EFFECT OF TRANSPLANTING GEOMETRY ON SCENTED FINE RICE VARIETIES IN *AMAN* SEASON

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CERTIFICATE

This is to certify that the thesis entitled ***"EFFECT OF TRANSPLANTING GEOMETRY ON SCENTED FINE RICE VARIETIES IN AMAN SEASON"*** *submitted to the department of Agricultural Botany, faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS)*** *in* ***AGRICULTURAL BOTANY*** *embodies the result of a piece of bona fide research work carried out by* ***S. M. BASHIR UDDIN*** *, registration no.* ***12-04748*** *under my supervision and guidance. no part of the thesis has been submitted for any other degree or diploma.*

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

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Dedicated to

My

"Be loved Parents"

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ABSTRACT

The present investigation entitled "Effect of transplanting geometry on scented fine rice varieties in *Aman* season" was conducted from July, 2017 to November, 2018 at the Research Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The experiment comprised of two factors; viz. Factors A: Five scented fine rice varieties (Chinigura, Kalijira, Kataribhog, BRRI dhan37 and BRRI dhan38) and Factor B: Three different spacing (20 cm x 20 cm, 25 cm x 15 cm and 20 cm x 10 cm). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Different treatment combinations expressed significant differences due to their interaction effect on plant growth determinants, yield attributing traits and yield. The tallest plant (161.3 cm), the maximum number of total tillers per hill (13.67), effective tillers per hill (11.33) and the longest panicle length (26.20 cm) were recorded from the combined treatment of V_1S_1 (Chinigura + 20 cm x 20 cm). The highest number of spikelets per panicle (175.0), filled grains per panicle (131.0), the highest grain yield (4.3 t/ha) and straw yield (10.7 t/ha) were recorded from the treatment combination of V_5S_2 (BRRI dhan38 + 25 cm x 15 cm) while the highest 1000 grain weight (19.07 g) was recorded from (V_5S_2) (Kalijira + 25 cm x 15 cm). However, the highest number of non-filled grains per panicle (59.67) and the highest harvest index (31.76%) were recorded from V_2S_1 (Kalijira + 20 cm x 20 cm). The shortest plant (130.3 cm) was obtained from V_5S_3 (BRRI dhan38 + 20 cm x 10 cm) while the lowest number of total tillers per hill (5.67), effective tillers per hill (4.0) and non-filled grains per panicle (17.0) was obtained from V_3S_1 (Kataribhog + 20 cm x 20 cm). The shortest panicle length (19.33 cm) was obtained from V_1S_3 (Chinigura + 20 cm x 10 cm) whereas the lowest number of spikelets per panicle (76.00) and filled grains per panicle (53.0) were obtained from V_1S_2 (Chinigura + 25 cm x 15 cm). The lowest 1000 grain weight (9.5 g) and straw yield (5.8 t ha^{-1}) were found from V_2S_1 (Kalijira + 20 cm x 20 cm) while the lowest grain yield (2.5 t ha^{-1}) and harvest index (22.73%) were resulted from V_5S_2 (BRRI dhan37 + 25 cm x 15 cm). Therefore, the treatment combination of V_5S_2 (BRRI dhan38 + 25 cm x 15 cm) produced the best results for grain yield and straw yield.

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LIST OF ACRONYMS

%	=	Percent
^0C	=	Degree Centigrade
AEZ	=	Agro-ecological Zone
BARI	=	Bangladesh Agricultural Research Institute
BBS	=	Bangladesh Bureau of Statistics
BRRI	=	Bangladesh Rice Research Institute
BCR	=	Benefit Cost Ratio
Cm	=	Centimeter
DAS	=	Days after sowing
DAT	=	Days after sowing
et al.	=	and others
FAO	=	Food and Agricultural Organization of the United Nations
G	=	gram (s)
Kg	=	Kilogram
Kg/ha	=	Kilogram/hectare
LER	=	Land Equivalent Ratio
LSD	=	Least Significant Difference
M	=	Meter
MoA	=	Ministry of Agriculture
MoP	=	Muriate of potash
p^H	=	Hydrogen ion conc.
RCBD	=	Randomized Complete Block Design
$t\ ha^{-1}$	=	ton per hectare
TSP	=	Triple Superphosphate
CV%	=	Percentage of coefficient of Variance
DF	=	Degree of Freedom

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the major staple foods in the world and is the most important food grain in the diet of billions of people of Asia, Africa and Latin America. Approximately 163.2 million hector area is covered with rice all over the world with an annual production of 719.7 million tonnes (FAOSTAT, 2013), while Asia contributes about 92% of the world rice harvest (IRRI, 1995). Globally, rice is the second most important crop in terms of area but it ranks number one as food since it provides more calorie than any other cereals. It accounts for 20% calorie consumed worldwide (Jones and Sheats, 2016).

Bangladesh is an agrarian country and it agro-ecological conditions are favourable for rice cultivation. Among the top rice producing countries of the world, Bangladesh ranks sixth next to China, India, Indonesia, Vietnam and Thailand (FAOSTAT, 2016). Rice is the most extensively cultivated crop of Bangladesh that covers 75% of the total cultivable area of which around 27% is occupied by fine rice varieties. It plays a dominant role in Bangladesh agriculture and is the prime commodity in our domestic market. Bangladesh is in fourth position with annual rice consumption per head (160 kilograms) after Brunei Darussalam (245 kilograms), Vietnam (166 kilograms) and Laos (163 kilograms) (FAOSTAT, 2016). In 2014-2015, about 11.42 million hectares of land were used for rice cultivation, producing 34.86 million metric tons yield of which transplanted *Aman* rice covered 5.53 million ha with a yield of 2.38 t/ha which was lower than the national average (3.05 t/ha). This yield was also much below the potential yield level compared to other leading rice growing countries. The lower yield of transplanted *Aman* rice has been attributed to several reasons, improper population density being the leading one.

Scented or aromatic rice constitutes a special group of rice genotypes well known in many countries across the world for their aroma and/or super fine grain quality (Sing *et al.*, 2000a). During recent years, Bangladeshi farmers are more interested in growing high yielding coarse grain varieties for achieving higher yield per unit area instead of fine rice. Yet, the aromatic fine quality rice varieties are the highly valued rice commodity in Bangladesh agricultural trade market due to having small grain, pleasant aroma and soft texture upon cooking (Dutta *et al.*, 1998). Consumer demand for the fine rice varieties both in internal and external markets is also high due to its good nutritional quality, palatability as well as special flavour and taste (Sood, 1978). Bangladesh produces several fine aromatic rice varieties with excellent eating qualities for regular consumption as steamed rice as well as for polau, biryani, jarda, khir, finny type preparations which are served on special occasions. Yet, Bangladeshi aromatic rice is virtually unknown due to insufficient production and lack of storage trade linkage.

Yield is the product of several components such as number of effective tillers per hill, number of grains per panicle and weight of individual grain. These components are influenced by variety, planting geometry and environment in which the crop grows. Planting geometry of a crop affects the interception of solar radiation, crop canopy coverage, dry matter accumulation and crop growth rate. Planting geometry is very crucial as optimum plant population can increase rice yield by 61% (Islam *et al*., 1994) and the yield and yield components of rice are greatly influenced by plant spacing (Khalil, 2001; Islam et al., 2008). Spacing is the key factor that needs to be considered for transplanted *Aman* (T. *Aman*) rice. The growth and development of T. *Aman* rice are greatly influenced by plant spacing. However, closer planting geometry causes competition among plants for light, water, and nutrients which consequently slow down growth as well as the grain yield. Optimum planting geometry ensures the proper growth of aerial as well as underground plant parts by efficient utilization of solar radiation, nutrients and water (Miah *et al.,* 1990). Similarly, the tillering habit and formation of spikelets per panicle are also influenced by the planting geometry, which is responsible for the yield of rice per unit area. As the tiller production in aromatic rice is very low and most of them are low yielding, the maximum benefit can be derived from rice if the crop is properly spaced. So, the planting geometry and plant spacing should be optimized by keeping in mind different aspects of cropping management techniques. Therefore, it is essential to find out the suitable transplanting geometry for the scented fine rice varieties in *Aman* season to get better yield and quality.

Selection of potential variety and optimum planting geometry can play an important role to increase yield. A large number of experiments have so far been carried out throughout the world to find out the optimum planting geometry in rice. However, sufficient research works have not yet been done on different plant density, especially with modern and local aromatic *Aman* rice varieties in Bangladesh. Such commonly grown fine rice cultivars as Chinigura, Kalijira, Kataribhog, BRRI dhan37 and BRRI dhan38 etc. require detailed study for their different agronomic traits, yield and yield contributing attributes for varietal improvement. Therefore, the present piece of research work was undertaken to select the potential scented fine rice varieties and to find out optimum transplanting geometry for obtaining maximum yield of aromatic rice in Bangladesh.

With the above background, a research experiment was undertaken to evaluate the effect of transplanting geometry on scented fine rice varieties in *Aman* season with the following objectives:

1. To study the effect of variety and transplanting geometry on growth and yield attributes of scented fine rice varieties in *Aman* season.
2. To assess the yield variation among scented fine rice varieties under different transplanting geometry.

CHAPTER II

REVIEW OF LITERATURE

Yield and yield contributing characteristics of rice are considerably depended on manipulation of basic ingredients of agriculture. The basic ingredients include varieties of rice, environment and agronomic practices (planting time & density, fertilizer, irrigation etc.). Among the mentioned factors planting geometry and varieties are more responsible for the growth and yield of rice. However, scented rice varieties are reputed for their grain quality and pleasant aroma. Traditional scented rice varieties are tall, lodging susceptible, photosensitive with low yield potential. The improvement of aromatic rice genotypes requires its collection and evaluation of existing cultivars of Bangladesh. The available relevant literatures related to planting geometry and some of the local aromatic genotypes and their performances in the recent past have been presented and discussed hereunder:

2.1 Effect of planting geometry on rice

Planting geometry for successful rice production widely depends on varietal life duration, sensitivity to photoperiod, temperature, rainfall and other environmental factors. Some literature related to planting geometry on growth and yield of rice are reviewed below-

Wang *et al*. (2014) conducted an experiment to determine the effects of hill seeding density (25 cm × 15 cm, 25 cm × 17 cm, 25 cm × 19 cm, 25 cm × 21 cm, and 25 cm × 23 cm; three to five seeds per hill) on plant growth and grain yield of a hybrid variety, in two fields with different fertility and reported that with increases in seeding spacing from 25 cm × 15 cm to 25 cm × 23 cm, productive tillers per hill increased by 34.2%. Panicles per m^2 declined with increases in seeding spacing. Grain yield was the maximum at 25 cm × 17 cm spacing. Results suggest that a seeding density of 25 cm × 17 cm was suitable for high yielding hybrid rice.

In order to investigation effect of planting date and planting density a field experiment was carried out by Moradpour *et al*. (2013) with planting date in 3 levels and planting density in 4 levels (17, 34, 51, 68 plant m^{-2}). Results showed that grain yield would be increased with increasing in plant density. Most grain yield (6403 kg ha^{-1}) was obtained in 68 plant m^{-2}.

The experiment was conducted by Islam *et al*. (2013) to find out the effect of planting density on the performance of hybrid rice variety Aloron with different planting densities were maintained using different spacing and number of seedlings per hill. These include 25 cm × 20 cm, 25 cm × 10 cm, 20 cm × 10 cm, 20 cm × 15 cm with single seedling per hill and 20 cm × 15 cm with two seedlings per hill and 20 cm × 15 cm with three seedlings per hill. Density of 20 cm × 10 cm with 1 seedling hill^{-1} i.e. 50 hills m^{-2} produced the highest grain yield of 7.5 t ha^{-1} and 4.6 t ha^{-1} in DS and WS respectively, which was significantly higher than the yield with recommended density (20 cm × 15 cm with 1 seedling per hill).

Bozorgi *et al*. (2011) carried out a study with three levels of plant spacing (a : 15 cm ×15 cm, a : 20 cm ×20 cm and a : 25 cm ×25 cm) and three levels of number of seedling per hill. Results showed that, highest grain yield among plant spacing levels was found from 15 cm ×15 cm treatment with 3415 kg ha^{-1}.

The field experiment was conducted by Sridhara *et al*. (2011) at College of Agriculture, Navile Farm, Shivamogga during Kharif to assess the response of genotypes, planting geometry and methods of establishment on root traits and yield of aerobic rice. The study revealed that among planting geometry, 30 cm × 30 cm recorded significantly higher root length (24.4 cm), root volume (60.30 cc), root number (154.2) and root weight (6.5 g) as compared to 45 cm × 20 cm. Direct seeded recorded significantly higher root length (25.9 cm), root volume (67.66 cc), root number (161.1) and root weight (7.6 g) compared to other methods. Significantly higher dry matter accumulation, number of panicles plant^{-1}, test weight was recorded in BI-43 with 30 cm × 30 cm spacing under direct seeding.

Krishna *et al*. (2008) conducted an investigation to evaluate the influence of system of rice intensification (SRI) on seed yield and quality in rice variety BPT-5204 was conducted at Agricultural Research Station (Paddy), Sirsi during kharif 2004-05. Wider spacing of 40 cm × 40 cm found to have significant influence on growth parameters.

Karmakar *et al*. (2004) reported that, conventional practice (25 cm ×15 cm spacing with 15 days old seedlings) gave higher yield that the SRI practices with wider spacing. Number of tillers and panicle per unit area were higher in closer spacing that contributed to obtain higher yield.

Mazid *et al*. (2003) found that conventional practices of rice cultivation gave significantly higher grain yield compared to the SRI method of crop establishment. SRI method with 30 cm × 30 cm and 40 cm × 40 cm spacing and younger seedlings increased number of panicles hill^{-1} but total number of panicles per unit area was found to below.

Venkatachalapathy and Veerabadran (2002) conducted a field experiment at the Agricultural College and Research Institute, Killikulam, Tamil Nadu, India on wet-seeded rice cv. ADT-36. The highest yield was recorded in drum seeding with 2 cm intra row spacing. However, the net return per rupee invested was higher with drill seeding at 2 cm. Direct seeding an effective alternative technology to transplanting, since it gave more gain without extra expenditure.

Aziz and Hasan (2000) reported that in SRI practice, the average number of tillers hill^{-1} and effective tillers hill^{-1} were 117 and 103; respectively in Parija variety at Rajshahi. The highest number of effective tillers m^{-2} (531) was found with 35 cm × 35 cm spacing in Department of Agricultural Extension trials at Kishoregonj. But with the same spacing the number was 342 m^{-2} in locality intensified farming enterprises trials at Kishoregonj. On the other hand, in farmers practice the average number of effective tillers m^{-2} was 290 and 393 with 20 cm × 20 cm and 20 cm × 15 cm spacing, respectively. At Kisoregonj the average number of filled grains per panicle with 35 cm × 35 cm spacing was found more promising, which was 173 filled grains per panicle and 42 unfilled grains per panicle. At Rajshahi the average number of filled grains per panicle was 106 in case of SRI practice for local Parija variety and 70 in case of farmers practices. The grain weight was found 12% higher with SRI practice over farmers' practice (FP). The weight of 1000 grains was the lowest (18.75 g) with 20 cm × 15 cm spacing in case of farmers practice (FP) and the higher (28 g) with 40 cm × 40 cm spacing in case of SRI. Spacing of 35 cm × 35 cm showed better performance both at locally Intensified Farming Enterprises and Department of Agricultural Extension trial at Kishoregonj where the average yield was 7.5 and 8.9 tons ha^{-1}, respectively. On the other hand, in case of farmers practice the average yields were 5.2 and 4.7 tons ha^{-1} with 20 cm × 15 cm spacing, respectively.

