EXPLORATION OF GENETICAL PURITY, YIELD PERFORMANCE AND GRAIN QUALITY OF SLENDER GRAIN HYBRID T. AMAN RICE

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BELOVED PARENTS AND RESPECTED SUPERVISORS

Chapter I

Introduction

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) belongs to the Poaceae family of cereal crops. After wheat in the world crops, rice ranked 2^{nd} in the world crops. Bangladesh ranks 4^{th} in both the rice region and production among the world are leading rice growing nations (BRRI, 2017). In Bangladesh, rice is the main food crop and around 11.35 million ha of the total arable land is used for rice cultivation (FAO, 2017). In addition, Bangladesh is the 3rd largest country in the world based on the cultivation of rice (BBS, 2019). Rice is used as a staple food by almost half of the world's population. In Asia, over 90% of the rice in the world is grown (BBS, 2013). Rice alone occupies about 77% of the total cultivated area among the 150 different crops grown in Bangladesh. In Bangladesh, the area and production of total rice is approximately 11.35 million hectares and 35.56 million metric tons (BRRI, 2017).

Annual per capita rice consumption in Bangladesh is the highest in the world (Nasiruddin, 1993). It accounts for 76% of the caloric intake and 66% of the protein intake (BNNC, 2008). Its share of agricultural GDP is approximately 70%, while its share of national revenue is one-sixth. It is, by far, the largest source of salary, business, reserve funds and interest in the economic sector. The population of Bangladesh continues to grow and will require about 47.26 million tons of rice for 2020 (BBS, 2016). But in Bangladesh, the average yield (2.98 t ha^{-1}) of rice is poor (BRRI, 2017). On the other hand, due to high population pressure as well as climate change, the rice production area is decreasing day by day. Food security has been and will continue to be a major concern in Bangladesh, as food requirements are increasing at an alarming rate due to population growth. In any way, Bangladesh needs to further develop the yield of rice in order to meet the growing need. The main source of livelihood is rice cultivation and about 72% of the agricultural production comes from rice. Therefore, the rice yield must be raised from the current 2.98 to 3.74 t ha^{-1} (BRRI, 2019).

Aus, Aman and Boro, there are three rice growing seasons that have appeared distinctly almost all over in Bangladesh. In the seasons of Aus, Aman and Boro, the total yield of rice was 2.92, 15.34 and 19.91 million metric tons, respectively (BBS, 2019). Thousands of local rice landraces exist in Bangladesh, many of which are either fine grain or aromatic types. Most of the aromatic rice varieties in Bangladesh are of a traditional type, sensitive to photoperiods and are grown during the Aman season in lowland rainfall (Das and Baqui, 2000). During the Aman season, 30 percent of the rice land in northern districts of Bangladesh was covered by aromatic rice cultivars (Islam *et al.*, 2012). Aromatic rice plays a vital role in the international trade in rice. Bangladesh mainly exports Kalizira, a highly aromatic variety, as well as other varieties such as Kataribhog, Bansful and Chinigura. Bangladesh has a bright prospect for export of fine rice thereby earning foreign exchange (Islam *et al.*, 2012).

The demand of aromatic rice in this country is increasing due to its special appeal for aroma and acceptability although grain yield is low. Aromatic rice is the most highly valued rice commodity in Bangladesh agricultural trade markets having small grain and pleasant aroma with soft texture upon cooking (Dutta *et al.*, 2002). However, the price of fine rice, especially the aromatic rice is 2-3 times higher than that of coarse rice (Ashrafuzzaman *et al.*, 2009). In spite of low yielding of aromatic rice, it requires less input compared to coarse rice. To achieve this goal, besides conventional breeding method, new strategies must be devised to elevate aromatic rice productivity to accommodate the growing demand. At the same time, with the application of almost the same amount of agricultural inputs, hybrid rice has a yielding advantage of approximately 15-20 percent over the best commercial rice cultivars (Babu *et al.*, 2013). Higher hybrid rice grain yield is an intricate result that produces higher yields than modern cultivars and attracts the attention of farmers (Lin and Yuan, 1980). In 1974, Chinese scientists successfully transferred the interaction between the male genotype and the environment. Hybrid rice grows well in China and the wild rice sterility gene creates the cytoplasmic male-sterile genetic (CMS) line and hybrid combination (Chen *et al.*, 2008). After China, Vietnam began to cultivate large-scale hybrid rice in 1992, followed by India, Bangladesh, Myanmar and the Philippines (Julfiquar *et al.*, 2006). Hybrid rice technology has proven to be one of the most feasible and readily acceptable approaches to breaking down the possibility for lower yields. Convinced of the potential of hybrid rice technology to enhance production, Bangladesh has adopted this technique and released almost a dozen hybrid rice varieties for further cultivation (Mamun *et al.*, 2012). The yield increases in the hybrid varieties of lower percentages of offtype plants resulted higher genetic purity which resulted mainly in higher yield potential (Jiang *et al*., 1995). Therefore, emphasis should be placed on increasing rice yields through enhanced technology and management practices, as a potential replacement may be hybrid rice. Therefore, it is considered essential to look for an alternative way to boost production. Proper practices are the most efficient means of increasing farmer-level rice yield that can be achieved by using inbred and hybrid varieties (BBS, 2005). By introducing a new approach to rice production through hybrid technology, scientists are quite optimistic about breaking the existing yield ceiling.

So, it is essentially required to know the impact of different hybrid rice varieties and also to determine their adaptability in prevailing environments of Bangladesh. Under the above circumstances, the present experiment was undertaken with the following objectives:

i. To explore the growth, yield and yield components and quality of hybrid genotype and check varieties grown in T. aman season.
ii. To evaluate candidate hybrid genotype with improved yield potential over inbred ones.
iii. To screen out the genetical purity of the hybrid genotype and the check varieties of rice and evaluating the best one.

Chapter II

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Due to the varietal execution of different rice cultivars and management practices, the growth and progress of rice is affected. Inbred and hybrid varieties could likewise be affected. Experimental findings are available from home and abroad to reveal that rice cultivars with high return potential can have an incredible degree of impact on growth and respect. In this part, important audits on the above perspectives were displayed and discussed.

2.1 Relationship and differences of plant growth and development characteristics of hybrid and inbred rice varieties

As is evident from its overall distribution, rice has a broad flexibility to distinct environmental conditions. Various parameters, such as plant height, effective tillers hill^{-1}, number of filled grain panicle^{-1} and number of unfilled grains panicle^{-1}, 1000-grain weight, panicle length and harvest index as well as environmental factors control the yield of a rice cultivar. Growth parameters such as plant height, effective tillers hill^{-1}, etc. are also important to evaluate the possibility of yield. Some accessible data and writing identified with the characters of hybrid and inbred rice cultivars in plant development are cited below:

2.2 Morphological attributes

2.2.1 Effect of rice varieties

Rice is the staple food and in the highly populated region of South and Southeast Asia, about ninety percent of rice is grown and consumed. Bangladesh produces hybrid rice varieties and, for regular consumption, most of them have excellent production and food quality. The impact of rice varieties on yield-contributing components and grain yield has been reported by various researchers. Some of the important and informative works and research results related to hybrid yield and quality, however, have been done at home and abroad so far, reviewed below-

2.2.2 Plant height (cm)

Masum *et al.* (2008) found that rice plant height was affected by varieties in the Aman season where Nizershail produced the higher plant height at different days after transplanting (DAT) than BRRI dhan44. Three varieties (cv. BRRI dhan28, BRRI dhan29 and Binadhan-14) and four water management systems were tested in an experiment to investigate the impact of the variety and water management system on boro rice growth, development and yield execution. The highest plant height, maximum number of tillers hill^{-1}, dry matter of shoot hill^{-1} and dry matter of root hill^{-1} were obtained from BRRI dhan29 at 100 DAT and the lowest grades were observed in Binadhan-14. With the exception of 1000-grain weight, variety had a significant impact on all the crop attributes under test. The highest grain yield from BRRI dhan29 was found and from Binadhan-14 the lowest grain yield was recorded (Murshida *et al.*, 2017).

An experiment was directed by Sarkar *et al.* (2014) to examine the yield and quality of aromatic fine rice as influenced by the management of variety and nutrients. Three aromatic fine rice varieties were included in the experiment: *viz.* BRRI dhan34, BRRI dhan37 and BRRI dhan38, respectively. In BRRI dhan34, the highest plant height (142.7 cm), the highest number of effective tillers hill^{-1} (10.02), grains panicle^{-1} (152.3), panicle length (22.71 cm), 1000-grain weight (15.55 g) and grain yield (3.71 t ha^{-1}) were achieved.

Islam *et al.* (2009) was conducted a pot experiments to contrast the growth and yield behavior of hybrid and inbred rice varieties under controlled conditions with the hybrid variety Sonarbangla-1 and inbred modern varieties BRRI dhan31 and BRRI hybrid dhanl. BRRI dhan3l had about 10-15 percent higher plant height, very similar tillers plant^{-1}, 15-25 percent higher leaf area compared to Sonarbangla-1 at all days after transplantation (DAT). At 25 DAT, Sonarbangla-1 resulted in about 40 % higher dry matter production but had very similar dry matter production at 50 and 75 DAT, 4-11% higher rooting depth at all DATs, about 22% higher dry root weight at 25 DAT, but 5-10% lower dry root weight at 50 and 75 DAT compared to BRRI dhan31. At 35 DAT (highest tillering phase), the photosynthetic rate was higher (20 μ mol m^{-2} sec^{-1}) in BRRI dhan3l, but at 65 DAT, Sonarbangla-l showed a higher photosynthetic rate of 19.5 μ mol m^{-2} sec^{-1}. BRRI dhan3l showed higher panicles $plant^{-1}$ than Sonarbangla-1, but Sonarbangla-1 resulted in higher grains number $panicle^{-1}$, 1000-grain weight and grain yield than BRRI dhan31. Anwar and Begum (2010) revealed that rice tiller separation time significantly affected plant height, total number of tillers $hill^{-1}$, number of bearing tillers and panicle length, but there was no effect on grain and straw yields. Sonarbangla-1 therefore appeared to be tolerant of tiller separation, and without hampering grain yield, separation should be done between 20 to 40 DAT.

2.2.3 Number of tillers hill^{-1} (no.)

Bhuiyan *et al.* (2014) conducted an experiment to explore various avenues to determine the adaptability and implementation of different hybrid rice varieties and to recognize and prescribe to rice farmers the best hybrid rice varieties in terms of yield. The different hybrid rice varieties evaluated had significant effects on the number of tillers and the number of productive tillers, based on the results of the study. As a planting material among hybrid rice varieties, RGBU010A × SL8R is therefore recommended because it has produced more productive tillers. During the Aman season, an experiment was performed to study their effects on the yield and yield contributing characters of rice varieties BR23 and Pajam with 2, 4 and 6 seedlings $hill^{-1}$. They disclosed that cv. in terms of yield and yield components, i.e. productive tillers number $hill^{-1}$, panicle length, l000-grain weight, grain yield and straw yield, BR23 showed better performance over Pajam.

The cultivar Pajam, on the other hand, delivered significantly the highest plant height, number of total grains panicle^{-1}, number of filled grains panicle^{-1} and number of unfilled grains panicle^{-1} (Kashem *et al.*, 2005).

A field experiment was conducted by Khatun *et al.* (2018) to evaluate the growth, yield and yield characteristics of aromatic rice (cv. Tulshimala) under the fertilization of cow dung (organic manure) and zinc (micronutrient). From the results of the experiment, the application of different levels of cow dung and zinc fertilizers showed that the total number of tillers hill^{-1}, productive number of tillers hill^{-1}, panicle length, test weight (g), grain yield hill^{-1} (g), straw yield hill^{-1} (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}), and biological yields over control were significantly increased. However, the combination of CD_1Zn_2 i.e. 10 t ha^{-1} cowdung and 12 kg ha^{-1} ZnSO4 together with other recommended inorganic fertilizer doses produced the highest yield of grain (2.79 t ha^{-1}) and straw yield (5.80 t ha^{-1}) over other treatments.

An experiment was directed by Islam *et al.* (2014) to examine the yield and quality of aromatic fine rice as influenced by the management of variety and nutrients. Three aromatic fine rice varieties were included in the experiment: viz. BRRI dhan34, BRRI dhan37 and BRRI dhan38, respectively. In BRRI dhan34, the highest plant height (142.7 cm), the highest number of effective tillers hill^{-1} (10.02), grains panicle^{-1} (152.3), panicle length (22.71 cm), 1000-grain weight (15.55 g) and grain yield (3.71 t ha^{-1}) were achieved. Chowdhury *et al.* (1993) stated that the BR23 cultivar showed superior performance over Pajam in terms of characters contributing to yield and yield i. e. Number of productive tillers hill^{-1}.

2.3 Phenological characters

2.3.1 Days to first panicle initiation

Parvez *et al.* (2003) observed that Sonarbangla-1 showed shorter field duration was observed in than the control. Ma *et al.* (2001) conducted a comparative study to screen out the performance of 8 rice hybrids. All hybrids showed shorter growth duration (97–107 days) than the controls (110– 116 days). They also experimented with ADTRH1 which is a rice hybrid.

This hybrid produced first panicle initiation than the other variety. It observed that a semi-dwarf variety and reached maturity in 115 days. Iftekharuddaula *et al.* (2001) reported that first panicle initiation, days to 50% panicle initiation, days to maturity, plant height and spikelets panicle^{-1} had positive and higher indirect effect on grain yield through grains panicle^{-1}. Padmavathi *et al.* (1996) reported that days to first panicle initiation, 50% panicle initiation had higher positive direct effects on number of panicles plant^{-1} and panicle length. Days to 50% flowering, number of grains panicle^{-1} and plant height had positive direct effects on grain yield.

2.3.2 Days to 50% panicle initiation

Most scientists indicated that days to 50% panicle initiation has direct and indirect effect on yield, grains panicle^{-1} and also on plant height. Vijayakumar *et al.* (1997) found that hybrids out yielded their parents when their days to 50% panicle initiation were similar or more than their respective restorers. Sathya *et al.* (1999) studied on eight quantitative traits in rice (*Oryza sativa*). Days to 50% panicle initiation 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. Iftekharuddaula *et al.* (2001) reported that days to first panicle initiation, days to 50% panicle initiation, days to maturity, plant height and spikelets panicle^{-1} had positive and higher indirect effect on grain yield through grains panicle^{-1}. Roy *et al.* (1989) concluded that generally the plants which needed more days for 50% panicle initiation gave more yield.

2.3.3 Days to 100% panicle initiation

Vijayakumar *et al.* (1997) found that hybrids out yielded their parents when their days to 100% panicle initiation were similar or more than their respective restorers. Padmavathi *et al.* (1996) suggested that days to 100% panicle initiation had higher positive direct effects on number of panicles plant^{-1} and panicle length. Days to 100% panicle initiation, number of grains panicle^{-1} and plant height had positive direct effects on grain yield.

Sathya *et al.* (1999) studied on eight quantitative traits in rice (*Oryza sativa*). 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.

2.3.4 Days to maturity

Swain *et al.* (2007) assessed an experiment and shown that among the medium-duration varieties (115–130 days), there was good agreement between simulated and observed leaf area index, biomass, and grain yield. The simulated biomass of long-duration varieties (135–150 days) showed large deviation from observed biomass at flowering. In the wet season of 2000, the model precisely anticipated the grain yield, biomass and leaf area index of medium and long-duration varieties.

Patnaik and Mohanty (2006) showed that there was a wider variation in the maturity duration of varieties. The flowering duration was the longest in CR 874-23 (153 days) followed by CR 758-16 (151 days). The earliest variety found to be Swarna (110 days). Wei *et al.* (2004) experimented with Yueza 122 which was bred by crossing GD-1S with Guanghui 122. They concluded that the hybrid showed wide adaptability, higher grain yield, moderate growth period and fine grain quality, high resistance to rice blast and medium resistance to bacterial blight.

Parvez *et al.* (2003) observed that Sonarbangla-1 showed shorter field duration was observed in than the control. Ma *et al.* (2001) conducted a comparative study to screen out the performance of 8 rice hybrids. All hybrids showed shorter growth duration (97–107 days) than the controls (110– 116 days). They also experimented with ADTRH1 which is a rice hybrid. This hybrid was semi-dwarf and reached maturity in 115 days.

Wang (2000) experimented in plot trials in 1998 and 1999, where growth period of early hybrid rice cv. Zhe 9516 was 116 and 117 days, respectively. The morphological and physiological attributes of Yueza 122 were investigated by Huang *et al.* (1999).

