TILLERING BEHAVIOUR, GRAIN STERILITY AND YIELD OF HYV RICE VARIETIES AS INFLUENCED BY SEEDLING AGE

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CERTIFICATE

*This is to certify that the thesis entitled '**Tillering Behaviour, Grain Sterility and Yield of HYV Rice Varieties as Influenced by Seedling Age**' submitted to the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE in AGRICULTURAL BOTANY**, embodies the results of a piece of bonafide research work carried out by **A. K. M. SAIFULLAH NADIM**, Registration No. **12-04863** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged.

Dated: December, 2017
Dhaka, Bangladesh

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TO

MY BELOVED PARENTS

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ABSTRACT

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka from December, 2017 to April 2018 to study the tillering behavior, grain sterility and yield of HYV rice varieties as influenced by seedling age. The experiment comprised of two factors: Factor A: Rice variety (4 varieties) e.g., V_1 = BRRI hybrid dhan3, V_2 = Hera 4, V_3 = Moina, V_4 = BRRI dhan28 (inbred) and Factor B: Seedling age (3 levels) e.g., A_1 = Tansplanting of 25 days old seedlings; A_2 = Tansplanting of 35 days old seedlings and A_3 = Tansplanting of 45 days old seedlings. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different growth characters, yield components and yield were recorded. Statistically significant differences were observed for different treatments and their combined effect. Considering all the varieties and seedling age, the tallest plant (113.15 cm) was recorded from the combination of V_1A_2 and the shortest plant (97.80 cm) was recorded from the V_4A_3. The maximum number of tillers hill^{-1} (17.07) was found from the combination of V_1A_2, whereas the minimum number (11.23) was observed from the combination of V_4A_3. The highest days to maturity (118.00) was recorded from the combination of V_3A_1, whereas the lowest (103.93 days) from V_2A_2. The maximum number of total tillers hill^{-1} (17.20) was recorded from the combination of V_1A_1, whereas the minimum number (10.87) from V_4A_3. The longest panicle (25.59 cm) was recorded from the combination of V_1A_2, whereas the shortest panicle (17.99 cm) from V_4A_3. The highest grain sterility (13.46%) was observed from the combination of V_4A_3, whereas the lowest (4.38%) was recorded from the combination of V_1A_2. The highest weight of 1000 grains (20.35 g) was recorded from the combination of V_1A_2, whereas the lowest weight (16.25 g) from V_3A_3. The highest grain yield (6.81 t ha^{-1}) was recorded from the combination of V_1A_2, whereas the lowest grain yield (3.21 t ha^{-1}) from V_4A_3. The highest straw yield (7.75 t ha^{-1}) was recorded from the combination of V_3A_2, whereas the lowest straw yield (4.92 t ha^{-1}) was found from V_4A_1. From the above results it can be concluded that BRRI hybrid dhan3 provided best yield contributing characters and yield with 35 days old seedlings.

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CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.), belongs to the family Poeaceae, is the most important food in tropical and subtropical regions (Singh *et al*., 2012). It is the staple food for more than 50% of the world's population (Jahan *et al.*, 2017). Rice grain is that has shaped the culture, diet, and economies of billions of people in the world. It is grown in more than a hundred of the countries of the world and total 474.86 million metric tons of rice was produced from 159.64 million hectares of land in the year of 2014-15 (USDA, 2015). Rice contributes on an average 20% of apparent calorie intake of the world and 30% of Asian populations (Hien *et al*., 2006). Bangladesh ranks 4th in both area and production and 6th in the production of per hectare yield (Sarkar *et al*., 2016). The country is said to have among the highest per capita consumption of rice is about 170 kg annually and its food security and economy largely depend on good harvests year after year (BBS, 2017).

In Bangladesh 11.39 million hectares of land is used for rice cultivation which is about 72.24% of total cropped area, with annual production of 34.71 million tons (BBS, 2017). According to FAO (2014) the average yield of rice of Bangladesh is about 2.92 t ha^{-1} which is very low compared to other rice growing countries like Korea (6.30 t ha^{-1}), China (6.30 t ha^{-1}) and Japan (6.60 t ha^{-1}). Population growth in Bangladesh demand a continuous increase of rice production and the highest priority has been given for this (Bhuiyan, 2004). World food security become challenged for increasing food demand and estimated that about 114 million tonnes of additional rice will be needed by 2035 which is equivalent to overall increase of 26% for next 25 years (Kumar and Ladha, 2011). Rice production has to be increased at least 60% by 2020 to meet up food requirement of increasing population (Masum, 2009). Thus, the population by the year 2030 will swell progressively to 223 million which will demand additional 48 million tons of food grains (Julfiquar *et al*., 2008).

Rice yields are either stagnating or declining in post green revolution era mainly due to different factors that are related to crop production (Prakash, 2010). The reasons for low productivity of rice includes various factors like unpredictable rainfall, drought, weed, insect pest diseases, unavailability of quality seeds and seedlings, non-adoption of recommended production technology and plant protection measure but the major reason attributed to prevalence of local varieties instead of high yielding varieties and without practicing proper management (Mandira *et al*., 2016). On the other hand, due to the storage of land, the possibility of horizontal expansion of rice production area has come to a standstill for Bangladesh, so the farmers and scientists are diverting their attention towards vertical expansion of rice production. Therefore, attempts should be taken to increase the rice yield from per unit area. For vertical expansion of rice yield it is necessary to use of modern production technologies such as use of quality high yielding varieties, seedlings raising techniques, optimum seedling age and time of transplanting, appropriate number of seedling hill^{-1}, proper plant protection measures, water management, use of appropriate doses of fertilizers, weed management and so on.

Depending upon the differences in genotypic characters, input requirements and ofcourcse the prevailing environmental conditions during the entire growing season Variety is the key component for producing higher yield of rice. Improving and increasing the world's supply will also depend upon the development and improvement of rice varieties with better yield potential, and to adopt various conventional and biotechnological approaches for the development of high yielding varieties that having resistance against biotic and abiotic stresses (Khush, 2005). In Bangladesh high yielding rice variety has been introduced through BRRI, BINA, IRRI and different seed companies and it gains positive monumentaion in rice production in three distinct growing seasons (Haque and Biswas, 2011). High yielding varieties typically yield 10-20% more than conventional varieties on similar soil due to the heterogenic effect (Li *et al*., 2009; Zhou *et al*., 2012).

The growth process of rice plants under a given agro-climatic condition differs due to specific rice variety (Alam *et al*., 2012). Hossain and Deb (2003) reported that farmers got about 16% yield advantage in the cultivation of hybrids compared to the popularly grown inbred varieties. Now a days different high yielding rice variety are available in Bangladesh which have more yield potential than conventional rice varieties (Akbar, 2004). During vegetative growth, high yielding rice variety accumulates more dry matter in the early and middle growth stages which results in more grain panicle^{-1}. Compared with conventional cultivars, the high yielding varieties have larger panicles, heavier seeds, resulting in an average rice grain yield increase of 7.27% (Bhuiyan *et al*., 2014). This variety however, needs further evaluation under different adaptive condition.

The age of rice seedling plays a vital role in the growth and development of rice and as well as the production of grain. Rajendran and Ganesa (2014) found that the effect of age of seedlings at transplanting is considered for influencing grain yield in water scarce rice production system, primarily by laying the foundation for determining the number of panicle at harvest. Early aged seedlings utilize maximum time for vegetative growth, whereas older seedling recover slowly particularly when injured during uprooting and produce fewer tillers, delay maturity and may reduce yield (De Datta, 1981).

Considering the above mentioned perspectives this research work was undertaken with the following objectives:

- To study the tillering pattern of HYV rice varieties in relation to seedling age in *Boro* season;
- To study the grain sterility and yield of different HYV rice; and
- To compare the tested rice varieties in the present experiment.

Chapter II

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Rice is the staple food more than three billion people in the world and around 90% of rice is grown and consumed in south and Southeast Asia, the highly populated area. Bangladesh produces different high yielding rice varieties and most of them have excellent production. Most of the rice varieties of Bangladesh have been developed by IRRI, BRRI and BINA. Variety itself is the genetical factor which contributes on yield and yield components. Different researcher reported the effect of rice varieties and seedling age on yield contributing component and grain yield. However, some of the important and informative works and research findings related to the morpho-physiological attributes, yield contributing characters and yield, so far been done at home and abroad, reviewed in this chapter under the following headings-

2.1 Varietal performance of rice

2.1.1 Plant height of different rice varieties

Haque and Biswash (2014) carried out an experiment with five varieties of hybrid rice and one hybrid and two checks in the experimental field of Bangladesh Rice Research Institute (BRRI). Varieties was Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid dhan1 and two checks was BRRI dhan28 and BRRI dhan29 and the highest plant height was 101.5 cm was recorded from BRRI dhan28 and the lowest plant height from Richer (82.5 cm).

Bhuiyan *et al*. (2014) conducted an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety in terms of plant growth. Based on the findings of the study it was revealed that the different hybrid rice varieties had significant effects on plant height at maturity.

An experiment was carried out by Jisan *et al*. (2014) at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh with a view to examine the yield performance of some T. *Aman* rice varieties as influenced by different levels of nitrogen. The experiment consisted of four varieties viz. BRRI dhan49, BRRI dhan52, BRRI dhan56, BRRI dhan57 and four levels of nitrogen. Data revealed that among the varieties, BRRI dhan52 produced the tallest plant (117.20 cm), while the lowest plant height by BRRI dhan57.

To assess the effect of nitrogen fertilizer and seedling age on Giza 178, H_1 and Sakha 101 field experiments was conducted by Salem *et al*. (2011) at the Rice Research and Training Center (RRTC), Sakha, Kafr-El Sheikh Governorate, Egypt during summer seasons. The results indicated that Sakha 101 variety surpassed than other varieties in terms of plant height.

