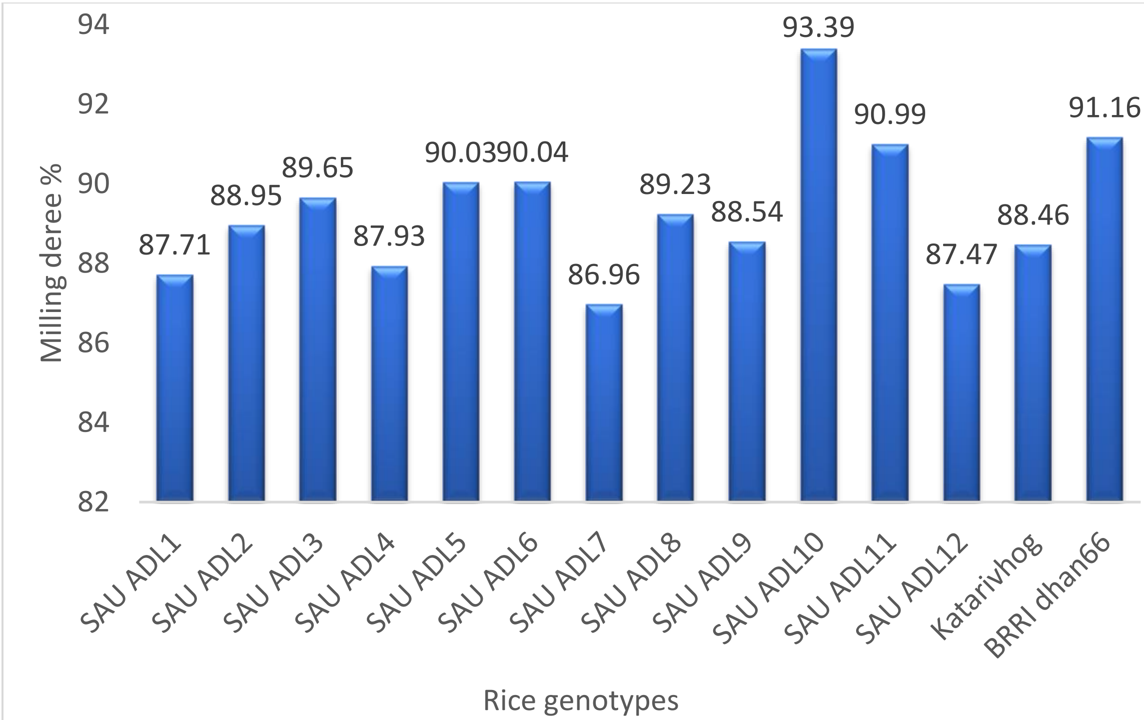

Figure 4. Milling degree (%) of screened local aromatic Aman rice genotypes, Kataribhog and BRRI dhan66

4.3.4 Head rice recovery

The proportion of whole grains is known as head rice recovery and is expressed as percentage of rough rice. If from a sample of 100 g of rough rice, 70 g of milled rice is obtained and 20 g of this is broken, head-rice recovery is 50 per cent (Cruz and Khush, 2000). Head rice yield can vary from zero, meaning all kernels broken, to as high as the milled rice yield (as much as 68-72 percent with no kernels broken).

Among the genotypes head rice recovery percentage ranged from 69.47% (BRRI dhan66) to 35.81% (SAU D7) (Figure 5) which was satisfactorily comparable to the reported values by Khush *et al.* (1979) for HRR (25-65%). On the other hand, Rebeira *et al.* (2014) also found head rice percentage of many varieties ranged from 55-73%.

Most of the genotypes gave more than 50% head rice recovery percentage except SAU ADL3, SAU ADL7, SAU ADL8 and SAU ADL12. Head rice out turn was dependent on grain size and shape, moreover it is a varietals characteristic (Ferdous *et al.*, 2004).

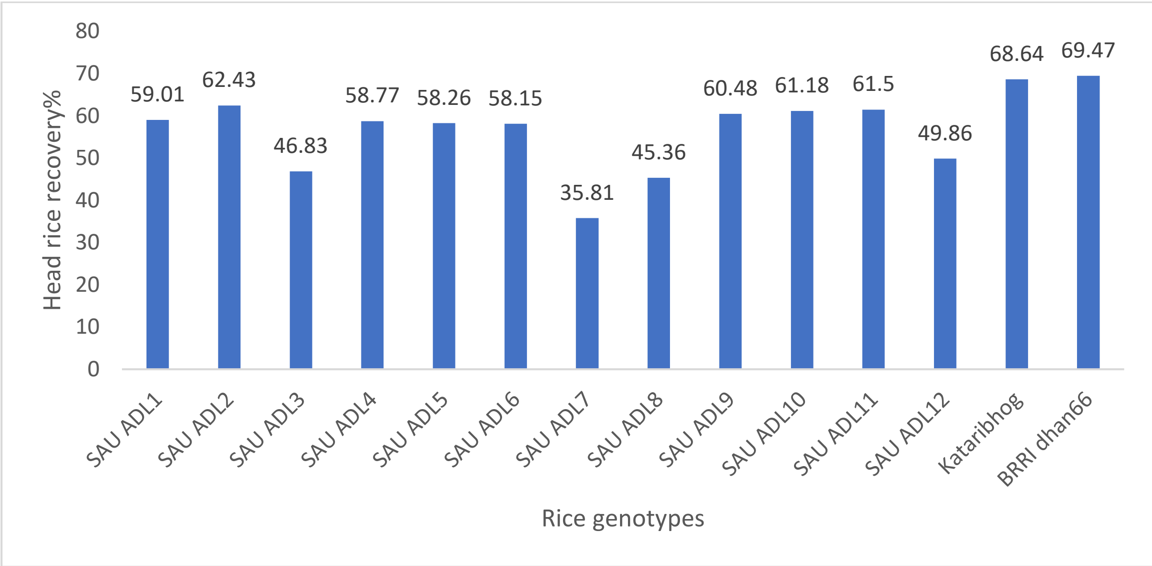

Figure 5. Head rice recovery (%) of screened local aromatic Aman rice genotypes, Kataribhog and BRRI dhan66