The results showed that in the early cropping season it was an early mature hybrid combination with a duration of 83 days from sowing to heading.

Pruneddu and Spanu (2001) conducted an experiment and concluded that Ebro was the earliest hybrid rice cultivar, reaching maturity 114 days after sowing; whereas, Balilla, Tejo and Thaibonnet were the latest; reaching maturity 128 days after sowing.

2.4 Correlation and differentiation in yield contributing characters and yield of hybrid and inbred rice varieties

Variety itself is a genetic factor that contributes greatly to the production of better rice yield. The performance of rice varieties on grain yield was evaluated by different researchers. Some available information and literature are discussed here relating to the yield contributing characteristics and yield of hybrid and inbred rice cultivars.

Haque and Biswash (2014) conducted five hybrid rice varieties collected from various private seed organizations and one Bangladesh Rice Research Institute (BRRI) hybrid and two inspections. Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid dhan1 were the varieties and BRRI dhan28 and BRRI dhan29 were the two controls. The highest plant height in the experiment was 101.5 cm for BRRI dhan28 and the lowest plant height was 82.5 cm for Richer. BRRI dhan29 required maximum days (116.3 days) and BRRI dhan28 required fewer days (95 days) in the event of 50 percent flowering. Hira showed the best performance in the number of effective tillers (17.7) and Sonarbangla-1 showed the lowest performance (13.3). Sonarbangla-1 required fewer days (118 days) and BRRI dhan29 needed the maximum days (148 days) to consider the days for development. Richer demonstrated the best performance (27.7 cm) in panicle length status, while BRRI dhan28 showed the least performance (26 cm). The number of filled grains panicle^{-1} was the most notable for BRRI dhan29 (163.3), though, Jagoron was only 118. The number of all out grains in BRRI dhan29 (201.7) was most noteworthy and for Jagoron it was only 133.7.

Then again, Aloron was the best hybrid for the 1000-grain weight. In the case of biological yield (g), the best return was shown by BRRI dhan29 (49.6 g) and only 18 g by Hira. Given the performance of the whole variety, the Aloron variety was the best variety in the study than the respective varieties.

Islam *et al.* (2010) considered yield capacity at the International Rice Research Institute (IRRI) farm under optimum crop management of 16 rice genotypes including 12 hybrids, 3 inbreds and 1 New Plant Type (NPT) to achieve the most extreme feasible yield during the wet season (WS) of 2004 and dry season (DS) of 2005. The yield and yield components at maturity have been determined. The most noteworthy grain yield (7.7 t ha^{-1}) was provided by IR76712H, followed in WS by IR75217H and Magat (7.6 t ha^{-1}). The most elevated grain yield (9.17 t ha^{-1}) was achieved by IR79118H in DS, followed by IR73855H (8.9 t ha^{-1}) and SL-8H (8.8 t ha^{-1}). The higher yield was due to a higher harvest index (0.50) for hybrid rice. Hybrid generated higher panicle^{-1} and 1000-grain weight of spikelets than inbred rice. The percentage of inbred spikelet filling was higher than hybrid rice. The NPT genotype of rice had the least percentage of spikelet filling, yet the most noteworthy 1000-grain weight over the season.

Halder *et al.* (2018) conducted an experiment to determine the effect of the variety and planting density on yield and yield contributing characteristics of local aromatic rice. The experiment was developed with three replications in a factorial randomized complete block design, consisting of three local aromatic rice varieties (Chinigura, Shakhorkhora and Kalizira) and four planting densities S1 (25 × 20 cm), S2 (20 × 20 cm), S3 (20 × 15 cm) and S4 (20 × 10 cm) respectively. The findings demonstrated that the local aromatic rice var. The most notable number of grain panicle^{-1} (131) and 1000-grain weight (13.8 g) grains were produced by the Shakhorkhora variety, resulting in higher grain (2.63 t ha^{-1}), followed by Kalizira (2.56 t ha^{-1}) and straw yield (4.21 t ha^{-1}). On the other hand, the higher number of tillers hill^{-1} (14.8), the number of grains panicle^{-1} (140 nos.) were found with higher grain yield in 20 cm × 20 cm spacing.

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

An experiment to evaluate the effect of variety and nitrogen levels on the yield performance of fine aromatic rice was conducted by Paul *et al.* (2014). The experiment consisted of three types, i.e. Kalizira, Binadhan-13 and dhan34 BRRI, and six nitrogen levels, viz. USG 1.8 g 4 hills^{-1} (55 kg N ha^{-1}) and USG 2.7 g 4 hills^{-1} (80 kg N ha^{-1}). 0, 30, 60, 90 kg N ha^{-1} It was noted from the results that the yield of aromatic rice was significantly affected by variety, level of nitrogen and their interaction. Binadhan-13 achieved the highest grain yield (3.33 t ha^{-1}), followed by BRRI dhan34 (3.16 t ha^{-1}), and Kalizira obtained the lowest grain yield (2.11 t ha^{-1}).

2.5 Yield components and yield

2.5.1 Number of effective tillers hill^{-1} (no.)

Sarkar *et al.* (2014) assessed the yield and quality of aromatic fine rice as influenced by the management of variety and nutrients and showed that the variation in plant height, number of effective tillers hill^{-1} and number of grains panicle^{-1} among the varieties was likely due to inheritance or varietal characteristics. Hossain *et al.* (2008) 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. Lee *et al.* (1992) reported that the quantity of spikelet panicle^{-1}, panicle length and grain yield panicle^{-1} were higher in the primary tiller and diminished with expanding tiller order with delaying panicle emergence in rice.

Metwally *et al.* (2012) reported that in the two seasons, aromatic rice varieties differed significantly in panicle number m^{-2}. The highest panicle number m^{-2} at harvest in the two seasons was noticeably produced by IR77510 variety. In the first and second seasons, IR 65610 and IR 71137 varieties produced the lowest panicle number of m^{-2}, respectively.

The increase in the number of panicles m^{-2} may be due to the increase in the number of tillers m^{-2}. Mahapatra and Padalia (1971) reported an increase in the production of effective tillers hill^{-1} with the increase in panicles which are responsible for higher yield.

2.5.2 Number of non-effective tillers hill^{-1} (no.)

Hossain *et al.* (2008) 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. Metwally *et al.* (2012) reported that in the two seasons, aromatic rice varieties differed significantly in panicle number m^{-2}. The highest panicle number m^{-2} at harvest in the two seasons was noticeably produced by IR77510 variety. In the first and second seasons, IR 65610 and IR 71137 varieties produced the lowest panicle number of m^{-2}, respectively. The increase in the number of panicles m^{-2} may be due to the increase in the number of tillers m^{-2}.

2.5.3 Total grains panicle^{-1} (no.)

An examination was directed by Sarkar *et al.* (2016) to evaluate the yield and nature of aromatic fine rice as influenced by variety and nutrient management during the period from June to December 2013. The test included three aromatic fine rice varieties *viz.* BRRI dhan34, BRRI dhan37 and BRRI dhan38, and eight nutrient management *viz.* control (no manures and fertilizers), suggested portion of inorganic fertilizers, cow-dung at 10 t ha^{-1}, poultry manure at 5 t ha^{-1}, 50% of suggested portion of inorganic fertilizers + 50% cow-dung, 50% of suggested portion of inorganic fertilizers + 50% poultry manure, 75% of suggested portion of inorganic fertilizers + 50% cow-dung and 75% of suggested portion of inorganic fertilizers + 50% poultry manure. The examination was laid out in a randomized complete block design with three replications. The tallest plant (142.7 cm), the most elevated number of effective tillers hill^{-1} (10.02), number of grains panicle^{-1} (152.3), panicle length (22.71cm), 1000-grain weight (15.55g) and grain yield (3.71 t ha^{-1}) were recorded in BRRI dhan34.

The most elevated grain protein content (8.17%) was found in BRRI dhan34 though the most elevated fragrance was found in BRRI dhan37 and BRRI dhan38. The most noteworthy number of effective tillers hill^{-1} (11.59), number of grains panicle^{-1} (157.6), panicle length (24.31 cm) and grain yield (3.97 t ha-1) were recorded in the supplement the executives of 75% suggested portion of inorganic fertilizers + 50% cow-dung (5 t ha^{-1}). The treatment control (no manures and fertilizers) gave the lowest values for these attributes. The most elevated grain yield (4.18 t ha-1) was found in BRRI dhan34 combined with 75% suggested portion of inorganic fertilizers + 50% cow-dung, which was factually indistinguishable from BRRI dhan34 joined with 75% of suggested portion of inorganic manures + half poultry manure and the least grain yield (2.7 t ha^{-1}) was found in BRRI dhan37 in charge (no manures and manures). The most elevated grain protein content (10.9 %) was acquired in the association of BRRI dhan34 with suggested portion of inorganic fertilizers which was in the same class as that of BRRI dhan38 and 75% of suggested portion of inorganic fertilizers + 50% poultry manure. The most noteworthy aroma was found in BRRI dhan38 combined with 75% suggested portion of inorganic fertilizers + 50% cow-dung.

A study was conducted by Saha *et al.* (2015) to assess the degree of variability between small grain aromatic (SGA) rice (*Oryza sativa* L.) genotypes for yield and yield components. At the BRAC Agricultural Research and Development Centre, Gazipur, Bangladesh, twenty four popular SGA rice genotypes were assessed for yield and yield-contributing characters. As the control variety, BRRI dhan34 was used. Chinikanai-1, which was followed by Kalijira PL-9, Kalijira PL3 and Badshabhog, experienced the highest grain yield per plant. Chinikanai-1 had the highest amount of grain per panicle. The correlation analysis revealed that the positive contribution to grain yield was the number of panicles per plant ($r = 0.646$) and the number of grains per panicle ($r = 0.525$). Based on a sensory test, 18 genotypes were found to be scented and six to be lightly scented. Following the assessment of yield components, four genotypes, namely Chinikanai-1, Kalijira PL-9, Kalijira PL-3 and Badshabhog, have been selected as outstanding genotypes which can be used as potential breeding materials for the subtropical environment of Bangladesh. Myung (2005) worked with four different panicle types of rice varieties and observed that the primary rachis branches (PRBs) panicle^{-1} and grains were more on Sindongjinbyeo and Iksan467 varieties, but secondary rachis branches (SRBs) were fewer than in Dongjin1 and Saegyehwa varieties. Ashvani *et al.* (1997) studied 22 genotypically different strains of hybrid rice to correspond yield contributing attributes. Number of effective tillers plant^{-1} demonstrated significant and positive relationship at genotypic and phenotypic levels with grain yield panicle^{-1}, 1000-grain weight and biological yield plant^{-1}.

2.5.4 Panicle length (cm)

Ramalingam *et al.* (1994) found that long-panicle varieties, higher number of filled grains panicle^{-1} and more primary rachis would be suitable for selection because these characters had a higher positive association and were correlated between themselves with grain yield. Hoque *et al.* (2013) investigated the performance of aromatic varieties on the growth and yield of aromatic rice and found that there were statistically significant differences between the varieties with respect to panicle length. Akbar (2004) revealed that almost all the crop characters differed significantly in variety, seedling age and their combined effect. BRRI dhan41 performed the best among the varieties in terms of the number of effective tillers hill^{-1}, panicle length, total spikelet panicle^{-1} and grain number panicle^{-1}. BRRI dhan41 also delivered the maximum grain and straw yields. Sonarbangla-1 positioned first in regard of total tillers hill^{-1} and 1000-grain weight but produced highest number of non-effective tillers hill^{-1} and sterile spikelet's panicle^{-1}. Grain, straw and biological yields were resulted highest in the combination of BRRI dhan41 with 15 day-old seedlings.

Idris and Matin (1990) found that the length of the panicle differed between the varieties and was greater in IR 20 than in any of the native and high yielding varieties. Behera (1998) reported that by increasing the number of spikelets per panicle and panicle length, respectively, increasing panicle length and plant height may have indirectly increased rice grain yield. An experiment was directed by Islam *et al.* (2014) to examine the yield and quality of aromatic fine rice as influenced by the management of variety and nutrients. Three aromatic fine rice varieties were included in the experiment: viz. BRRI dhan34, BRRI dhan37 and BRRI dhan38, respectively. In BRRI dhan34, the highest plant height (142.7 cm), the highest number of effective tillers hill^{-1} (10.02), grains panicle^{-1} (152.3), panicle length (22.71 cm), 1000-grain weight (15.55 g) and grain yield (3.71 t ha^{-1}) were achieved.

2.5.5 Number of filled grains panicle^{-1} (no.)

An experiment with six varieties of rice genotypes Mangala, Madhu, J-13, Sattari, CR 666-16 and Mukti were conducted by Murthy *et al.* (2004) and they observed that Mukti (5.268 t ha^{-1}) out yielded the other genotypes and recorded the maximum number of filled grains and had lower spikelet sterility (25.85%) contrasted with the others.

An experiment was conducted to study their impacts on the yield and yield contributing characters of rice varieties BR23 and Pajam with 2, 4 and 6 seedlings hill^{-1} during the *Aman* season. They revealed that the cv. BR23 demonstrated better performance over Pajam in regard of yield and yield components i.e. productive tillers number hill^{-1}, panicle length, l000-grain weight, grain yield and straw yield. On the other hand, the cultivar Pajam delivered significantly the highest plant height, number of total grains panicle^{-1}, number of filled grains panicle^{-1} and number of unfilled grains panicle^{-1} (Kashem *et al.*, 2005). Parvez *et al.* (2003) reported that yield advantage for the hybrid rice was mainly due to the proportion of filled grains panicle^{-1}, heavier grain weight (35%) and increased harvest index values than the control (28%).

Shrirame and Mulley (2003) conducted an experiment on the variability and relationship of different biometric and morphological plant characteristics with grain yield. Grain yield was noticeably affected by the number of grains filled with panicle^{-1}. Ganesan (2001) experimented with 48 hybrids of rice.

Filled grain panicle^{-1} (0.895) had the highest positive direct effect on yield plant^{-1} followed by number of tillers plant^{-1} (0.688), panicle length (0.167) and plant height (0.149). Roy *et al.* (2014) evaluated 12 indigenous varieties of Boro rice where the height of the plant and tillers hill^{-1} at different DAT varied significantly between the varieties until harvest. The tallest plant (123.80 cm) was recorded in Bapoy at the time of harvest and the shortest (81.13 cm) in GS. Maximum hill^{-1} tillers (46.00) were observed at Sylhety Boro and minimum tillers (19.80) at

Bere Ratna. With the exception of grain yield, biological yield and harvest index, all yield and yield contributing characteristics varied significantly at the 1 % level of significance. The maximum effective hill^{-1} tillers (43.87) were recorded in the Sylhety Boro variety, while the lowest effective hill^{-1} tillers (17.73) were produced by Bere ratna. The highest (110.57) and lowest (42.13) filled grains panicle^{-1} was observed in the Koijore and Sylhety Boro varieties, respectively. The weight of one thousand grains was the highest (26.35 g) in Kali Boro and the lowest (17.83 g) in GS 1. Grain did not differ significantly among the varieties but numerically the highest grain yield (5.01 t ha^{-1}) was found in the variety Koijore and the lowest in GS one (3.17 t ha^{-1}).

An experiment was conducted by Shiyam *et al.* (2014) to evaluate the performance of four Chinese hybrid rice varieties in which FARO 15 was comparatively superior to the hybrids in all assessed growth and yield components. With more productive tillers (11.0), higher spikelets plant^{-1} (166.0), higher filled grain panicle^{-1} (156.17), higher filled grains (92.17 percent), higher 100 grain weight of 2.63 g and higher paddy yield (5.021 t ha^{-1}) than others, FARO 15 was taller (140 cm) than others. Xudao151 came close to FARO 15 with a grain yield of 2,987 t ha-1 despite the relative poor performance of the hybrids. Mahamud *et al.* (2013) showed that rice cultivars vary considerably in all growth patterns, such as plant height, number of tillers and dry matter weight of different plant parts, panicle length, filled grain, unfilled grain, grain filling percentage, 1000 grain weight, grain yield and straw yield.

2.5.6 Number of unfilled grains panicle^{-1} (no.)

Chowdhury *et al.* (1995) reported that the cultivar BR23 showed superior performance over Pajam in respect of yield and yield contributing characters i.e. number of productive tillers hill^{-1}, length of panicle, 1000-grain weight, grain and straw yield. On the other hand, the cultivar Pajam produced significantly taller plant, higher number of total spikelets panicle^{-1}, grains panicle^{-1} and unfilled spikelets panicle^{-1}. 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.