Khalifa (2009) conducted a field experiment at the experimental farm of Rice research and training centre (RRTC), Sakha, Kafr-El sheikh governorate, Egypt rice season for physiological evaluation of some hybrid rice varieties under different sowing dates. Four hybrid rice H_1, H_2, GZ 6522 and GZ 6903 was evaluated at six different sowing dates. Results indicated that H_1 hybrid rice variety surpassed other varieties in terms of plant height.

Masum *et al*. (2008) observed that plant height of rice affected by varieties in *Aman* season where Nizershail produced the taller plant height than BRRI dhan44 at different days after transplanting (DAT).

Mandavi *et al.* (2004) found from their experiment that plant height was negatively correlated with grain yield. Thus, in improved genotypes, plant height was not a limiting factor for grain yield because of reduced lodging and conducted better translocation of assimilates.

Murthy *et al.* (2004) conducted an experiment with six varieties of rice genotypes namely Mangala, Madhu, J-13, Sattari, CR 666-16 and Mukti, and the findings revealed that the variety Mukti gave the longest plant compared to the others of their experiment.

Ghosh (2001) carried out an experiment with four rice hybrids and four high yielding rice cultivars and concluded that hybrids have higher plant height as compared with high yielding varieties. Pruneddu and Spanu (2001) conducted an experiment and found that plant height ranged from less than 65 cm to 80–85 cm in Mirto, Tejo, Gladio, Lamone and Timo.

Chen-Liang *et al*. (2000) reported that the cross between Peiai 64s and the new plant type lines had longest plant height compared to the others. On the other hand, Xu and Li (1998) observed that the maintainer lines was generally shorter than restorer line.

Munoz *et al.* (1996) observed that IR8025A hybrid rice cultivar produced 16% longer plant than the commercial variety Oryzica Yacu-9. Hosain and Alam (1991) found that the plant height in modern rice varieties BR3, BR11, BR14 and Pajam was 90.4, 94.5, 81.3 and 100.7 cm, respectively.

Miah *et al*. (1990) conducted an experiment where rice cv. Nizersail and mutant lines Mutant NSI and Mutant NSS was planted and found that plant height was greater in Mutant NSI than Nizersail. Shamsuddin *et al*. (1988) conducted a field trial with nine different rice varieties and observed that plant height differed significantly among the varieties tested.

2.1.2 Tillering pattern of different rice varieties

An experiment was conducted by Sarkar *et al*. (2016) to evaluate the performance of five hybrid rice varieties namely Shakti 2, Suborna 8, Tia, Aloron and BRRI hybrid dhan 2 in *Aman* season with an inbred BRRI dhan33 as checked. The result showed that hybrid varieties exhibited superiority in respect of tillers hill^{-1} and these hybrid varieties showed higher effective tillers hill^{-1}.

Jisan *et al*. (2014) carried out an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh with a view to examine the yield performance of some transplant *Aman* rice varieties as influenced by different levels of nitrogen. The experiment consisted of four varieties viz. BRRI dhan49, BRRI dhan52, BRRI dhan56, BRRI dhan57 and four levels of N. Among the varieties, BRRI dhan52 produced the highest number of effective tillers hill^{-1} (11.28), while the lowest values of these parameters were produced by BRRI dhan57.

Haque and Biswash (2014) experimented with five varieties of hybrid rice which was collected from different private seed companies and one hybrid and two checks from Bangladesh Rice Research Institute (BRRI). Varieties were Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid dhan1 and two checks was BRRI dhan28 and BRRI dhan29. In case of no. of effective tillers, Hira showed the best performance (17.7) and Sonarbangla-1 showed the least performance (13.3).

Bhuiyan *et al*. (2014) conducted an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety in terms of yield and recommend it to rice farmers. Based on the findings of the study, the different hybrid rice varieties evaluated had significant effects on number of tillers, number of productive tillers. RGBU010A × SL8R is therefore recommended as planting material among hybrid rice varieties because it produced more productive tillers.

A field experiment was conducted by Khalifa (2009) at the experimental farm of Rice research and training centre (RRTC), Sakha, kafr-El sheikh governorate, Egypt for physiological evaluation of some hybrid rice varieties under different sowing dates. Four hybrid rice H_1, H_2, GZ 6522 and GZ 6903 was evaluated at six different sowing dates. Results indicated that H_1 hybrid rice variety surpassed other varieties in consideration of effective and total tillers hill^{-1}.

Masum *et al*. (2008) stated that number of total tillers hill^{-1} was significantly influenced by cultivars at all stages of crop growth. Nizersail was achieved maximum (25.63) tiller at 45 DAT, then with advancement to age it declined up to maturity, whereas in the case of BRRI dhan44, maximum (18.92) tiller production was observed around panicle initiation stage at 60 DAT.

Murthy *et al.* (2004) conducted an experiment with six varieties of rice genotypes Mangala, Madhu, J-13, Sattari, CR 666-16 and Mukti, and observed that Mukti gave the highest tillers hill^{-1} compared to the others. Song *et al.* (2004) found that hybrids produced a significantly higher number of tillers than their parental species and Minghui-63 had the least number of tillers.

Bhowmick and Nayak (2000) conducted an experiment with two hybrids (CNHR2 and CNHR3) and two high yielding varieties (IR36 and IR64) of rice and five levels of nitrogenous fertilizers. They observed that CNHR2 produced more number of productive tillers (413.4/m^2) than other tested varieties.

Devaraju *et al*. (1998) in a study with two rice hybrids, Karnataka Rice Hybrid 1 (KRHI) and Karnataka Rice Hybrid-2 (KRH2), using HYV IR20 as the check, found that IR20, the tiller number was higher than that of KRH2.

Islam (1995) in an experiment with four rice cultivars *viz*. BR10, BR11, BR22 and BR23 found that the highest number of non bearing tillers hill^{-1} was produced by cultivar BR11 and the lowest number by BR10.

2.1.3 Dry matter content of different rice varieties

Sarkar *et al*. (2016) carried out an experiment to evaluate the performance of five hybrid rice varieties namely Shakti 2, Suborna 8, Tia, Aloron and BRRI hybrid dhan 2 in *Aman* season with an inbred BRRI dhan33 as checked. The result showed that the hybrid varieties exhibited superiority in respect of total dry matter (TMD) hill^{-1} and the highest TDM hill^{-1} (84.0 g) was observed Tia and lowest TDM hill^{-1} (70.10 g) was observed in BRRI dhan33.

Field experiments were conducted by Haque *et al*. (2015) including two popular indica hybrids (BRRI hybrid dhan2 and Heera2) and one elite inbred (BRRI dhan45) rice varieties. Both hybrids accumulated higher amount of biomass before heading and exhibited greater remobilization of assimilates to the grain in early plantings compared to the inbred variety.

In order to evaluate the response to planting date in rice hybrids line dry method of working, was carried out by Shaloie *et al*. (2014) at the Agricultural Research Station, Agriculture and Natural Resources Research Center of Khuzestan Shavuor. Hybrid rice Hb2 and Hb1 was used in the sub plots. Results showed traits was significantly affected in terms of dry matter and mentioned trait was more in hybrid Hb_2 than Hb_1.

Masum *et al*. (2008) found that total dry matter production differed due to varieties. Total dry matter of BRRI dhan44 Nizershail significantly varied at different sampling dates. Xie *et al.* (2007) found that Shanyou-63 variety gave the higher yield (12 t ha^{-1}) compared to Xieyou46 variety (10 t ha^{-1}).

Amin *et al.* (2006) conducted a field experiment to find out the influence of variable doses of N fertilizer on growth, tillering and yield of three traditional rice varieties (*viz.* Jharapajam, Lalmota, Bansful Chikon) was compared with that of a modern variety (*viz.* KK-4) and reported that traditional varieties accumulated higher amount of vegetative dry matter than the modern variety.

Amin *et al*. (2006) conducted a field experiment to find out the influence of variable doses of N fertilizer on growth, tillering and yield of three traditional rice varieties (Jharapajam, Lalmota, Bansful Chikon) was compared with that of a modern variety (KK-4) and reported that traditional varieties accumulated higher amount of vegetative dry matter than the modern variety did.

Mandavi *et al.* (2004) carried out an experiment to study on the morphological and physiological indicators of rice genotypes, a field experiment was conducted at the Rice Research Institute of Iran. In that study, Onda had the greater total dry matter (TDM) among other genotypes (this genotype also had the highest grain yield). Higher TDM was obtained from improved genotype than traditional genotypes (1445 and 1626 GDD, respectively). At flowering the dry matter weight was higher for Jasesh and was lower for Ramazan Ali Tarom (923.93 g m^{-2} and 429 g m^{-2}, respectively). So the photosynthetic potential of improved genotypes was higher as reflected by their TDM which had positive correlation with grain yield.

Sharma and Haloi (2001) conducted an experiment in Assam during the kharif season with 12 varieties of scented rice cultivars and observed that cv. Kunkuni Joha consistently maintained a higher rate of dry matter production at all growth stages and the highest dry matter accumulation at the panicle initiation stage.

Evans and Fisher (1999) reported that achieving higher yield depends on increasing total crop biomass, because there is little scope to further increase the proportion of that biomass allocated to grain.

Son *et al*. (1998) reported that dry matter production of four inbred lines of rice (low-tillering large panicle type), YR15965ACP33, YR17104ACP5, YR16510-B-B-B-9, and YR16512-B-B-B-10, and cv. Namcheonbyeo and Daesanbyeo, was evaluated at plant densities of 10 to 300 plants m^{-2} and reported that dry matter production of low-tillering large panicle type rice was lower than that of Namcheonbyeo, regardless of plant density.