Sorour *et al*. (1998) observed in field experiments in 1993-94 at Kafr El-Sheikh, Egypt, the short duration rice cultivar Giza 177 and the traditional cultivar Giza 176 were planted using the following methods: traditional transplanting (TT, no fixed number of hills or seedlings hill^{-1}), hand transplanting (HT) in hills at a spacing of 20 cm × 20 cm or 15 cm × 15 cm, mechanical transplanting (MT) in hills at a spacing of 30 cm × 14 cm or 30 cm × 12 cm, broadcasting (B), mechanical drilling (MD), or planted in puddled soil (D) in hills at a spacing of 20 cm × 20 cm or 15 cm × 15 cm. D 15 cm × 15 cm, HT 15 cm × 15 cm and MT 30 cm × 12 cm gave significantly better results than TT as regards dry matter production, LAI, crop growth rate, plant height, number of panicles m^{-2} and grain yield feddan^{-1}. The net assimilation rates for B, MD, TT and HT 20 cm × 20 cm exceeded those for other methods.

Rao (1990) conducted an experiment with plant derived from primary, secondary and tertiary tillers and transplanted at 20 cm × 10 cm spacing produced harvest index which were 45.3, 45.3, 9.1 and 45.1% for plants derived from primary, secondary and tertiary tillers and control plants respectively.

Rao *et al*. (1981) conducted a field experiment and reported that number of productive tillers m^{-2} were higher in local method of planting as compared to transplanting in 15 cm × 10 cm spacing but both grain yield and straw yield were higher in transplanting in row than local planting method with transplanting in 15 cm × 10 cm. They further found no significant difference in panicle length, number of grains and 1000 grains weight between local planting method and transplanting in rows.

2.2 Growth parameters

2.2.1 Plant height

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

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

Jewel *et al.* (2011) evaluated, twenty-six (26) aromatic rice genotypes for agronomic characteristics and aroma detection. They reported that plant height, IR 50 had the minimum and Basmoti 370 had the maximum height and ranged from 71.0 to 121.6 cm and the mean value for this trait was 93.00 cm.

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

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

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

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

Kataribhog (158.8cm). Mohammad *et al.* (2002) reported that plant height is mostly governed by the genetic makeup of the cultivar, but the environmental factors also influence it.

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

BRRI (1998a) reported that highest plant height was obtained from Kataribhog (153 cm) followed by Khaskani (143 cm), BR 4384-213-2-24 (130 cm), 13114384-28-2-2-6 (125 cm) and BR 4384-2B-2-2-211R3 (125 cm) lines. Reddy and Redd (1997) reported that plant height is one of the important growth parameters of any crop as it determines or modifies yield contributing characteristics and finally shapes the grain yield.

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

Anonymous (1993) evaluated the performance of four varieties/advanced lines, IRAT-OM, BR 14, BINA 13 and BINA 19 and noticed that varieties / advanced lines differed significantly for plant height. Anonymous (1991) reported that height differed among the varieties.

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

2.2.2 Number of tillers hill^{-1}

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

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

Roy *et al.* (2014) conducted an experiment to evaluate the growth, yield and yield attributing characteristics of 12 indigenous *Boro* rice varieties collected from South-Western regions of Bangladesh namely; Nayonmoni, Tere bale, Bereratna, Ashanboro, Kajollata, Koijore, Kali boro, Bapoy, Lataibalam, Choiteboro, GS one and Sylhetyboro. They reported that tiller numbers in most of the treatments increased exponentially up to harvest.

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

Metwally *et al.* (2012). reported that aromatic rice varieties significantly varied in tillers numbers m^{-2} in the two seasons. Plants of IR 77510 variety produced the greatest tillers numbers m^{-2} at harvest in the two seasons. Plants of IR 65610 and IR 71137 varieties produced the lowest tillers numbers m^{-2} in the first and second seasons, respectively.

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

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

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

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

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

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

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

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

2.2.3 Leaf area index

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

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

Metwally *et al.* (2012) explained that aromatic rice varieties exhibited significant differences in leaf area index in the two seasons. The rice variety Egyptian Yasmin and IR 77510 were among those which having the highest leaf area index. The variety IR 65610 produced the lowest leaf area index in both seasons. The superiority of Egyptian Yasmin and IR 77510 varieties in leaf area index could be attributed to high number of tillers and leaves. They also reported that the genotype differences in leaf area index, as here obtained, reflect different genetic make-up or genetic constitution.

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

2.2.4 Days to flowering and maturity

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

Jewel *et al.* (2011) evaluated, twenty-six (26) aromatic rice genotypes for agronomic characteristics and aroma detection. Reported that days to 50% flowering, the period ranged from 90 days to 145 days. PSB RC18 (IR 51672-62-2-1-1-2-3) was found to be required more days whereas Basmati 370 took fewer days and the mean value was 127.07. The period of maturity of 26 germplasm ranged from 127 to 167 days. Basmati 370 was found to be the earliest maturing, whereas, YN96-5021 took maximum time to mature and the mean value for this trait was 155 days.

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

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

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

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

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

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

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

2.3 Yield and yield contributing characters

2.3.1 Number of effective tillers m^{-2}

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

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

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

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

Metwally *et al.* (2012) reported that aromatic rice varieties significantly varied in panicle number m^{-2} in the two seasons. Plants of IR 77510 variety markedly produced the highest panicle number m^{-2} at harvest in the two seasons. Plants of IR 65610 and IR 71137 varieties produced the lowest panicle number m^{-2} in the first and second seasons, respectively. The increase in panicle number m^{-2} may be due to increase in tillers number m^{-2}.

Jewel *et al.* (2011) evaluated twenty-six (26) aromatic rice genotypes for agronomic characteristics and aroma detection. Reported that number of effective tillers per plant ranged from 9 to 20 and significant variation was observed among the genotypes. IR 71144-393-2-2-3-1 had the maximum number of effective tillers and Binadhan7 had the lowest.

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

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

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

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

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

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

Sawant *et al.* (1986) reported that the maximum effective tillers hill^{-1} (12.4) and minimum non-effective tillers hill^{-1} (2.7) were found from V_4 (ACI hybrid dhan2) which was statistically similar (12.9) with V_3 (BRRI hybrid dhan2) and closely followed (11.0) by V_2 (BRRI dhan29). The minimum effective tillers hill^{-1} (9.6) and maximum non-effective tillers hill^{-1} (3.5) were found from V_1 (BRRI dhan28) and V_2 (BRRI dhan29). The previous findings reported that variable effect of variety on the effective and non-effective tillers hill^{-1}.

2.3.2 Number of ineffective tillers m^{-2}

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

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

2.3.3 Panicle length

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

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

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

Islam *et al.* (2013a) observed that panicle length recorded was the highest (23.25 cm) in the variety Morichsail and the variety Kalijira produced lowest panicle length (20.03 cm). They showed a simple linear regression using panicle length as independent variable and yield as dependent variable showed a positive but non-significant relationship. The value of R2 (0.59) indicates that about 60% variation in yield could be explained by the variation in panicle length.

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

Hossain *et al.* (2008a) evaluated the effect of different nitrogen levels on the performance of four aromatic rice varieties in transplanted *Aman* (monsoon) season as BRRI dhan38 and BRRI dhan 19.

Kalizira, Badshabhog and Tulsimala. The length of panicle was significantly affected by variety. Longest panicles (25.84 cm) were observed in BRRI dhan38. Whilst shortest panicles (20.95 cm) were recorded in Tulsimala.

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

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

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

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

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

2.3.4 Primary branches panicle^{-1}

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

Mia and Shamsuddin (2011) determined the physio-morphological attributes in relation to yield potential of modern and aromatic rice varieties and reported that number of primary branches revealed significant difference among the varieties. The highest number of primary branches showed in Ukunmadhu followed by BRRI dhan32 and Kataribhough.

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

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

2.3.5 Flag leaf length

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

2.2.6 Filled grains panicle^{-1}

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

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

Jewel *et al.* (2011) evaluated, twenty-six (26) aromatic rice genotypes for agronomic characteristics and aroma detection. Reported that number of filled grains per plant ranged from 750 to 1217. IR 73887-1-8-1-4 had the highest number of filled grains per plant, whereas IR 72869-52-1-1-1 had the minimum number of grains per plant.

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

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

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

BRRI (1994) conducted an experiment to observe the performance of BR14, Pujam, BR5 and Tulsimala. They observed that Tulsimala produced the highest number of spikelets panicle^{-1} and BR14 produced the lowest number of spikelets panicle^{-1}. Anonymous (1994) reported that the number of filled grains panicle^{-1} influenced significantly due to variety. The results were also supported by Singh and Gangwer (1989).

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

2.3.7 Unfilled grains per panicle

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

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

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

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

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

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

2.3.8 Total number of grains panicle^{-1}

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

Hossain *et al.* (2008b) evaluated the yield and quality performance of some aromatic rice varieties of Bangladesh and showed that the maximum number of spikelets panicle^{-1} (154.5) was observed in Badshabhog and the minimum (93.3) was obtained from Madhumala.

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

Tahir *et al.* (2002) reported significant variation among the different genotypes for number of spikelets per panicle. Patel *et al.* (2010) found that among the yield components assessed, sink size (spikelets per panicle) contributed more to the yield and is considered to be most important factor responsible for yield gap between aerobic and flooded rice.

2.3.9 1000-grains weight

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

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

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

Metwally *et al.* (2012) reported that aromatic rice varieties exhibited significant differences in 1000-grain weight in the two seasons. The relative ranking of varieties with respect to 1000-grain weight was inconsistent in the two seasons. The Egyptian Yasmin variety and IR 65610 and IR 78530 varieties were among those having the heaviest 1000-grain weight in both seasons.

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

BRRI (1998a) reported that the 1000- grain weight of Kuieha Binni, Leda Binni. Chanda Binni, Dudh Methi, Maraka Binni, Nizcrshail and one high yielding variety BR 25 were

24. 22, 25, 20. 23, 18 and 17g. respectively. BRRI (1998b) found that 1000-grain weight of some aromatic rice varieties ranged from 12 to 20 g and it differed significantly from variety to variety.

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

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

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

2.3.10 Grain yield

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

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

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

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

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

Tyeb *et al.* (2013) and Islam *et al.* (2012) reported that variety exerted variable effect on yield and yield contributing characters of rice.

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

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

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

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

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

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

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

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

BRRI (1994) found that BR I4 produced the highest yield (3.75 t ha^{-1}) followed by Pajarn and Tuishimala while BR5 produced the lowest yield (2.61 t ha^{-1}). Rao *et al.* (1993) found that the highest grain yield was obtained in the wet seasons by local variety Badshabhog (3.21 t ha^{-1}) than the other ones (cv. Kastui. Ranbir. Basmati and lET 8579) and mean yields varied from 2.22-2.58 t ha^{-1}.

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

2.3.11 Straw yield

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

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

Mia and Shamsuddin (2011) reported highest straw yield in BRRI dhan32 and lowest in Ukunmadhu. Metwally *et al.* (2012) reported that aromatic rice varieties exerted a significant effect on straw yield in the two seasons. Plants of Egyptian Yasmin and IR 77510 in markedly produced the highest straw yield in the two seasons. Plants of IR 65610 variety produced the lowest straw yield in the two seasons. The superiority of Egyptian Yasmin and IR 77510 variety might have resulted from its better growth.

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

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

2.3.12 Biological yield

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

Islam *et al.* (2013a) observed that the highest biological yield (9.46 t ha^{-1}) was obtained from the variety Kachra and the lowest biological yield (3.87 t ha^{-1}) was recorded from the variety Kalijira. From the result, it was observed that biological yield differed due to combined effect of grain yield and straw yield. Plotting grain yield against biological yield gave a significant positive linear relationship which indicates that as biological yield increased, grain yield also increased.

2.3.13 Harvest index

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

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

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

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

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

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

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

From the above literature, it is evident that planting geometry and varieties have a significant influence on yield and yield components of rice. The literature suggests that optimum planting geometry and suitable variety increases the grain yield of rice. Reduction in grain yield is mainly attributed by the reduced number of tiller hill^{-1}, grains panicle^{-1}, panicle length and thousand grain weight due to restriction of development of these parameters for the effect of planting geometry and variety itself.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to find out the effect of transplanting geometry on scented fine rice varieties in *Aman* season. The details of the materials and methods i.e. experimental period, location, soil and climatic condition of the experimental area, materials used, treatments and design of the experiment, growing of crops, data collection and data analysis procedure that followed in this experiment has been presented under the following headings:

3.1 Experimental period

The field experiments were conducted during the period of July, 2017 to November, 2018.

3.2 Description of the experimental site

3.2.1 Location of the experimental field

The experiment was carried out on the farm of Sher-e-Bangla Agricultural University, Dhaka. The location of the site is $23^{0}74^{/}$N latitude and $90^{0}35^{/}$E longitude with an elevation of 8.2 meter from sea level.

3.2 2 Characteristics of the soil

The experimental site belongs to the ago-ecological zone of Modhupur Tract (AEZ-28) (FAO, 1988). Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and has organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land.

3.2.3 Climate

Subtropical in nature, characterized by three distinct seasons. The geographical location of the experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to February and the pre-monsoon period or hot season from March to April and monsoon period from May to October (Edris *et al*., 1979). Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e Bangla Nagar, presented in Appendix 2.

3.3 Plant material

In this research, five scented fine rice varieties namely Chinigura (V_1), Kalijira (V_2), Kataribhog (V_3), BRRI dhan37 (V_4) and BRRI dhan38 (V_5) were used. The seeds were collected from the Bangladesh Rice Research Institution (BRRI), Joydeppur, Gajipur.

3.4 Experimental design

The experiment followed a randomized complete block design (RCBD) with three replications and it laid out following unit plot size of 3 m x 3 m.

3.5 Treatments

The experiment were conducted to justify the effect of transplanting geometry on scented fine rice varieties in *Aman* season. It consisted of two factors as mentioned below:

Factor A: Variety (5)

(i) Chinigura (V_1)

(ii) Kalijira (V_2)

(iii) Kataribhog (V_3)

(iv) BRRI dhan37 (V_4)

(v) BRRI dhan38 (V_5)

Factor B: Spacing (3)

(i) 20 cm x 20 cm (S_1)

(ii) 25 cm x 15 cm (S_2)

(iii) 20 cm x 10 cm (S_3).

Treatment Combinations:

1. V_1S_1: Chinigura + (20 cm x 20 cm)
2. V_2S_1: Kalijira + (20 cm x 20 cm)
3. V_3S_1: Kataribhog + (20 cm x 20 cm)
4. V_4S_1: BRRI dhan37 + (20 cm x 20 cm)
5. V_5S_1: BRRI dhan38 + (20 cm x 20 cm)
6. V_1S_2: Chinigura + (25 cm x 15 cm)
7. V_2S_2: Kalijira + (25 cm x 15 cm)
8. V_3S_2: BRRI dhan38 + (25 cm x 15 cm)
9. V_4S_2: BRRI dhan37 + (25 cm x 15 cm)
10. V_5S_2: BRRI dhan38 + (25 cm x 15 cm)
11. V_1S_3: Chinigura + (20 cm x 10 cm)
12. V_2S_3: Kalijira + (20 cm x 10 cm)
13. V_3S_3: Kataribhog + (20 cm x 10 cm)
14. V_4S_3: BRRI dhan37 + (20 cm x 10 cm)
15. V_5S_3: BRRI dhan38 + (20 cm x 10 cm)

3.6 Procedure of experiment

3.6.1 Raising seedling

3.6.1.1 Seed collection

Vigorous and healthy seeds of Chinigura, Kalijira, Kataribhog, BRRI dhan37 and BRRI dhan38 were collected from BRRI (Bangladesh Rice Research Institute), Gazipur, Bangladesh.