In all growth characteristics, such as plant height, the number of tillers and dry matter weight, length of the panicle, filled grains, unfilled grains, 1000 grains weight, grain yield and straw yield were varied considerably due to varietal execution (Mahamud *et al.*, 2013). Chowdhury *et al.* (1993) reported that the variation in number of unfilled grains panicle^{-1} might be due to genetic characteristics of the varieties.

2.5.6 1000-grain weight (g)

Halder *et al*. (2018) conducted an experiment to find out the effect of variety and planting density on the yield and yield contributing characters of local aromatic rice. The experiment was laid out in a factorial randomized complete block design with three replications, which consisted of three local aromatic rice varieties (Chinigura, Shakhorkhora and Kalizira) and four planting densities were *viz.* S_1 (25 cm × 20 cm), S_2 (20 cm × 20 cm), S_3 (20 cm × 15 cm) and S_4 (20 cm × 10 cm). The results showed that the local aromatic rice var. Shakhorkhora variety produced the most noteworthy number of grains panicle^{-1} (131) and 1000-grain weight (13.8 g), consequently higher grain (2.63 t ha^{-1}), followed by Kalizira (2.56 t ha^{-1}) and straw yield (4.21 t ha^{-1}). One the other hand, higher number of tillers hill^{-1} (14.8), number of grains panicle^{-1} (140 nos.) were found in 20 cm × 20 cm spacing with higher grain yield.

Islam *et al*. (2014) directed an experiment to examine the yield and quality of aromatic fine rice as influenced by variety and nutrient management. The experiment contained three aromatic fine rice varieties *viz*. BRRI dhan34, BRRI dhan37 and BRRI dhan38.

The highest plant height (142.7 cm), the highest number of effective tillers $hill^{-1}$ (10.02), grains number $panicle^{-1}$ (152.3), panicle length (22.71cm), 1000-grain weight (15.55g) and grain yield (3.71 t ha^{-1}) were achieved in BRRI dhan34. Mahamud *et al*. (2013) showed that rice cultivars differed significantly in all growth characters, such as plant height, tillers number and dry matter weight of different plant parts, panicle length, filled grain, unfilled grain, filled grain percentage, 1000 grain weight, grain yield and straw yield. Uddin *et al.* (2001) conducted an experiment to determine the yield of hybrid, inbreed and locally improved rice varieties and reported that the variety had a significant effect on all crop characteristics under study. Sonarbangla-1 ranked first in 1000-grain weight, followed by Alok 6201 and Habigonj.

Mante (2016) reported that the weight of 1000 grains was significantly impacted by land preparation, crop establishment and varieties tested, similar to filled grains. There was interaction between treatments, but the significant differences may have been due to the varieties genetic characteristics.

Srivastava and Tripathi (1998) conducted an experiment and showed that the increased efficient tillers m^{-2}, fertile grains $panicle^{-1}$, panicle weight and 1000-grain weight could be attributed to an increase in grain yield in local control compared with hybrid. By using 1 seedling $hill^{-1}$, Wen and Yang (1991) found a higher 1000-grain weight than with 4 seedlings $hill^{-}$ Ashraf *et al.* (1999) reported that the genetic character least influenced by the environment is 1000-grain weight, an important yield-determining component. An experiment was conducted by Islam *et al.* (2009) and reported that BRRI dhan3l had a higher weight of 1000 grains than BRRI dhan31 in 2001. Sonarbangla 1 had the highest 1000grain weight in 2002, followed by BRRI dhan31.

2.6.1 Grain yield (t ha^{-1})

Twenty-one advanced cultivars were examined in transplanted condition during 2005 wet season in a replicated trial along with three checks (Swarna, Pooja and Gayatri) for yield and yield contributing attributes like plant height, days to flowering and number of ear bearing tillers. Variety Swarna (4.864 t ha^{-1}) and CR 874-59 (4.675 t ha^{-1}) shown higher grain yield compared with others. (Patnaik and Mohanty, 2006).

Talukdar *et al.* (2004) was carried out a field experiment at RDRS Bangladesh farm, Monthana, Rangpur, Bangladesh during July to December 2016 to evaluate the yield performance of seven aromatic rice varieties of Bangladesh viz. Jirakatari, Chiniatab, Chinigura, Kataribhog, Kalizara, Badshabhog and BRRI dhan34. Results from the study showed that, the entire yield contributing characters and quality parameters varied significantly among the aromatic rice varieties. The longest plant height (167.0 cm) was observed in the variety Chinigura and the shortest (120.1 cm) in the variety Chiniatab. In the variety, Kataribhog filled grains number panicle^{-1} was discovered most elevated (255.6) and the least (130.7) was recorded in the variety Badshabhog. Badshabhog delivered the most elevated 1000-grain weight (18.3 g) and the least (11.4 g) was recorded from the variety Kataribhog. The most elevated grain yield (2.54 t ha^{-1}) was acquired from Kataribhog and the least grain yield (1.83 t ha^{-1}) was gotten from Kalizara. Among the seven aromatic rice varieties under North-west condition Kataribhog and BRRI dhan34 are reasonable in regard of yield.

Hassan *et al.* (2003) observed that grain yield is a capacity of interaction of various yield components such as number of productive tillers plant^{-1}, spikelets panicle^{-1} and 1000-grain weight. Shrirame and Mulley (2003) revealed that grain yield shown a very strong positive correlation with harvest index. Grain yield was also significantly correlated with dry matter weight hill^{-1}, effective tillers hill^{-1} and no. of filled grains panicle^{-1}. Islam *et al.* (2015) was carried out an experiment was done by at Mymensingh, Bangladesh with four fragrant fine rice viz. 'Chinisagar', 'Chiniatab', 'Basmati' and 'Awnless Minicat' with three distinctive date of relocating 20 January, 5 February and 20 February. Among the fragrant fine rice 'awnless Minicat' gave the best return (3.10 t ha^{-1}) yet that was at standard with those of Basmati (1.77 t ha^{-1}). Bhuiyan *et al.* (2014) conducted an experiment to observe and recommend to rice farmers the adaptability and performance of various hybrid rice varieties and to find the best hybrid rice variety in terms of yield and yield components.

The various hybrid rice varieties evaluated had significant effects on yield, based on the findings of the study. Therefore, RGBU010A SL8R is recommended among hybrid rice varieties as a planting material because it has produced favorable yields. Srinivasulu *et al*. (1999) reported that planting 1 seedling $hill^{-1}$ in case of rice gave higher grain yield comparable to that of 2 seedlings $hill^{-1}$.

Julfiquar *et al.* (1998) reported that six hybrids produced the control varieties in the International Rice Hybrid Observational Nursery (IRHON-96), of which three hybrids-IR6229A / IR29723-143-3-2-1R, IR58025A / IR34683-179-1-2-1R and IR58025A / IR21-567-18-3R gave 1 ton more yield than the same duration control variety. Six hybrids were researched for grain characters by Geetha *et al.* (1994). The highest yield (19.7 g $plant^{-1}$) was ADRH4. In this hybrid, the increased yield was due to higher grain number $plan^{-1}$. Correlation analysis showed that only grains $plant^{-1}$ had a strong positive association with grain yield. Eleven hybrid cultivars were evaluated by Leenakumari *et al.* (1993) against four standard control varieties: Jaya, Rasi, IR20 and Margala.

They concluded that the highest yield was 7.9 t ha^{-1} from the hybrid cultivar OR 1002, followed by the hybrid cultivar OR 1001 (6.2 t ha^{-1}). Jaya gave the highest yield (8.4 t ha^{-1}) among the control varieties. Suprihatno and Sutaryo (1992) assessed the performance of seven IRRI hybrids and 13 Indonesian hybrids using IR64 and Way-Seputih as control varieties. They found that the control varieties were highly yielding than the hybrids, the highest yield was IR64, considerably yielding IR6461H, IR64610H and IR62829A / IR54, which Way-Seputih in turn yielded.

2.6.2 Straw yield (t ha^{-1})

Halder *et al*. (2018) conducted an experiment to find out the effect of variety and planting density on the yield and yield contributing characters of local aromatic rice. The experiment was laid out in a factorial randomized complete block design with three replications, which consisted of three local aromatic rice varieties (Chinigura, Shakhorkhora and Kalizira) and four planting densities were *viz.* S_1 (25 cm × 20 cm), S_2 (20 cm × 20 cm), S_3 (20 cm × 15 cm) and S_4 (20 cm × 10 cm). The results showed that the local aromatic rice var. Shakhorkhora variety produced the most noteworthy number of grains panicle^{-1} (131) and 1000-grain weight (13.8 g), consequently higher grain (2.63 t ha^{-1}), followed by Kalizira (2.56 t ha^{-1}) and straw yield (4.21 t ha^{-1}). One the other hand, higher number of tillers hill^{-1} (14.8), number of grains panicle^{-1} (140 nos.) were found in 20 cm × 20 cm spacing with higher grain yield.
Summers *et al.* (2003) conducted an experiment at multiple sites for the 1999 and 2000 seasons with eight common California rice cultivars and found variability in the quantity and quality of straw that can have critical effects on biomass industries. The highly recommended attribute for the straw yield was the length of the pre-heading period. Cutting height with a non-linear distribution, resulting in almost half of the straw biomass occurring in the lower third of the plant, also strongly affects the harvested straw yield.

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

Kalizera, followed by BRRI dhan37 and BRRI dhan38. 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 IR77510 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.

2.6.3 Biological yield (t ha^{-1})

Islam *et al.* (2013) 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 30 gave a significant positive linear relationship which indicates that as biological yield increased, grain yield also increased.

A field experiment was conducted by Khatun *et al*. (2018) to evaluate the growth, yield and yield characters of aromatic rice (cv. Tulshimala) under the fertilization of cow dung (organic manure) and zinc (micronutrient). From the results of the experimentation showed that, the application of different levels of cow dung and zinc fertilizers considerably increased the total tillers number hill^{-1}, productive tillers number hill^{-1}, length of panicle, test weight (g), grain yield hill^{-1} (g), straw yield hill^{-1} (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}), and biological yields over control. However, the treatment combination of CD_1Zn_2 i.e. 10 t ha^{-1} cowdung and 12 kg ha^{-1} $ZnSO_4$ along with other recommended doses of inorganic fertilizers produced the highest grain yield (2.79 t ha^{-1}) and straw yield (5.80 t ha^{-1}) over other treatments.

Peng *et al.* (2000) concluded that the increasing trend in cultivar yield due to the improvement in the harvest index (HI) was associated with yield trends for cultivar lines, while the increase in total biomass. Ramesha *et* *al.* (1998) found that increased total biomass and increased panicle weight, with almost the same level of harvest index, resulted in the superior yielding capacity of the hybrids over the controls.

Kim and Rutger (1988) reported that greater biomass was also produced by hybrids that gave greater grain yields. Furthermore, for hybrid rice and conventional rice, biomass yield at different growth stages showed different patterns. In the early and middle growth stages, hybrid rice has more dry matter accumulation.

2.6.4 Harvest index (%)

Senapati and Sarker (2004) observed the adaptability of aman paddy under the sundarban regions of West Bengal. In 40 aman rice genotypes cultivated during the Kharif seasons of 1997, 1998, 1999 and 2000 under rainfed lowland conditions of Kakdwip, West Bengal, India, grain yield and number of days to maturity were evaluated. For both traits, they found distinct genetic variation and genotype-environment interaction. Twenty-one genotypes were found to be stable for several days until maturity. Of these, the late matured varieties CR-626-26-2-3, CR-383-10, Dudhraj, Lilabati, Dhusari and Bogamanohar were desirable for the cultivation of aman rice in the Sundarban regions. For grain yield, twenty-two genotypes were highly stable and widely adapted to the Sundarban areas.

Shrirame and Mulley (2003) experimented with variability and relationship studies of different biometric and morphological plant characteristics of rice with grain yield. It was conducted with the TNRH10, TNRH13 and TNRH18 rice hybrids and the Jaya cultivar. They found that the grain yield showed a very positive and significant correlation with the harvest index. Grain yield has also been significantly correlated with dry matter weight hill^{-1}, efficient tillers hill^{-1} and number of filled grains panicle^{-1}. In an experiment, Kiniry *et al.* (2001) stated distinct parameters describing crop growth and yield production processes. In each of the 2 years, the mean harvest index was 0.32 (32 percent) for all four cultivars over the two harvests. They concluded that variations in yield among cultivars were due to differences in the harvest index.

Peng *et al.* (2000) concluded that the increasing trend in yield of cultivars released before 1980 was mainly due to the improvement in harvest index (HI), while an increase in total biomass was correlated to increasing yield trends for cultivars–lines developed after 1980. Cui *et al.* (1998) conducted a varietal trial of Japanese rice varieties (J group) along with 20 high yielding Asian rice varieties (H group).

They reported significantly higher yield and harvest index in H group than that of the J group. Days to heading (DTH) showed significantly positive correlation with total dry matter weight and a significantly negative correlation with harvest index.

Sitaramaiah *et al.* (1998) assessed six promising rice hybrids with two control varieties and found that MTUHR 2033, MTUHR 2020 and MTUHR 2037 hybrids gave higher grain yield, higher production of biomass and harvest index than other varieties. Higher yielding hybrids were also recorded for higher biomass yield and harvest index, they also showed. Hybrids were found to have a superior performance due to more panicle grains-1, which was indicated by a higher harvest index.

Jiang *et al.* (1995) assessed 10 varieties for yield components. The increase in yield of dwarf over high varieties was mainly due to higher harvest index, while the increase in yield of hybrid rice over dwarf varieties was mainly due to higher production of biomass. Hoque *et al.* (2013) stated that harvest index is a vital character having physiological importance. They found 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 %).

2.7 Yield advantage of fine hybrid varieties

A comparative study to assess four imported hybrid rice cultivars with a high yielding variety (BRRI Dhan29) was evaluated by Parvez *et al.* (2003). The Chinese Sonarbangla-1 cultivar showed the best performance in terms of all the parameters under consideration. The other three Indian cultivars had lower performance than the control (Amarsiri-1, Aalok and Loknath). Sonarbangla-1 produced a 20% higher grain yield than the control (6.26 t ha^{-1}) (7.55 t ha^{-1}). The hybrid rice yield benefit was mainly due to the heavier grain weight (35 percent).

Ma *et al.* (2001) tested the comparative performance of 8 rice hybrids and the PS02 and PTT1 control cultivars.

As well as higher yields, the hybrids had more leaves (12-15.9) than the local cultivars (15.1-15.3). The highest yield (7,142 t ha^{-1}) was produced by NN49, which was 58.78 percent and 26.52 percent higher than PS02 and PTT1. They have also been experimenting with ADTRH1, a rice hybrid. ADTRH1 showed a 26.9 percent and 24.5 percent higher yield over CORH1 and ASD18 respectively in various field studies, with an average yield of 6.6 t ha^{-1}.

BAU (1998) conducted a field experiment at boro season, it was observed that hybrid rice Alok 6201 out-yielded the modern variety Iratom 24 by 29.48%. The higher numbers of tillers $hill^{-1}$, effective tillers $hill^{-1}$, spikelets $panicle^{-1}$ and panicle length was found from Alok 6201; whereas, Iratom 24 was found better in terms of 1000-grain weight only.

An experiment with 24 trial hybrid rice varieties was conducted by Widyastuti *et al.* (2015).

The outcomes demonstrated that grains yields were influenced by areas, seasons, and genotypes. The genotypes × areas × seasons cooperation impact was significant; along these, the best hybrid was different for each area and season. A7/PK36 hybrid has the best execution in Batang during the dry season, while A7/PK40 and A7/PK32 are the best hybrids in the rainy season. In Sukamandi, 9 hybrids were recognized as better yielder over that of the check variety in the dry season, but not so in the rainy season. Ramana *et al.* (1998) was carried out an experiment and observed that the mean grain yield of the best performing rice hybrids was 37.7% higher than the conventional cv. IR-64 during 1993; while in 1995, the maximum yield of rice hybrid MTUHR 2037 was 10.3%, 17.4% and 31.1% higher than that of comparing cultivars Chaitanya, BPT 5204 and Tellahamsa, respectively. The mean grain yield of rice hybrids during 1996 was 23.7% and 26% higher than BPT 5204 and Tellahamsa, respectively.