2.1.4 Yield attributes of different rice varieties

Sarkar *et al*. (2016) carried out an experiment to evaluate the performance of five hybrid rice varieties namely Shakti 2, Suborna 8, Tia, Aloron and BRRI hybrid dhan2 in *Aman* season with an inbred BRRI dhan33 as checked and these hybrid varieties also showed higher 1000-grain over the inbred.

Dou *et al*. (2016) carried out an experiment with the objective to determine the effects of water regime/soil condition (continuous flooding, saturated, and aerobic), cultivar (‘Cocodrie’ and ‘Rondo’), and soil texture (clay and sandy loam) on rice grain yield, yield components and water productivity using a greenhouse trial. The spikelet number of Cocodrie was 29% greater than that of Rondo, indicating that rice cultivar had greater effect on spikelet number.

Results indicated that cultivar selection is an important factors in deciding what water management option to practice.

Field experiments were conducted by Haque *et al*. (2015) including two popular indica hybrids (BRRI hybrid dhan2 and Heera2) and one elite inbred (BRRI dhan45) rice varieties. Filled grain (%) declined significantly at delayed planting in the hybrids compared to elite inbred due to increased temperature impaired inefficient transport of assimilates.

An experiment was conducted by Hosain *et al*. (2014) at the research farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during *Aus* season to observe the effect of transplanting dates on the yield and yield attributes of exotic hybrid rice varieties. The experiment comprised of three rice varieties (two hybrids-Heera2, Aloron and one inbred- BRRI dhan48). Hybrid varieties Heera2 (3.03 t ha^{-1}) and Aloron (2.77 t ha^{-1}) gave the higher spikelet sterility.

Haque and Biswash (2014) experimented with five varieties of hybrid rice which was collected from different private seed companies and one hybrid and two checks from Bangladesh Rice Research Institute (BRRI). Varieties were Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid dhan1 and two checks were BRRI dhan28 and BRRI dhan29. In panicle length status, Richer showed the best performance (27.7 cm) while BRRI dhan28 showed the least performance (26 cm). Number of filled grains $panicle^{-1}$ was the highest for BRRI dhan29 (163.3), whereas, Jagoron only 118. Number of total grains was highest in BRRI dhan29 (201.7) and for Jagoron it was only 133.7. On the other hand, for 1000-grain weight, Aloron was the best than other hybrids.

Bhuiyan *et al*. (2014) conducted an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety in terms of yield and recommend it to rice farmers. Based on the findings of the study, the different hybrid rice varieties evaluated had significant effects on number of filled and unfilled grains, length of panicle and yield. RGBU010A × SL8R is therefore recommended as planting material among hybrid rice varieties because it produced longer panicles and heavy seeds. In the absence of this variety, RGBU02A × SL8R, RGBU003A × SL8R and RGBU0132A × SL8R may also be used as planting material.

In order to evaluate the response to planting date in rice hybrids Line dry method of working, was carried out by Shaloie *et al*. (2014) at the Agricultural Research Station, Agriculture and Natural Resources Research Center of Khuzestan Shavuor. Hybrid rice Hb2 and Hb1 was used in the sub plots. Results showed traits was significantly affected in terms of panicle length, fertility percentage, and mentioned traits was more in hybrid Hb_2 than Hb_1.

Jisan *et al*. (2014) carried out an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh with a view to examine the yield performance of some transplant *Aman* rice varieties as influenced by different levels of nitrogen. The experiment consisted of four varieties viz. BRRI dhan49, BRRI dhan52, BRRI dhan56, BRRI dhan57 and four levels of N. Data revealed that variety exerted significant influence on yield contributing characters. Among the varieties, BRRI dhan52 produced the grains panicle^{-1} (121.5) and 1000-grain weight (23.65 g), whereas the lowest values of these parameters was produced by BRRI dhan57.

Forty five aromatic rice genotypes were evaluated by Fatema *et al*. (2011) to assess the genetic variability and diversity on the basis of nine characters. Significant variations were observed among the genotypes for all the characters. Thousand grain weight have been found to contribute maximum towards genetic diversity in 45 genotypes of aromatic rice.

Two field experiments was conducted by Salem *et al*. (2011) at the Rice Research and Training Center (RRTC), Sakha, Kafr-El Sheikh Governorate, Egypt during summer seasons to study the effect of nitrogen fertilizer and seedling age on Giza 178, H1 and Sakha 101. The results indicated that Sakha 101 variety surpassed than other varieties in terms of 1000 seeds weight.

Islam *et al.* (2010) studied yield potential of 16 rice genotypes including 12 hybrids, 3 inbreds and 1 New Plant Type (NPT) at the International Rice Research Institute (IRRI) farm under optimum crop management to achieve maximum attainable yield during the wet season (WS) of 2004 and dry season (DS) of 2005. Yield and yield components was determined at maturity. Hybrid produced higher grain panicle^{-1} and 1000-grain weight than inbred rice. Spikelet filling percent was higher in inbred than hybrid rice. The NPT rice genotype had the lowest spikelet filling percent, but the highest 1000-grain weight across the season.

A field experiment was conducted by Khalifa (2009) at the experimental farm of Rice research and training centre (RRTC), Sakha, kafr-El sheikh governorate, Egypt rice season for physiological evaluation of some hybrid rice varieties under different sowing dates. Four hybrid rice H_1, H_2, GZ 6522 and GZ 6903 was evaluated at six different sowing dates. Results indicated that H_1 hybrid rice variety surpassed other varieties for studied characters except for number of days to panicle initiation and heading date.

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

Wang *et al*. (2006) studied the effects of plant density and row spacing (equal row spacing and one seedling hill^{-1}, equal row spacing and 3 seedlings hill^{-1}, wide-narrow row spacing and one seedling hill^{-1}, and wide-narrow row spacing and 3 seedlings hill^{-1} on the yield and yield components of hybrids and conventional cultivars of rice. Compared with conventional cultivars, the hybrids had larger panicles, highest total grains, heavier seeds, resulting in an average yield increase of 7.27%.

Myung (2005) worked with four different panicle types of rice varieties and observed that the primary rachis branches (PRBs) panicle^{-1} and grains was more on Sindongjinbyeo and Iksan467 varieties, but secondary rachis branches (SRBs) was fewer than in Dongjin1 and Saegyehwa varieties.

Chaturvedi *et al.* (2004) evaluated newly released commercial rice hybrids (DRRH 1, PHB 71, Pro-Agro 6201, KHR 2, ADTHR 1, UPHR 1010 and Pant Sankar Dhan 1) and two high yielding varieties as checks (Pant Dhan 4 and Pant Dhan 12) for their agronomic and morpho-physiological traits in a field experiment. Hybrids although could not excel the best HYV owing to high percentage of spikelet sterility but they showed potential for higher yield as these produced large sink (higher number of grain m^{-2}).

Obulamma *et al.* (2004) recorded hybrid APHR 2 significantly higher grain yield than hybrid DRRH 1. The increased grain yield was due to increase in number of panicles m^{-2} and number of filled grain panicle^{-1} in hybrid APHR 2 than hybrid DRRH 1.

Guilani *et al*. (2003) carried out an experiment on crop yield and yield components of rice cultivars (Anboori, Champa and LD183) in Khusestan, Iran. They observed that grain number panicle^{-1} was not significantly different among cultivars. The highest grain number panicle^{-1} was obtained with Anboori. Grain fertility percentages were different among cultivars. Among cultivars, LD183 had the highest grain weight. BRRI (2003) reported that the best age for transplanting wet-bed seedling is 20-30 days for panicle length.

Idris and Matin (1990) also observed that panicle length differed among the six rice varieties and it was longer in IR20 than in indigenous high yielding varieties.

2.1.5 Yield of different rice varieties

Ashraf *et al*. (2017) conducted an experiment at Tamil Nadu Agricultural University, Coimbatore in wetland during *samba* season with an objective to study the effect of seedling age on growth and physiological parameters in rice landraces under irrigated rice ecosystem. The treatments were three age of seedlings and rice landraces *viz., Chandikar, Kuliyadichan, Kuruvaikalanjiyam, Norungan*, *Nootripathu*, *Black Kavuni*, *Red Kavuni*, *Njavara* and CO(R) 50 (one high yielding variety). The study concludes that in rice landraces, *Red Kavuni* recorded enhanced yield compared to other rice landraces.

Sarkar *et al*. (2016) carried out an experiment to evaluate the performance of five hybrid rice varieties namely Shakti 2, Suborna 8, Tia, Aloron and BRRI hybrid dhan2 in *Aman* season with an inbred BRRI dhan33 as checked. The highest grain yield was achieved from Tia (7.82 t ha^{-1}), which was closely followed by Shakti 2 (7.65 t ha^{-1}). These two hybrid varieties produced 24.0% higher yield over the inbred BRRI dhan33.

Yield test of 41 entries, 32 new hybrids, 8 male parents restore lines and 1 inbred variety, was conducted by Huang and Yan (2016) on the farm of University of Arkansas at Pine Bluff (UAPB). Results showed that the yields of 7 hybrids were 25.7%-30.7% higher than check Francis. Hybrid 28s/BP23R had the highest yield, 10846.6 kg/hectare and over check by 30.7%. The yield of hybrid 28s/PB-24, was 10628.9 kg/hectare and over check by 28.1%. The yields of hybrid 28s/PB-22 and 33A/PB24 were 10549.8 and 10539.8 kg/hectare and over check by 27.1% and 27.0%, respectively.