4.3.5 Broken rice percentage

Broken rice is a grade of rice consisting of grains broken in the milling process. On milling *Oryza sativa*, commonly known as Asian rice or paddy rice, produces around 50% whole rice then approximately 16% broken rice, 20% husk, 14% bran and meal. If a variety possesses high broken percentage, its marketability will be reduced.

Among the screened rice genotypes broken rice % ranged from 0.99% to 23.08% (Figure 6). The highest broken rice% (23.08%) was found in SAU ADL8 and lowest (0.99%) was found in modern variety BRRI dhan66. The highest broken rice % might be due to size and shape of grain.

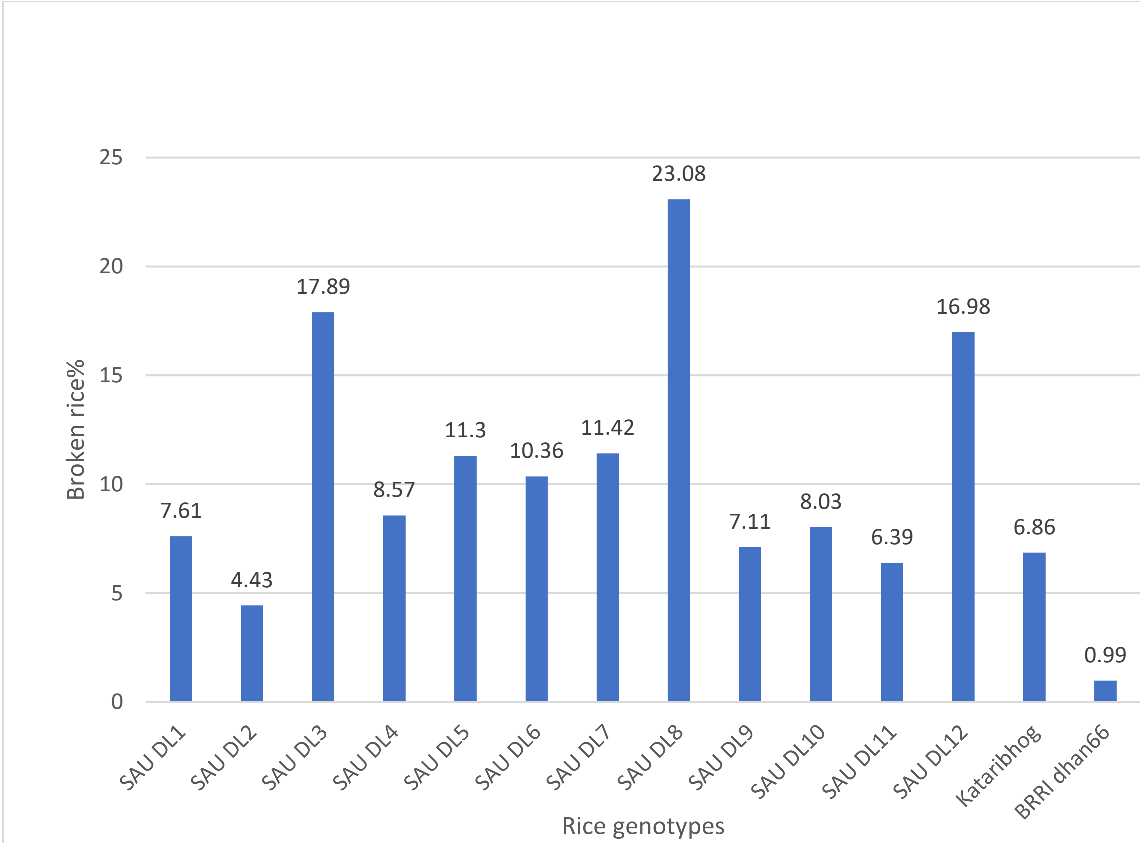

Figure 6. Broken rice (%) of screened local aromatic Aman rice genotypes, Kataribhog and BRRI dhan66

4.4 Physico-chemical characters

4.4.1 Kernel length and breadth

Kernel length, breadth and L/B ratio are considered important traits especially in quality rices. Rita and Sarawgi (2008) reported that kernel shape and L/B ratio are important features for grain quality assessment. Aromatic variety with kernel length 6.0 mm and above is considered widely acceptable size (Kaul, 1970). The L/B ratio of above 3 is generally considered as slender (IRRI, 1980).

Kernel length (mm) and breath (mm) ranged from7.31mm-4.87mm and 2.62mm to 1.8 mm respectively (Appendix IX and Table 10). The highest kernel length (7.31mm) was obtained from SAU ADL1 followed by SAU ADL9 (7.22 mm). Our local aromatic rice genotypes offered kernel size of more than 6.0 mm i.e. acceptable size. Again, highest kernel breadth (2.62 mm) was obtained from SAU ADL2. The lowest kernel length (4.87 mm) and breadth (1.8 mm) was obtained from Kataribhog. This was also supported by Dipti *et al.* (2002) who reported wide variation in grain length from 3.6 to 6.5mm and breadth from 1.7 to 3.7 mm in six fine rice varieties grown in Pakistan.