In an experiment with hybrid rice cultivars IR62829A / IR46R and MH841-1A / MR 167, Guok *et al.* (1997) found that the two hybrid rice lines, IR62829A / IR46R and MH841-1A / MR 167, had a yield advantage of approximately 24% to 26% over the best local control in 1995-96. Khush and Aquino (1994) in an experiment reported that the yield capability of modern high yielding varieties grown under the best tropical conditions is 9–10 t ha^{-1}.Tropical rice hybrids under similar condition have shown yield potential about 12 t ha^{-1}.

2.8 Evaluation of genetical purity

2.8.1 Offtype plants (%)

Among those varieties, Jiang *et al.* (1995) compared 10 varieties for yield components and offtype plant percentages. The yield increases in the varieties of lower percentages of offtype plants resulted mainly in higher yield potential. Hossain *et al.* (2005) examined the association between grain yield with the percentages of five local and three modern aromatic rice varieties of offtype plants. With the lowest percentage of offtype plants, Kataribhog produced the highest grain yield (3.2 t ha^{-1}) than the BRRI dhan38.

2.9 Quality contributing characters

2.9.1 Amylose content (%)

As the main parameter of cooking and eating quality, the amylose content of rice is considered (Juliano, 1972). It is preferred to have intermediate to high amylose rice with a low to intermediate gelatinization temperature. Dahiphale *et al.* (2004) worked at Akola, found that quality parameters viz. kernel length (cm), kernel breadth (cm), kernel L/B ratio, kernel length after cooking, elongation ratio and amylose content (%) were not influenced significantly among Basmati genotypes.

Many of the cooking and eating characteristics of milled rice are influenced by the ratio of two kinds of starch, amylose and amylopectin in rice grain. The amylose content of nonwaxy rice ranges from 7 to 34% of the milled rice on dry weight basis or 8 to 37% of the starch itself, glutinous or waxy varieties contain virtually no amylose. Most people in Bangladesh prefer high-amylose containing rice. In the majority of tropical Asia, including Bangladesh, high amylose rice is preferred. The content of amylose influences the properties of cooked rice, if the quantity is low, sticky. The content of amylose influences volume expansion, water absorption, cooked rice tenderness and stickiness. The amylose content in rice is used as the single most significant feature in the description and prediction of the quality of rice cooking (Kaul *et al.*, 1982).

In the non-glutinnous varieties, amylose is the linear fraction of starch, while amylopectin, the branched fraction, makes up the rest of the starch. The content of amylose correlates negatively with the taste panel scores for boiled rice cohesiveness, tenderness, color and gloss. In waxy (glutinous) rice, amylose is almost absent. Suchrice does not expand in volume, is glossy and sticky when cooked, and stays firm. In northern and north-eastern Thailand and Lao PDR, this rice is the staple food of individuals. A large majority of the rice has high amylose content from Vietnam, Thailand, Myanmar and the Indian subcontinent.

The ratio of the amylose and amylopectin in the rice grain influence the cooking and eating characteristics of rice. A high degree of flakiness is shown in this rice. It cooks dry, is less tender and, when cooled, becomes hard. Wet and sticky, low-amylose rice is cooked. All Japanese varieties from temperate regions have a low content of amylose. Varieties grown in the Philippines, Malaysia and Indonesia have intermediate amylose content and are moist and tender to cook and are not difficult to cool. With the increase of harvesting time amylose, carbohydrate and protein content are increased: they also concluded that expansion volume is also affected by the change of amylose content (Marzempi and Edi, 1990). Islam and Virmani (1990) observed that all the hybrids showed high amylose content than the parents.

2.9.2 Protein content (%)

In most developing countries, the source of protein for human consumption is cereals and pulses. Since rice is the staple food for Asians, the need to improve the amount of protein in rice is of paramount importance as a major item in their diet. One of the principal sources of protein for human beings is milled rice protein. The potential for quantitative and quantitative improvements in rice proteins appears to be considerable (Satoh *et al.*, 1990).

Kader *et al.* (2018) found that BRRI dhan70 is another aromatic, high yielding and extra-long fine grain containing transplanted Aman rice variety that is an enhancement over BRRI dhan37, existing premium quality rice. In the proposed preliminary variety directed at the farmer's field, BRRI dhan70 was pleasantly gone. This assortment for business development in the wet season (T. Aman) of Bangladesh in 2015 was therefore affirmed by the National Seed Board (NSB). The straw shaded extra-long thin, higher lengthening capacity and odor of the cooked rice is the important element of BRRI dhan70. The length of development of BRRI dhan70 is 130 days, which is 10-15 days earlier than that of BRRI dhan37.

The assortment's one thousand grain weight is 20 g and it has a hued grain tip and a pointed awn. At 9.5% protein content, the rice has 21.7% amylose content. Dwelling resilience is the exceptional character of the assortment. It has long, erect dark green banner leaf. BRRI dhan70 can create 4.8-5.0 ha^{-1} yield with legitimate administration which is around 1.0-1.35 tha^{-1} higher yield than BRRI dhan37. The exportable aromatic rice BRRI dhan70 is a brilliant assortment for developing in the wet (T. Aman) season and ranchers can be profited by the development of BRRI dhan70.

Marzempi and Edi (1990) found that the amylose, carbohydrate and protein content increased with the increase in harvesting time. Rice is mainly the major source of calories, but to some extent it supplements protein.

2.9.3 Length of grain rice (mm)

Kishine *et al.* (2008) reported that rice grain quality largely depends on the physicochemical properties which are greatly influenced by the genotype. Size and shape (Length, breadth and L/B) are considered to be the first important criteria for the development of new variety for commercial production.

Dahiphale *et al.* (2004) worked at Akola, found that quality parameters viz. kernel length (cm), kernel breadth (cm), kernel L/B ratio, kernel length after cooking, elongation ratio and amylose content (%) were not influenced significantly among Basmati genotypes. Water uptake ratio which is a good indication of volume increase has a positive influence on grain elongation (Sood & Saddiq, 1986). Amylose content showed significant and positive correlation with length of grain and cooking time (Danbaba *et al.*, 2011). Samal *et al.* (2014) noticed that there are 21 species in the genus Oryza, of which *Oryza sativa* and *Oryza glaberrima* are the only cultivated species derived from their perennial wild progenitors, *Oryza rufipogan* and *Oryza longistaminata*.

Diversifying the *O. sativa* is not limited to these three sub-species, but through selection under various agro-climatic conditions, cultural practices and quality preferences, develops into many more varietal groups. The present study suggests that, on the basis of morphological, biochemical and genetic variations, the divergences of 78 genotypes of aromatic rice, including international control varieties, traditional Basumati and evolved Basumati.

The height of the plant ranged from 85.91 cm to 159.67 cm among the genotypes, while the panicles / plant ranged from 6.06 to 16.22 with a mean value of 9.56. In all the evolved Basmati genotypes, the grain length is highest, followed by indigenous aromatic rice. In 'Jala', 'Magura' and 'Ratnasundari' showed the lowest grain length and 'Kusumabhog' and 'Gatia' showed highest grain length. Eight genotypes have recorded the smallest breadth of grain. The alkali spreading value (ASV) varied, indicating very wide variability, from 2.0 (IR-64) to 6.17 (Jalaka). The current investigation also highlighted the inter-population and intra-population diversity of 78 genotypes of rice, with a view to assessing the potential and impact of traditional farming on the farm management of rice landraces.

2.9.4 Breadth of grain rice (mm)

Dahiphale *et al.* (2004) worked at Akola, found that quality parameters viz. kernel length (cm), kernel breadth (cm), kernel L/B ratio, kernel length after cooking, elongation ratio and amylose content (%) were not influenced significantly among Basmati genotypes. Samal *et al.* (2014) observed that in indigenous aromatic rice the grain length ranged from 4.90 to 12.41 mm and grain width was 1.80 to 3.50 mm.

2.9.5 Length/breadth ratio of grain rice

Higher/greater surface area, which is indicated by the higher L/B ratio, allows the grain to absorb more water than the grain with lower ratio. In addition short and medium grain varieties have higher water absorption than long grain types (Hogan and Plank, 1958). Generally, rice varieties with higher elongation ratio are considered as high quality rice throughout the world (Kumar, 1989).Lipika and Bhaben (2017) conducted an experiment and reported highest l/b ratio (3.75) for the local white rice, whereas, the lowest ratio was recorded for brown rice (2.09) in locally grown and imported rice varieties marketed.

2.9.6 Milled rice (%)

The grain elongation on cooking is very much dependent on genetic factors as well as the degree of milling (Sarkar *et al.*, 2016).

It is evident from the above literature that the effects of varieties have a significant impact on rice yield, yield components, and quality. The literature suggests that the appropriate variety increases the rice grain yield. The reduction in grain yield is mainly due to the decreased number of tiller hill^{-1}, grains panicle^{-1}, panicle length and thousand grain weights and the quality due to the limited development of these varieties themselves.

Chapter III

Materials & Methods

CHAPTER III
MATERIALS AND METHODS

The experiment was carried out in order to explore the growth, yield and quality of various hybrid rice cultivated in various experiments. This chapter provides a brief description of the experimental site, climate, soil, soil preparation, planting materials, experimental design, soil preparation, application of fertilizers, transplantation, irrigation and drainage, intercultural operation, data collection, data recording and analysis of the materials and methods of the experiment. Details of the investigation to achieve the stated objectives are outlined below.

3.1 Site description

The experiment was conducted during the period from July 2018 to November 2018 at the research farm of Sher-e-Bangla Agricultural University, Dhaka. The experimental site was located at 23 ° 74′ N latitude and 90 ° 35′ E longitudes at an altitude of 8.2 m.

3.2 Agro-ecological region

The experimental site belongs to the “Madhupur Tract” agro-ecological zone, AEZ-28 (Anon., 1988a). This was an area of complex relief and soils created above the Madhupur clay, where the analyzed edges of the Madhupur Tract were covered by floodplain sediments, leaving small hills of red soils as ‘islands’ encompassed by floodplain (Anon., 1988b). The experimental site is shown for better understanding in the AEZ Map of Bangladesh in Appendix I.

3.3 Climate and weather

The geographical location of the experimental site was characterized by three specific seasons in the sub-tropical climate, namely the monsoon or rainy season from May to October, associated with high temperatures, high humidity and heavy rainfall; the winter or dry season from November to February, associated with moderately low temperatures; and the pre-monsoon period. Information on the monthly maximum and minimum temperature, rainfall, relative humidity and sunshine during the period of the experimental site study was collected from the Meteorological Department of Bangladesh, Agargaon, and is provided in Appendix III.

3.4 Soil characteristics

The experiment was conducted in the typical rice-growing soil of the Madhupur Tract. Top soil was silty clay in texture, red brown terrace soil type, olive-gray with common fine to medium dark yellowish brown mottles. The pH of the soil was 5.6 and the organic carbon was 0.45%. With good irrigation facilities, the experimental land was well drained. The experimental site was a medium-high land. It was above the level of the flood. During the experimental period, sufficient sunshine was available. Soil series: Tejgaon, General soil: Non-calcareous Dark Grey (Appendix II). The morphological characteristics of the soil of the experimental plots are as follows. Appendix II presents the physicochemical properties of the soil.

3.5 Planting materials and main features

Planting materials including advance lines, hybrid and inbred varieties were used in this experimentation. Among them, two varieties viz. BRRI dhan49 and BRRI dhan34 were used as inbred check; whereas, 5 were used as hybrid genotype and rest were hybrid varieties. The hybrid materials were designated as follows and the characteristics are given as well.

i. SAU Test Cross-6
ii. SAU Test Cross-7
iii. SAU Test Cross-8
iv. SAU Test Cross-9
v. SAU Test Cross-10
vi. Dhani gold
vii. Hira 16
viii. Win 19
ix. Win 707
x. AZ 7006
xi. BRRI dhan34
xii. BRRI dhan49

Grain Characteristics:

SAU Test Cross-6: Medium and slender	Hira 16: Medium and slender
SAU Test Cross-7: Medium and slender	Win 19: Long and slender
SAU Test Cross-8: Long and slender	Win 707: Medium and slender
SAU Test Cross-9: Medium and slender	AZ 7006: Medium and slender
SAU Test Cross-10: Medium and slender	BRRI dhan49: Medium and medium
Dhani gold: Medium and slender	BRRI dhan34: Short and bold

3.6 Experimental details

3.6.1 Treatment of the experiment

Single factor experiment was carried out to explore the performance of hybrid rice genotype comparing to the inbred check varieties in T. Aman season.

3.6.2 Experimental design

The experiment was conducted in Randomized Complete Block Design (RCBD) with three replications. The experimental layout was prepared for the distribution of the varieties. The experimental field was divided into three blocks. Once again, each block was divided into 12 plots. The total number of unit plots of the experiment was 36 (12 × 3). The unit plot size was 2.8 m × 1.3 m (3.64 m^2). There was a width of 1 m and a depth of 20 cm for drains between the blocks. Each treatment was again separated by a 0.75 m wide and 20 cm deep drainage channel. Treatments were randomized to each block following the experimental design (Appendix IV).

3.7 Growing of crops

3.7.1 Raising of seedlings

3.7.1.1 Collection of seeds

The seeds of the test crops were collected from Nilsagor Seeds and Seed dealers. Although some of the seeds of hybrid genotype are not released as variety for commercial cultivation.

3.7.1.2 Seeds sprouting

Healthy seeds were selected by specific gravity strategy and subsequently immersed for 24 hours in water containers and then kept tightly in gunny bags in the wake of the disposal of water in containers. The seeds began to grow after 3 days and were planted in a nursery bed.

3.7.1.3 Preparation of nursery bed and seed sowing

According to BRRI recommendation seedbed was prepared with 1 m width. Sufficient amount of seeds were sown in the seedbed on 13 July 2018 in order to have seedlings of 25 days old. No fertilizer was used in the seedbed.

3.7.2 Main field preparation

The selected plot for the experiment was opened with a power tiller on 3 August 2018 and was exposed to the sun for a week. The chosen soil was harrowed, ploughed and cross-ploughed several times on 10 August 2018, followed by laddering to obtain a good tilth. Weeds and stubbles were removed and finally a desired tilth was acquired for seedlings transplanting.

3.7.3 Fertilizers application

Fertilizers were applied as recommended doses to each plot. Fertilizers such as Urea, TSP, MoP, Gypsum and Zinc Sulfate have been used as sources for N, P, K, S and Zn, respectively. Full doses of all fertilizers and one third of urea were applied as a basal dose to each plot during final land preparation on 10 August 2018 at the time of final soil preparation by means of a broadcasting method. The first urea split was applied on 6 September 2018, 25 days after transplantation (DAT) and the second urea split was applied on 25 September at the maximum tilling stage.

The doses of fertilizers with their sources are given below:

Nutrient	Source	Doses for Source (kg ha^{-1})
N (Nitrogen)	Urea	200
P (phosphorus)	TSP	30
K (potassium)	MoP	100
S (Sulphur)	Gypsum	75
Zn (Zinc)	Zinc sulphate	15

Source: Adhunik Dhaner Chash, BRRI

3.7.4 Seedlings uprooting

25 days old seedlings were carefully uprooted and kept in soft mud in shade. The seed beds were wet by application of water the day before the rooting of the seedlings to minimize the mechanical injury of the roots.

3.7.5 Seedlings transplanting in the main field

On 10 August 2018, the seedlings were transplanted as per experimental treatment without causing much mechanical injury to the roots. Line to line distance was 20 cm and hill to hill distance was 15 cm. Two seedlings $hill^{-1}$ were used during planting in the plots. There were 14 rows in each plot; each row contained 5 rows of rice seedlings. There were a total of 70 hills in each plot.

3.7.6 Cultural operations

Different cultural operations carried out in the course of the experiment are described below:

3.7.6.1 Irrigation and drainage

The experimental field was irrigated with adequate water and was maintained throughout the period of crop growth. Flood irrigation was provided to maintain 3-5 cm of water in the rice field as and when necessary. A good drainage facility for the immediate release of excess rainwater from the field has also been maintained.

3.7.6.2 Gap filling

Minor gap filling was done at 7–10 days after transplanting (DAT) with the same aged seedlings from the same source.

3.7.6.3 Weeding

Some common weeds infested experimental plots, which were removed twice by uprooting. The first weeding of each plot was done at 20 DAT and the second weeding of each plot was done at 40 DAT.