3.6.1.2 Seed sprouting

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

3.6.1.3 Preparation of nursery bed and seed sowing

As per BRRI recommendation seedbed was prepared with 1 m wide adding nutrients as per the requirements of soil. Seeds were sown in the seed bed on 20 july, 2017 in order to transplant the seedlings in the main field.

3.6.2 Preparation of the main field

The plot selected for the experiment was opened in the 2nd week of August, 2017 with a power tiller and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross ploughed several times followed by laddering to obtain a good tilt. Weeds and stubble were removed, and finally obtained a desirable tilt of soil for transplanting of seedlings.

3.6.3 Fertilizers and manure application

The fertilizers N, P, K, S and B in the form of Urea, TSP, MoP, Gypsum and Zinc Sulphate, respectively were applied. All fertilizers except urea were applied at the time of final land preparation and urea was top-dressed into three equal splits each at 15, 30 and 45 days after transplanting (DAT). The dose and method of application are shown in Table 1.

Table 1. Dose and method of application of fertilizers in rice field

Fertilizers	Dose (kg/ha)	Application (%)			
		Basal	1st installment	2nd installment	3rd installment
Urea	120	0	33.33	33.33	33.33
TSP	100	100	--	--	--
MoP	70	70	--	--	--
Gypsum	60	60	--	--	--
Zinc Sulphate	10	10	--	--	--

3.6.4 Uprooting of seedlings

The nursery bed was made wet by application of water one day before uprooting the seedlings. The seedlings were uprooted on 15 August, 2017 without causing much mechanical injury to the roots.

3.6.5 Transplanting of seedlings in the field

Thirty (30) days old seedlings were transplanted in the experimental plots using three seedlings per hill on 15 August, 2017.

3.6.6 Intercultural operations

After establishment of seedlings, all intercultural operations were accomplished for better growth and development of the rice seed lings as and whenever necessary.

3.6.6.1 Irrigation and drainage

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

3.6.6.2 Gap filling

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

3.6.6.3 Weeding

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

3.6.6.4 Top dressing

The urea fertilizer was top-dressed in 3 equal installments at 15, 30 and 45 days after transplanting (DAT).

3.6.6.5 Plant protection

There were some incidence of insects specially grasshopper, stem borer, rice ear cutting caterpillar, thrips and rice bug which was controlled by spraying Curator 5G and Smithton. The disease, Brown spot of rice was controlled by spraying Tilt.

3.7 Harvesting, threshing and cleaning

Five hills were randomly selected at maturity (when 80% of the grains became golden yellow) and uprooted from each unit plot prior to harvest for recording data. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. The grains were threshed, cleaned and sun dried (adjusted to 12% moisture content) to record grain yield plot^{-1}. Straws were also sun-dried to record its yield plot^{-1} and both grain and straw yields plot^{-1} were then converted to t ha^{-1}.

3.8 Data recording

The following data were collected during the study period:

1 Plant height
2 Total tillers hill^{-1}
3 Effective tillers hill^{-1}
4 Panicle length (cm)
5 Fertile spikelets (Filled grains) panicle^{-1}
6 Sterile spikelets (Un-filled grains) pancle^{-1}
7 No. of spikelet panicle^{-1}
8 1000 grain weight
9 Grain yield
10 Straw yield
11 Harvest index

3.9 Procedure of recording data

3.9.1 Plant height

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

3.9.2 Number of total tillers hill^{-1}

Total tillers which had at least one leaf visible were counted. It includes both productive and unproductive tillers.

3.9.3 Number of effective tillers hill^{-1}

The total number of effective tillers hill^{-1} was counted as the number of panicle bearing hill plant^{-1}.

Data on effective tillers $hill^{-1}$ were counted from 5 selected hills at harvest and average value was recorded.

3.9.4 Panicle length

The length of panicle was measured in centimeter (cm) from 10 selected panicles and the average value was recorded.

3.9.5 Fertile spikelets (Filled grains) $panicle^{-1}$

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

3.9.6 Sterile spikelets (Non-filled grains) $panicle^{-1}$

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

3.9.7 No. of spikelet $panicle^{-1}$

The total number of grains was calculated by adding filled and unfilled grains and then average number of grains $panicle^{-1}$ was recorded.

3.9.8 1000 seed weight

One thousand seeds were counted randomly from the total cleaned harvested seeds of each individual plot and then weighed in grams and recorded.

3.9.9 Grain yield ha^{-1}

Grains obtained from each unit plot were sun-dried and weighed carefully. The central 3 lines from each plot were harvested, threshed, dried, weighed and finally converted to t ha^{-1} basis.

3.9.10 Straw yield ha^{-1}

Straw obtained from each unit plot were sun-dried and weighed carefully. The dry weight of straw of central 3 lines were harvested, threshed, dried and weighed and finally converted to t ha^{-1} basis.

3.9.11 Harvest index

The harvest index was calculated with the following formula:

Harvest index = (Grain yield / Biological yield) x 100

Biological yield = Grain yield + Straw yield

3.10 Statistical Analysis

All the data collected on different parameters wear statistically analysed following the analysis of variance (ANOVA) technique using MSTAT-C computer package program and the mean difference were adjudged by least significant difference (LSD) test at 5% level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

The present investigation entitled “Effect of transplanting geometry on scented fine rice varieties in *Aman* season”. The findings obtained from the study have been presented, discussed and compared in this chapter through different tables and figures. The analyses of variance (ANOVA) and other table on different parameters have been presented in Appendices III-XII. The results have been presented and discussed with the help of tables and graphs and possible interpretations have been given under the following sub-headings.

4.1 Growth performances

4.1.1 Plant height

4.1.1.1 Effect of variety

Statistically significant variation was recorded among the rice varieties for plant height (Figure 1 and Appendix III). Data revealed that the tallest plant (150.5 cm) was observed from Kalijira, which was followed by and statistically similar to Kataribhog (148.8 cm), whereas the shortest plant (137.4 cm) was recorded from BRRI dhan38. This confirms the report of Hossain *et al.* (1991) and BINA (1993) that plant height differed from variety to variety. Plant height was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

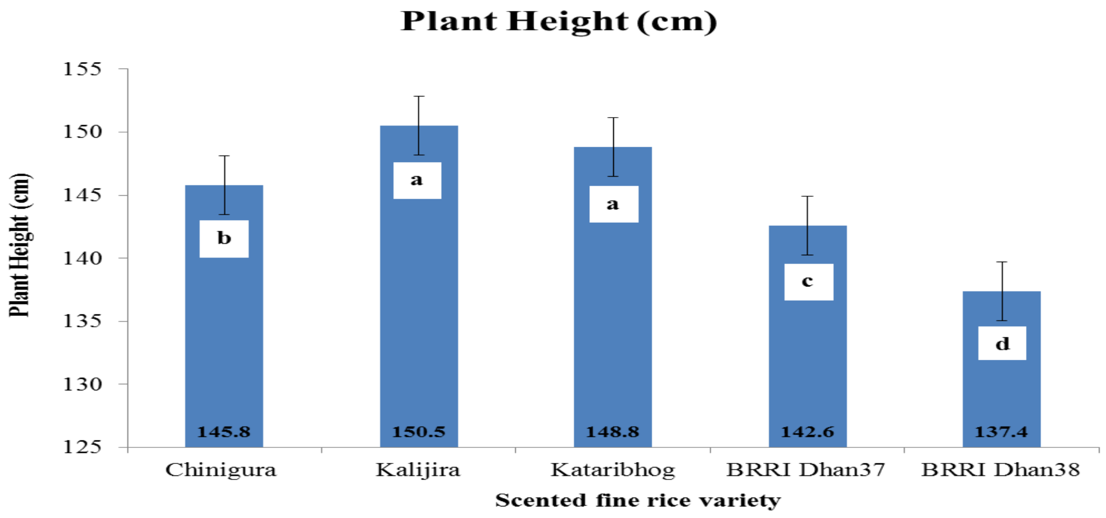

Figure 1. Effect of variety on the plant height of scented rice (Vertical bars represent standard error)

4.1.1.2 Effect of spacing

Significantly different variation in plant height of rice was observed in case of different spacing (Figure 2 and Appendix III). Among the different spacing, the maximum plant height (150.2 cm) was observed from S_1 (20 cm x 20 cm) followed by 148.5 cm in case of S_2 (25 cm x 15 cm) which were statistically similar and minimum plant height (136.3 cm) was recorded from S_3 (20 cm x 10 cm). It might be due to the fact that widely spaced plants absorb more light, air and food materials which facilitated the plant to develop fully. Similar results were also reported by Kanda and Kalra (1986) and Shahi *et al.* (1976).

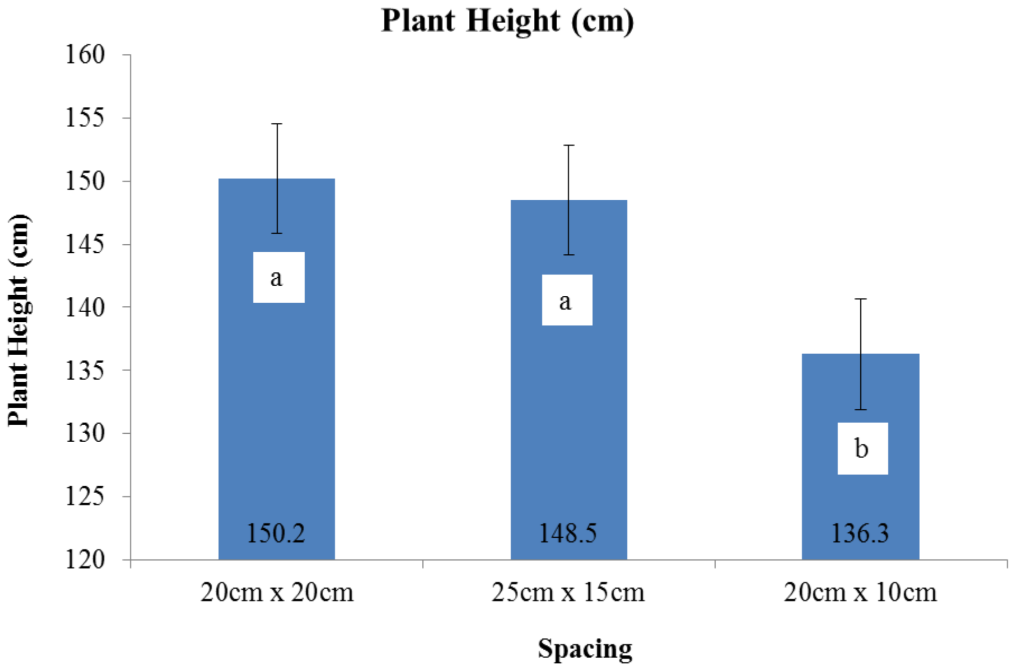

Figure 2. Effect of different spacing on plant height of scented rice varieties (Common letter(s) within the same column do not differ significantly at 5% level of significance; Vertical bars represent standard error)

4.1.1.3 Interaction effect of different varieties and spacing

Different varieties and spacing expressed significant differences due to their interaction effect on plant height of scented rice (Table 2 and Appendix III). Significantly the maximum plant height (161.3 cm) was recorded from the treatment of Chinigura (V_1) + 20 cm x 20 cm (S_1) which was statistically identical to the treatment combination of BRRI dhan38 (V_5) + 20 cm x 20 cm (S_1). The shortest plant (130.3 cm) was obtained from the combined treatment of BRRI dhan38 (V_5) + 20 cm x 10 cm (S_3).

Table 2: Effect of variety and spacing on plant height of scented rice

Treatment combinations	Plant height (cm)
V_1S_1	161.3a
V_2S_1	135.0e
V_3S_1	141.0d
V_4S_1	156.6b
V_5S_1	159.7a
V_1S_2	135.3e
V_2S_2	151.2c
V_3S_2	155.2b
V_4S_2	140.0d
V_5S_2	141.3d
V_1S_3	151.5c
V_2S_3	135.0e
V_3S_3	140.7d
V_4S_3	141.3d
V_5S_3	130.3f
$LSD_{(0.05)}$	3.035
CV (%)	1.25

Values in column having different letter(s) are significantly different and same letter are not significantly different at 0.05 level of probability. V_1= Chinigura, V_2= Kalijira, V_3= Kataribhog, V_4= BRRI dhan37, V_5= BRRI dhan38 , S_1= 20 cm x 20 cm, S_2= 25 cm x 15 cm, S_3= 20 cm x 10 cm.

4.1.2 Total tillers hill^{-1}

4.1.2.1 Effect of variety

Statistically significant variation was recorded among the rice varieties for total tillers per hill (Figure 3 and Appendix IV). Data revealed that the highest number of tillers per hill (10.56) was observed from Chinigura, which was followed by BRRI dhan37 (9.89) and BRRI dhan38 (9.78). The lowest number of tillers per hill was recorded from Kataribhog (9.33).

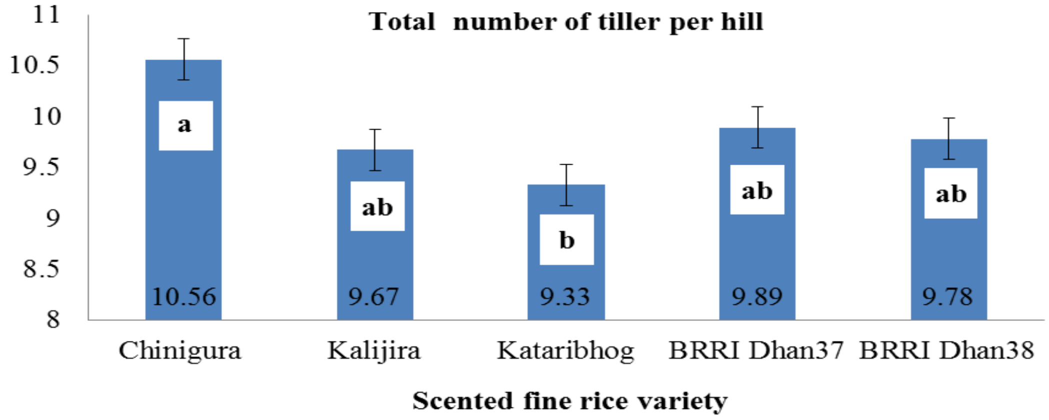

Figure 3. Effect of variety on the total number of tiller hill^{-1} of scented rice (Common letter(s) within the same column do not differ significantly at 5% level of significance; Vertical bars represent standard error)

4.1.2.2 Effect of spacing

The different spacing had significantly influenced the formation of total tillers hill^{-1}. The widest spacing i.e. 20 cm x 20 cm (S_1) produced the highest total number of tillers hill^{-1} (10.6) followed by 9.93 in case of S_2 (25 cm x 15 cm) which were statistically similar. The closest spacing of 20 cm x 10 cm (S_3) plants produced the lowest number of tillers hill^{-1} (9.0). The widest spaced plants produced the highest number of tillers hill^{-1} which might be due to the fact that wider spaced plants absorbed more nutrient, moisture and intercept light which ultimately leads the plants to grow more tillers plant^{-1}. Haque and Nasiruddin (1988) also observed that wider spacing produced higher number of total tillers hill^{-1}.