4.4.2 Kernel size and shape

The appearance of milled rice is important to the consumer. Thus, grain size and shape are the first criteria of rice quality that breeders consider in developing new varieties for release for commercial production (Adair *et al.*, 1966). The length:breadth ratio (L/B) falling between 2.5 and 3.0 has been considered widely acceptable as long as the length is more than 6 mm (Kaul, 1970).

Preference for grain size and shape vary from one group of consumers to the other. Some ethnic groups prefer short bold grains, some have a preference for medium long grains, and long slender grains are highly prized by others

Grain size and shape were determined on the basis of length (mm) and length, breadth ratio. Kernel length and breadth ratio of the studied materials ranged from 3.73 mm to 2.39 mm (Appendix X and Table 10) The highest ratio was obtained from SAU ADL8 followed by SAU ADL7, SAU ADL3, SAU ADL10 and SAU ADL1. However, the lowest ratio was obtained from SAU ADL2. All local genotypes showed length and breadth ratio of more than 2.5 which was considered as widely acceptable shape.

SAU ADL1, SAU ADL3, SAU ADL7 and SAU ADL8 genotypes were of long slender type. SAU ADL11 was medium slender type. SAU ADL2, SAU ADL12 and modern variety BRRI dhan66 were of medium type. Check variety Kataribhog was of short medium. In general, long grains are preferred in the Indian subcontinent, but in Southeast Asia the demand is for medium to medium long rice. In temperate areas, short grain varieties are prevalent. There is a strong demand for long grain rice on the international market (Cruz and Khush, 2000).

Table 10. Kernel length (mm), kernel size, kernel breadth (mm), L/B ratio and kernel shape of local aromatic Aman rice, Kataribhog and BRRI dhan66

Treatments	Kernel length (mm)	Kernel size	Kernel breadth (mm)	L/B ratio	Kernel shape
SAU ADL1	7.31a	long	2.23 de	3.28 bc	slender
SAU ADL2	6.27 h	medium	2.62 a	2.39 i	medium
SAU ADL3	7.13 b-d	long	2.1 f	3.4 b	slender
SAU ADL4	7.01 b-e	long	2.25 de	3.13 cd	slender
SAU ADL5	6.78 e-g	long	2.33 cd	2.92 ef	medium
SAU ADL6	6.93 c-e	long	2.43 bc	2.86 fg	medium
SAU ADL7	6.62 fg	long	1.93 g	3.43 b	slender
SAU ADL8	7.19 bc	long	1.93 g	3.73 a	slender
SAU ADL9	7.22 b	long	2.52 ab	2.88 fg	medium
SAU ADL10	6.89 d-f	long	2.09 f	3.29 bc	slender
SAU ADL11	6.57 g	medium	2.13 ef	3.08 de	slender
SAU ADL12	6.6 g	medium	2.33 cd	2.87 fg	medium
kataribhog	4.87 j	short	1.80 h	2.7 gh	medium
BRRI dhan66	5.8 i	medium	2.23 de	2.59 h	medium
Acceptable range	>6mm	-	-	>3	-
LSD $_{(0.05)}$	0.280	-	0.120	0.190	-
CV (%)	2.46	-	3.5	3.75	-

4.4.3 Kernel length after cooking

Some varieties expand more in size than others upon cooking. Lengthwise expansion without increase in girth is considered a highly desirable trait in some high-quality rices. *(*Cruz and Khush, 2000; Mohapatra and Bal, 2006).

Results revealed that kernel length after cooking (KLAC) of screened rices ranged from 8 mm to 9.98 mm (Figure 7). The highest KLAC (9.98mm) was found in SAU ADL5 and the lowest KLAC (6.77mm) was found in Kataribhog. Where Bhonsle, S. J. (2010) found KLAC 2.31-3.76 mm in aromatic traditionally cultivated rice and 4.62-5.88 mm in basmati rice. On the other hand, Shobha (2003) reported that the kernel length after cooking of nine released hybrids of India ranged from 10.2 to 12.4 mm.

Difference in grain elongation among screened rice genotypes might be the genetical make-up of those one. This was supported by Mohapatra and Bal (2006) who stated that the grain elongation on cooking is dependent on genetic factors as well as the degree of milling.