3.7.6.4 Plant protection measures

In the experimental plots, some plants were infested with rice stem borer, leaf roller and rice bug to some extent; which was successfully controlled by application of insecticides on 11 September 2018 such as Diazinon and Ripcord @10 ml/10 liter of water for 5 decimal lands. The insecticides (Virtago+ Advantage + Cypermethrine) were applied on 25 September 2018 to controlled rice stem borer and leaf roller. Crop was protected from birds and rats during the grain-filling period. For controlling birds, scarecrow and net were given and watching was done properly; especially during morning and afternoon.

3.8 Harvesting and post-harvest operation

Depending on the maturity of the plant, the rice plant is harvested. Harvesting was done from each plot manually. Harvesting began with 116 DAT and continued with up to 135 DAT. When 80% of the grains became golden yellow in color, the maturity of the crop was determined. The harvested crop was bundled separately from each plot, tagged correctly and brought to the threshing floor. Proper care was taken when rice seeds were harvested, threshed and cleaned. Fresh grain and straw weight were recorded plot wise. The grains have been cleaned and dried by the sun. The weight was adjusted to 14% moisture content. Straw has also been properly dried by the sun. Grain and straw yield plot^{-1} were eventually recorded and converted to t ha^{-1}. Five pre-selected hills per plot from which various data were collected; harvested separately, properly bundled, tagged separately from outside and then brought for grain and straw yield recording to the threshing floor.

3.9 Plant data recording

During the study period, for all entries on five randomly selected hills per plot from the middle rows in each replication, data on physical characters and yield components were recorded as follows:

3.9.1 Crop growth characters

a) Plant height

b) Number of tillers hill^{-1}

3.9.2 Phenological characters

a) Days to first panicle emergence

b) Days to 50% panicle emergence

c) Days to 100% panicle emergence

d) Days to maturity

3.9.3 Yield contributing attributes

a) Number of effective tillers hill^{-1}

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

c) Total grains panicle^{-1}

d) Panicle length

e) Number of filled grains panicle^{-1}

f) Number of unfilled grains panicle^{-1}

g) Weight of 1000 grains

3.9.4 Yields

a) Grain yield

b) Straw yield

c) Biological yield

d) Harvest index

3.9.5 Genetical purity evaluation

a) Offtype plants

3.9.6 Quality contributing characters

a) Amylose content

b) Protein content

c) Length of grain rice

d) Breadth of grain rice

e) Length/breadth ratio of grain rice

f) Milled rice

3.9.7 Procedure of recording data

3.9.7.1 Plant height (cm)

Plant height was recorded in centimetre (cm) at the time of 30, 50, 70, 90 DAT and at harvest. Data were recorded as the average of same 5 hills selected at random from the outer side rows (started after 2 rows from outside) of each plot. The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf before heading; and to the tip of panicle after heading.

3.9.7.2 Number of tillers hill^{-1} (no.)

The number of total tillers hill^{-1} was recorded at 30, 50, 70, 90 DAT and at harvest by counting total tillers as the average of same 5 hills pre- selected at random from the inner rows of each plot.

3.9.8.1 Days to first panicle emergence

Days to first panicle emergence was considered when first plants within a plot were showed up with panicle emergences. The number of days to first panicle emergence was recorded from the date of sowing.

3.9.8.2 Days to 50% panicle emergence

Days to 50% panicle emergence was considered when 50% of the plants within a plot were showed up with panicle emergences. The number of days to 50% panicle emergence was recorded from the date of sowing.

3.9.8.3 Days to 100% panicle emergence

Days to 100% panicle emergence was considered when 100% of the plants within a plot were showed up with panicle emergences. The number of days to 100% panicle emergence was recorded from the date of sowing.

3.9.8.4 Days to maturity

Days to maturity was considered when the 80% grains of the plants within a plot become golden yellow in color. The number of days to maturity was recorded from the date of sowing.

3.9.9.1 Number of effective tillers hill^{-1} (no.)

Total no. of panicle bearing tillers in a plant was counted at the time of harvesting.

3.9.9.2 Number of non-effective tillers hill^{-1} (no.)

The tillers having no panicle were regarded as non-effective tiller.

3.9.9.3 Number of grains panicle^{-1} (no.)

The total number of grains was collected from the randomly selected 5 panicles in each plot and then average number of grains panicle^{-1} was calculated.

3.9.9.4 Panicle length (cm)

Measurement of panicle length was taken from basal node of the rachis to apex of each panicle. Each observation was an average of 5 panicles.

3.9.9.5 Number of filled grains panicle^{-1} (no.)

Panicle was considered to be fertile if any kernel was present there in. The number of total filled grains present on each panicle was recorded.

3.9.9.6 Number of unfilled grains panicle^{-1} (no.)

Panicle was considered to be sterile if no kernel was present there in. The number of total unfilled grains present on each panicle was recorded.

3.9.9.7 Weight of 1000 grains (g)

One thousand cleaned dried seeds were counted randomly from the total cleaned harvested grains of each individual plot and then weighed with a digital electric balance at the stage the grain retained 14%-16% moisture and the mean weight were expressed in gram.

3.9.10.1 Grain yield (t ha^{-1})

The grain of the whole plot excluding the border row was (2.8 m × 1.3 m = 3.64 m^2) harvested, cleaned, threshed, dried and weighed. Finally, grain yield plot^{-1} was converted and expressed in t ha^{-1} on 14%-16% moisture basis. Grain moisture content was measured by using a digital moisture tester.

3.9.10.2 Straw yield (t ha^{-1})

The dry weight of straw of the whole plot excluding the border row was (2.8 m × 1.3 m = 3.64 m^2) harvested, cleaned, threshed, dried and weighed. Finally, straw yield plot^{-1} was converted and expressed in t ha^{-1} on 14%-16% moisture basis.

3.9.10.3 Biological yield (t ha^{-1})

Biological yield is the summation of grain yield and straw yield. It was calculated as the following formula:

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

3.9.10.4 Harvest index (%)

Harvest Index denotes the ratio of grain yield to biological yield and was calculated with the following formula:

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

It was expressed in percentage.

3.9.11 Genetical purity evaluation (%)

Estimation of offtype plants percentages in the different plots or varieties.

3.9.12.1 Amylose content (%)

Amylose content was determined by procedure of Juliano (1972).

3.9.12.2 Protein content (%)

Protein content was calculated from nitrogen and it was determined by the micro Kjeldahl method (AOAC, 1990).

3.9.12.3 Length of grain rice (%)

Ten (10) milled grain rice was selected from the bulk sample after the milling of each entry was measured by slide callipers for their length.

3.9.12.4 Breadth of grain rice

Ten (10) milled grain rice was selected from the bulk sample after the milling of each entry was measured by slide callipers for their breadth.

3.9.12.5 Length/breadth ratio of grain rice

Ten (10) milled grain rice was selected from the bulk sample after the milling of each entry and calculated their length and breadth ratio.

3.9.12.6 Milled rice (%)

After the milling of 100 brown rice, the milled rice was counted and recorded in percent (%).

3.10 Statistical analysis

The data obtained for different characters were statistically analyzed following the analysis of variance techniques to obtain the level of significance by using MSTAT-C. The significant differences among the treatment means were compared by Least Significant Difference (LSD) at 5% levels of probability (Gomez and Gomez, 1984).

Chapter IV

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to exploration of genetical purity, yield performance and grain quality of slender hybrid rice in T. aman. The analyses of variance (ANOVA) of the data on crop growth characters, yield components, yield and quality of slender hybrid rice varieties are presented in Appendix V-XI. The results obtained from the experiment have been presented under separate headings and sub-headings as follows:

4.1 Growth characters

4.1.1 Plant height (cm)

Plant height of hybrid rice was gradually increased up to 90 DAT and after that a slower rate of increase was observed up to harvest. Significant effect on plant height was observed in slender hybrid varieties/lines of T. aman rice (Table 1 and Appendix V). From the results of the experiment showed that at 30 DAT, Win 707 showed the highest plant height (45.33 cm) which was statistically similar with BRRI dhan34 where the shortest plant height was achieved from Win 19 (32.00 cm) which was statistically similar with AZ 7006, SAU Test Cross-7, SAU Test Cross-10, SAU Test Cross-6, BRRI dhan49 and SAU Test Cross-9. At 50 DAT, the longest plant height (77.67 cm) was obtained from Win 707 which was statistically similar with BRRI dhan34 and Hira 16 where the shortest plant (58.83 cm) was obtained from Win 19. At 70 DAT, the tallest plant (105.10 cm) was obtained from the variety BRRI dhan34 which was statistically similar with Win 707 where the shortest plant (75.22 cm) was obtained from the variety Win 19 which was statistically similar with BRRI dhan49 and SAU Test Cross-10. At 90 DAT, the highest plant height (130.30 cm) was observed from the variety BRRI dhan34 which was statistically similar with Win 707, Hira 16 and SAU Test Cross-6 where the shortest plant height (98.67 cm) was obtained from the variety Win 19 which was statistically similar with SAU Test Cross-7, SAU Test Cross-9, SAU Test Cross-10, AZ 7006, SAU Test Cross-8 and AZ 7006. At harvest, the longest plant (148.70 cm) was observed from the variety

BRRI dhan34 which was statistically similar with Win 707 where the shortest plant height (121.00 cm) was obtained from the variety Win 19 which was statistically similar with SAU test cross-8, SAU Test Cross-9, SAU Test Cross-10 and SAU Test Cross-7. The results of our experiment also coincide with the findings of Patel *et al*. (2012) who explained that different plant height was observed from the varieties due to their varietal characters and also the genetical influences. Similar findings were reported by Islam *et al*. (2009) and Bisne *et al.* (2006).

Table 1. Effect of variety on plant height at different days after transplant (DAT) in T. aman season

Treatments	**Plant height (cm) at different days after transplanting**				
	30 DAT	**50 DAT**	**70 DAT**	**90 DAT**	**At Harvest**
SAU Test Cross-6	35.00 bc	66.00 ab	86.00 bc	116.50 a-c	130.80 a-c
SAU Test Cross-7	34.67 bc	67.11 ab	83.00 bc	111.70 b-d	130.00 bc
SAU Test Cross-8	35.11 bc	64.67 ab	83.33 bc	107.70 cd	127.30 bc
SAU Test Cross-9	36.00 bc	68.00 ab	83.78 bc	111.00 cd	128.70 bc
SAU Test Cross-10	34.56 bc	65.78 ab	82.67 c	110.00 cd	129.00 bc
Dhani gold	33.44 bc	66.56 ab	83.13 bc	114.10 bc	133.20 a-c
Hira 16	35.33 bc	73.00 a	95.33 ab	120.50 a-c	135.00 a-c
Win 19	32.00 c	58.83 b	75.22 c	98.67 d	121.00 c
Win 707	45.33 a	77.67 a	100.9 a	126.00 ab	144.00 ab
AZ 7006	36.22 b	68.33 ab	83.89 bc	110.30 cd	135.30 a-c
BRRI dhan49	35.78 bc	67.22 ab	80.43 c	114.30 bc	133.00 a-c
BRRI dhan34	41.22 a	74.67 a	105.10 a	130.30 a	148.70 a
$LSD_{(0.05)}$	**4.153**	**13.31**	**12.43**	**14.49**	**18.07**
CV(%)	**6.77**	**11.54**	**8.45**	**7.49**	**8.02**

Within a column, means followed by the same letter(s) are not significantly different at 5% level of probability by LSD and those having dissimilar letter(s) differ significantly at 5% level of probability by LSD.

4.1.2 Number of total tillers hill^{-1} (no.)

The production of tillers number hill^{-1} was gradually increased up to 90 DAT and thereafter decreased at harvest. Statistically significant influence was observed on number of tillers hill^{-1} by the tested different slender hybrid varieties/lines under the experiment (Table 2 and Appendix VI). Tillers number of the varieties increased with the increase of growth stages but not consistent because it could reduce number of tillers hill^{-1} at harvest time in most of the slender hybrid varieties/lines as death of some tillers at the time of harvest. Results showed that BRRI dhan34 showed the highest number of tillers hill^{-1} (10.27, 17.33, 20.65, 24.67 and 23.00 at 30, 50, 70, 90 and harvest, respectively). On the other hand, minimum tillers hill^{-1} (6.90, 9.67, 11.22, 15.33 and 14.00 at 30, 50, 70, 90 and harvest, respectively) was obtained by Win 707. Islam *et al.* (2009), Bisne *et al.* (2006) and Bhowmick and Nayak (2000) reported similar trend of tillering habits with different varieties of rice.

Table 2. Effect of variety on number of tillers hill^{-1} at different days after transplanting (DAT) in T. aman season

Treatments	**Tillers number (no.) hill^{-1} at different days after transplanting**				
	30 DAT	**50 DAT**	**70 DAT**	**90 DAT**	**At Harvest**
SAU Test Cross-6	8.70 b	15.00 b-d	20.33 a	24.29 ab	22.67 a
SAU Test Cross-7	9.50 ab	15.33 bc	16.44 cd	20.73 bc	19.00 b-d
SAU Test Cross-8	7.57 c	12.56 e	14.85 d	19.73 c	18.33 c-e
SAU Test Cross-9	7.13 c	13.00 e	14.22 d	19.67 c	16.67 e
SAU Test Cross-10	7.13 c	13.00 e	17.55 bc	21.95 a-c	20.48 b
Dhani gold	10.00 a	16.67 ab	19.04 ab	21.67 a-c	20.00 bc
Hira 16	9.33 ab	15.22 bc	16.59 b-d	20.22 c	17.11 de
Win 19	7.25 c	13.67 c-e	17.48 bc	21.40 a-c	20.33 bc
Win 707	6.90 c	9.667 f	11.22 e	15.33 d	14.00 f
AZ 7006	8.89 b	14.17 c-e	14.67 d	19.67 c	17.50 de
BRRI dhan49	8.89 b	13.33 de	16.37 cd	20.00 c	18.58 b-e
BRRI dhan34	10.27 a	17.33 a	20.65 a	24.67 a	23.00 a
LSD$_{(0.05)}$	**1.030**	**1.678**	**2.450**	**3.801**	**2.143**
CV (%)	**7.19**	**7.04**	**8.7**	**10.8**	**6.67**

Within a column, means followed by the same letter(s) are not significantly different at 5% level of probability by LSD and those having dissimilar letter(s) differ significantly at 5% level of probability by LSD.

4.2 Phenological characters

4.2.1 Days to first panicle emergence

First panicle emergence was significantly influenced by variety. Results of the experiment noted that, the number of days taken for first panicle emergence ranged from 69.33 to 85 days (Table 3 and Appendix VII). Among the slender hybrid varieties under the present study, SAU Test Cross-6 showed minimum days to first panicle emergence (69.33 days). On the other hand, BRRI dhan34 showed delayed first panicle emergence (85.00 days). Most of the slender hybrid varieties showed minimum days to first panicle emergence than the other check varieties under the present study. Check varieties were taller than the hybrid varieties and took more days to first panicle emergence. However, considering this characteristics, SAU Test Cross-6 could be expected to harvest a bit early. The findings of the study was coincide with the findings of Endo *et al.* (2000) who said that panicle emergence occurred by 70-75 days after seedling emergence of hybrid.

4.2.2 Days to 50 % panicle emergence

Statistically significant influence was showed on days to 50 % panicle emergence due to varietal execution under the present study. The number of days taken for 50 % panicle emergence ranged from 76.33 days to 94.33 days (Table 3 and Appendix VII). From the results of the experiment showed that BRRI dhan34 showed maximum days to 50 % panicle emergence (94.33 days) where SAU Test Cross-6 showed minimum days to 50 % panicle emergence (76.33 days). Among the slender hybrid varieties, SAU Test Cross-6 showed earlier to 50 % panicle emergence where BRRI dhan34 showed delayed 50 % panicle emergence. Considering with the check variety, BRRI dhan49 took a little bit earlier to 50% panicle emergence than BRRI dhan34. Most of the slender hybrid varieties showed minimum days to 50 % panicle emergence than the check varieties. All the check varieties were taller than the slender hybrid varieties and took more days to 50 % panicle emergence. However, considering this parameter, SAU Test Cross-6 could be expected to harvest a bit early.

The findings of the study was coincide with the findings of Endo *et al.* (2000) who said that panicle emergence occurred by 88 days after seedling emergence of hybrid.