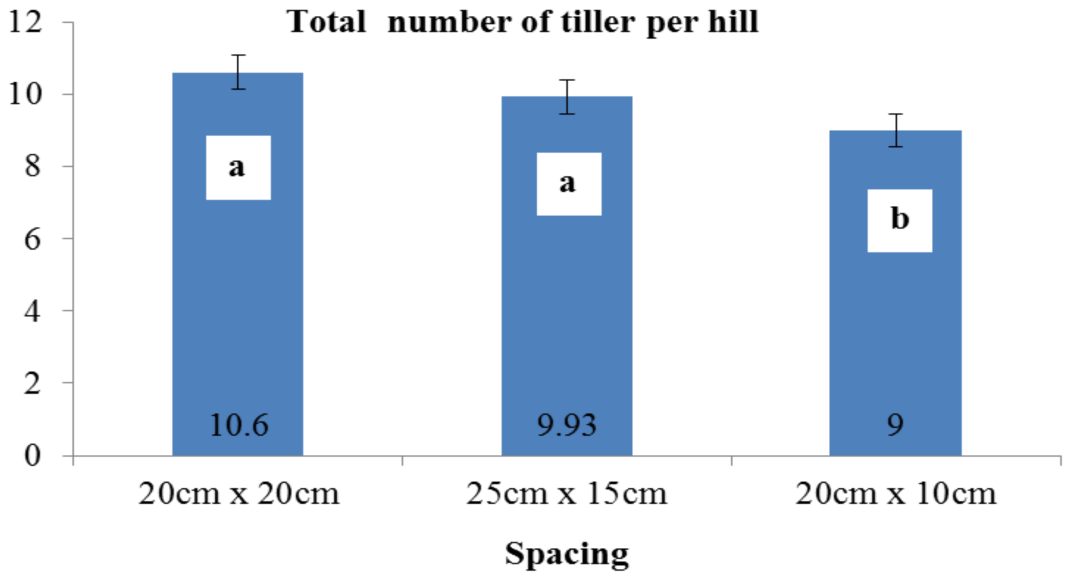

Figure 4. Effect of different spacing on the total number of tiller hill^{-1} of scented rice (Common letter(s) within the same column do not differ significantly at 5% level of significance; Vertical bars represent standard error)

4.1.2.3 Interaction effect of different varieties and spacing

Different varieties and spacing expressed significant differences due to their interaction effect on number of total tillers hill^{-1}of scented rice (Table 3 and Appendix IV). Significantly the maximum number of total tillers hill^{-1} (13.67) was recorded from the treatment of Chinigura (V_1) + 20 cm x 20 cm (S_1) which was followed by the treatment combination of BRRI dhan38 (V_5) + 20 cm x 10 cm (S_3) i.e. 12.67. The minimum number of total tillers hill^{-1} (5.67) was obtained from the combined treatment of Kataribhog (V_3) + 20 cm x 20 cm (S_1).

Table 3: Effect of variety and spacing on number of total tillers hill^{-1}

Treatment combinations	Number of total tillers hill^{-1}
V_1S_1	13.67a
V_2S_1	12.33bc
V_3S_1	5.67i
V_4S_1	11.33de
V_5S_1	7.0h
V_1S_2	10.67e
V_2S_2	7.67h
V_3S_2	11.67cd
V_4S_2	8.67g
V_5S_2	10.67e
V_1S_3	11.67cd
V_2S_3	7.333h
V_3S_3	9.67f
V_4S_3	7.0h
V_5S_3	12.67b
$LSD_{(0.05)}$	0.86
CV(%)	5.28

Values in column having different letter(s) are significantly different and same letter are not significantly different at 0.05 level of probability. V_1= Chinigura, V_2= Kalijira, V_3= Kataribhog, V_4= BRRI dhan37, V_5= BRRI dhan38 S_1= 20 cm x 20 cm, S_2= 25 cm x 15 cm, S_3= 20 cm x 10 cm.

4.1.3 Number of effective tillers hill^{-1}

4.1.3.1 Effect of variety

The rice varieties significantly influenced the number of effective tillers hill^{-1} (Figure 5 and Appendix V). The variety Chinigura produced the maximum number of effective tillers hill^{-1} (8.44) but BRRI Dhan37 produced the minimum (7.22) number of effective tillers hill^{-1}, followed by the rest three varieties viz, Kataribhog, BRRI Dhan38 and Kalijira (7.44, 7.56 and 7.67 respectively) which were statistically similar. The probable reason of variation in producing the number of effective tillers hill^{-1} is the genetic makeup of the varieties which are primarily influenced by heredity. These results were in agreement with the findings of BINA (1993) in which rice varieties significantly influenced for the number of effective tillers per hill.

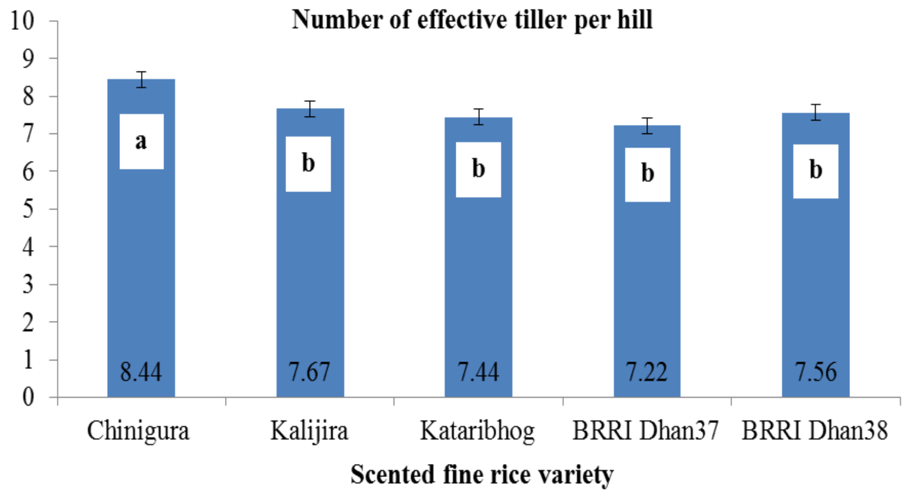

Figure 5. Effect of variety on the number of effective tiller hill^{-1} of scented rice (Common letter(s) within the same column do not differ significantly at 5% level of significance; Vertical bars represent standard error)

4.1.3.2 Effect of spacing

The different spacing had significantly influenced the formation effective tillers hill^{-1}. The widest spacing i.e. 20 cm x 20 cm (S_1) produced the highest effective number of tillers hill^{-1} (8.33) followed by 7.8 in case of S_2 (25 cm x 15 cm) which were statistically similar. The closest spacing of 20 cm x 10 cm (S_3) plants produced the lowest number of effective tillers hill^{-1} (6.87). A gradual decrease in tiller number was observed as the spacing become closer between lines and hills. The wider spacing allowed much more area for growth of the plant and brought in less competition between them resulting in more number of effective tillers hill^{-1}.

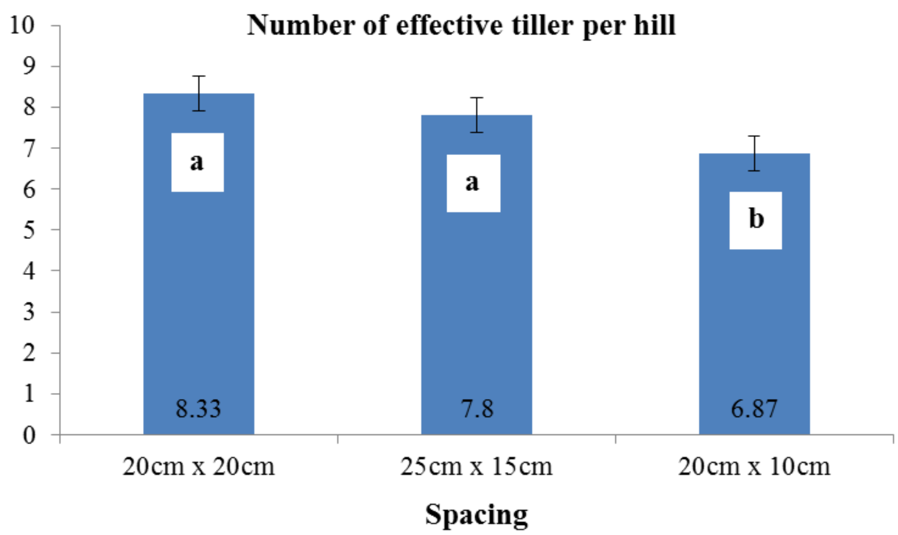

Figure 6. Effect of different spacing on the effective number of tiller hill^{-1} of scented rice (Common letter(s) within the same column do not differ significantly at 5% level of significance; Vertical bars represent standard error)

4.1.3.3 Interaction effect of different varieties and spacing

Different varieties and spacing expressed significant differences due to their interaction effect on number of effective tillers hill^{-1} of scented rice (Table 4 and Appendix V). Significantly the maximum number of effective tillers hill^{-1} (11.33) was recorded from the treatment of Chinigura (V_1) + 20 cm x 20 cm (S_1) which was followed by the treatment combination of Kalijira (V_2) + 20 cm x 20 cm (S_1) and BRRI dhan38 (V_5) + 20 cm x 10 cm (S_3) both producing 10.0 effective tillers hill^{-1}. The minimum number of effective tillers hill^{-1} (4.0) was obtained from the combined treatment of Kataribhog (V_3) + 20 cm x 20 cm (S_1).

Table 4: Effect of variety and spacing on number of effective tillers hill^{-1} of scented rice

Treatment combinations	Number of effective tillers hill^{-1}
V_1S_1	11.33a
V_2S_1	10.0b
V_3S_1	4.0g
V_4S_1	9.0c
V_5S_1	6.0e
V_1S_2	8.0d
V_2S_2	5.67e
V_3S_2	9.0c
V_4S_2	7.67d
V_5S_2	8.0d
V_1S_3	9.0c
V_2S_3	4.67f
V_3S_3	7.67d
V_4S_3	5.0f
V_5S_3	10.0b
$LSD_{(0.05)}$	0.56
CV(%)	4.41

Values in column having different letter(s) are significantly different and same letter are not significantly different at 0.05 level of probability. V_1= Chinigura, V_2= Kalijira, V_3= Kataribhog, V_4= BRRI dhan37, V_5= BRRI dhan38, S_1= 20 cm x 20 cm, S_2= 25 cm x 15 cm, S_3= 20 cm x 10 cm

4.1.4 Panicle length

4.1.4.1 Effect of variety

Highly significant variation on panicle length was observed due to variety (Figure 7 and Appendix VI) and Chinigura (V_1) produced the longest panicle (25.20 cm) followed by BRRI dhan38 (23.63 cm). On the contrary, the shortest panicle (22.13 cm) was observed in Kataribhog (V_3). The variety Kalijira (V_2) produced intermediate length of panicle (23.07 cm) followed by BRRI dhan37 (22.39 cm). The probable reason of variation in producing the panicle length is the genetic makeup of the varieties, which is primarily influenced by heredity.

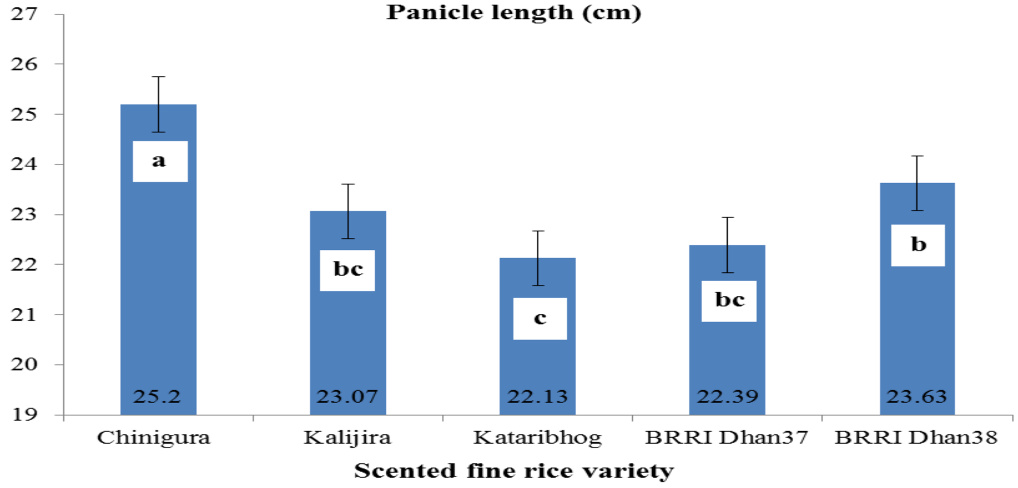

Figure 7. Effect of variety on the panicle length of scented rice (Common letter(s) within the same column do not differ significantly at 5% level of significance; Vertical bars represent standard error)

4.1.4.2 Effect of spacing

The panicle length of rice plants was also significantly persuaded by the action of plant spacing (Figure 8 and Appendix VI). The longest panicle length was 25.15 cm with the spacing 20 cm x 20 cm (S_1) which was followed by 20 cm x 10 cm (S_3) (22.42 cm). The shortest panicle length was observed for the spacing 25 cm x 15 cm (22.29 cm). This confirmed the results of Rao *et al.* (1990), Thanamuthu and Subramanian (1983), Liou (1987) who stated that panicle length was significantly influenced by plant population.

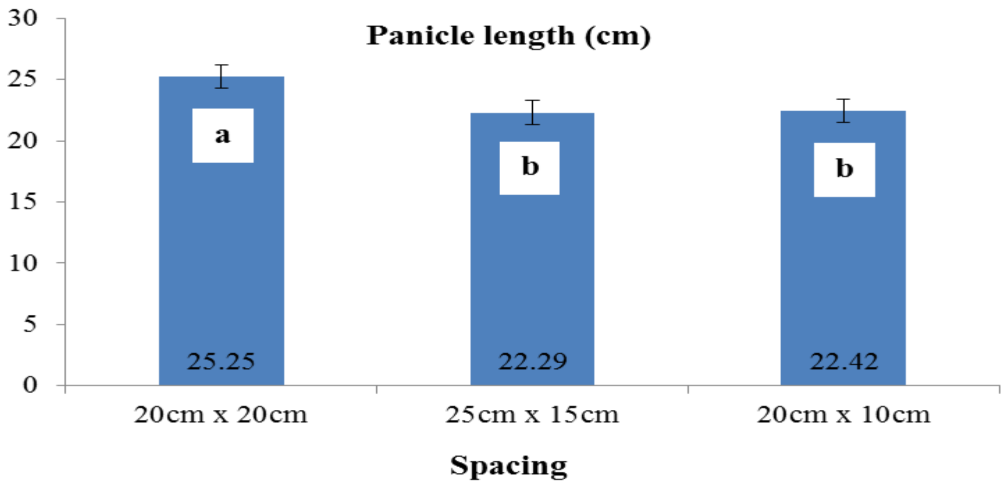

Figure 8. Effect of different spacing on the panicle length of scented rice (Common letter(s) within the same column do not differ significantly at 5% level of significance; Vertical bars represent standard error)

4.1.4.3 Interaction effect of different varieties and spacing

Different varieties and spacing expressed significant differences due to their interaction effect on panicle length of scented rice (Table 5 and Appendix VI). Significantly the longest panicle length (26.20 cm) was recorded from the treatment of Chinigura (V_1) + 20 cm x 20 cm (S_1) which was followed by and statistically identical to the treatment combination of BRRI dhan38 (V_5) + 25 cm x 15 cm (S_2). The shortest panicle length (19.33 cm)was obtained from the combined treatment of Chinigura (V_1) + 20 cm x 10 cm (S_3).