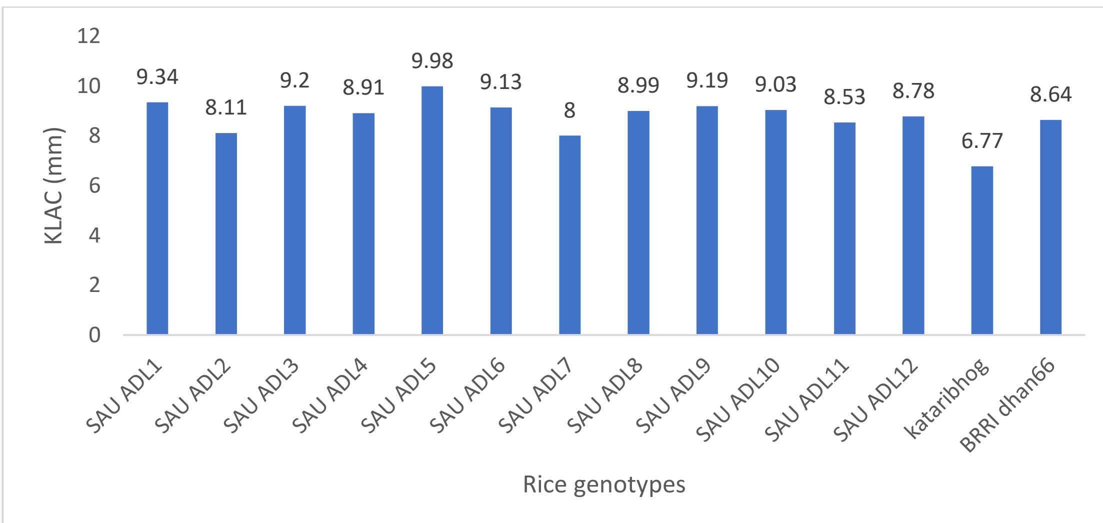

Figure 7. Kernel length after cooking (mm) of screened local aromatic Aman rice genotypes, Kataribhog and BRRI dhan66

4.4.4 Elongation ratio

Shahidullah *et al.* (2009b) and Singh *et al.*, (2000a) reported that higher elongation ratio (ER) of the cooked rice is preferred than lower ER.

Elongation ratio ranged from 1.21 to 1.49 (Figure 8). The highest elongation ratio was recorded in BRRI dhan66 and the lowest was recorded in SAU ADL7. Rest genotypes showed intermediate status.

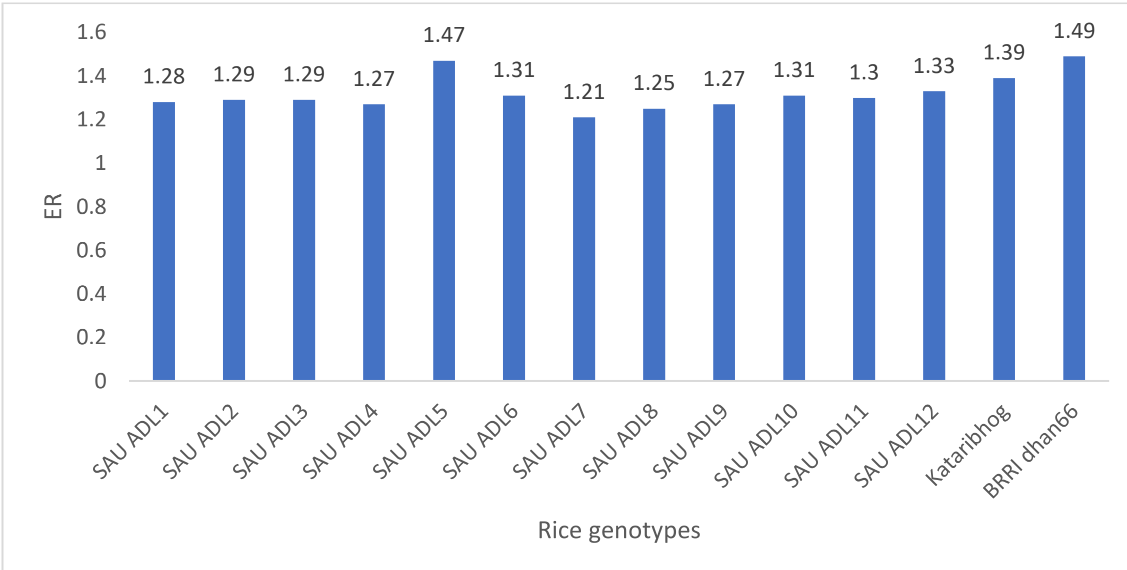

Figure 8. Elongation ratio of screened local aromatic Aman rice genotypes, Kataribhog and BRRI dhan66

4.4.5 Cooking Time

Among the screened rice genotypes variation in cooking time (min.) was found (Figure 9). The highest (19 min) cooking time was found in SAU ADL8 and lowest (14.35 min.) in Kataribhog.

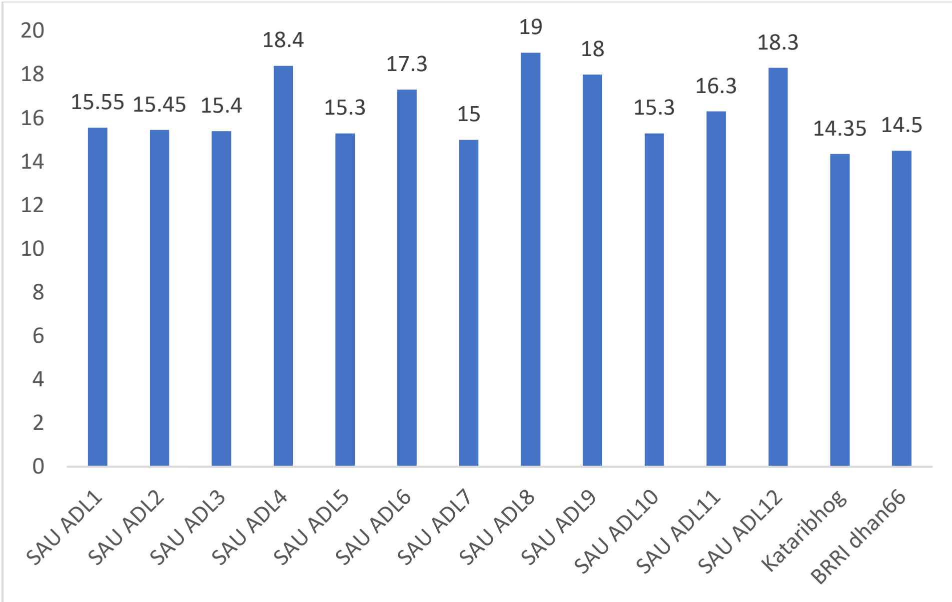

Figure 9. Cooking time (minutes) of screened local aromatic Aman rice genotypes, Kataribhog and BRRI dhan66