A study was conducted by Mandira *et al*. (2016) in South Tripura district of Tripura for three consecutive kharif seasons to evaluate the performance of rice variety gomati at farmers field under rainfed conditions. The gomati variety of rice was found superior over farmers' existing practices with local varieties. Rice variety gomati with improved production technologies followed in FLDs, increased mean grain yield by 41.62% over farmers' existing practices with only Rs. 1817 ha^{-1} extra expenditure on inputs.

A study was design by Wagan *et al*. (2015) to compare the economic performance of hybrid and conventional rice production and reported that total costs per hectare of hybrid rice was 148992.23 Rs per hectare which was more then conventional rice was 140661.68 Rs per hectare. There was 16.64 percent increase in hybrid rice yield comparing with conventional rice which gives additional income to poor farmers.

Field experiments were conducted by Haque *et al*. (2015) including two popular indica hybrids (BRRI hybrid dhan2 and Heera2) and one elite inbred (BRRI dhan45) rice varieties. Both hybrid varieties out yielded the inbred. However, the hybrids and inbred varieties exhibited statistically identical yield in late planting.

Kanfany *et al*. (2014) conducted an experiment by at the Africa Rice Sahel Regional Station during two wet seasons with the aim of assessing the performances of introduced hybrid cultivars along with an inbred check cultivar under low input fertilizer levels. The grain yield of rice hybrids (bred by the International Rice Research Institute) was not significantly higher than that of the check cultivar widely grown in Senegal.

An experiment was conducted by Hosain *et al*. (2014) at the research farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during *Aus* season (March to July 2010) to observe the effect of transplanting dates on the yield and yield attributes of exotic hybrid rice varieties. The experiment comprised of three rice varieties (two hybrids-Heera2, Aloron and one inbred- BRRI dhan48). BRRI dhan48 produced the highest grain yield (3.51 t ha^{-1}).

Jisan *et al*. (2014) carried out an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh with a view to examine the yield performance of some transplant *Aman* rice varieties as influenced by different levels of nitrogen. Data revealed that highest grain yield (5.69 t ha^{-1}) was obtained from BRRI dhan52 followed by BRRI dhan49 (5.15 t ha^{-1}) and the lowest one (4.25 t ha^{-1}) was obtained from BRRI dhan57.

Bhuiyan *et al.* (2014) conducted an experiment with aimed to determine the adaptability and performance of different hybrid rice varieties and to identify the best hybrid rice variety in terms of yield and recommend it to rice farmers. Findings revealed that different hybrid rice varieties had significant effects on yield. RGBU010A × SL8R is therefore recommended as planting material among hybrid rice varieties because it produced favorable yield.

Haque and Biswash (2014) experimented with five varieties of hybrid rice which was collected from different private seed companies and one hybrid and two checks from Bangladesh Rice Research Institute (BRRI). Varieties were Sonarbangla-1, Jagoron, Hira, Aloron, Richer, BRRI hybrid dhan1 and two checks were BRRI dhan28 and BRRI dhan29. In case of biological yield (g), BRRI dhan29 showed highest yield (49.6 g) and Hira only 18 g.

An experiment was carried out by Alam *et al.* (2012) at Agronomy Field Laboratory, Department of Agronomy and Agricultural Extension, University of Rajshahi during the kharif season to study the effect of variety, spacing and number of seedlings $hill^{-1}$ on the yield potentials of transplant *Aman* rice. They reported that variety had significant effects on almost all the yield component characters and yield. Variety BR11 produced the highest grain yield (5.92 t ha^{-1}).

Samonte *et al.* (2011) reported that the two elite lines recommended for release are high yielding in Texas. RU0703190 is also very early maturing conventional long grain rice. The high yield potential of these new releases will impact grain production of rice farmers and their income.

Tabien and Samonte (2007) observed that several elite lines at the multi-state trials had high yield potential relative to the check varieties and these can be released as new varieties after series of yield trials. With improved yield, the new varieties are expected to increase rice production. The elite lines generated are also potential germplasm for rice improvement projects.

Swain *et al*. (2006) reported from their experiment that the control cultivar IR64, with high translocation efficiency and 1000-grain weight and the lowest spikelet sterility recorded a grain yield of 5.6 t ha^{-1} that was statistically similar to the hybrid line PA6201.

Several *indica or japonica* (I/J) lines was screened and evaluated by Roy (2006) for higher grain yield in the *Boro* season. The highest grain yield of 9.2 t ha^{-1} was obtained from selected I/J line IR58565-2B-12-2-2, which was equal to that of indica hybrid CNHR3 and significantly higher than that of modern variety IR36.

Molla (2001) reported that Pro-Agro6201 (hybrid) had a significant higher yield than IET4786 (HYV), due to more mature panicles m^{-2}, higher number of filled grains $panicle^{-1}$ and greater seed weight.

Patel (2000) studied the varietal performance of Kranti and IR36. He observed that Kranti produced significantly higher grain and straw yield than IR36 did. The mean yield increased with Kranti over IR36 was 7.1 and 10.0% for grain and straw, respectively.

Julfiquar *et al*. (1998) reported that BRRI evaluated 23 hybrids along with three standard checks during *Boro* season. It was reported that five hybrids (IR58025A/IR54056, IR54883, PMS8A/IR46R) out yielded the check varieties (BR14 and BR16) with significant yield difference. Two hybrids out yielded the check variety of same duration yielded by more than 1 t ha^{-1}.

Kamal *et al.* (1998) conducted an experiment to assess the yield of 9 modern varieties (MV) and 6 local improved varieties (LIV) and observed that modern variety BR11 gave the highest grain yield followed by BR10, BR23, Binasail and BR4.

Chowdhury (1997) undertook a research on BINA-19, BR14, BR3 and Iratom-24 varieties with different methods of transplanting. He found that the yields for BINA-19, BR14, BR3 and Iratom-24 was 6.49 t ha^{-1}, 6.22 t ha^{-1}, 6.22 t ha^{-1}, 5.75 t ha^{-1} and 5.60 t ha^{-1}, respectively.

Nematzadeh *et al*. (1997) reported that local high quality rice cultivars Hassan Sarai and Sang-Tarom was crossed with improved high yielding cultivars Amol 3, PND160-2-1 and RNR1446, which gave an average grain yield of 8 t ha^{-1}, twice as much as local cultivars. Radhakrisna *et al.* (1996) conducted a trial at Mamdya, Karnataka and found that hybrid cultivar KRH-2 gave an average yield of 9.3 t ha^{-1} with an yield advantage of 1.5 t ha^{-1} over the best check variety Jaya.

Chowdhury *et al*. (1995) studied seven varieties of rice, of which three was native (Maloti, Nizersail and Chandrashail) and four was improved (BR3, BR11, Pasam and Mala). They reported that both the grain and straw yields were higher in the improved than the native varieties. Liu (1995) conducted a field trial with new indica hybrid rice You 92 and found an average yield of 7.5 t ha^{-1} which was 10% higher than that of standard hybrid Shanyou 64.

Leenakumari *et al.* (1993) evaluated eleven hybrid cultivars against four standard check varieties-Jaya, Rasi, IR20 and Margala. They concluded that hybrid cultivar OR 1002 gave the highest yield of 7.9 t ha^{-1} followed by the hybrid cultivar OR 1001 (6.2 t ha^{-1}). Among the control varieties, Jaya gave the highest yield (8.4 t ha^{-1}). Among the cv. BR22 gave the highest grain yield from most of the sowing dates for both of the years (Ali *et al*., 1993).

Chowdhury *et al*. (1993) reported that the cultivar BR23 showed superior performance over Pajam in respect of yield and yield contributing characters i.e. grain yield straw yield. Suprihatno and Sutaryo (1992) conducted an experiment with seven IRRI hybrids and 13 Indonesian hybrids using IR64 and way-seputih.

2.2 Seedling age on the growth and yield of rice

A field study was conducted by Ashraf *et al*. (2017) at Tamil Nadu Agricultural University, Coimbatore in wetland during *samba* season with an objective to study the effect of seedling age on growth and physiological parameters in rice landraces under irrigated rice ecosystem. The treatments were three age of seedlings *viz*., 15, 20 and 25 days old seedlings and rice landraces *viz.*, *Chandikar*, *Kuliyadichan*, *Kuruvaikalanjiyam*, *Norungan*, *Nootripathu*, *Black Kavuni*, *Red Kavuni*, *Njavara* and CO(R) 50 (one high yielding variety). Observations were recorded on growth parameters such as plant height, tiller numbers, dry matter production, and the physiological parameters like LAI, CGR and RGR. The study concludes that 15 days old seedling in all the eight rice landraces and one high yielding variety, recorded higher growth and physiological parameters. In rice landraces, *Red Kavuni* recorded enhanced growth characters and yield compared to other rice landraces.

Vijayalaxmi *et al*. (2016) carried out an experiment at college farm, college of agriculture, PJTSAU, to find out the effects of three plant densities and four age of seedlings (15, 25, 35 and 45 days old seedlings) on *Kharif* rice in sandy loam soils of Hyderabad. The results revealed that, among the age of seedlings 25 days old seedlings recorded more tiller number (407 m^{-2}), LAI (1.58) and dry matter production (1415 g m^{-2}) and productive tillers (286) with more grain $panicle^{-1}$ (118), filled grain $panicle^{-1}$ (112), panicle length (21.4 cm) and panicle weight (2.5 g) resulted in grain and straw yield of 6583 kg ha^{-1} and 7570 kg ha^{-1}. The higher harvest index was obtained with 5 seedlings $hill^{-1}$ (45) and 25 days old seedlings (47).

Kavitha *et al.* (2010) carried out a field experiment during kharif seasons to study the effect of age of seedlings, weed management practices and humic acid application on SRI. Transplanting 14 days old seedlings improved growth parameters, yield attributes of rice.