Table 5: Effect of variety and spacing on panicle length of scented rice

Treatment combinations	Panicle length (cm)
V_1S_1	26.20a
V_2S_1	25.0ab
V_3S_1	24.40bc
V_4S_1	24.90abc
V_5S_1	21.60ef
V_1S_2	22.70de
V_2S_2	23.60cd
V_3S_2	20.40fg
V_4S_2	22.40de
V_5S_2	26.13a
V_1S_3	19.33g
V_2S_3	21.70ef
V_3S_3	24.90abc
V_4S_3	25.10ab
V_5S_3	20.90f
$LSD_{(0.05)}$	1.21
CV(%)	3.13

Values in column having different letter(s) are significantly different and same letter are not significantly different at 0.05 level of probability. V_1= Chinigura, V_2= Kalijira, V_3= Kataribhog, V_4= BRRI dhan37, V_5= BRRI dhan38 , S_1= 20 cm x 20 cm, S_2= 25 cm x 15 cm, S_3= 20 cm x 10 cm

4.1.5 Number of spikelets per panicle

4.1.5.1 Effect of variety

Highly significant variation on total spikelets per panicle was observed due to the effect of variety (Figure 9). The variety Chinigura (V_1) produced the highest number of spikelets per panicle (134.2) followed by BRRI dhan38 (120.70 cm). The lowest number of spikelets per panicle (106.6) was observed for Kalijira (V_2) followed by 111.7 in Kataribhog (V_3). The findings are in agreement with the results of Hossain *et al.* (1991) who found that rice varieties statistically influenced on the number of grain panicle^{-1}. The probable reason of variation in producing the total spikelets panicle^{-1} is the longest panicle length which is primarily influenced by heredity. These results were also in agreement with the findings of BINA (1993).

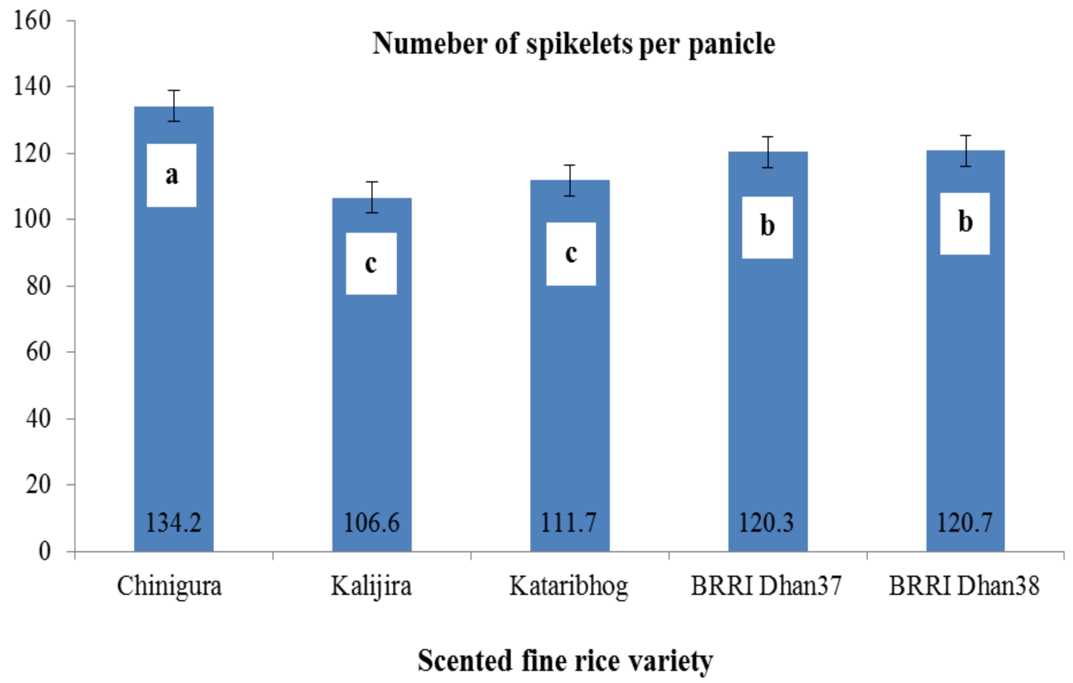

Figure 9. Effect of variety on the number of spikelets per panicle of scented rice (Common letter(s) within the same column do not differ significantly at 5% level of significance; Vertical bars represent standard error)

4.1.5.2 Effect of spacing

Spacing had highly significant effect on total spikelet panicle^{-1} (Figure 10). It was revealed that 20 cm x 20 cm (S_1) spacing produced the highest number of spikelets panicle^{-1} (149.8) compared to other spacing. The lowest spikelets panicle^{-1} (90.87) was produced in 20 cm x 10 cm (S_3). The spacing 25 cm x 15 cm (S_2) produced intermediary number of spikelets panicle^{-1} (115.4). Similar results were also reported by Quddus and Huda (1975) and Rao *et al.* (1990) who confirmed that wider spacing plants produced the highest number of grains panicle^{-1}. Due to more number of effective tillers hill^{-1} and longest panicle length enhanced more number of total spikelets panicle^{-1} by wider spacing.

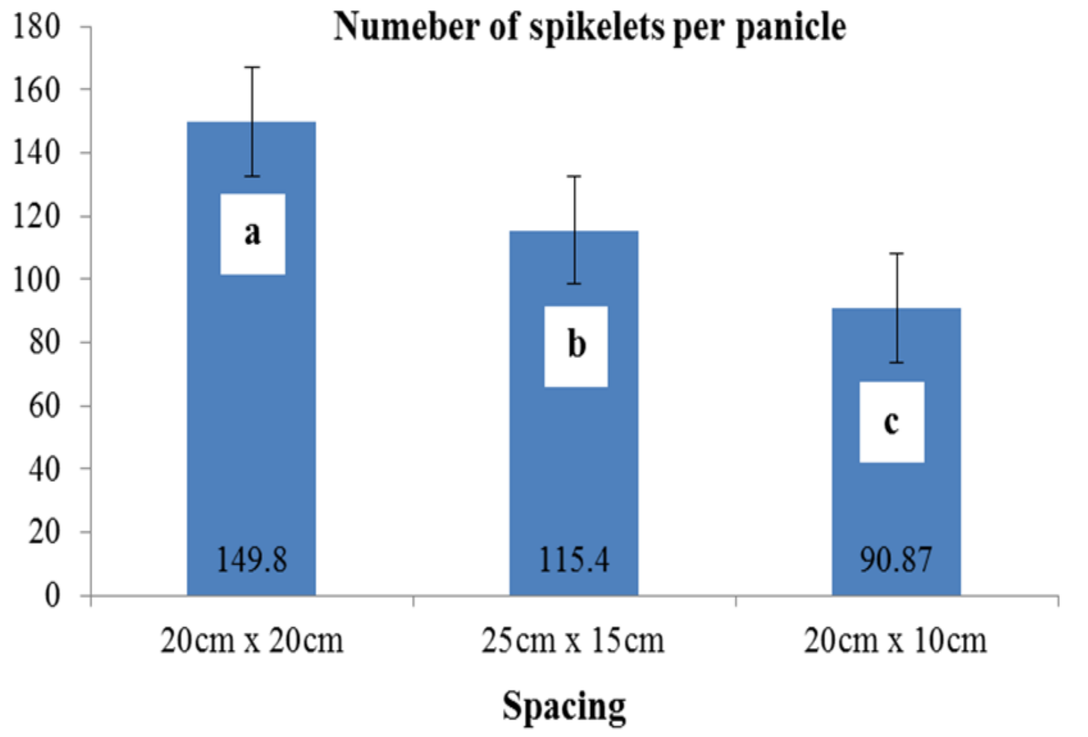

Figure 10. Effect of different spacing on the number of spikelets per panicle of scented rice (Common letter(s) within the same column do not differ significantly at 5% level of significance; Vertical bars represent standard error)

4.1.5.3 Interaction effect of different varieties and spacing

Different varieties and spacing expressed significant differences due to their interaction effect on the number of spikelets per panicle of scented rice (Table 6 and Appendix VI). Significantly the highest number of spikelets per panicle (175.0) was recorded from the treatment of BRRI dhan38 (V_5) + 25 cm x 15 cm (S_2) which was followed by and statistically identical to the treatment combination of Kataribhog (V_3) + 20 cm x 10 cm (S_3). The lowest number of spikelets per panicle (76.00) was obtained from the combined treatment of Chinigura (V_1) + 25 cm x 15 cm (S_2) which was followed by and statistically identical to the treatment combination of BRRI dhan38 (V_5) + 20 cm x 10 cm (S_3).

Table 6: Effect of variety and spacing on number of spikelets per panicle of scented rice

Treatment combinations	Number of spikelets per panicle
V_1S_1	141.0c
V_2S_1	160.7b
V_3S_1	101.0gh
V_4S_1	132.0d
V_5S_1	111.7f
V_1S_2	76.0j
V_2S_2	126.0e
V_3S_2	109.0f
V_4S_2	100.0h
V_5S_2	175.0a
V_1S_3	89.67i
V_2S_3	96.33h
V_3S_3	175.0a
V_4S_3	106.0fg
V_5S_3	81.00j
$LSD_{(0.05)}$	5.7
CV(%)	2.87

Values in column having different letter(s) are significantly different and same letter are not significantly different at 0.05 level of probability.V_1= Chinigura, V_2= Kalijira, V_3= Ka-taribhog, V_4= BRRI dhan37, V_5=BRRI dhan38 ,S_1= 20 cm x 20 cm, S_2= 25 cm x 15 cm, S_3= 20 cm x 10 cm.

4.1.6 Number of filled grains per panicle

4.1.6.1 Effect of variety

Number of filled grains panicle^{-1} was highly significant due to the effect of variety (Figure 11). The variety Chinigura (V_1) produced the highest number of filled grains panicle^{-1} (101) followed by 90.33 in case of BRRI dhan37 (V_4). But the lowest number (85.33) of filled grains panicle^{-1} was found in the variety Kalijira (V_2). Hossain *et al.* (1991) also observed varietal variation in number of filled grains panicle^{-1}.

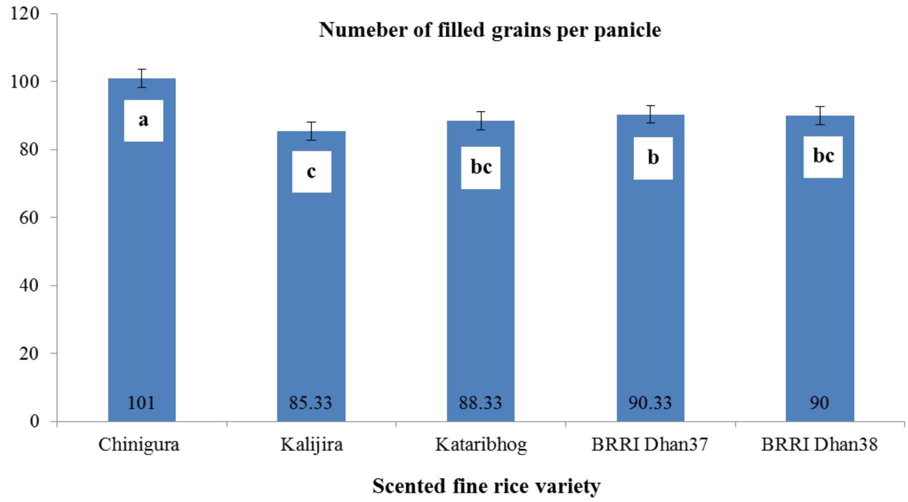

Figure 11. Effect of variety on the number of filled grains per panicle of scented rice (Common letter(s) within the same column do not differ significantly at 5% level of significance; Vertical bars represent standard error)

4.1.6.2 Effect of spacing

Spacing had highly significant effect on number of filled grains panicle^{-1} (Figure 12). The spacing 20 cm x 20 cm (S_1) produced the highest number of filled grains panicle^{-1} (116.4) but it was the lowest (70.2) in the closest spacing of 20 cm x 10 cm (S_3). However, spacing 25 cm x 15 cm (S_2) produced significantly higher filled grains panicle^{-1} than spacing S_3. This result was in compliance with those of Quddus and Huda (1975) and Rao *et al.* (1990) who found that wider spacing produced higher number of filled grains panicle^{-1}.

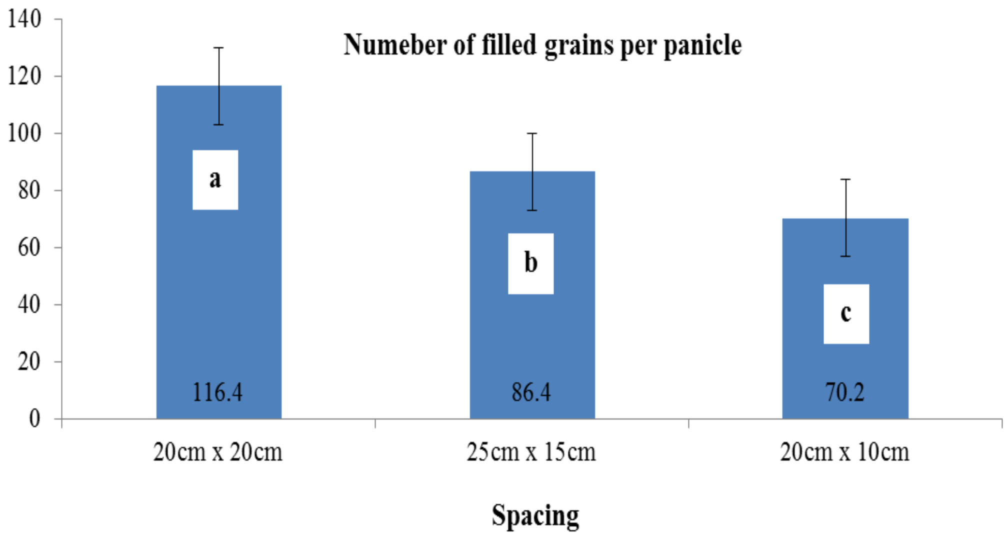

Figure 12. Effect of different spacing on the number of filled grains per panicle of scented rice (Common letter(s) within the same column do not differ significantly at 5% level of significance; Vertical bars represent standard error)

4.1.6.3 Interaction effect of different varieties and spacing

From the combined treatment of Chinigura (V_1) + 25 cm x 15 cm (S_2) which was followed Different varieties and spacing expressed significant differences due to their interaction effect on the number of filled grains per panicle of scented rice (Table 7 and Appendix VII). Significantly the highest number of filled grains per panicle (131.0) was recorded from the treatment combination of BRRI dhan38 (V_5) + 25 cm x 15 cm (S_2) which was followed by and statistically identical (127.0) to the treatment combination of Kataribhog (V_3) + 20 cm x 10 cm (S_3). The lowest number of filled grains per panicle (53.0) was obtained by 58.0 in case of the combined treatment of BRRI dhan38 (V_5) + 20 cm x 10 cm (S_3).

Table 7: Effect of variety and spacing on number of filled grains per panicle

Treatment combinations	Number of filled grains per panicle
V_1S_1	118.0b
V_2S_1	101.0d
V_3S_1	84.0hi
V_4S_1	110.0c
V_5S_1	93.0ef
V_1S_2	53.0m
V_2S_2	96.0e
V_3S_2	89.0fg
V_4S_2	80.0ij
V_5S_2	131.0a
V_1S_3	64.0k
V_2S_3	76.0j
V_3S_3	127.0a
V_4S_3	85.0gh
V_5S_3	58.0l
$LSD_{(0.05)}$	4.44
CV(%)	2.92

Values in column having different letter(s) are significantly different and same letter are not significantly different at 0.05 level of probability. V_1=Chinigura, V_2= Kalijira, V_3= Kataribhog, V_4= BRRI dhan37, V_5= BRRI dhan38 ,S_1= 20 cm x 20 cm, S_2= 25 cm x 15 cm, S_3= 20 cm x 10 cm.