4.4.6 Protein and moisture content (%)

Variety had significant effect on qualitative characters like grain protein content (%) and aroma Protein % of screened aromatic rice genotypes and BRRI dhan66 ranged from 7.5% to 10.6% in brown rice (Figure 10). The highest protein (10.6%) was obtained from SAU ADL7 followed by SAU ADL11, SAU ADL1 and Kataribhog. The lowest protein (7.5%) was obtained from BRRI dhan66. Shahidullah *et al.* (2009b) reported 8.30% protein in Kataribhog. But Hossain *et al.* (2008b) observed protein content of 6.6% from Kataribhog by micro Kjeldahl method. Differnce in protein content result might be due to the different method of analysis. Moisture % ranged among the screened genotypes 11.9 to 12.6% (Figure 10).

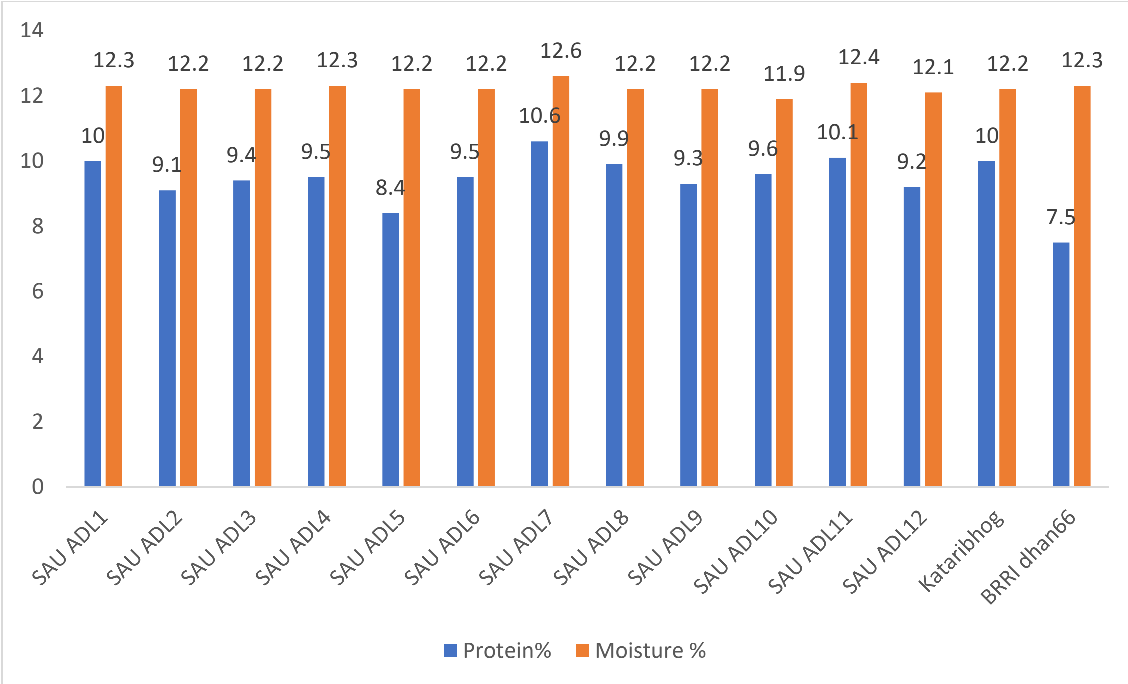

Figure 10. Protein and moisture content (%) of screened local aromatic Aman rice genotypes, Kataribhog and BRRI dhan66

4.5 Organoleptic characteristic

4.5.1 Aroma

The 2-acetyl-l-pyrroline was an important compound contributing to the aromatic odor and it was a major contributor to the popcorn-like aroma in several of the Asian aromatic rice varieties. (Buttery *et al.*, 1982).

Aroma varied among the varieties (Table 11). Aroma development is influenced by both genetic and environmental factors. Hot weather during flowering and grain development, nitrogenous fertilizers particularly urea can affect aroma. In addition to field factors, there are other factors like storage conditions, milling and processing methods, cooking methods, parboiling etc. which might influence the aroma. These factors must be standardized to harness maximum aroma from rice (Singh *et al*., 1997).

Presence of aroma was recorded in SAU ADL3, SAU ADL5, SAU ADL7, SAU ADL9, SAU ADL10, SAU ADL11, SAU ADL11 and Kataribhog.