Thakur *et al*. (2010) carried out an experiment in eastern India over three years, to compare the performance of certain System of Rice Intensification (SRI) practices: transplanting single, young (10 days old) seedlings the Central Rice Research Institute of India. These selected SRI practices out-yielded RMP by 42%, with the higher yield. Significant measurable changes were observed in physiological processes and plant characteristics, such as longer panicles, more grains panicle^{-1} and higher percentage of grain-filling.

Krishna and Biradarpatil (2009) conducted an experiment to study the Influence of age of seedlings and spacings on seed yield and quality under SRI (system of Rice Intensification) method of cultivation in ES-18 short duration variety during rabi season at Agricultural Research Station Gangavati, Karnataka and reported that the younger seedlings (8 days-old) flowered early. Time of 50% flowering increased as the age of the seedling increased from 8 days old to 12 days old, 16 days old, 25 days old.

Krishna *et al.* (2008) carried out 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 and reported that the 12 days seedlings produced more number of tillers per plant and productive tillers per plant. The younger seedlings (8 days-old) flowered about four to five days earlier as compared to 25 days-old seedlings. Significantly higher seed yield (3.19 t ha^{-1}) was produced by 12 days seedlings.

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.

Banarjee *et al.* (1992) reported that seedlings of 25 days old were the best yield potential of *aman* rice. The optimum age of seedling for transplanting *aus*, *aman* and *boro* rice are 20-30, 30-40 and 35-45 days respectively. Tillering is one of the most important development stages of rice, since it has a decisive character bearing on yield. Tiller number, particularly effective tiller is strongly correlated with grain yield, depending on the cultivar and crop environment. The number of tillers is regulated by tillering duration, which varies with cultivars seedling age, environmental conditions, availability of nutrients in the soil, etc.

Roy *et al.* (1992) reported other wise, where they mentioned that the number of panicles plant^{-1} decreased as seeding age increased. The 20 days old seedlings of IR 50 produced 24 panicles and this number decreased to 21 in 80 days old seedlings. In highest number of field grains/panicle of BR 14 and IR 50 was obtained with 60 days old seedlings than those of 20 and 40 days old seedlings. The older seedlings had reduced number of tillers per plant due to the reduction in field duration and thus, low yield were observed. Harvest index increased with the increase of seedling age. It was 0.41 for 20 and 0.51 for 80 days old seedlings of BR 14 and for IR50 it was 0.45 for 20 and 0.57 for 80 days old seedling. The lower harvest index with younger seedlings indicated that the partitioning of dry matter in their case was less efficient as compared to the older seedlings.

Harun *et al.* (1991) however, mentioned that grain yield decreased gradually with increased of seedling age in *Boro* rice. Mannan *et al.* (1991) mentioned that the average number of panicles in the September 30 planting did not differ significantly due to seedling age while in the October 15 planting, 60 days old seedlings contributing to more number of panicles than the seedling 30, 45 and 75 days old in T. *aman* rice. In 15 September planting, 30 and 45 days old seedlings gave slightly higher grain yield than 60 days old seedlings in Joydebpur (BRRI, 1991). BRRI (1991) further reported that 20 to 40 days old seedling produce higher grain yield.

Ashraf and Mahmood (1989) studied the effect of over aged seedlings of two Basmati rice varieties and reported that yield and yield attributes declined significantly with the increase in seedling age; the reduction in yield was partly attributed to fewer productive tillers per hill and fewer grain per panicle. The filled grain percentage and 1000 grain weight were significantly higher with 30 and 40 days old seedlings than with 50 days old ones during the wet season at Pantnagar, India (Datta and Goutam, 1988).

Seedling quality was affected considerably by management and seedling age and the proper age of rice seedling during transplanting was of prime importance for uniform stand establishment (Kosta *et al.*, 1987). Maurya and Yadav (1987) in India observed that yield components were adversely affected by planting over-aged seedlings resulting in lower grain yield irrespective of the varieties. In Southern India planting of up to 50 day old seedling did not affect plant height and yield components during the wet season (Balasubramaniyan, 1987).

Sattar *et al.* (1986) reported that seedling quality affects growth and development of the plant after transplanting. The older seedling (50 days old) was better than the younger ones (30 days old) for increasing yield of late T. *aman* rice (BRRI, 1986).

Older seedling reduced field duration more than the younger seedlings and compared to 30 days old seedlings, 60 days old seedlings of BR 6 enhanced crop maturity by more than one week, respectively (BRRI, 1985). BRRI (1985) reported a decrease in field duration with the increase in seedling age irrespective of the *aus* season. Seedling age affects dry matter accumulation. Crop raised with young seedling showed higher dry matter accumulation than older seedling (Mondal and Roy, 1984).

Seedling height and seedling strength at transplanting increased with the increase in seedling age (BRRI, 1983). However, management practices also influence plant height as well. Twenty day old seedling produced the tallest plant as compared to seedling age of 28 and 36 days (Sundersingh *et al.*, 1983 and Kosta *et al.*, 1982).

Padalia (1981) concluded that the decrease in yield components was possibly due to shorter effective duration. He also indicated that it was the panicle weight but not the panicle number that decreased with increase in seedling age of the photo-period sensitive varieties in wet season.

De Datta (1981) reported that younger seedling recover faster than the older seedling when transplanted. The grain yield was affected by seedling age but the effect was not similar in all varieties. In BR14 the highest grain yield (6.61 tha^{-1}) was obtained from 40 days old seedlings which was statistically similar to that from 20 and 60 days old seedlings but in IR50 the highest grain yield (6.30 tha^{-1}) was obtained from 20 days old seedling although yield with age up to 80 days did not vary significantly.

Although the field duration was shorter when older seedlings were transplanted, the total growth duration was higher with older seedling that with younger seedlings (BRRI, 1981). However, this increase was not proportional to the increase in seedling age. Lal *et al.* (1981) mentioned otherwise where they reported that the yield reduction caused by transplanting older (55 days) seedlings were small and non significant as compared to younger (25 days) ones. In *Boro*, optimum seedling ages were 20-40 days for long and 20 days for short duration varieties but in *aus* rice, seedling age had no effect on grain yield.

Chapter III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to find out the tillering behavior, spikelet sterility and yield of hybrid rice varieties as influenced by seedling age. The details of the materials and methods i.e. experimental period, location, soil and climatic condition of the experimental area, materials that were used, experimental treatment and design, growing of crops, data collection and analysis procedure that followed for the conduction of this experiment has been presented under the following headings and sun-headings:

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted at the period of December, 2017 to April 2018.

3.1.2 Experimental location

The present research work was conducted in the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, 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. Experimental location presented in Appendix I.

3.1.3 Climatic condition

The geographical location of the experimental site was under the subtropical climate and its climatic conditions is characterized by three distinct seasons, namely winter season from the month of November to February, the pre-monsoon period or hot season from the month of March to April and monsoon period from the month of May to October (Edris *et al*., 1979). Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during experimental period has been presented in Appendix II. During the experimental period the maximum temperature (34.4^0C), highest relative humidity (79%) and highest rainfall (128 mm) was recorded for the month of April, 2018, whereas the minimum temperature (12.2^0C), minimum relative humidity (64%) and no rainfall was recorded for the month of January, 2018.

3.1.4 Soil characteristics

The soil belonged to "The 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 6.2 and had organic carbon 0.43%. The experimental area was flat having available irrigation and drainage system and above flood level. The soil was having a texture of sandy loam with pH and organic matter 5.9 and 1.15%, respectively. The results showed that the soil composed of 26% sand, 43% silt and 31% clay. Details morphological, physical and chemical properties presented in Appendix III.

3.2 Experimental details

3.2.1 Planting material

Differnt rice varieties were used as the test crop in this experiment.

3.2.2 Treatment of the experiment

The experiment comprised of two factors.

Factor A: Rice variety (4 varieties) as

i. V_1 = BRRI hybrid dhan3
ii. V_2 = Hera 4
iii. V_3 = Moina
iv. V_4 = BRRI dhan28 (inbred)

Factor B: Seedling age (3 levels) as

i. A_1 = Tansplanting of 25 days old seedlings
ii. A_2 = Tansplanting of 35 days old seedlings
iii. A_3 = Tansplanting of 45 days old seedlings

As such there were 12 (4×3) treatments combinations viz., V_1A_1, V_1A_2, V_1A_3, V_2A_1, V_2A_2, V_2A_3, V_3A_1, V_3A_2, V_3A_3, V_4A_1, V_4A_2 and V_4A_3.

3.2.3 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The entire experimental area was divided into three blocks representing the replications to reduce soil heterogenetic effects. Each block was divided into 12 unit plots demarked with raised bunds and thus the total numbers of plots were 36. The unit plot size was 3.0 m × 1.0 m. The distance maintained between two blocks and two plots were 1.0 m and 0.5 m, respectively. The layout of the experiment presented in Figure 1.