4.2.3 Days to 100 % panicle emergence

The number of days taken for 100 % panicle emergence ranged from 86.33 days to 105.00 days (Table 3 and Appendix VII). From the results of the experiment showed that SAU Test Cross-6 showed minimum days to 100 % panicle emergence (86.33 days) where BRRI dhan34 showed maximum days to 100 % panicle emergence (105.00 days). Among the slender hybrid varieties, SAU Test Cross-6 showed earlier to 100 % panicle emergence where BRRI dhan34 showed delayed 100 % panicle emergence. Most of the slender hybrid varieties showed minimum days to 100 % panicle emergence than the check varieties. All the check varieties were taller than the slender hybrid varieties and took more days to 100 % panicle emergence. However, considering this character, SAU Test Cross-6 could be expected to harvest a bit early. The findings of the study was coincide with the findings of Endo *et al.* (2000) who said that panicle emergence occurred by 88 days after seedling emergence of hybrid.

4.2.4 Days to maturity

Days to maturity among the slender hybrid varieties ranged from 116.33 days to 134.70 days (Table 3 and Appendix VII). Results of the study showed that, SAU Test Cross-6 showed earlier days to maturity (116.33 days) where BRRI dhan34 and BRRI dhan49 matured (134.70 days and 127.70 days) 5-20 days later than the SAU Test Cross-6. The hybrid varieties matured 5 to 20 days earlier than the check varieties. From the table it can be concluded that most of the slender hybrid varieties are early maturing compared to the check varieties (BRRI dhan34 and BRRI dhan49) under the present study.

Table 3: Effect of variety on phonological characters in T. aman season

Treatments	Days to first panicle emergence	Days to 50% panicle emergence	Days to 100% panicle emergence	Days to maturity
SAU Test Cross-6	69.33 b	76.33 d	86.33 b	116.30 b
SAU Test Cross-7	70.00 b	78.33 cd	88.33 b	119.70 b
SAU Test Cross-8	74.00 b	84.67 a-d	93.00 ab	124.70 ab
SAU Test Cross-9	75.67 b	85.00 a-d	93.33 ab	120.70 ab
SAU Test Cross-10	71.00 b	80.33 b-d	89.00 b	120.00 b
Dhani gold	70.33 b	80.67 b-d	89.67 b	121.00 ab
Hira 16	75.00 b	84.33 a-d	94.00 ab	120.00 b
Win 19	70.67 b	81.33 b-d	92.33 ab	121.70 ab
Win 707	75.67 b	86.00 a-d	96.67 ab	128.30 ab
AZ 7006	76.67 ab	89.00 ab	98.00 ab	130.30 ab
BRRI dhan49	76.33 ab	87.33 a-c	99.67 ab	127.70 ab
BRRI dhan34	85.00 a	94.33 a	105.0 a	134.70 a
$LSD_{(0.05)}$	**9.161**	**10.42**	**14.08**	**14.49**
CV (%)	**7.30**	**7.33**	**8.87**	**6.91**

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD. Within a column, means followed by the same letter(s) are not significantly different at 5% level of probability by LSD.

4.3 Yield contributing characters

4.3.1 Number of effective tillers hill^{-1} (no.)

Statistically significant variation was observed on number of effective tillers hill^{-1} due to varietal execution under the present study (Table 4 and Appendix VIII). From the results of the study indicated that the highest number of effective tillers hill^{-1} (21.33) was obtained from BRRI dhan34 which was statistically similar to SAU Test Cross-6 (20.56) where the lowest number of effective tillers hill^{-1} (11.56) was obtained from the variety/line Win 707 which was statistically dissimilar with the other slender hybrid varieties/lines under the present study. The results of our study was coincide with the findings of Patnaik *et al.* (1990) who observed that effective tillers producing capacity depends on the performance of different varieties.

4.3.2 Number of non-effective tillers hill^{-1} (no.)

Significant influence was exerted on number of non-effective tillers hill^{-1} due to varietal execution under the present study (Table 4 and Appendix VIII). From the results of the study indicated that the highest number of non-effective tillers hill^{-1} (3.20) was obtained from SAU Test Cross-10 which was statistically similar to SAU Test Cross-7 (2.90) where the lowest number of non-effective tillers hill^{-1} (1.11) was obtained from the variety SAU Test Cross-9 which was statistically similar with the variety AZ 7006 under the present study. The results of our study was coincide with the findings of Patnaik *et al.* (1990) and who observed that effective tillers producing capacity depends on the performance of different varieties.

4.3.3 Panicle length (cm)

There was marked influence was observed on panicle length due to varietal variation under the present study (Table 4 and Appendix VIII). Different varieties/lines showed the different panicle length due to its varietal performance. Results of the experiment showed that the longest panicle (30.78 cm) was produced by the variety AZ 7006 which was statistically similar with SAU Test Cross-6, SAU Test Cross-8, SAU Test Cross-10, AZ 7006 and SAU Test Cross-7. On the other hand, the shortest panicle length (22.39 cm) was found in BRRI dhan34 which was statistically similar with BRRI dhan49 and Win 19. The results obtained from the present study were coinciding with the findings of Wang *et al.* (2006).

4.3.4 Number of total grains panicle^{-1} (no.)

Significant influence was observed on different slender hybrid varieties/lines in respect of number of total grains panicle^{-1} (Table 4 and Appendix VIII).

The highest number of total grains panicle^{-1} (180.10) was observed in BRRI dhan34 which was statistically similar with SAU Test Cross-6 and SAU Test Cross-8. Among the slender hybrid varieties/lines, SAU Test Cross-6 showed better performance for number of total grains panicle^{-1} than all the other hybrids. On the other hand, the lowest number of total grains panicle^{-1} (137.10) was obtained from the variety Win 19 which was statistically similar with Hira 16, BRRI dhan49, Win 707, AZ 7006, SAU Test Cross-9 and SAU Test Cross-10.

4.3.5 Number of filled grains panicle^{-1}

Number of filled grains panicle^{-1} was significantly influenced by different slender hybrid varieties/lines under the present study (Table 4 and Appendix VIII). BRRI dhan34 produced the highest number of filled grains panicle^{-1} (163.50) which was statistically similar with SAU Test Cross-6, SAU Test Cross-8 and AZ 7006 where the lowest number of filled grains panicle^{-1} (109.60) was obtained from Win 19 which was statistically similar with BRRI dhan49, Hira 16, Win 707, AZ 7006 and SAU Test Cross-9. The results obtained by Murthy *et al.* (2004) and Bhowmick and Nayak (2000) were in agreement with findings of present study.

4.3.6 Number of unfilled grains panicle^{-1} (no.)

Statistically significant effect was observed on unfilled grains panicle^{-1} due to varietal differences under the study (Table 4 and Appendix VIII). Results showed that the highest number of unfilled grains panicle^{-1} was obtained from Win 19 (27.53) which was statistically similar with SAU Test Cross-9 and BRRI dhan49. On the other hand, the lowest number of unfilled grains panicle^{-1} (13.10) was obtained from SAU Test Cross-6 which was statistically similar with AZ 7006, SAU Test Cross-8, BRRI dhan34 and SAU Test Cross-10.

4.3.7 Weight of 1000 grains (g)

There was marked influence was observed on 1000-grain weight due to different varietal performances (Table 4 and Appendix VIII). From the results of the experiment showed that the highest 1000- grain weight (30.83 g) was obtained from SAU Test Cross-6 which was statistically as par with AZ 7006,
Hira 16, Win 707, SAU Test Cross-7, SAU Test Cross-8 and SAU Test Cross-9. On the other hand, the lowest 1000-grains weight was observed from BRRI dhan34 (14.30 g) which was statistically dissimilar with the other slender hybrid varieties/lines. The results are in agreement with the findings of Murshida *et al.* (2017) who observed the varied 1000 grains weight among different varieties of rice.

Table 4. Yield contributing characters of selected slender hybrid varieties/lines and check varieties of rice in T. aman season

Treatments	Effective tillers hill^{-1}(no.)	Non-effective tillers hill^{-1} (no.)	Panicle length (cm)	Total grains panicle^{-1} (no.)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000 grain weight (gm)
SAU Test Cross-6	20.56 a	2.11 cd	30.29 a	169.4 ab	156.3 ab	13.10 e	30.83 a
SAU Test Cross-7	16.10 c-e	2.90 ab	27.62 ab	158.5 a-d	138.8 b-d	19.73 b-d	27.97 a-c
SAU Test Cross-8	16.00 c-e	2.33 c	28.95 ab	164.9 a-c	148.7 a-c	16.13 de	27.90 a-c
SAU Test Cross-9	15.56 de	1.11 f	26.75a-c	151.9 b-d	124.7 c-e	27.13 a	26.73 a-c
SAU Test Cross-10	17.28 b-d	3.20 a	27.70 ab	154.5 b-d	137.1 b-d	17.47 c-e	26.27 bc
Dhani gold	17.83 bc	2.16 c	30.78 a	158.1 a-d	142.6 a-d	15.50 de	29.13 ab
Hira 16	14.78 e	2.33 c	26.26a-c	141.5 cd	120.1 de	21.47 bc	28.83 ab
Win 19	18.28 b	2.05 cd	25.57 bc	137.1 d	109.6 e	27.53 a	23.93 c
Win 707	11.56 f	2.44 bc	26.93a-c	146.2 b-d	127.5 c-e	18.77 cd	28.17 a-c
AZ 7006	16.00 c-e	1.50 ef	27.64 ab	148.8b-d	129.6 c-e	19.20 b-d	24.33 c
BRRI dhan49	16.11 c-e	2.47 bc	24.39 bc	143.8 cd	120.0 de	23.80 ab	24.77 bc
BRRI dhan34	21.33 a	1.66 de	22.39 c	180.1 a	163.5 a	16.60 c-e	14.30 d
LSD$_{(0.05)}$	**1.908**	**0.500**	**4.696**	**24.010**	**24.280**	**4.956**	**4.453**
CV(%)	**6.72**	**13.44**	**10.23**	**9.17**	**10.63**	**14.86**	**10.08**

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD. Within a column, means followed by the same letter(s) are not significantly different at 5% level of probability by LSD.

4.4 Yield parameters

4.4.1 Grain yield (t ha^{-1})

There was marked variation on grain yield due to varietal differences (Table 5 and Appendix IX). Among the tested 7 varieties and 5 lines, SAU Test Cross-6 showed it's superiority in producing highest grain yield (8.58 t ha^{-1}) which was statistically similar with AZ 7006 and SAU Test Cross-9. On the other hand, lowest grain yield (5.12 t ha^{-1}) was obtained from the variety BRRI dhan34 which was statistically similar with Win 19, Win 707 and BRRI dhan49. The results were in agreement with the findings of Islam *et al.* (2009), Bisne *et al.* (2006) and Murshida *et al.* (2017) who stated that grain yield differed significantly among the varieties.

4.4.2 Straw yield (t ha^{-1})

Statistically straw yield influenced significantly due to the varietal difference (Table 5 and Appendix IX). From the result of the study, variety AZ 7006 produced the highest straw yield (8.97 t ha^{-1}) which was statistically similar with SAU Test Cross-10, SAU Test Cross-6 and SAU Test Cross-9. The lowest straw yield was obtained from AZ 7006 (6.70 t ha^{-1}) which was statistically similar with Win 19 and Win 707. The differences in straw yield among the slender hybrid varieties/lines may be characterized to the genetic make-up of the varieties. The results of our study was coincide with the findings of Islam *et al.* (2014) and Paul *et al.* (2014) where they concluded that straw yield differed significantly among the varieties.

4.4.3 Biological yield (t ha^{-1})

Statistically significant variation was observed on biological yield due to varietal differences (Table 5 and Appendix IX). Among the 12 varieties/lines, biological yield ranged from 12.11 t ha^{-1} in Win 707 to 17.39 t ha^{-1} in SAU Test Cross-6. Results of the study showed that, highest biological yield (17.39 t ha^{-1}) was obtained from the variety SAU Test Cross-6 which was statistically at par with AZ 7006, SAU Test Cross-9 and SAU Test Cross-10 where the lowest biological yield (12.11 t ha^{-1}) was obtained from the variety Win 707 which was statistically similar with Win 19, AZ 7006, BRRI dhan49 and BRRI dhan34. Most of the slender hybrid varieties/lines showed higher biological yield than the check varieties. The differences in biological yield might be characterized to the genetic make-up of the varieties.

4.4.4 Harvest index (%)

There was marked variation was observed on harvest index due to varietal execution under the present study (Table 5 and Appendix IX). Results indicated that the highest harvest index (49.39%) was observed in SAU Test Cross-6 which was statistically as par with AZ 7006. On the other hand, the lowest harvest index (40.86%) was observed in BRRI dhan34. From the results of the study concluded that, almost all the slender hybrid varieties/lines exhibited better harvest index than the check varieties under the present study. Jiang *et al.* (1995) compared 10 varieties for yield components.

Table 5. Yield contributing characters and harvest index (%) of selected slender hybrid varieties of rice in T. aman

Treatments	Grain yield (t/ha)	Straw yield (t/ha)	Biological yield (t/ha)	Harvest index (%)
SAU Test Cross-6	8.58 a	8.80 ab	17.39 a	49.39 a
SAU Test Cross-7	7.32 cd	8.13 a-c	15.46 bc	47.26 ab
SAU Test Cross-8	6.81 d	7.87 a-c	14.68 c	46.78 ab
SAU Test Cross-9	7.921 a-c	8.73 ab	16.65 ab	47.75 ab
SAU Test Cross-10	7.63 b-d	8.83 ab	16.47 ab	46.58 ab
Dhani gold	8.33 ab	8.97 a	17.29 a	48.25 a
Hira 16	7.23 cd	8.15 a-c	15.38 bc	46.85 ab
Win 19	5.43 ef	6.73 c	12.16 d	44.47 ab
Win 707	5.28 ef	6.83 c	12.11 d	43.63 ab
AZ 7006	5.94 e	6.70 c	12.64 d	46.86 ab
BRRI dhan49	5.32 ef	7.07 bc	12.38 d	43.07 ab
BRRI dhan34	5.12 f	7.43 a-c	12.55 d	40.86 b
$LSD_{(0.05)}$	**0.821**	**1.803**	**1.649**	**6.964**
CV(%)	**7.19**	**13.56**	**6.67**	**8.94**

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD. Within a column, means followed by the same letter(s) are not significantly different at 5% level of probability by LSD.

4.5 Yield performance of slender hybrid varieties/lines over check variety (%)

Comparative yield performance of slender hybrid varieties/lines over the check variety has been presented in tabular form in Table 7. Yield hectare^{-1} for slender hybrid varieties/lines and check variety (BRRI dhan34) ranged from 5120.00 kg to 8585.00 kg under the present study.

From the table 6 showed that the yield performances of slender hybrid varieties ranged from 3.08% to 67.67% yield advantages over the check variety (BRRI dhan34). From the results of the study showed that, the highest yield performances (67.67%) was observed on SAU Test Cross-6 over the check variety BRRI dhan34 where the lowest yield advantages (3.08%) was observed on Win 707 over the check variety BRRI dhan34. The findings of the study was in collaborated with the findings of Yuan *et al.* (2005) who reported that *indica* hybrid showed yield increases of 38.46% against an improved inbred variety in Jiangsu province of China and Mishra (2003) reported 18% to 44.9% yield advantage of 17 released *indica* hybrids over standard check from on farm evaluation trial in India. Yield hectare^{-1} for slender hybrid varieties/lines and check variety (BRRI dhan49) ranged from 5316.00 kg to 8585.00 kg under the present study.

From The Table 6 showed the yield performances of slender hybrid varieties ranged from -0.71% to 61.49% yield advantages over the check variety (BRRI dhan49). The results remarked that the highest yield performances (61.49%) was exerted on SAU Test Cross-6 over the check variety BRRI dhan49 where the lowest yield advantages (-0.71%) was observed on Win 707 over the check variety BRRI dhan49. The findings of the study was in collaborated with the findings of Yuan *et al.* (2005) who reported that *indica* hybrid showed yield increases of 38.46% against an improved inbred variety in Jiangsu province of China and Mishra (2003) reported 18% to 44.9% yield advantage of 17 released *indica* hybrids over standard check from on farm evaluation trial in India.