Table 11. Aroma of local aromatic Aman rice, Kataribhog and BRRI dhan66

Treatments	Aroma
SAU ADL1	non-aromatic
SAU ADL2	non-aromatic
SAU ADL3	moderately aromatic
SAU ADL4	non-aromatic
SAU ADL5	moderately aromatic
SAU ADL6	non-aromatic
SAU ADL7	moderately aromatic
SAU ADL8	non-aromatic
SAU ADL9	moderately aromatic
SAU ADL10	moderately aromatic
SAU ADL11	moderately aromatic
SAU ADL12	Slightly aromatic
Kataribhog	Strongly aromatic
BRRI dhan66	non-aromatic

CHAPTER 5

SUMMARY AND CONCLUSION

The field experiment was conducted at the experimental farm of Sher-e-Bangla Agricultural University (SAU), Dhaka, during the period from July 2016 to December 2016 to study the performance and quality of different aromatic rice genotypes in Aman season under the Modhupur Tract (AEZ-28). The experiment consisted of 14 rice genotypes viz. (i) SAU ADL1, (ii) SAU ADL2, (iii) SAU ADL3, (iv) SAU ADL4, (v) SAU ADL5, (vi) SAU ADL6, (vii) SAU ADL7, (viii) SAU ADL8, (ix) SAU ADL9, (x) SAU ADL10, (xi) SAU ADL11, (xii) SAU ADL12, (xiii) Kataribhog, (xiv) BRRI dhan66. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications of each treatment. Thirty days old seedlings were transplanted following line to line distance 25 cm and hill to hill distance 15 cm with 1 seedling hill^{-1}.

The data on crop growth parameters like plant height, number of tillers hill^{-1}, leaf area index at different growth stages, SPAD reading and time of 50% flowering and maturity were recorded. Yield parameters like number of effective and ineffective tillers m^{-2}, panicle length, primary branches panicle^{-1}, flag leaf length, number of grains panicle^{-1}, filled and unfilled grains panicle^{-1}, 1000-grains weight, grain and straw yield, biological yield and harvest index were recorded after harvest. Quality data hulling %, milling %, milling degree, head rice recovery, broken rice%, kernel length, breadth, L/B ratio, KLAC, ER, cooking time, protein and moisture %, aroma were recorded from combined samples per genotypes. Data were analyzed using CROPSTAT package. The mean differences among the treatments were compared by least significant difference test (LSD) at 5% level of significance.

Significant variation was recorded for all data (crop growth parameters, yield and yield contributing parameters). Rice genotypes also differed widely for qualitative parameters. The rapid increase of plant height was observed. At harvest, the highest plant height (219.08 cm) was in SAU ADL10 and lowest plant height (101.00 cm) was in modern variety BRRI dhan66 that was statistically similar to SAU ADL11. The highest number of tillers hill^{-1} (18.75) was obtained from SAU ADL10 and the lowest (6.53) was from SAU ADL12. The highest LAI (2.45) at harvest was found in SAU ADL10 statistically similar to SAU ADL11 and the lowest was found in SAU ADL7. Maximum SPAD value (47.29) was recorded from SAU ADL8 which was statistically similar with SAU ADL1 and minimum value was in (38.49) SAU ADL10. The SAU ADL12 needed longest time for flowering (104.33 days) which was statistically similar with SAU ADL9 and SAU ADL1. The SAU ADL12 also needed longest time for maturity (139.67 days) which was statistically similar with SAU ADL11, SAU ADL10, SAU ADL6 and SAU ADL7. On the other hand, BRRI dhan66 needed shortest time (71.33 days) for flowering and maturity (106.67 days).

SAU ADL10 produced maximum number of effective tillers m^{-2} (446.723) that was statistically similar with Kataribhog but SAU ADL12 provided minimum effective tiller m^{-2} (142.20) statistically similar to SAU ADL6. The longest panicle length (32.63 cm) was in SAU ADL10 and shortest (24.74 cm) was in BRRI dhan66. The highest number of rachis branches panicle^{-1} was found in SAU ADL7 and the lowest (10.00) was in Kataribhog. The longest flag leaf (46.82 cm) was obtained from SAU ADL9 which was statistically similar with SAU ADL12 and SAU ADL10. But the shortest flag leaf (32.02 cm) was in SAU ADL5 statistically similar with BRRI dhan66. The highest number of filled grains panicle^{-1} (198.33) was obtained from SAU ADL2 which was statistically similar to Kataribhog and BRRI dhan66. On the other hand, the lowest number of filled grains panicle^{-1} (50.33) was obtained from SAU ADL7 and that was statistically similar to SAU ADL1. However, the maximum number of grains panicle^{-1} (229.47) was counted in SAU ADL9 and the minimum number (170.13) was obtained from SAU ADL1.

The highest weight of 1000-grains (31.06 g) was obtained from SAU ADL1 and that was statistically similar to SAU ADL9 and the lowest weight of 1000-grains (23.04g) was obtained from Kataribhog. BRRI dhan66 produced the highest grain yield (5.24 t ha^{-1}) which was statistically similar to SAU ADL5, SAU ADL2, SAU ADL9 and SAU ADL3. On the other hand, the lowest grain yield (2.28 t ha^{-1}) was recorded in SAU ADL7 which was statistically similar to SAU ADL12, SAU ADL6, Kataribhog and SAU ADL8. The highest straw yield (12.63 t ha^{-1}) and biological yield (16.55 t ha^{-1}) was obtained from SAU ADL10. The lowest straw yield (5.39 t ha^{-1}) and biological yield (8.49 t ha^{-1}) was obtained from SAU ADL8. The highest harvest index (47.63%) was obtained from SAU ADL2 which was statistically similar to SAU ADL14 where lowest harvest index (17.31%) was obtained from SAU ADL7.

Kataribhog gave the highest hulling percentage (85.82%) and milling recovery (75.92%) where SAU ADL7 gave the lowest hulling percentage (56.46%) and milling recovery (49.01%). Milling degree (%) was highest in SAU ADL10 (93.39%) and lowest in SAU ADL7 (86.96%). The highest head rice recovery (%) was recorded in BRRI dhan66 (69.47%) and the lowest was in SAU ADL7 (35.81%). The highest broken rice% (23.08%) was found in SAU ADL8 and the lowest (0.99%) was found in modern variety BRRI dhan66.