3.3 Growing of crops

3.3.1 Seed collection and sprouting

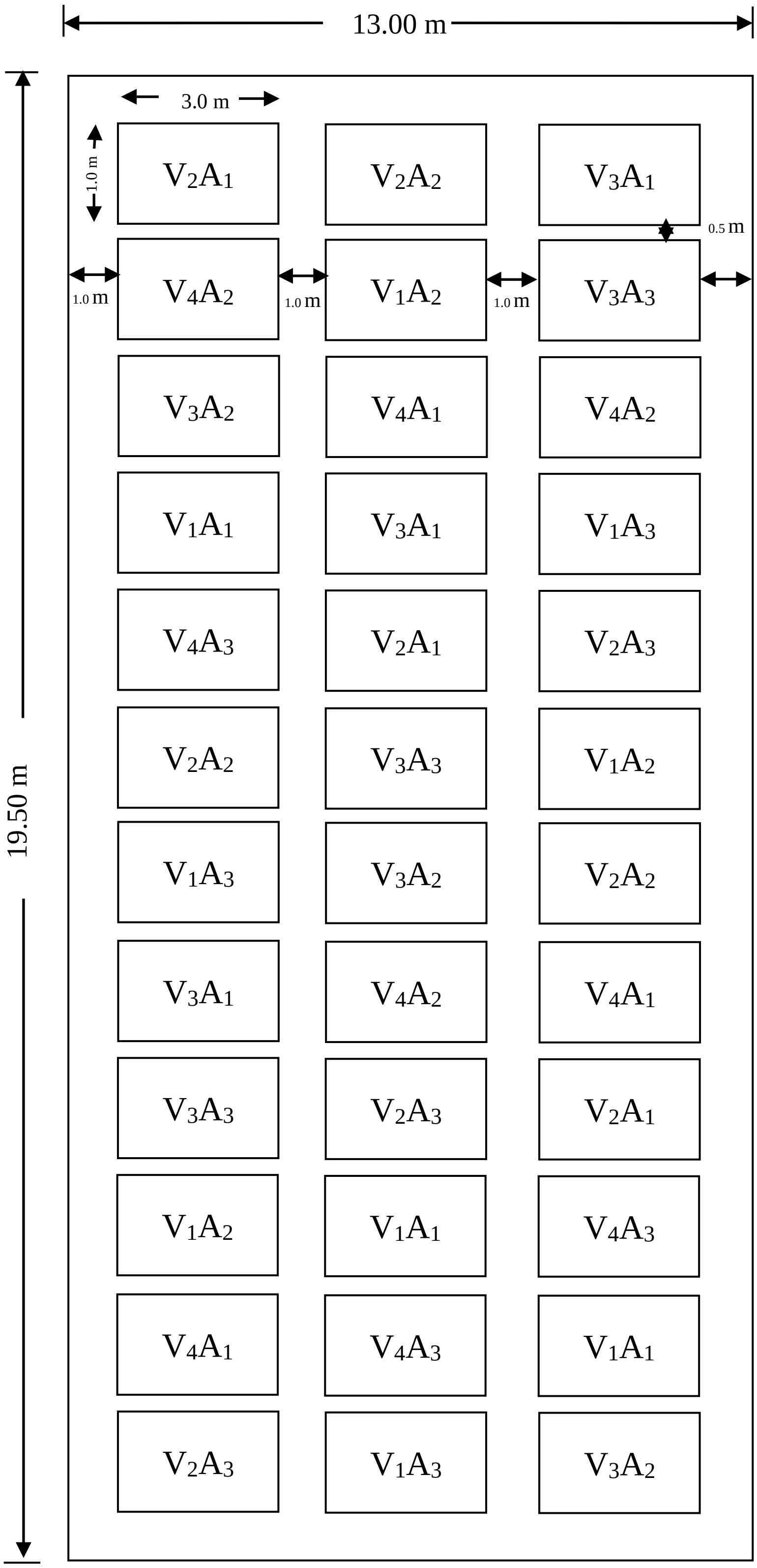
Seeds were collected from BRRI (Bangladesh Rice Research Institute), Gazipur and local market just 20 days ahead of the sowing of seeds in seed bed. For seedlings clean seeds were immersed in water in a bucket for 24 hours. The imbibed seeds were then taken out of water and kept in gunny bags. The seeds started sprouting after 48 hours which were suitable for sowing in 72 hours.

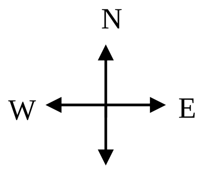
3.3.2 Raising of seedlings

The nursery bed was prepared by puddling with repeated ploughing followed by laddering. The sprouted seeds were sown on beds as uniformly as possible. Irrigation was gently provided to the bed when needed. No fertilizer was used in the nursery bed. For 45, 35 and 25 days old seedlings rice seeds were sown in seed beds at 25th November, 05 and 15 the December 2017, respectively.

3.3.3 Land preparation

The plot selected for conducting the experiment was opened in the 02th January 2018 with a power tiller, and left exposed to the sun for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain good puddle condition. Weeds and stubbles were removed. The experimental plot was partitioned into unit plots in accordance with the experimental design. Organic and inorganic manures as indicated below were mixed with the soil of each unit plot.





Plot size: 3.0 m × 1.0 m

Plot spacing: 0.50 m

Between block: 1.00 m

Factor A: Rice variety (4 varieties) as

i. V_1 = BRRI hybrid dhan3

ii. V_2 = Hera 4

iii. V_3 = Moina

iv. V_4 = BRRI dhan28 (inbred)

Factor B: Seedling age (3 levels) as

i. A_1 = Tansplanting of 25 days old seedlings

ii. A_2 = Tansplanting of 35 days old seedlings

iii. A_3 = Tansplanting of 45 days old seedlings

Figure 1. Layout of the experimental plot

3.3.4 Fertilizers and manure application

The fertilizers N, P, K, S, Zn and B in the form of urea, TSP, MoP, Gypsum, zinc sulphate and borax, respectively were applied @ 80 kg, 60 kg, 90 kg, 12 kg, 2.0 kg and 10 kg (BRRI, 2016). The entire amount of TSP, MoP, gypsum, zinc sulphate and borax were applied during the final preparation of experimental plot. Urea was applied in two equal installments as top dressing at tillering and panicle initiation stages.

3.3.5 Planting of seedling

Seedlings were carefully uprooted from the nursery bed and transplanted on 10th January, 2018 in well puddled plot with spacing of 25 × 15 cm. Two seedlings hill^{-1} was transplanted in each hill. After one week of transplanting all plots were checked for any missing hill, which was filled up with extra seedlings of the same source whenever required.

3.3.6 Intercultural operations

Intercultural operations were done to ensure normal growth of the crop. Plant protection measures were followed as and when necessary. The following intercultural operations were done.

3.3.6.1 Irrigation and drainage

In the early stages to establishment of the seedlings irrigation was provided to maintain a constant level of standing water upto 6 cm and then maintained the amount drying and wetting system throughout the entire vegetative phase. No water stress was encountered in reproductive and ripening phase. The plot was finally dried out at 15 days before harvesting.

3.3.6.2 Weeding

Weeding was done to keep the plots free from weeds, which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully at 30 DAT (days after transplanting) and 60 DAT by mechanical means.

3.3.6.3 Insect and pest control

There was no infection of diseases in the field but leaf roller (*Chaphalocrosis medinalis*) was found in the field and used Malathion @ 1.12 L ha^{-1} at 30 DAT with using a hand sprayer.

3.4 Harvesting, threshing and cleaning

The crop was harvested at full maturity based on variety when 80-90% of the grains were turned into straw color. The harvested crop was bundled separately, properly tagged and brought to threshing floor. The grains were dried, cleaned and weighed for individual plot. The weight was adjusted to a moisture content of 12%. Yields of rice grain and straw were recorded from each plot and converted to hectare yield and expressed in t ha^{-1}.

3.5 Data recording

3.5.1 Plant height

The height of plant was recorded in centimeter (cm) at 20, 40, 60, 80 DAT and at harvest. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the panicle.

3.5.2 Number of tillers hill^{-1}

Number of tillers hill^{1} was recorded at 20, 40, 60 and 80 DAT as the average of randomly selected 5 plants from the inner rows of each plot.

3.5.3 Leaf area index

Leaf area index (LAI) was measured in terms of total leaf area (cm^2) per square meter of the land area at the time of 20, 40, 60 and 80 DAT. Data were recorded as the average of 05 plants selected at random the inner rows of each plots and their area were measured with Portable Area Meter Model LI-3000, USA. The leaf area index (LAI) was worked out by using the formula of Yoshida (1981).

$$\text{Leaf area index} = \frac{\text{Total leaf area (cm}^2\text{)}}{\text{Unit land area (cm}^2\text{)}}$$

3.5.4 Effective tillers hill^{-1}

The total number of effective tillers hill^{-1} was counted as the number of panicle bearing tillers during harvesting. Data on effective tillers hill^{-1} were counted from 5 selected hills and average value was recorded.

3.5.5 Non-effective tillers hill^{-1}

The total number of non-effective tillers hill^{-1} was counted as the number of non-panicle bearing tillers during harvesting. Data on non-effective tillers hill^{-1} were counted from 5 selected hills and average value was recorded.

3.5.6 Total tillers hill^{-1}

The total number of tillers hill^{-1} was counted by adding the number of effective tillers hill^{-1} and ineffective tillers hill^{-1}. Data on total tillers hill^{-1} were counted from 5 selected hills and average value was recorded.

3.5.7 Panicle length

The length of panicle was measured with a meter scale from 5 selected panicle and the average length was recorded as per panicle in cm.

3.5.8 Filled grains panicle^{-1}

The total numbers of filled grain were collected randomly from selected 5 panicle of a plot on the basis of grain in the spikelet and then average numbers of filled grains panicle^{-1} was recorded.

3.5.9 Unfilled grains panicle^{-1}

The total numbers of unfilled grain was collected randomly from selected 5 plants of a plot on the basis of not grain in the spikelet and then average numbers of unfilled grains panicle^{-1} was recorded.

3.5.10 Total grains panicle^{-1}

The total numbers of grain was collected randomly from selected 5 plants of a plot by adding filled and unfilled grain and then average numbers of grains panicle^{-1} was recorded.