4.1.7 Number of non-filled grains per panicle

4.1.7.1 Effect of variety

The effect of variety was statistically significant in respect of the number of non-filled grains panicle^{-1} (Figure 13). The variety Chinigura (V_1) produced the highest number of non-filled grains panicle^{-1} (33.22) followed by 30.67 in case of BRRI dhan38 (V_5). On the contrary, the lowest number (21.22) of non-filled grains panicle^{-1} was found in the variety Kalijira (V_2).

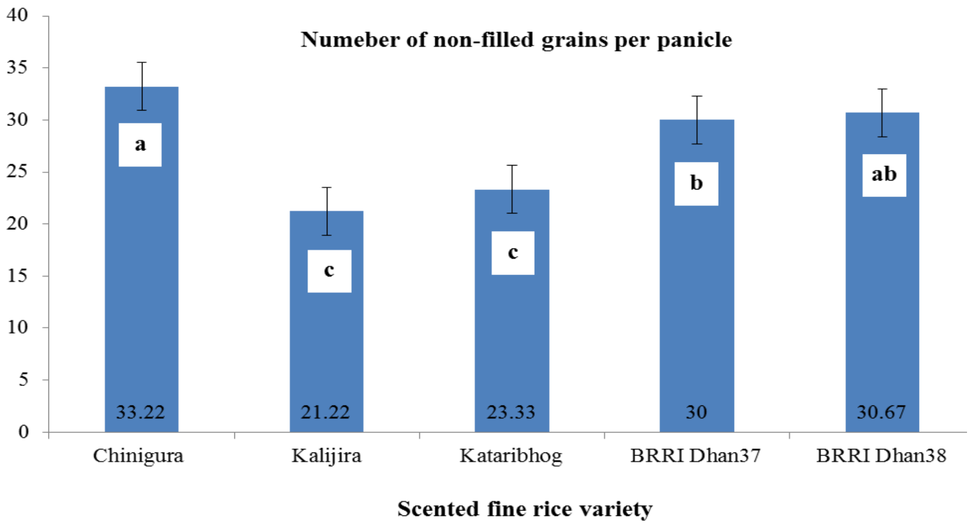

Figure 13. Effect of variety on the number of non-filled grains per panicle of scented rice (Common letter(s) within the same column do not differ significantly at 5% level of significance; Vertical bars represent standard error)

4.1.7.2 Effect of spacing

A significant effect of spacing was observed in the number of non-filled grains panicle^{-1} (Figure 14). A gradual increase in the number of non-filled grains was observed as the spacing become wider between the lines and hills. The widest spacing 20 cm x 20 cm (S_1) produced the highest number of non-filled grains panicle^{-1} (33.4) and it was the lowest (20.67) in the closest spacing i.e. 20 cm x 10 cm (S_3). The spacing 25 cm x 15 cm (S_2) produced inter mediate number of non-filled grains panicle^{-1} (29).

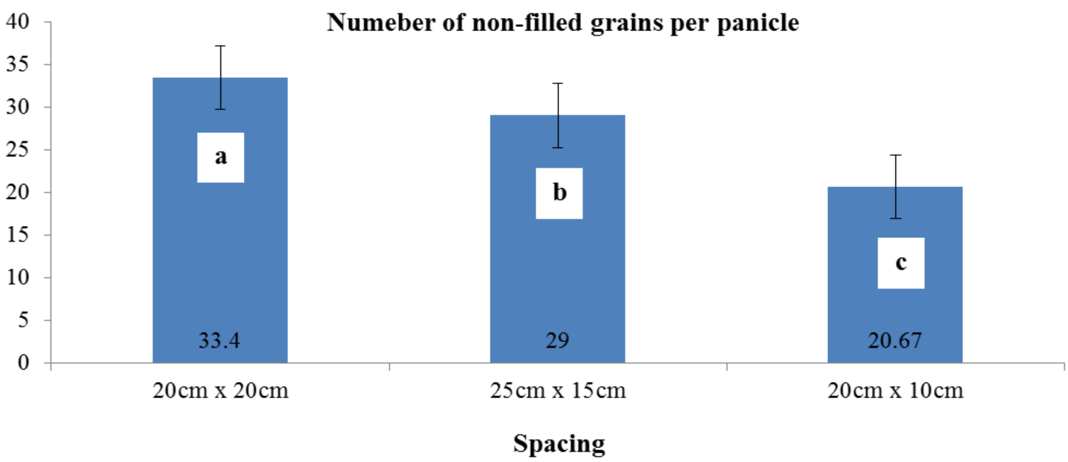

Figure 14. Effect of different spacing on the number of filled grains per panicle of scented rice (Common letter(s) within the same column do not differ significantly at 5% level of significance; Vertical bars represent standard error)

4.1.7.3 Interaction effect of different varieties and spacing

Different varieties and spacing expressed significant differences due to their interaction effect on the number of non-filled grains per panicle of scented rice (Table 8 and Appendix VIII). Significantly the highest number of non-filled grains per panicle (59.67) was recorded from the treatment combination of Kalijira (V_2) + 20 cm x 20 cm (S_1) while the lowest number of non-filled grains per panicle (17.0) was obtained from the combined treatment of Kataribhog (V_3) + 20 cm x 20 cm (S_1).

Table 8: Effect of variety and spacing on number of non-filled grains per panicle

Treatment combinations	Number of non-filled grains per panicle
V_1S_1	23.0ef
V_2S_1	59.67a
V_3S_1	17.0i
V_4S_1	22.0fg
V_5S_1	18.67hi
V_1S_2	23.0ef
V_2S_2	30.0d
V_3S_2	20.0fgh
V_4S_2	20.0fgh
V_5S_2	44.0c
V_1S_3	25.67e
V_2S_3	20.33fgh
V_3S_3	48.0b
V_4S_3	21.0fgh
V_5S_3	23.0f
$LSD_{(0.05)}$	2.63
CV(%)	5.69

Values in column having different letter(s) are significantly different and same letter are not significantly different at 0.05 level of probability. V_1= Chinigura, V_2= Kalijira, V_3= Kataribhog, V_4= BRRI dhan37, V_5= BRRI dhan38, S_1= 20 cm x 20 cm, S_2= 25 cm x 15 cm, S_3= 20 cm x 10 cm.

4.1.8 1000 grain weight

4.1.8.1 Effect of variety

It was observed that 1000-grain weight was highly significant due to variety (Figure 15). The variety BRRI dhan38 (V_5) produced the highest 1000-grain weight (14.84 g) followed by Kataribhog (13.99g) and BRRI dhan38 (13.96 g), whereas the lowest was produced in Chinigura (11.43 g). It might be due to varietal variation, which is primarily influenced by heredity.

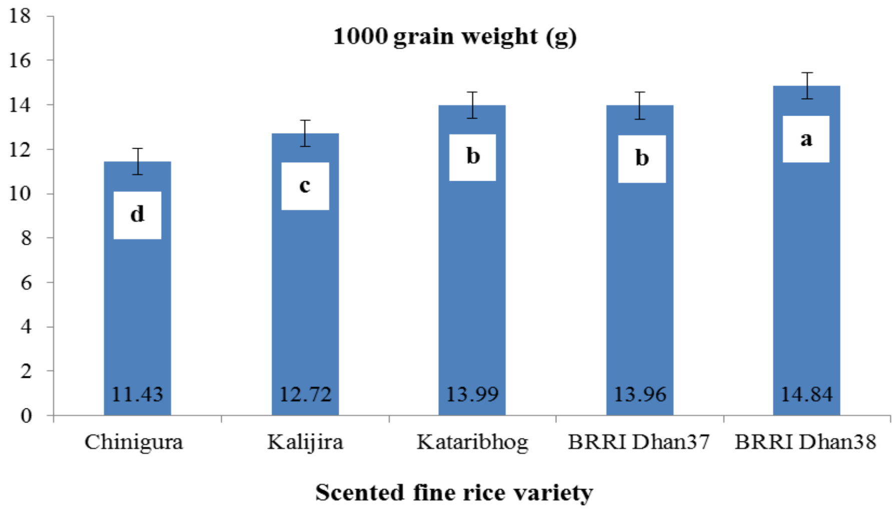

Figure 15. Effect of variety on 1000- grain weight (g) of scented rice (Common letter(s) within the same column do not differ significantly at 5% level of significance; Vertical bars represent standard error)

4.1.8.2 Effect of spacing

A significant effect of spacing was observed in 1000 grain weight (Figure 16). A gradual increase in 1000 grain weight was observed as the spacing become wider between the lines and hills. The widest spacing 20 cm x 20 cm (S_1) produced the highest 1000 grain weight (17.11 g) followed by 12.58 g in case of spacing 25 cm x 15 cm (S_2). The lowest 1000 grain weight (10.47 g) was observed in the closest spacing i.e. 20 cm x 10 cm (S_3).

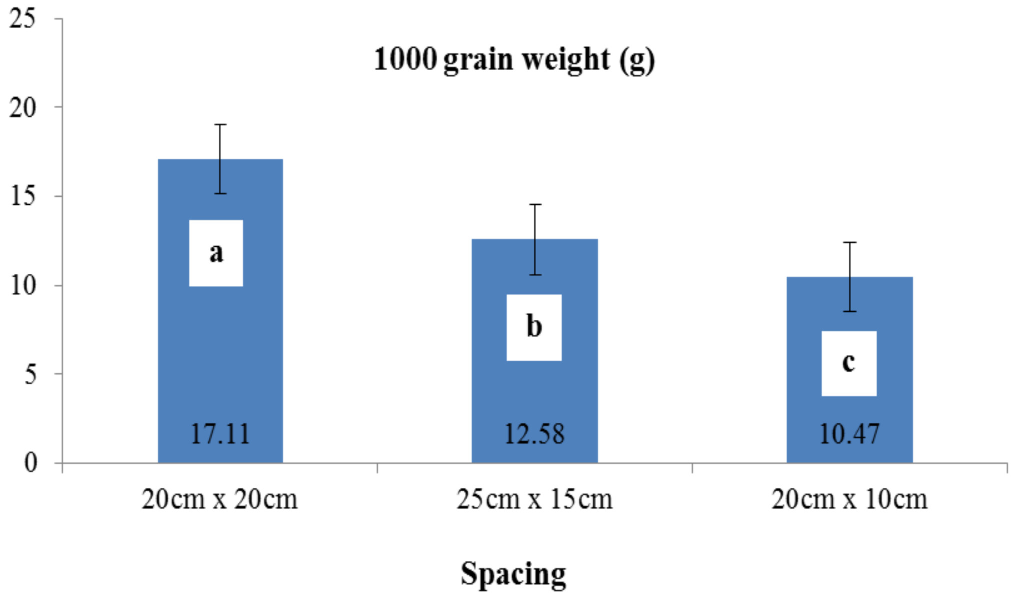

Figure 16. Effect of different spacing on the number of filled grains per panicle of scented rice (Common letter(s) within the same column do not differ significantly at 5% level of significance; Vertical bars represent standard error)

4.1.8.3 Interaction effect of different varieties and spacing

Different varieties and spacing expressed significant differences due to their interaction effect on 1000 grain weight of scented rice (Table 9 and Appendix IX). Significantly the highest 1000 grain weight (19.07 g) was recorded from the treatment combination of Kalijira (V_2) + 25 cm x 15 cm (S_2) which was followed by (18.97 g) in case of the treatment combination of BRRI dhan38 (V_5) + 25 cm x 15 cm (S_2). The lowest 1000 grain weight (9.5 g) was obtained from the combined treatment of Kalijira (V_2) + 20 cm x 20 cm (S_1).

Table 9: Effect of variety and spacing on 1000 grain weight

Treatment combinations	1000 grain weight (g)
V_1S_1	14.5d
V_2S_1	9.5m
V_3S_1	10.3k
V_4S_1	14.2e
V_5S_1	13.8f
V_1S_2	10.17k
V_2S_2	19.07a
V_3S_2	12.90g
V_4S_2	10.0l
V_5S_2	18.97ab
V_1S_3	11.70h
V_2S_3	11.20i
V_3S_3	18.83b
V_4S_3	15.0c
V_5S_3	10.7j
$LSD_{(0.05)}$	0.15
CV(%)	0.72

Values in column having different letter(s) are significantly different and same letter are not significantly different at 0.05 level of probability. V_1= Chinigura, V_2= Kalijira, V_3= Kataribhog, V_4= BRRI dhan37, V_5= BRRI dhan38 ,S_1= 20 cm x 20 cm, S_2= 25 cm x 15 cm, S_3= 20 cm x 10 cm.

4.1.9 Grain yield

4.1.9.1 Effect of variety

Grain yield mainly depends on the yield contributing characters like number of effective tiller per unit area, number of spikelets panicle^{-1}, filled grains panicle^{-1} and weight of individual grains. Interestingly, the results revealed that varieties did not influence statistically on the grain yield (Figure 17). The highest grain yield (3.3 t ha^{-1}) was recorded at the variety BRRI dhan37 and the lowest (3.13 t ha^{-1}) was obtained from the variety Kalijira and Chinigura (Figure 18).

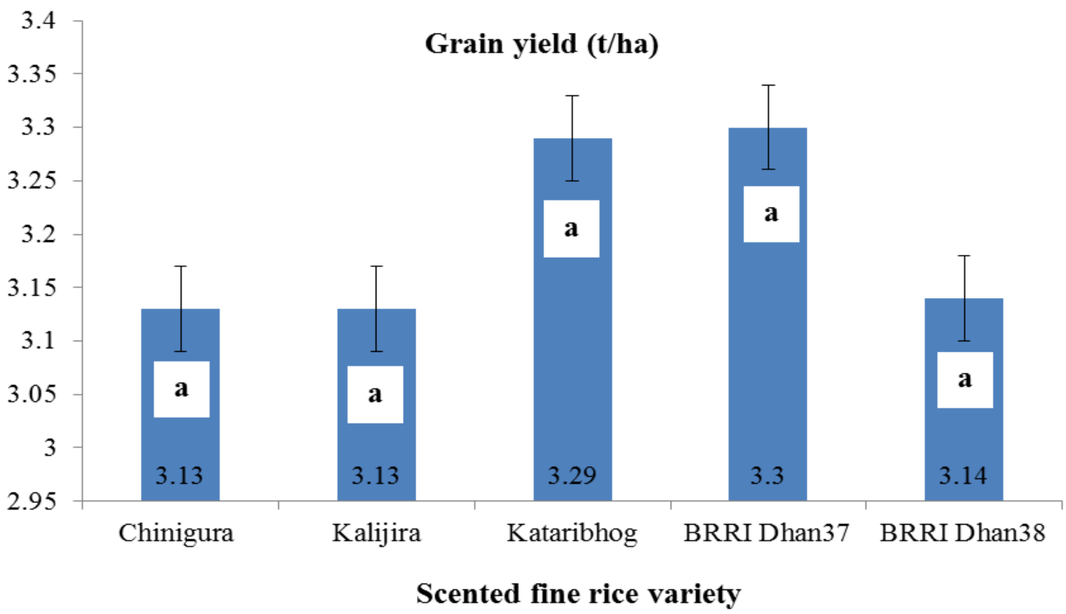

Figure 17. Effect of variety on grain yield (t/ha) of scented rice (Common letter(s) within the same column do not differ significantly at 5% level of significance; Vertical bars represent standard error)

4.1.9.2 Effect of spacing

Different plant spacing had significant effect on the grain yield of the aromatic rice varieties. A gradual increase of grain yield was observed with the increase of spacing (Figure 18). The spacing 20 cm x 20 cm (S_1) produced the highest grain yield (3.56 t/ha) due to optimum and more number of effective tillers m^{-2} area, whereas 20 cm x 10 cm (S_3) produced the lowest grain yield (2.88 t/ha) due to less hill m^{-2} area.