The highest kernel length (7.31mm) was obtained from SAU ADL1 followed by SAU ADL9 (7.22 mm). Again, the highest kernel breadth (2.62 mm) was obtained from SAU ADL2. The lowest kernel length (4.87 mm) and breadth (1.8 mm) was recorded in Kataribhog. The highest L/B ratio was obtained from SAU ADL8 followed by SAU ADL7, SAU ADL3, SAU ADL10 and SAU ADL1. The lowest L/B ratio was in SAU ADL2.

SAU ADL1, SAU ADL3, SAU ADL7 and SAU ADL8 genotypes were of long slender type and SAU ADL11 was medium slender type. SAU ADL2, SAU ADL12 and modern variety BRRI dhan66 were of medium medium type. Check variety Kataribhog was of short medium. The highest KLAC (9.98mm) was found in SAU ADL5 and the lowest KLAC (8mm) was found in SAU ADL7. The highest elongation ratio was recorded in BRRI dhan66 and the lowest was recorded in SAU ADL7. The highest (19 min) cooking time was found in SAU ADL8 and lowest (14.35 min.) in Kataribhog. The highest protein (10.6%) was obtained from SAU ADL7 followed by SAU ADL11, SAU ADL1 and Kataribhog. The lowest protein (7.5%) was obtained from BRRI dhan66. Presence of aroma was recorded in SAU ADL3, SAU ADL5, SAU ADL7, SAU ADL9, SAU ADL10, SAU ADL11, SAU ADL12 and Kataribhog.

Based on the results of the present study, the following conclusions may be drawn-

- Different genotypes showed different results for different parameters.

- The SAU ADL11 is a short stature genotype (escaping lodging) of which maximum characters are similar to those of modern variety BRRI dhan66 and it provided 18.75% higher yield than Kataribhog. It has medium slender type grain with aroma. Hulling percentage was 74.93% and HRR was 61.5% with medium slender type grain with aroma.

- Grain yield of SAU ADL3, SAU ADL5, SAU ADL9 genotypes was similar to that of modern variety BRRI dhan66 providing almost 70% higher yield than Kataribhog. They provided long slender or long medium grain with aroma. Their hulling % was 72- 77 and HRR was 46.83-60.48% with long slender or long medium grain and aroma

- The genotype SAU ADL10 provided almost 29% higher yield than Kataribhog with long slender grain and aroma. Hulling % was 74.13 % and HRR was 60.18%.

- SAU ADL7 and SAU ADL12 genotypes' yield was lower than Kataribhog but have aroma with acceptable grain shape and size.

- It needs further research to find out the all qualitative characters of these genotypes.

However, to reach a specific conclusion and recommendation the same experiment needs to be repeated and more research work should be done over different Agro-ecological zones.

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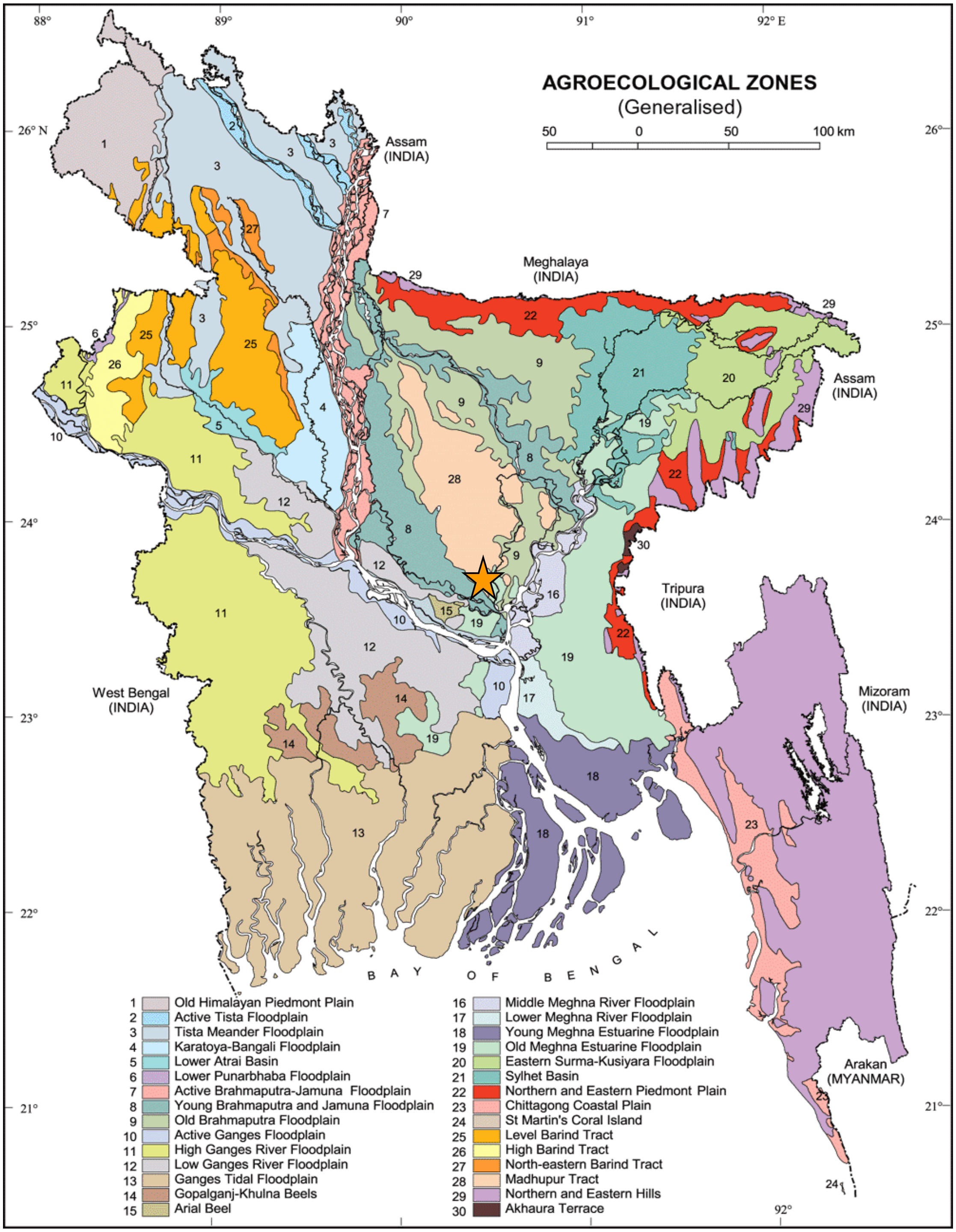
APPENDICES