Table 6: Yield performance of selected slender hybrid lines and check varieties

Name of varieties/lines	Grain yield (kg ha^{-1})	Yield advantage over check variety (%)	
		BRRI dhan34	BRRI dhan49
SAU Test Cross-6	8585	67.67	61.49
SAU Test Cross-7	7322	43.00	37.74
SAU Test Cross-8	6813	33.06	28.16
SAU Test Cross-9	7921	54.70	49.00
SAU Test Cross-10	7632	49.06	43.57
Dhani gold	8326	62.61	56.62
Hira 16	7230	41.21	36.00
Win 19	5429	6.04	2.13
Win 707	5278	3.08	-0.71
AZ 7006	5944	16.09	11.81
Check Variety			
BRRI dhan34	5120	0.00	-3.69
BRRI dhan49	5316	3.83	0.00

4.6 Evaluation of genetical purity

Statistically significant variation was observed on genetical purity (offtype percentage) under the present study (Table 7 and Appendix X). Results showed that the highest percentages of offtype (6.427) were observed in AZ 7006 where lowest offtype percentages (1.33%) were observed from SAU Test Cross-6. Because of the lowest percentages of offtype plants in that variety SAU Test Cross-6 showed the highest yield and genetical purity among that slender hybrid varieties. The results of this experiment were coincided with the findings of Jiang *et al.* (1995). Whose compared 10 varieties for yield components and offtype percentages among those varieties. The yield increases of lower percentages of offtype plant in the varieties mainly resulted higher yield potential.

Table 7: Effect of variety on genetical purity (offtype percentages) of slender hybrid rice varieties and check varieties

Treatments	Offtype percentages (%)
SAU Test Cross-6	1.330 i
SAU Test Cross-7	4.767 d
SAU Test Cross-8	3.197 f
SAU Test Cross-9	2.767 g
SAU Test Cross-10	4.833 d
Dhani gold	2.400 h
Hira 16	3.457 f
Win 19	5.517 b
Win 707	5.167 c
AZ 7006	6.427 a
BRRI dhan49	3.933 e
BRRI dhan34	5.067 cd
LSD$_{(0.05)}$	**0.3301**
CV (%)	**4.81**

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD. Within a column, means followed by the same letter(s) are not significantly different at 5% level of probability by LSD.

4.7 Quality contributing parameters

4.7.1 Amylose content (%)

There was marked influence was observed on amylose content due to varietal execution under the present study (Table 8 and Appendix XI). It was observed that the highest amylose content (28.20%) was obtained from SAU Test Cross-6 where the lowest amylose content was observed in BRRI dhan34 (24.05%). The results are in agreement with the findings of Juliano (1972) who reported that amylose content varied due to varietal differences.

4.7.2 Protein content (%)

Statistically significant variation was observed in terms of protein content due to varietal differences (Table 8 and Appendix XI). Results showed that the highest protein content was observed in SAU Test Cross-6 (9.85%) which was statistically similar with SAU Test Cross-7 and AZ 7006. On the other hand, the lowest protein content (7.03%) was obtained from BRRI dhan49 which was statistically similar with Win 707 and BRRI dhan34. The results are in agreement with the findings of Islam and Virmani (1990) and Marzempi and Edi (1990) who observed the varied protein content among different varieties of rice.

Table 8: Effect of variety on amylose content (%) and protein content (%)

Treatments	Amylose content (%)	Protein content (%)
SAU Test Cross-6	28.20 a	9.85 a
SAU Test Cross-7	26.35 ab	8.90 ab
SAU Test Cross-8	26.20 ab	8.06 bc
SAU Test Cross-9	26.70 ab	7.80 bc
SAU Test Cross-10	27.60 ab	8.40 bc
Dhani gold	25.03 ab	8.11 bc
Hira 16	25.13 ab	8.09 bc
Win 19	25.87 ab	7.80 bc
Win 707	24.83 ab	7.20 c
AZ 7006	27.44 ab	8.90 ab
BRRI dhan49	26.32 ab	7.03 c
BRRI Dhan34	24.05 b	7.23 c
$LSD_{(0.05)}$	**3.82**	**1.43**
CV (%)	**8.64**	**10.41**

Values in a column with different letters are significantly different at $p \leq 0.05$ applying LSD. Within a column, means followed by the same letter(s) are not significantly different at 5% level of probability by LSD.

4.7.3 Length of grain rice (mm)

There was marked significant variation in respect of length of grain rice due to different slender hybrid varieties/lines under the present study (Figure 1). It was noted that from the results of the experimentation, the highest length of grain (7.217 mm) was observed from the variety Win 19 which was at statistically par with the variety, SAU Test Cross-8. On the other hand, the lowest length of grain (4.400 mm) was obtained from BRRI dhan34 which was statistically dissimilar with the other varieties under the study. The results on grain yield agreement with the findings of Talukdar *et al.* (2004), Islam *et al.* (2015), Sarkar *et al*. (2016), Khatun *et al.* (2018).

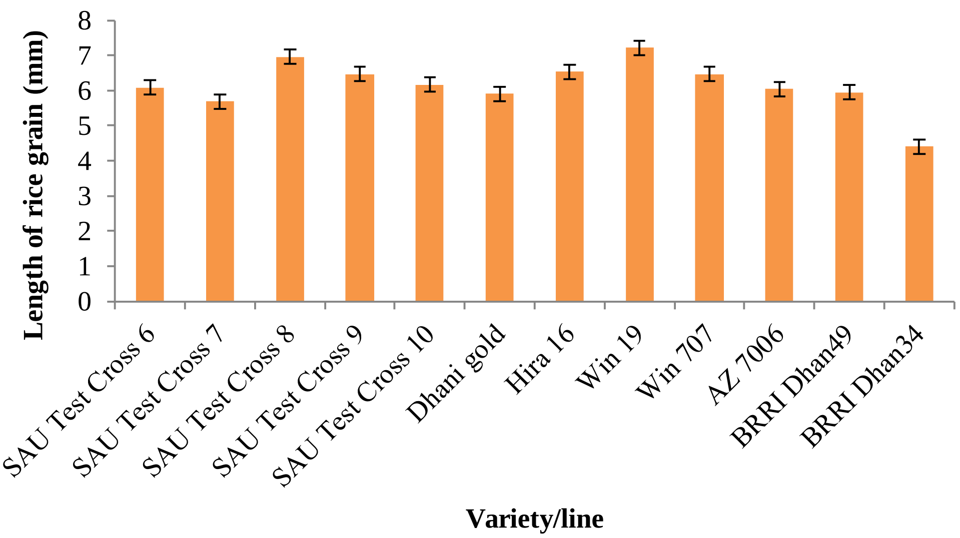

Figure 1. Effect of variety on length of grain rice (mm) ($LSD_{(0.05)}$= 0.514).

4.7.4 Breadth of grain rice (mm)

Statistically remarked differences were recorded in terms of breadth of grain rice for different slender hybrid rice varieties/lines under the present study (Figure 2). Results of the study noted that the highest breadth of grain (2.120 mm) was observed from BRRI dhan49 which was statistically similar with Win 19. On the other hand, the lowest breadth of grain (1.864 mm) was found from variety Hira 16 which was statistically similar with SAU Test Cross-6, AZ 7006 and SAU Test Cross-7. The results on breadth of grain rice were agreement with the findings of Talukdar *et al.* (2004), Islam *et al.* (2015) and Dahiphale *et al.* (2004).

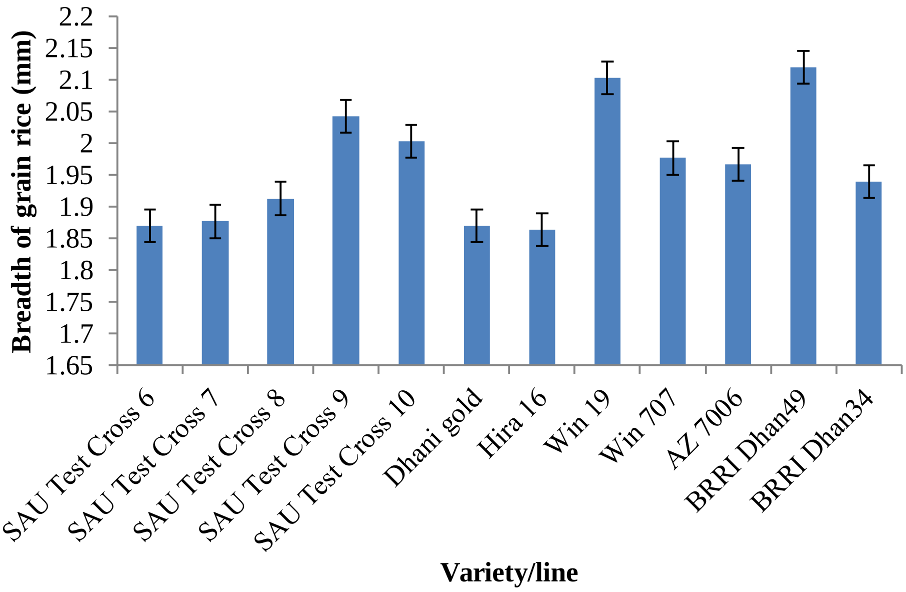

Figure 2. Effects on breadth of grain rice by different slender hybrid rice varieties ($LSD_{(0.05)}$= 0.207).

4.7.5 Length/breadth ratio of grain rice

Statistically significant influence was remarked in respect of length/breadth ratio for different slender hybrid rice varieties/lines under the present study (Figure 3). Results obtained from the study stated that the highest length and breadth ratio (3.642) was observed from SAU Test Cross-8 which was statistically similar with Hira16 (3.520) and Win 19 (3.438). On the other hand, the lowest length/breadth ratio (2.276) was found from BRRI dhan34. The results of the study were similar with the findings of Dahiphale *et al.* (2004).

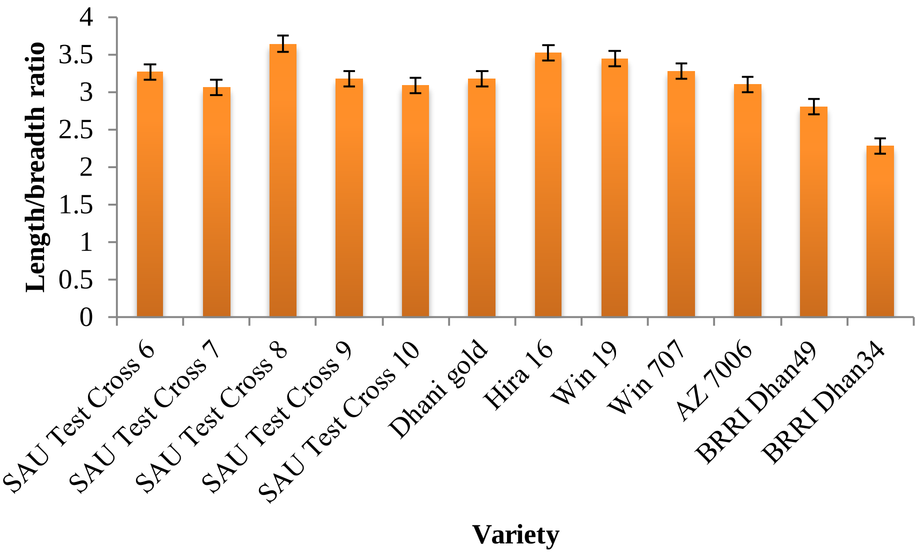

Figure 3. Effect of variety on length and breadth ratio ($LSD_{(0.05)}$=0.496).

4.7.6 Milled rice (%)

Statistically significant variation was remarked in respects of milled rice for different slender hybrid rice varieties/lines under the present study (Figure 6). The highest milled rice (77.17 %) was observed from Win 707 which was statistically at par with SAU Test Cross-6 (76.57 %), Hira 16 (76.33 %), Win 19 (75.00 %) and SAU Test Cross-8 (75.00 %). On the other hand, the lowest milled rice (64.67 %) was found from BRRI dhan34. The results of the study were in collaborated with the findings of Dahiphale *et al.* (2004).

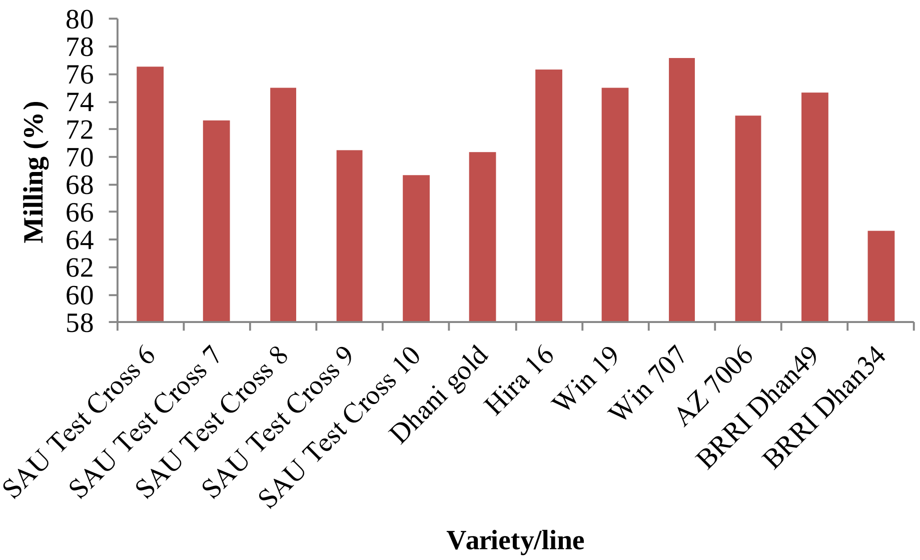

Figure 4. Effects of variety on milled rice (%) ($LSD_{(0.05)}$=3.241).

Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The field experiment was carried out during the period from July 2018 to November 2018 at Sher-e-Bangla Agricultural University, Dhaka, to study the "Exploration of genetical purity and yield performance and grain quality of fine grain hybrid rice genotype in T. aman".

The experiment consisting of a total 12 varieties and genotype *viz.* (i) BRRI dhan49 (check), (ii) BRRI dhan34 (check), (iii) SAU Test Cross-6, (iv) SAU Test Cross-7, (v) SAU Test Cross-8, (vi) SAU Test Cross-9, (vii) SAU Test cross-10, (viii) Dhani gold, (ix) Hira 16, (x) Win 19, (xi) Win 707 and (xii) AZ 7006.

The size of the unit plot was 2.8 m × 1.3 m (3.64 m^2) having 12 treatments for the present study with three replications. The total number of unit plots of the experiment was 36 (12 × 3). All management practices were done in proper time.

Following the experimental design, the experimental treatments were randomly assigned to each replication. The experiment was carried out in randomized Complete Block Design (RCBD). Seedlings aged 25 days were transplanted with 2 seedlings $hill^{-1}$ following line to line distance 20 cm and hill to hill distance 15 cm.

Statistical difference was identified for growth, phonological characters, yield and yield contributing attributes and quality parameters comprising experimental materials. Data were collected on crop growth characters like plant height (cm), tillers $hill^{-1}$ were recorded at different days after transplanting in the field. Data were collected on crop phenological characters like days to first panicle initiation, days to 50% panicle initiation, days to 100% panicle initiation and days to maturity were recorded at different days after transplanting in the field and yield as well as yield contributing attributes like effective tillers $hill^{-1}$, non-effective tillers $hill^{-1}$, total grains $panicle^{-1}$, panicle length (cm), filled grains $panicle^{-1}$, unfilled grains panicle^{-1}, weight of 1000-grains (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%) were recorded after harvest and the genetical purity contributing characters offtype plant (%) and the quality contributing parameters like amylose content (%), protein content (%), length of grain rice (mm), breadth of grain rice (mm), length/breadth ratio of grain rice and milled rice (%) were recorded after harvest.

For the collection of data on different crop characters, five hills (excluding border hills) were randomly selected from each plot prior to harvest. After sampling, all the plots were harvested at maturity. Data from the randomly selected hills in each plot on different crop parameters were recorded. After harvesting the entire plot, grain and straw yields were recorded.

The analysis was performed using the MSTAT-C computer package program. The mean differences among the treatments were compared by least significant difference test (LSD) at 5 % level of probability.

Records on the plant height at harvest revealed that BRRI dhan34 showed the highest plant (148.70 cm) while Win 19 produced the shortest plant (121.00 cm). In respects of total tillers hill^{-1}, BRRI dhan34 produced the maximum tillers hill^{-1} (23.00). On the other hand, Win 707 produced minimum tillers hill^{-1} (14.00).

In case of required days to first panicle initiation, SAU Test Cross-6 took minimum days to first panicle initiation (69.33 days) while BRRI dhan34 took maximum days to first panicle initiation (85 days). In respects of 50% panicle initiation, BRRI dhan34 took maximum days (94.33 days) where SAU Test Cross-6 took fewer days (76.33 days). In case of 100% panicle initiation, SAU Test Cross-6 took fewer days (86.33 days) than BRRI dhan34 (105 days). In regards of days to maturity, SAU Test Cross-6 matured (116.30 days) earlier than the check variety, BRRI dhan34 (134.70 days).