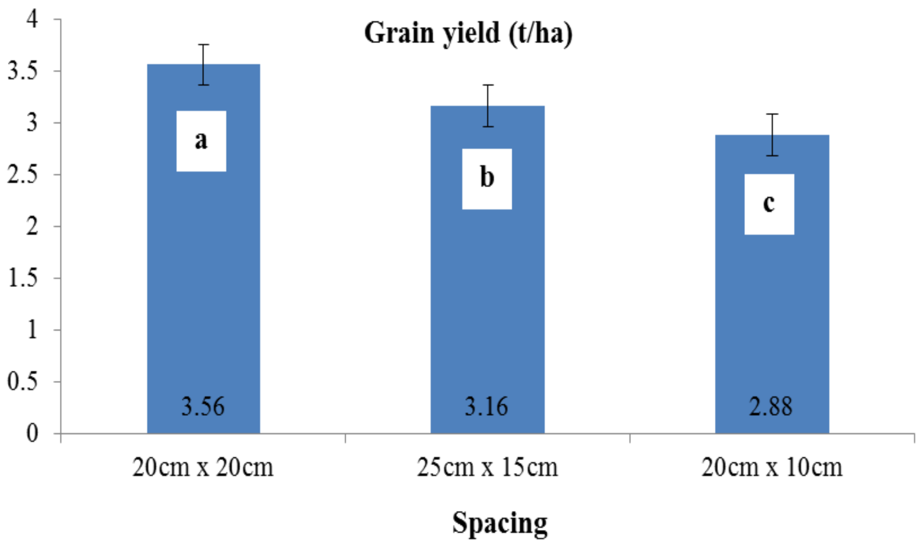

Figure 18. Effect of different spacing on the grain yield (t/ha) of scented rice (Common letter(s) within the same column do not differ significantly at 5% level of significance; Vertical bars represent standard error)

4.1.9.3 Interaction effect of different varieties and spacing

Different varieties and spacing expressed significant differences due to their interaction effect on grain yield (t/ha) of scented rice (Table 10 and Appendix X). Significantly the highest grain yield (4.3 t/ha) was recorded from the treatment combination of BRRI dhan38 (V_5) + 25 cm x 15 cm (S_2) which was followed by (4.0 t/ha) in case of the treatment combination of Chinigura (V_1) + 20 cm x 20 cm (S_1). The lowest grain yield (2.5 t/ha) was obtained from the combined treatment of BRRI dhan37 (V_4) + 25 cm x 15 cm (S_2).

Table 10: Effect of variety and spacing on grain yield (t/ha)

Treatment combinations	Grain yield (t/ha)
V_1S_1	4.0b
V_2S_1	2.7e
V_3S_1	2.7e
V_4S_1	3.0d
V_5S_1	3.2d
V_1S_2	3.2d
V_2S_2	3.467c
V_3S_2	3.9b
V_4S_2	2.5f
V_5S_2	4.3a
V_1S_3	2.8e
V_2S_3	2.8e
V_3S_3	3.033d
V_4S_3	3.2d
V_5S_3	3.2d
$LSD_{(0.05)}$	0.18
CV(%)	3.39

Values in column having different letter(s) are significantly different and same letter are not significantly different at 0.05 level of probability. V_1= Chinigura, V_2= Kalijira, V_3= Kataribhog, V_4= BRRI dhan37, V_5= BRRI dhan38, S_1= 20 cm x 20 cm, S_2= 25 cm x 15 cm, S_3= 20 cm x 10 cm.

4.1.10 Straw yield

4.1.10.1 Effect of variety

It was observed that straw yield was highly significant due to variety (Figure 19). The variety Kataribhog (V_3) produced the highest straw yield (9.07 t/ha) followed by (8.73 t/ha) in Kalijira (V_2), whereas the lowest straw yield (7.47 t/ha) was produced in BRRI dhan38. It might be due to varietal variation, which is primarily influenced by heredity.

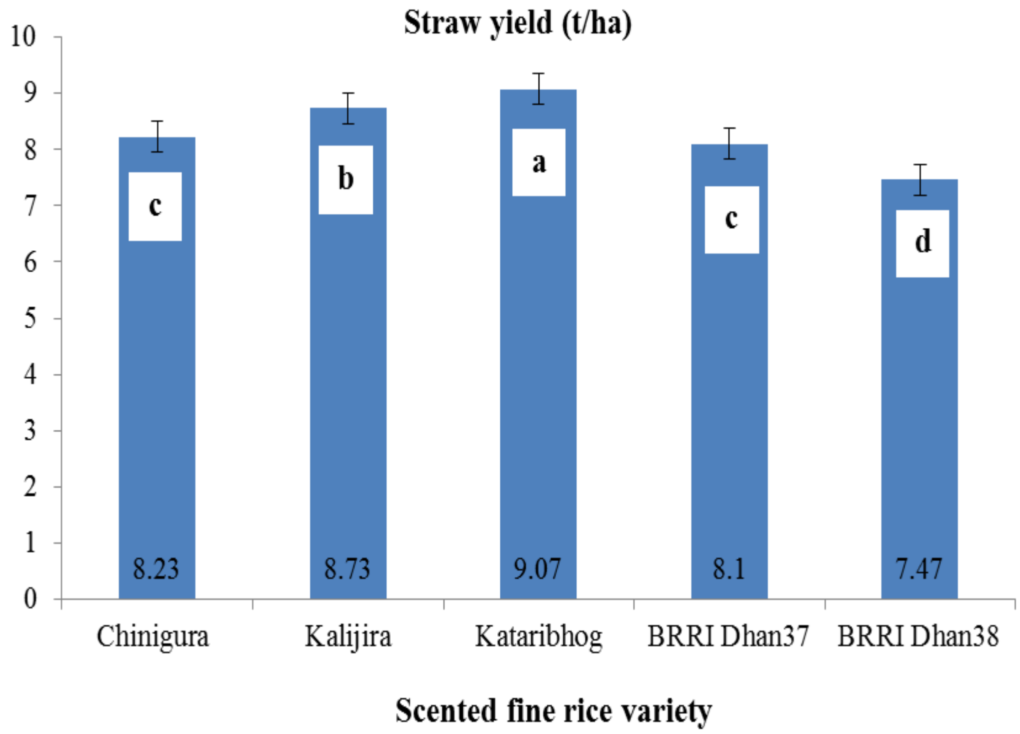

Figure 19. Effect of variety on straw yield (t/ha) of scented rice (Common letter(s) within the same column do not differ significantly at 5% level of significance; Vertical bars represent standard error)

4.1.10.2 Effect of spacing

Different plant spacing had significant effect on the straw yield of the aromatic rice varieties. A gradual increase of straw yield was observed with the increase of spacing (Figure 20). The spacing 20 cm x 20 cm (S_1) produced the highest straw yield (8.86 t/ha), whereas 20cm x 10 cm (S_3) produced the lowest straw yield (8.02 t/ha) which was followed by and statistically identical to the result (8.08 t/ha) shown by the spacing 25 cm x 15 cm (S_2).

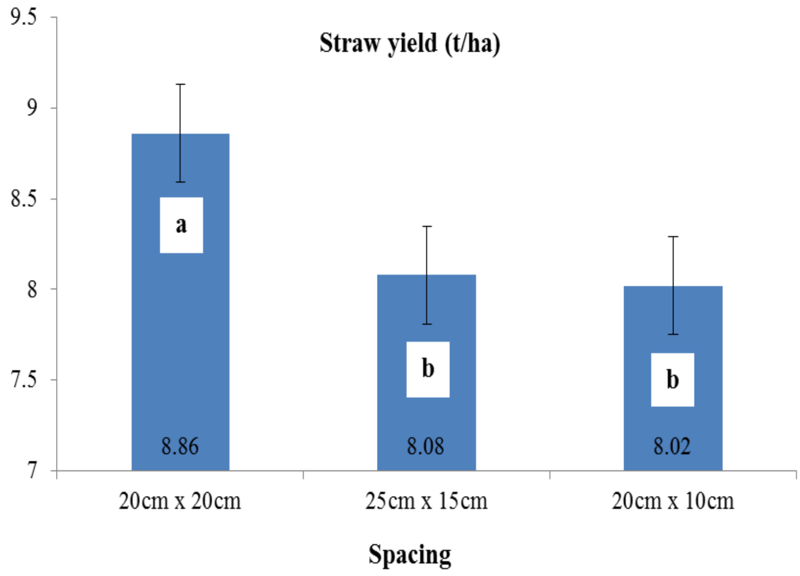

Figure 20. Effect of different spacing on the straw yield (t/ha) of scented rice (Common letter(s) within the same column do not differ significantly at 5% level of significance; Vertical bars represent standard error)

4.1.10.3 Interaction effect of different varieties and spacing

Different varieties and spacing expressed significant differences due to their interaction effect on straw yield (t/ha) of scented rice (Table 11 and Appendix XI). Interaction effect of different varieties and spacing differ each other. It is revealed that the number of days required for scented rice to reach to flowering stage vary from variety to variety and the location. So some variety gives highest straw yield and some gives lowest straw yield. Rao *et al*. (1981) conducted a field experiment and reported that number of productive tillers m^{-2} were higher in local method of planting as compared to transplanting in 15 cm × 10 cm spacing but both grain yield and straw yield were higher in transplanting in row than local planting method with transplanting in 15 cm × 10 cm. It was investigated the relationship between grain yield with the morphological parameters of five local and three modern aromatic rice varieties. It is found that Significantly the highest straw yield (10.7 t/ha) was recorded from the treatment combination of BRRI dhan38 (V_5) + 25 cm x 15 cm (S_2) which was followed by (10.30 t/ha) in case of the treatment combination of Chinigura (V_1) + 20 cm x 20 cm (S_1). The lowest straw yield (5.8 t/ha) was obtained from the combined treatment of Kalijira (V_2) + 20 cm x 20 cm (S_1).

Table 11: Effect of variety and spacing on straw yield of scented rice

Treatment combinations	Straw yield (t/ha)
V_1S_1	10.3b
V_2S_1	5.8i
V_3S_1	8.6e
V_4S_1	7.3gh
V_5S_1	9.0d
V_1S_2	9.9c
V_2S_2	8.5e
V_3S_2	10.2bc
V_4S_2	8.5e
V_5S_2	10.7a
V_1S_3	7.5g
V_2S_3	6.1i
V_3S_3	7.5g
V_4S_3	7.9f
V_5S_3	7.0h
$LSD_{(0.05)}$	0.32
CV(%)	2.30

Values in column having different letter(s) are significantly different and same letter are not significantly different at 0.05 level of probability. V_1= Chinigura, V_2= Kalijira, V_3= Kataribhog, V_4= BRRI dhan37, V_5= BRRI dhan38, S_1= 20 cm x 20 cm, S_2= 25 cm x 15 cm, S_3= 20 cm x 10 cm.

4.1.11 Harvest index (%)

4.1.11.1 Effect of variety

It was observed that harvest index was highly significant due to variety (Figure 21). The variety BRRI dhan38 (V_5) produced the highest harvest index (29.66%) which was followed by and statistically identical to (29.1%) in BRRI dhan37 (V_4). Hoque et al. (2013) reported that BRRI dhan50 produced the highest straw yield (10.17 t ha^{-1}) and the lowest straw was recorded in Tulsimala (7.03 t ha-1) which was similr to Kowla (7.23 t ha^{-1}) and kalizira (7.53 t ha^{-1}). The lowest harvest index was produced in Kataribhog (26.45%) which was followed by and statistically identical (26.59%) to Kalijira (V_2).

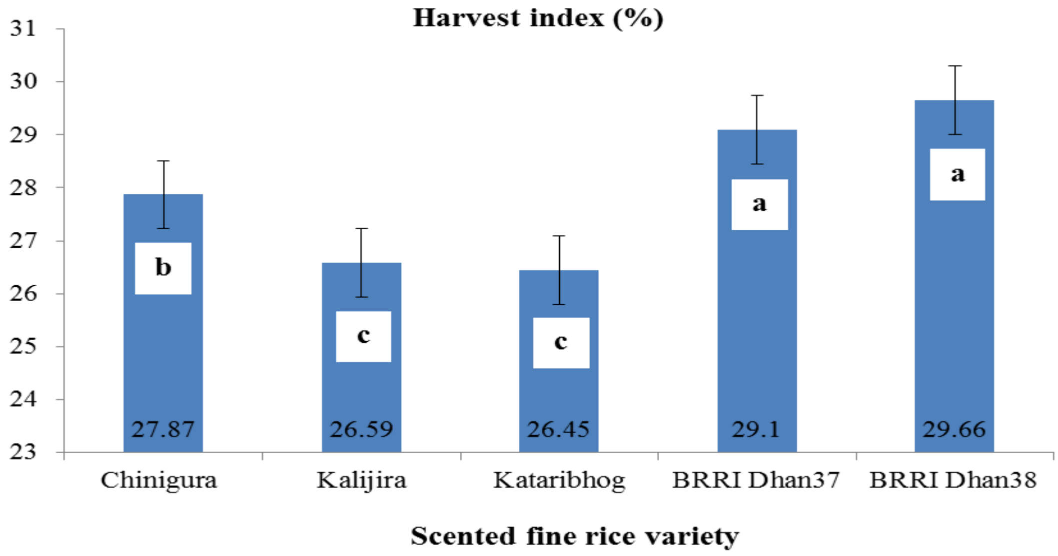

Figure 21. Effect of variety on harvest index (%) of scented rice (Common letter(s) within the same column do not differ significantly at 5% level of significance; Vertical bars represent standard error)

4.1.11.2 Effect of spacing

Different plant spacing had significant effect on the harvest index (%) of the aromatic rice varieties. A gradual increase of harvest index was observed with the increase of spacing (Figure 22). The spacing 20 cm x 20 cm (S_1) produced the highest harvest index (28.71%) which was followed by and statistically identical (28.33%) to the spacing 25 cm x 15 cm (S_2). However, the spacing 20 cm x 10 cm (S_3) produced the lowest harvest index (26.77%).