3.5.11 Grain sterility

Grain sterility was computed using the formula:

$$\text{Grain sterility (\%)} = \frac{\text{Unfilled grains panicle}^{-1}}{\text{Total grains panicle}^{-1}} \times 100$$

3.5.12 Weight of 1000-grain

One thousand grains were counted randomly from the total cleaned harvested grains and then weighed in grams and recorded.

3.5.13 Grain yield

Grains obtained from each unit plot were sun-dried and weighed carefully. The dry weight of grains of each plot were taken the final grain yield plot^{-1} and finally converted to ton hectare^{-1} (t ha^{-1}).

3.5.14 Straw yield

Straw obtained from each unit plot were sun-dried and weighed carefully. The dry weight of straw from each plot and finally converted to ton hectare^{-1} (t ha^{-1}).

3.5.15 Biological yield

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

Biological yield = Grain yield + Straw yield.

3.5.16 Harvest index

Harvest index was calculated from the grain and straw yield of rice for each plot and expressed in percentage.

$$\text{HI} = \frac{\text{Economic yield (grain weight)}}{\text{Biological yield (total dry weight)}} \times 100$$

3.6 Statistical Analysis

Data obtained from different characters were statistically analyzed. The mean values of all the characters were calculated and analysis of variance was done by using MSTAT-C software. The mean values were separated by Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

Chapter IV

Results and Discussion

CHAPTER IV

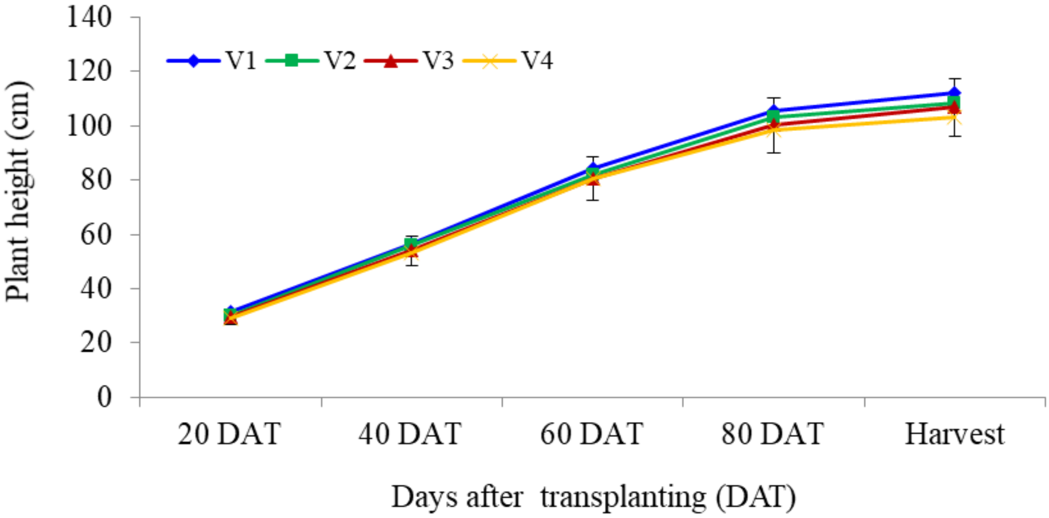
RESULTS AND DISCUSSION

The experiment was conducted to find out the tillering behavior, spikelet sterility and yield of hybrid rice varieties as influenced by seedling age. Data on different growth characters, yield components and yield were recorded. The results have been presented on tables and graphs and possible interpretations given under the following headings:

4.1 Plant height

Plant height of rice at 20, 40, 60, 80 days after transplanting (DAT) and at harvest varied significantly due to varietal effect (Figure 2). At 20, 40, 60, 80 DAT and harvest, the tallest plant (31.66, 56.51, 84.40, 105.66 and 112.00 cm, respectively) was recorded from V_1 (BRRI hybrid dhan3) which was statistically similar (30.15, 55.77, 82.11, 103.26 and 108.19 cm, respectively) with V_2 (Hera 4), whereas the shortest plant (29.16, 53.12, 80.69, 98.53 and 102.97 cm, respectively) was observed from V_4 (BRRI dhan28-inbred) which was statistically similar (29.66, 53.94, 80.61, 100.09 and 106.67) with V_3 (Moina). Generally plant height is a genetical character and it is controlled by the genetic make up of the varieties. Bhuiyan *et al*. (2014) reported that the different hybrid rice varieties had significant effects on plant height. Khalifa (2009) reported that H_1 hybrid rice variety surpassed other varieties in terms of plant height.

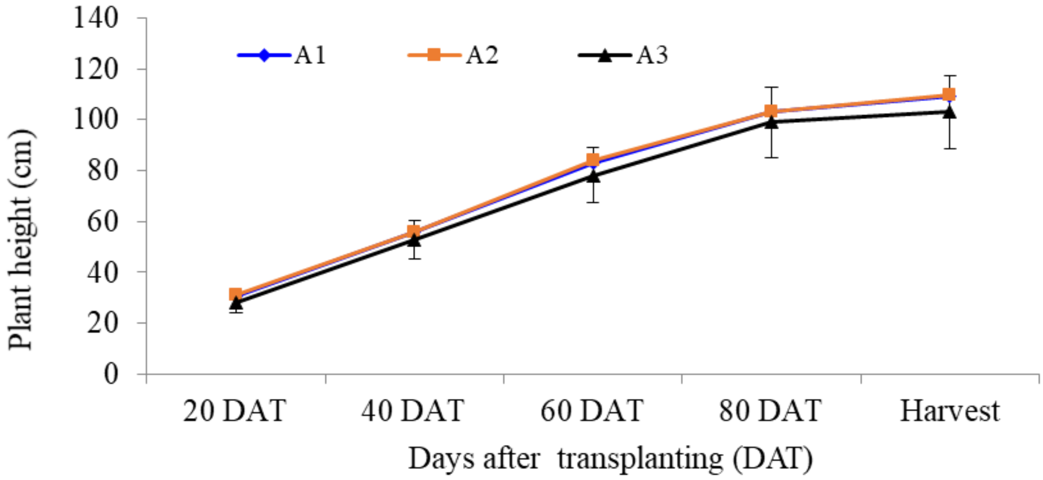
Seedling age had significant effect on plant height of rice at 20, 40, 60, 80 DAT and harvest (Figure 3). At 20, 40, 60, 80 DAT and harvest, the tallest plant (31.35, 55.93, 84.33, 103.47 and 110.00 cm, respectively) was observed from A_2 (Tansplanting of 35 days old seedlings) which was statistically similar (30.80, 55.73, 83.31, 103.22 and 109.33 cm, respectively) with A_1 (Tansplanting of 25 days old seedlings), while the shortest plant (28.32, 52.85, 78.22, 98.97 and 103.04 cm, respectively) was recorded from A_3 (Tansplanting of 45 days old seedlings). Touhiduzzaman (2011) also recorded similar results of plant height with BRRI dhan50.



V_1: BRRI hybrid dhan3 V_2: Hera 4

V_3: Moina V_4: BRRI dhan28 (inbred)

Figure 2. Effect of different varieties on plant height of rice. (Vertical bars represent LSD value at 5% level of probability)



A_1: Tansplanting of 25 days old seedlings

A_2: Tansplanting of 35 days old seedlings

A_3: Tansplanting of 45 days old seedlings

Figure 3. Effect of different seedling age on plant height of rice. (Vertical bars represent LSD value at 5% level of probability)

Combined effect of different rice variety and seedling age showed statistically significant differences in terms of plant height of rice at 20, 40, 60, 80 DAT and harvest (Table 1). At 20, 40, 60, 80 DAT and harvest, the tallest plant (32.80, 59.49, 87.72, 107.48 and 113.15 cm, respectively) was recorded from the combination of V_1A_2 (BRRI hybrid dhan3 and Tansplanting of 35 days old seedlings) and the shortest plant (25.34, 49.92, 75.88, 95.80 and 97.80 cm, respectively) was found from the combination of V_4A_3 (BRRI dhan28-inbred and Tansplanting of 45 days old seedlings).

4.2 Number of tillers hill^{-1}

Statistically significant differences was observed in terms of number of tillers hill^{-1} of rice at 20, 40, 60 and 80 DAT due to different rice variety (Figure 4). At 20, 40, 60 and 80 DAT, the maximum number of tillers hill^{-1} (4.44, 9.25, 14.31 and 15.79, respectively) was found from V_1 which was statistically similar (4.33, 9.13, 14.15 and 15.43, respectively) with V_2 and closely followed (4.16, 8.60, 13.61 and 14.21, respectively) by V_3, while the minimum number (3.83, 6.81, 10.48 and 12.56, respectively) was recorded from V_4.

Number of tillers hill^{-1} at 20, 40, 60 and 80 DAT showed significant differences due to different seedling age (Figure 5). At 20, 40, 60 and 80 DAT, the maximum number of tillers hill^{-1} (4.44, 8.90, 13.90 and 15.29, respectively) was found from A_2 which was statistically similar (4.36, 8.72, 13.59 and 14.91, respectively) with A_1, whereas the minimum number (3.77, 7.72, 11.92 and 13.29, respectively) was found from A_3. Touhiduzzaman (2011) also recorded similar increment of number of tillers hill^{-1} having variety BRRI dhan50.

Variety and seedling age showed statistically significant differences for their combined effect in terms of number of tillers hill^{-1} of rice at 20, 40, 60 and 80 DAT (Table 2). At 20, 40, 60 and 80 DAT, the maximum number of tillers hill^{-1} (4.75, 9.95, 15.34 and 17.07, respectively) was found from the combination of V_1A_1, whereas the minimum number (3.57, 6.62, 10.50 and 11.23, respectively) was observed from the combination of V_4A_3.