Appendix I. Map showing the experimental sites under study



The experimental site under study

Appendix II. Physical characteristics of field soil analyzed in Soil Resources Development Institute (SRDI) laboratory, Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy field, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resources Development Institute (SRDI)

Appendix III. Field layout of the Experiment in Randomized Complete Block Design

Appendix IV. Summary of analysis of variance for plant height of aromatic Aman rice genotypes and BRRI dhan66 at different days after transplanting

Sources of variation	Degrees of freedom	Mean square values at different days after transplanting				
		At transplant	25	50	75	At harvest
Replication	2	2.28	2.52	7.88	47.75	26.62
Treatment	13	140.59*	298.02*	1131.94*	2522.31*	4690.72*
Error	26	5.78	7.68	7.43	18.68	24.98

* Significant at 5% level

Appendix V. Summary of analysis of variance for tiller numbers hill^{-1} of aromatic Aman rice genotypes and BRRI dhan66 at different days after transplanting

Sources of variation	Degrees of freedom	Mean square values at different days after transplanting		
		25	50	At harvest
Replication	2	2.78	1.69	2.62
Treatment	13	5.57*	31.89*	22.38*
Error	26	2.09	6.03	3.71

* Significant at 5% level

Appendix VI. Summary of analysis of variance for leaf area index of aromatic Aman rice genotypes and BRRI dhan66 at different days after transplanting

Sources of variation	Degrees of freedom	Mean square values at different days after transplanting		
		25	**50**	**At harvest**
Replication	2	0.04	0.5	0.11
Treatment	13	0.14*	4.71*	0.43*
Error	26	0.04	0.97	0.07

* Significant at 5% level

Appendix VII. Summary of analysis of variance for duration of 50% flowering, duration of maturity, SPAD reading, number of effective tillers m^{-2}, number of ineffective tillers m^{-2}, panicle length and number of primary branches panicle^{-1} of aromatic Aman rice genotypes and BRRI dhan66

Sources of variation	Degrees of freedom	Mean square values						
		Duration of flowering	**Duration of maturity**	**SPAD reading**	**Effective tillers m^{-2}**	**Ineffective tillers m^{-2}**	**Panicle length**	**Primary branches panicle^{-1}**
Replication	2	4.79	9.5	0.84	1422.90	370.24	0.073	0.33
Treatment	13	189.70*	193.57*	24.27*	15476.3*	3129.27*	14.02*	4.30*
Error	26	4.66	8.76	2.12	3567.85	454.98	0.61	0.31

* Significant at 5% level

Appendix VIII. Summary of analysis of variance for flag leaf length, number of filled grains/ panicle, number of unfilled grains panicle $^{-1}$, number of total grains/ panicle, sterility percentage, 1000-grain weight of aromatic Aman rice genotypes and BRRI dhan66

Sources of variation	Degrees of freedom	Mean square values					
		Flag leaf length	Filled grains panicle $^{-1}$	Unfilled grains panicle $^{-1}$	Total grains panicle $^{-1}$	Sterility percentage	1000-grain weight
Replication	2	6.19	31.03	84.89	17.76	6.63	0.16
Treatment	13	60.24*	5433.79*	4051.89*	1028.74*	1002.99*	61.44*
Error	26	8.11	225.99	261.28	511.263	21.80	0.22

* Significant at 5% level

Appendix IX. Summary of analysis of variance for yield characters of aromatic Aman rice genotypes and BRRI dhan66

Sources of variation	Degrees of freedom	Mean square values			
		Grain yield	Straw yield	Biological yield	Harvest index
Replication	2	0.30	0.29	0.71	5.32
Treatment	13	2.50*	18.97*	20.63*	263.65*
Error	26	0.28	1.89	2.61	14.905

* Significant at 5% level

Appendix X. Summary of analysis of variance for kernel length, kernel breadth, L/B ratio of aromatic Aman rice genotypes and BRRI dhan66

Sources of variation	Degrees of freedom	Mean square values		
		Kernel length	Kernel breadth	L/B ratio
Replication	2	0.02	0.029	0.028
Treatment	13*	1.30*	0.161*	0.399*
Error	26	0.027	0.006	0.013

* Significant at 5% level