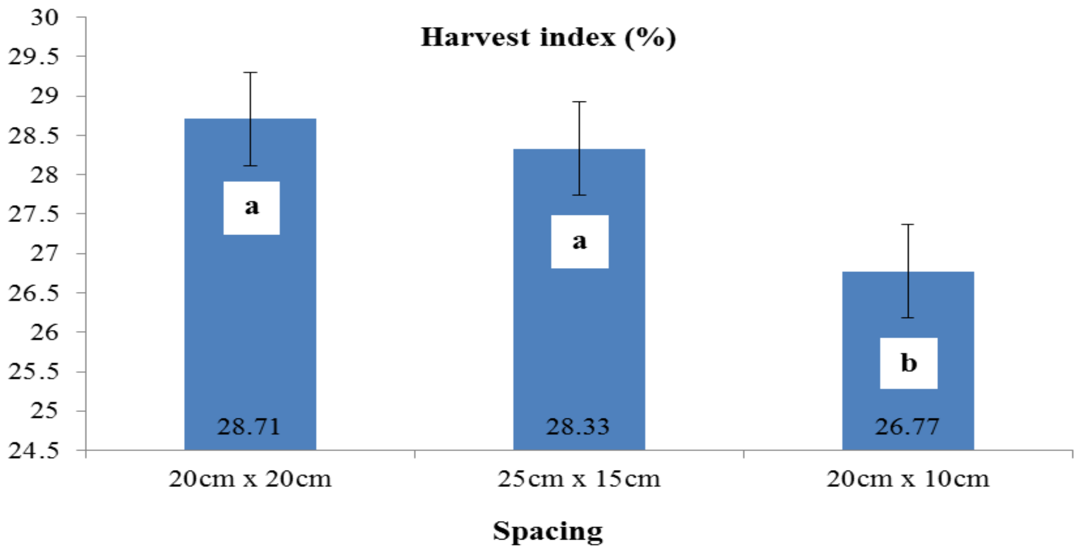

Figure 22. Effect of different spacing on the straw yield (t/ha) of scented rice (Common letter(s) within the same column do not differ significantly at 5% level of significance; Vertical bars represent standard error)

4.1.11.3 Interaction effect of different varieties and spacing

Different varieties and spacing expressed significant differences due to their interaction effect on harvest index (%) of scented rice (Table 12 and Appendix XII). Significantly the highest harvest index (31.76%) was recorded from thetreatment combination of Kalijira (V_2) + 20 cm x 20 cm (S_1), which was followed by and statistically identical to the treatment combinations Kalijira (V_2) + 20 cm x 10 cm (S_3) and BRRI dhan38 (V_5) + 20 cm x 10 cm (S_3) (31.45% and 31.37% respectively). The lowest-harvest index (22.73%) was obtained from the combined treatment of BRRI dhan37 (V_4) + 25 cm x 15 cm (S_2).

Table 12: Effect of variety and spacing on harvest index (%) of scented rice

Treatment combinations	Harvest index (%)
V_1S_1	27.97cd
V_2S_1	31.76a
V_3S_1	23.88g
V_4S_1	29.12b
V_5S_1	26.22f
V_1S_2	24.42g
V_2S_2	28.97b
V_3S_2	27.66de
V_4S_2	22.73h
V_5S_2	28.67bc
V_1S_3	27.18e
V_2S_3	31.45a
V_3S_3	28.8b
V_4S_3	28.82b
V_5S_3	31.37a
$LSD_{(0.05)}$	0.07
CV(%)	1.51

Values in column having different letter(s) are significantly different and same letter are not significantly different at 0.05 level of probability. V_1= Chinigura, V_2= Kalijira, V_3= Kataribhog, V_4= BRRI dhan37, V_5= BRRI dhan38, S_1= 20 cm x 20 cm, S_2= 25 cm x 15 cm, S_3= 20 cm x 10 cm.

CHAPTER V

SUMMARY AND CONCLUSION

The present investigation entitled "Effect of transplanting geometry on scented fine rice varieties in *Aman* season" was conducted during the period from July, 2017 to November, 2018 at the Agricultural research field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The experiment comprised of two factors; viz. Factors A: Five scented fine rice varieties (Chinigura, Kalijira, Kataribhog, BRRI dhan37 and BRRI dhan38) and Factor B: Three different spacing (20 cm x 20 cm, 25 cm x 15 cm and 20 cm x 10 cm). The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. There were 15 treatment combinations and total numbers of unit plots were 45. The size of unit plot was 9 m^2 (3 m × 3 m). The field was fertilized with nitrogen, phosphate, potash, sulphur and zinc at the rate of 120, 100, 70, 60 and 10 kg/ha, respectively in the form of urea, triple super phosphate, muriate of potash, gypsum and zinc-sulphate. Results revealed that planting geometry, variety and their interactions had significant effect on plant growth determinants, yield attributing traits and yields detailed below:-

The tallest plant (150.5 cm at harvest) was observed from Kalijira, whereas the maximum number of tillers per hill (10.56), effective tillers per hill (8.44), the longest panicle (25.20cm), the highest number of spikelets per panicle (134.2), filled grains per panicle (101) and non-filled grains per panicle (33.22) were observed from Chiniguravariety. The highest 1000-grain weight (14.84 g) and harvest index (29.66%) were attained from BRRI Dhan38, while the maximum grain yield (3.3 t/ha) and straw yield (9.07 t/ha) were found from Kataribhog variety.

The shortest plant (137.4 cm at harvest) and minimum straw yield (7.47 t/ha) were recorded from BRRI dhan38, whereas the minimum number of tillers per hill (9.33), the shortest panicle (22.13 cm) and the lowest harvest index (26.45%) were observed in Kataribhog. The lowest number of spikelets per panicle (106.6), filled grains per panicle (85.33) and non-filled grains per panicle (21.22) were observed from Kalijira variety. The lowest 1000-grain weight (11.43 g) was found in Chinigura and minimum number of effective tillers per hill (7.22) was produced by BRRI Dhan37. However, the lowest grain yield (3.13 t/ha) was obtained from both the variety Kalijira and Chinigura.

Among the different spacing, the tallest plant (150.2 cm), the highest total number of tillers per hill (10.6), effective tillers per hill (8.33), spikelets per panicle (149.8), filled grains per panicle (116.4), non-filled grains per panicle (33.4), the highest 1000 grain weight (17.11 g), grain yield (3.56 t ha^{-1}), straw yield (8.86 t ha^{-1}), harvest index (28.71%) and the longest panicle length (25.15 cm) were recorded from S_1 (20 cm x 20 cm). On the contrary, the shortest plant (136.3 cm), the lowest total number of tillers per hill (9.0), effective tillers per hill (6.87), spikelets per panicle (90.87), filled grains per panicle (70.2), non-filled grains per panicle (20.67), 1000 grain weight (10.47 g), grain yield (2.88 t ha^{-1}), straw yield (8.02 t ha^{-1}) and harvest index (26.77%) were recorded from S_3 (20 cm x 10 cm). However, the shortest panicle length (22.29 cm) was found from S_2 (25 cm x 15 cm).

Different treatment combinations expressed significant differences due to their interaction effect on plant growth determinants, yield attributing traits and yield. The tallest plant (161.3 cm), the maximum number of total tillers per hill (13.67), effective tillers per hill (11.33) and the longest panicle length (26.20 cm) were recorded from the combined treatment of V_1S_1 (Chinigura + 20 cm x 20 cm). The highest number of spikelets per panicle (175.0), filled grains per panicle (131.0), the highest grain yield (4.3 t ha^{-1}) and straw yield (10.7 t ha^{-1}) were recorded from the treatment combination of V_5S_2 (BRRI dhan38 + 25 cm x 15 cm) while the highest 1000 grain weight (19.07 g) was recorded from the combined treatment of (V_5S_2) (Kalijira + 25 cm x 15 cm). However, the highest number of non-filled grains per panicle (59.67) and the highest harvest index (31.76%) were recorded from the treatment combination of V_2S_1 (Kalijira + 20 cm x 20 cm).

The shortest plant (130.3 cm) was obtained from the combined treatment of (V_5S_3) (BRRI dhan38 + 20 cm x 10 cm). The lowest number of total tillers per hill (5.67), effective tillers per hill (4.0) and non-filled grains per panicle (17.0) was obtained from the combined treatment of V_3S_1 (Kataribhog + 20 cm x 20 cm). The shortest panicle length (19.33 cm) was obtained from the combined treatment of V_1S_3 (Chinigura + 20 cm x 10 cm) whereas the lowest number of spikelets per panicle (76.00) and filled grains per panicle (53.0) were obtained from the combined treatment of V_1S_2 (Chinigura + 25 cm x 15 cm). The lowest 1000 grain weight (9.5 g) and straw yield (5.8 t ha^{-1}) were found from the combined treatment of V_2S_1 (Kalijira + 20 cm x 20 cm) while the lowest grain yield (2.5 t ha^{-1}) and harvest index (22.73%) were resulted from the combined treatment of V_5S_2 (BRRI dhan37 + 25 cm x 15 cm).

Conclusion

1. Kataribhog provided the highest grain yield and straw yield among the test cultivars.
2. Maximum grain and straw were achieved from BRRI dhan38 with spacing, 25 cm x 15 cm.

Recommendation

Therefore, the findings of the study may be used for obtaining higher yield of scented fine rice in Bangladesh.

However, further research work should be carried out to investigate the effect of planting geometry on scented fine rice varieties in different Agro-ecological Zone of Bangladesh.

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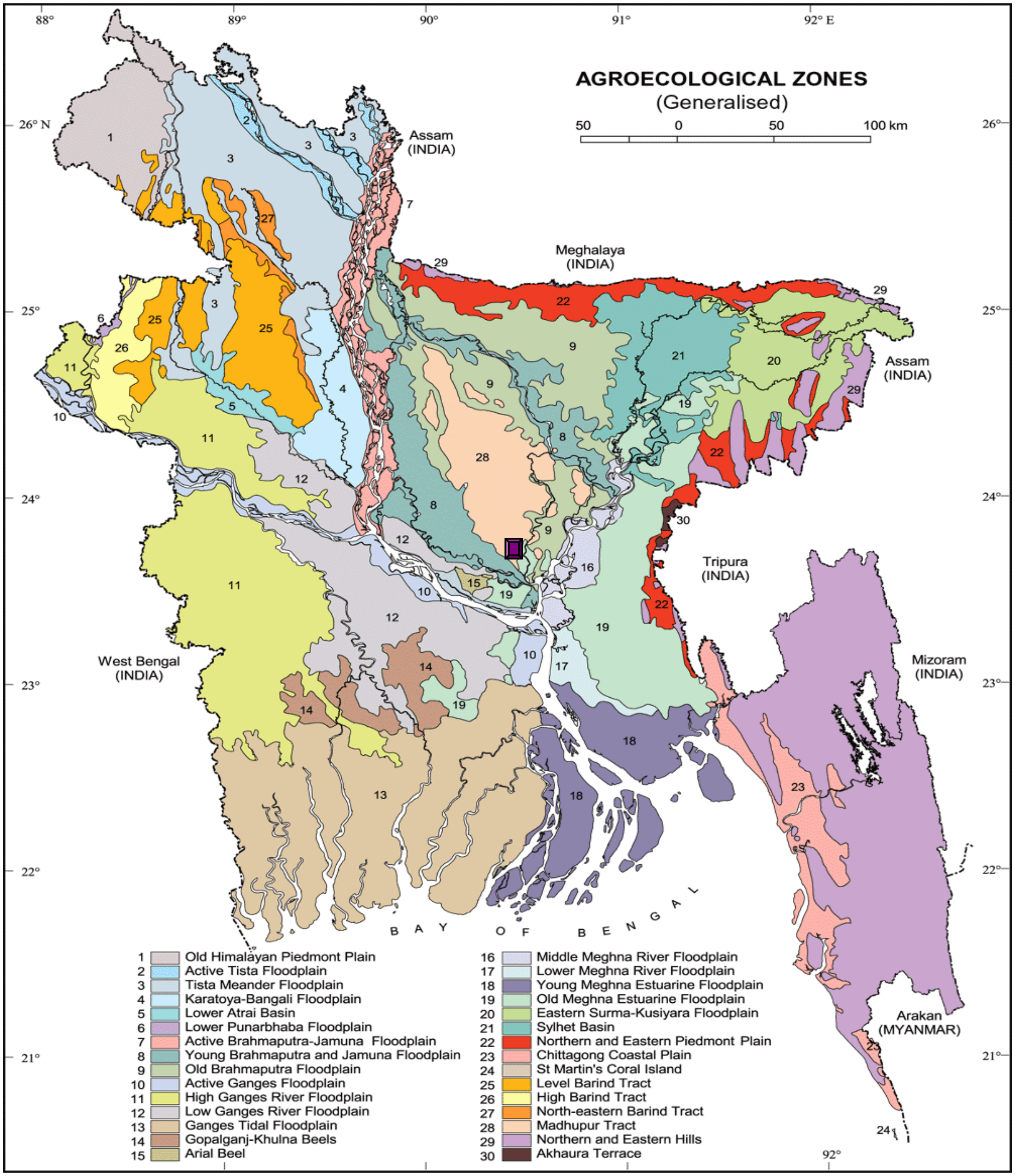
APPENDICES

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

Map showing the experimental sites under study



■ **The experimental site under study**

Morphological characteristics of the experimental field

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

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

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

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

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

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

Appendix IV. Analysis of variance of the data on plant height of rice as influenced by planting geometry and variety

Source of variation	Degrees of freedom	Mean square
		Plant Height
Replication	2	17.14
Factor A	4	244.47*
Factor B	2	863.40*
AxB	8	186.202*
Error	28	3.192

* Significant at 5% level

Appendix V. Analysis of variance of the data on total tiller of rice as influenced by planting geometry and variety

Source of variation	Degrees of freedom	Mean square
		Total tillers
Replication	2	0.556
Factor A	4	1.81*
Factor B	2	9.689*
AxB	8	28.57*
Error	28	0.27

* Significant at 5% level

Appendix VI. Analysis of variance of the data on effective tiller of rice as influenced by planting geometry and variety

Source of variation	Degrees of freedom	Mean square
		Effective tiller
Replication	2	0.067
Factor A	4	1.944*
Factor B	2	8.267*
AxB	8	21.794*
Error	28	0.114

* Significant at 5% level

Appendix VII. Analysis of variance of the data on panicle length of rice as influenced by planting geometry and variety

Source of variation	Degrees of freedom	Mean square
		Panicle length
Replication	2	0.830
Factor A	4	13.423*
Factor B	2	39.08*
AxB	8	8.08*
Error	28	0.531

* Significant at 5% level

Appendix VIII. Analysis of variance of the data on number of spikelet/panicle of rice as influenced by planting geometry and variety

Source of variation	Degrees of freedom	Mean square
		Number of spikelet
Replication	2	54.422
Factor A	4	999.967*
Factor B	2	13145.95*
AxB	8	1607.40*
Error	28	11.637

* Significant at 5% level

Appendix IX. Analysis of variance of the data on filled grain of rice as influenced by planting geometry and variety

Source of variation	Degrees of freedom	Mean square
		Filled Grain
Replication	2	32.067
Factor A	4	316.50*
Factor B	2	8242.20*
AxB	8	710.700*
Error	28	7.067

* Significant at 5% level

Appendix X. Analysis of variance of the data on Non filled grain of rice as influenced by planting geometry and variety

Source of variation	Degrees of freedom	Mean square
		Non Filled Grain
Replication	2	3.622
Factor A	4	237.63*
Factor B	2	627.35*
AxB	8	557.467*
Error	28	2.479

* Significant at 5% level

Appendix XI. Analysis of variance of the data on 1ooo grain weight of rice as influenced by planting geometry and variety

Source of variation	Degrees of freedom	Mean square
		1000 grain weight
Replication	2	0.002
Factor A	4	15.904*
Factor B	2	172.697*
AxB	8	8.609*
Error	28	0.009

* Significant at 5% level

Appendix XII. Analysis of variance of the data on grain yield of rice as influenced by planting geometry and variety

Source of variation	Degrees of freedom	Mean square
		Grain Yield
Replication	2	0.002
Factor A	4	0.067*
Factor B	2	1.752*
AxB	8	0.949*
Error	28	0.012

* Significant at 5% level

Appendix XIII. Analysis of variance of the data on straw yield of rice as influenced by planting geometry and variety

Source of variation	Degrees of freedom	Mean square
		Straw Yield
Replication	2	0.006
Factor A	4	3.403*
Factor B	2	3.29*
AxB	8	9.40*
Error	28	0.037

* Significant at 5% level

Appendix XIV. Analysis of variance of the data on harvesting index of rice as influenced by planting geometry and variety

Source of variation	Degrees of freedom	Mean square
		Harvest Index
Replication	2	0.151
Factor A	4	18.806*
Factor B	2	15.811*
AxB	8	25.193*
Error	28	0.179

* Significant at 5% level