Results remarked that the highest number of effective tillers hill^{-1} (21.33) was achieved by BRRI dhan34, whereas; the lowest number of effective tillers hill^{-1} was obtained from Win 707 (11.56). In case of non-effective tillers hill^{-1}, maximum number of non-effective tillers hill^{-1} was obtained from SAU Test Cross-10 (3.20) where the minimum number of non-effective tillers hill^{-1} (1.11) was obtained from SAU Test Cross-9. In case of panicle length, the longest panicle (30.78 cm) was produced by Dhani gold and the shortest panicle (22.39 cm) was found in BRRI dhan34. The highest number of total grains panicle^{-1} (180.10) was observed in BRRI dhan34 and the lowest number of total grains panicle^{-1} (137.10) was found in Win 19. From the experiment, it was observed that BRRI dhan34 produced the highest number of filled grains panicle^{-1} (163.50).

The lowest number of filled grains panicle^{-1} was obtained from Win 19 (109.60). Results showed that the highest number of unfilled grains panicle^{-1} was observed in Win 19 (27.53), whereas; the lowest number of unfilled grains panicle^{-1} (13.10) was obtained from SAU Test Cross-6. From the result remarked that the highest 1000-grain weight (30.83 g) was obtained from SAU Test Cross-6. On the other hand, the lowest 1000-grains weight was obtained from BRRI dhan34 (14.30 g).

In respects of yield, SAU Test Cross-6 showed it's superiority in producing maximum grain yield (8.585 t ha^{-1}) where the minimum grain yield (5.120 t ha^{-1}) was obtained from the variety, BRRI dhan34. The maximum straw yield (8.967 t ha^{-1}) was noted from the variety, Dhani gold whereas the minimum straw yield (6.700 t ha^{-1}) was observed in AZ 7006. Results from the experiment stated that highest biological yield (17.39 t ha^{-1}) which was obtained by SAU Test Cross-6 whereas the lowest biological yield (12.11 t ha^{-1}) was achieved by the variety, Win 707. It was attained that the highest harvest index (49.39%) was obtained from the variety, SAU Test Cross-6 while the lowest harvest index (40.86 %) was achieved from the variety, BRRI dhan34.

Results focused that the highest offtype plants (6.427%) was observed in AZ 7006 and the lowest offtype plants (1.33%) was observed in SAU Test Cross-6. Results focused that the highest amylose content (28.20%) was observed in SAU Test Cross-6 where the lowest amylose content (24.05%) was observed in BRRI dhan34. Among the tested 12 varieties and genotypes, SAU Test Cross-6 showed its superiority in producing highest protein content (9.85 %) whereas; BRRI dhan49 (7.03%) produced the lowest protein content among all the varieties under the present study.

In respects of length of the grain rice, the highest length of grain (7.22 mm) was observed from the variety Win 19 where the lowest length of grain (4.40 mm) was obtained from BRRI dhan34. The maximum breadth of the grain (2.12 mm) was obtained from the variety, BRRI dhan49 and the minimum grain breadth (1.86 mm) was obtained from the variety, Hira 16. Results focused on length and breadth ratio that the highest length/breadth ratio (3.64) was achieved by the variety, SAU Test Cross-8 where the lowest length/breadth ratio (2.27) was observed from BRRI dhan34. The highest milled rice (77.17 %) was exerted by the variety, Win 707. On the other hand, the lowest milled rice (64.67 %) was obtained from BRRI dhan34.

From the above summary of the study, it can be concluded that among the twelve varieties, SAU Test Cross-6 demonstrated the best performance followed by Dhani gold and SAU Test Cross-9. On the other hand, Win 707, BRRI dhan34, BRRI dhan49 and Win 19 showed lower performance regarding growth, yield and yield contributing characters and quality contributing characters. In case of check varieties, BRRI dhan49 and BRRI dhan34 showed comparatively lower performance in terms of yield and quality than the SAU Test Cross-6.

Conclusion:

Based on the experimental results, it may be concluded that, SAU Test Cross-6 showed better performance in respect of yield (8.58 t ha^{-1}), biological yield (17.39 t ha^{-1}), harvest index (49.39%) and other characters than other tested genotypes and varieties. The same experiment can be repeated at different agro-ecological zones of the country for further validation of present findings.

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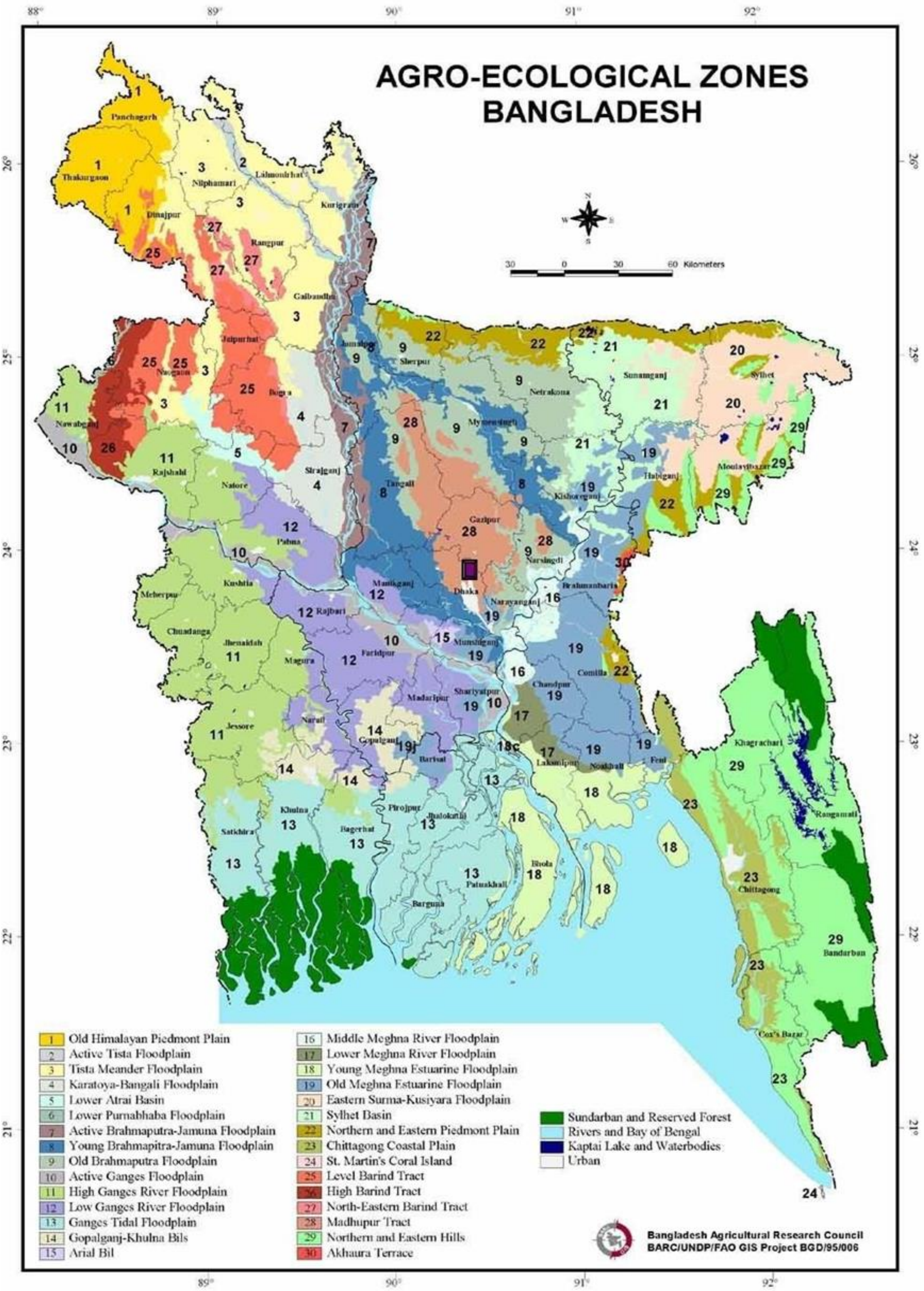
Appendices

APPENDICES

Appendix I: Map showing the experimental sites under study



■ The experimental site under study

Appendix II: Characteristics of soil of experimental site is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

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

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 (%)	0.077
Available P (ppm)	20.00
Exchangeable K (mel 1.00 g soil)	0.10
Available S (ppm)	45

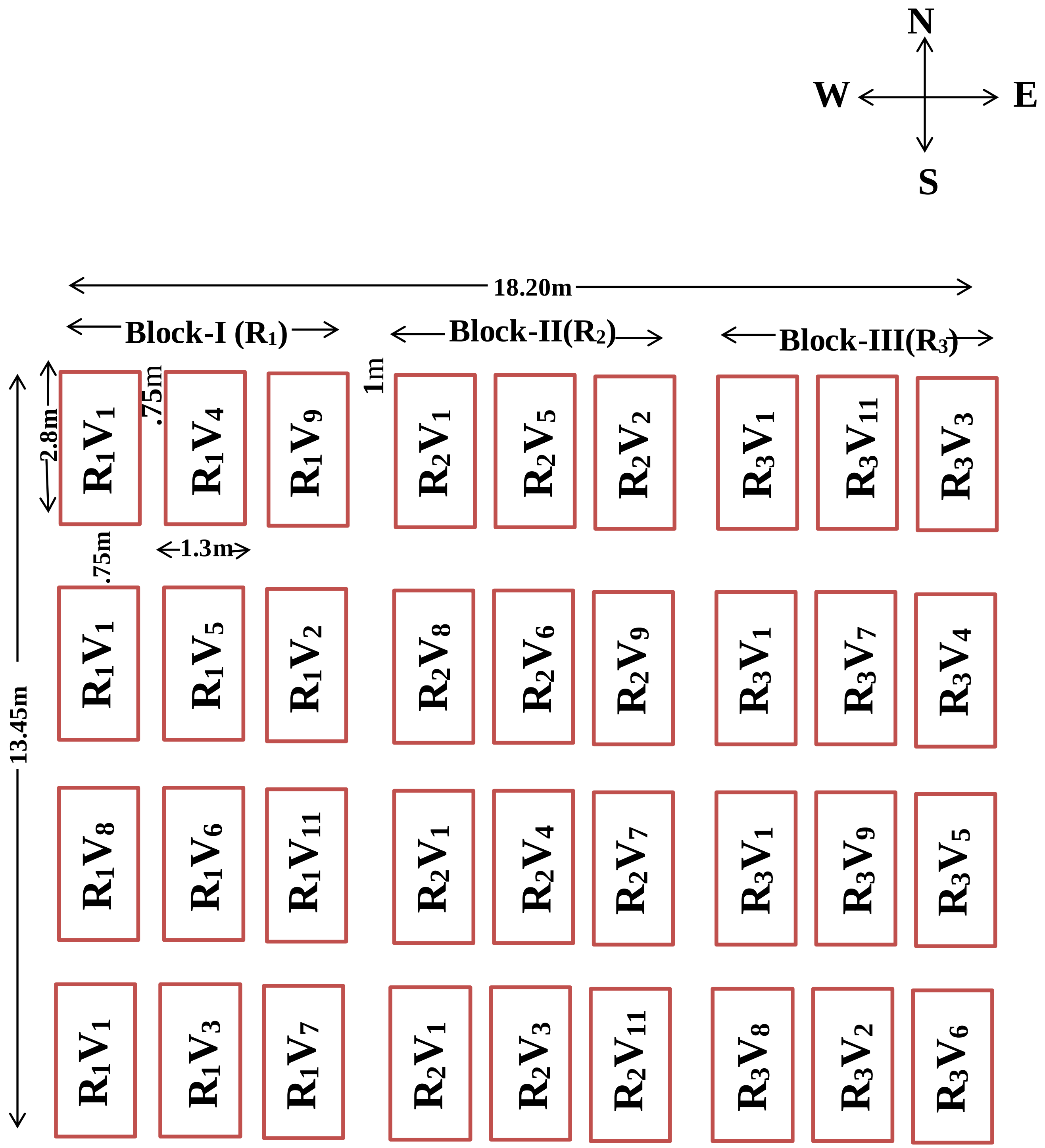
Source: SRDI, 2014

Appendix III: Monthly average of Temperature, Relative humidity, total Rainfall and sunshine hour of the experiment site during the period from June 2018 to November 2018

Month (2018)	Air temperature (^{0}c)		Relative Humidity (%)	Rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
June	35.8	23.2	78	312	5.4
July	36.2	24.8	83	563	5.1
August	36.0	23.9	81	318	5.0
September	34.9	24.5	80	279	4.4
October	26.6	19.6	81	22	6.9
November	25.8	16.2	78	00	6.8

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

Appendix IV. Layout of the experimental field



Appendix V. Analysis of variance (mean square) of plant height of selected hybrid genotype and check varieties at different days after transplanting

Source of Variation	Degrees of freedom	Mean Square of plant height at different days after transplanting				
		30 DAT	50 DAT	70 DAT	90 DAT	At Harvest
Replication	2	151.720	862.840	1064.779	2109.000	3336.223
Treatment	11	38.873**	73.713^{NS}	233.156**	212.090*	163.779^{NS}
Error	22	6.014	61.815	53.914	73.185	113.826

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

Appendix VI. Analysis of variance (mean square) of Total tiller hill^{-1} of selected hybrid genotype and check varieties at different days after transplanting

Source of Variation	Degrees of freedom	Mean Square of tiller number hill^{-1} at different days after transplanting				
		30 DAT	50 DAT	70 DAT	90 DAT	At Harvest
Replication	2	0.028	26.633	0.044	0.132	59.724
Treatment	11	4.398**	12.507**	21.658**	17.491**	19.442**
Error	22	0.370	0.982	2.093	5.040	1.602

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

Appendix VII. Analysis of variance (mean square) of days to first flowering, 50% flowering, 100% flowering and maturity of selected hybrid genotype and check varieties

Source of Variation	Degrees of freedom	Mean Square first panicle initiation, 50% panicle initiation, 100% panicle initiation and maturity			
		Days to first panicle initiation	Days to 50 % panicle initiation	Days to 100 % panicle initiation	Days to Maturity
Replication	2	176.361	363.111	70.528	901.583
Treatment	11	57.604^{NS}	73.907^{NS}	85.778^{NS}	87.523^{NS}
Error	22	29.270	37.899	69.164	73.220

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

Appendix VIII. Analysis of variance (mean square) of yield components of selected hybrid genotype and check varieties

Source of Variation	Degrees of freedom	Mean Square of yield components					
		Effective tillers hill^{-1}	Panicle length	Grains panicle^{-1}	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	1000-grain weight
Replication	2	0.170	1.392	1329.722	1128.187	10.946	2.090
Treatment	11	23.450**	16.590^{NS}	465.491*	767.940**	61.676**	54.364**
Error	22	3.885	7.692	201.130	205.649	8.567	6.917

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

Appendix IX. Analysis of variance (mean square) of yield of selected hybrid genotype and check varieties

Source of Variation	Degrees of freedom	Mean square of yields and harvest index			
		Grain yield	Straw yield	Biological yield	Harvest index
Replication	2	4.443	0.498	7.444	35.350
Treatment	11	4.865**	2.309^{NS}	13.402**	18.160^{NS}
Error	22	0.235	1.134	0.948	16.914

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

Appendix X. Analysis of variance (mean square) of Genetical purity of selected hybrid genotype and check varieties

Source of Variation	Degrees of freedom	Mean Square of Genetical Purity
		Offtype Plant
Replication	2	2.288
Treatment	11	6.563**
Error	22	0.038

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

Appendix XI: Analysis of variance (mean square) of Amylose content and protein content of selected hybrid genotype and check varieties

Sources of variation	Degrees of freedom	Mean Square of Amylose content and Protein content	
		Amylose Content	Protein Content
Replication	2	3.945	0.184
Treatment	11	4.597^{NS}	1.967*
Error	22	5.100	0.713

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

Appendix XII: Analysis of variance (mean square) of length of grain rice, breadth of grain rice, length/breadth ratio and milled rice (%)

Source of Variation	Degrees of freedom	Mean square of			
		Length grain rice	Breadth of grain rice	L/B Ratio of grain	Milling rice
Replication	2	0.554	0.128	0.040	614.205
Treatment	11	1.508**	0.024^{NS}	0.380**	41.862**
Error	22	0.092	0.015	0.086	3.663

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