Table 1. Combined effect of different varieties and seedling age on plant height of rice

Treatment	Plant height (cm) at				
	20 DAT	40 DAT	60 DAT	80 DAT	Harvest
V_1A_1	31.26 ab	55.61 a-c	84.36 ab	106.32 a	112.37 a-c
V_1A_2	32.80 a	59.49 a	87.72 a	107.48 a	113.15 a
V_1A_3	30.91 ab	54.42 b-d	81.13 b-d	103.18 ab	110.47 a-d
V_2A_1	31.40 ab	56.86 a-c	84.66 ab	106.57 a	112.81 ab
V_2A_2	31.41 ab	57.57 ab	84.16 ab	106.87 a	111.58 a-d
V_2A_3	27.65 cd	52.89 b-d	77.51 de	96.34 bc	100.19 ef
V_3A_1	30.05 a-c	53.76 b-d	81.43 b-d	98.56 bc	104.88 b-f
V_3A_2	29.55 bc	53.88 b-d	82.05 b-d	101.16 a-c	111.45 a-d
V_3A_3	29.37 bc	54.18 b-d	78.34 c-e	100.55 a-c	103.68 d-f
V_4A_1	30.48 a-c	56.67 a-c	82.81 bc	101.42 a-c	106.49 a-e
V_4A_2	31.66 ab	52.78 cd	83.39 ab	98.37 bc	104.62 c-f
V_4A_3	25.34 d	49.92 d	75.88 e	95.80 c	97.80 f
$LSD_{(0.05)}$	2.718	4.108	4.235	6.174	7.036
CV(%)	5.25	4.37	5.43	4.40	6.69

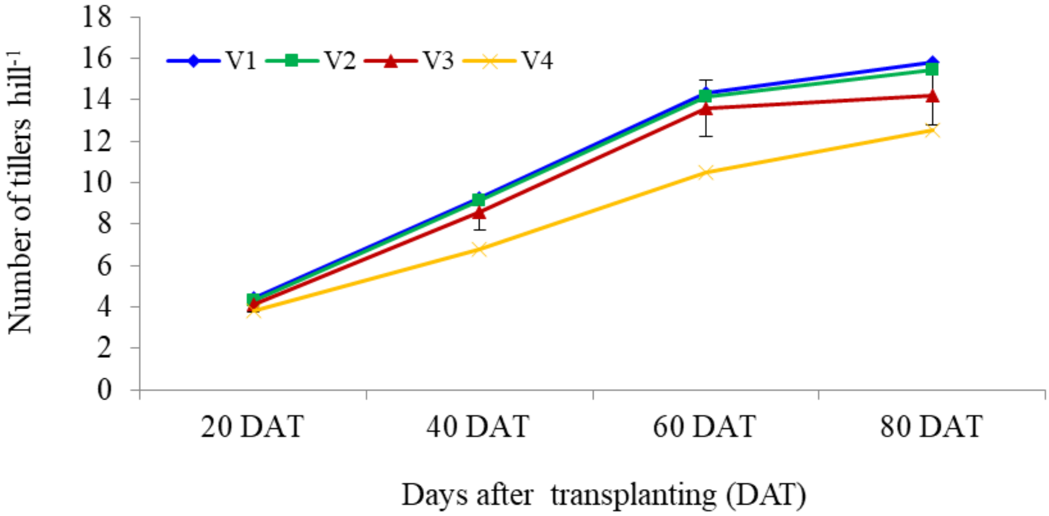
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: BRRI hybrid dhan3 | A_1: Tansplanting of 25 days old seedlings

V_2: Hera 4 | A_2: Tansplanting of 35 days old seedlings

V_3: Moina | A_3: Tansplanting of 45 days old seedlings

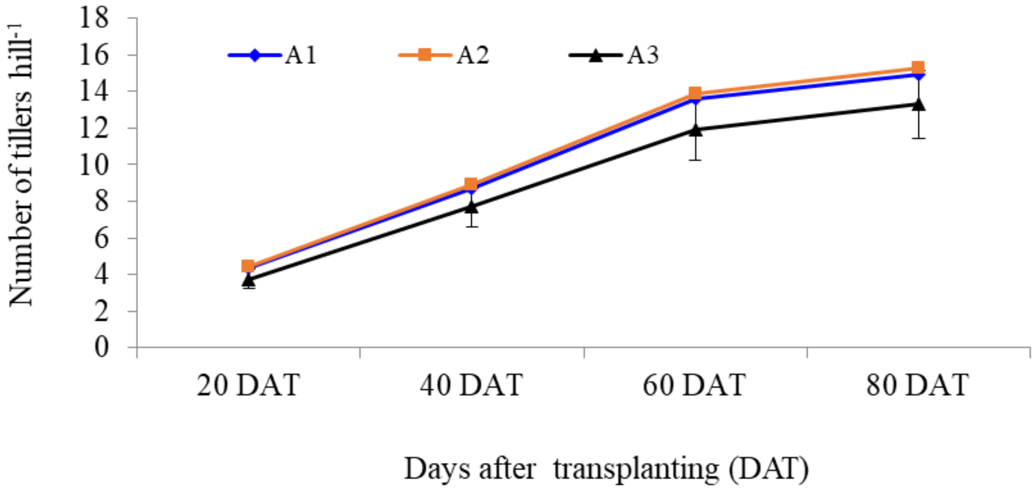
V_4: BRRI dhan28 (inbred)



V_1: BRRI hybrid dhan3 V_2: Hera 4

V_3: Moina V_4: BRRI dhan28 (inbred)

Figure 4. Effect of different varieties on number of tillers hill^{-1} of rice. (Vertical bars represent LSD value at 5% level of probability)



A_1: Tansplanting of 25 days old seedlings

A_2: Tansplanting of 35 days old seedlings

A_3: Tansplanting of 45 days old seedlings

Figure 5. Effect of different seedling age on number of tillers hill^{-1} of rice. (Vertical bars represent LSD value at 5% level of probability)

Table 2. Combined effect of different varieties and seedling age on number of tillers hill^{-1} of rice

Treatment	Number of tillers hill^{-1} at			
	20 DAT	40 DAT	60 DAT	80 DAT
V_1A_1	4.75 a	9.95 a	15.34 a	17.07 a
V_1A_2	3.96 cd	8.34 c	12.63 d	14.67 c
V_1A_3	4.60 a	9.46 ab	14.97 ab	15.63 bc
V_2A_1	4.54 a	9.48 ab	14.87 ab	15.40 bc
V_2A_2	4.62 a	9.75 a	15.14 a	16.70 ab
V_2A_3	3.84 cd	8.15 c	12.44 d	14.20 cd
V_3A_1	4.24 b	8.97 b	14.24 c	14.20 cd
V_3A_2	4.53 a	9.05 b	14.47 bc	15.37 bc
V_3A_3	3.72 de	7.76 c	12.12 d	13.07 de
V_4A_1	4.05 bc	6.96 d	10.30 e	14.40 cd
V_4A_2	3.88 cd	6.85 d	10.63 e	12.03 ef
V_4A_3	3.57 e	6.62 d	10.50 e	11.23 f
$LSD_{(0.05)}$	0.077	0.208	0.181	0.434
CV(%)	3.24	4.27	5.39	5.19

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: BRRI hybrid dhan3 — A_1: Tansplanting of 25 days old seedlings

V_2: Hera 4 — A_2: Tansplanting of 35 days old seedlings

V_3: Moina — A_3: Tansplanting of 45 days old seedlings

V_4: BRRI dhan28 (inbred)

4.3 Leaf area index

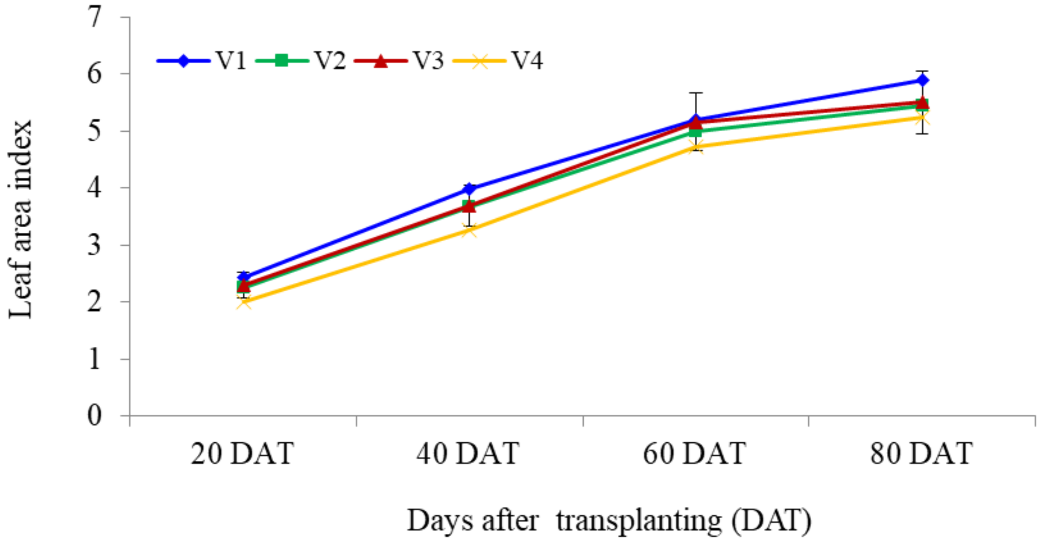
Different rice variety varied significantly in terms of leaf area index of rice at 20, 40, 60 and 80 DAT (Figure 6). At 20, 40, 60 and 80 DAT, the highest leaf area index (2.42, 3.99, 5.19 and 5.88, respectively) was found from V_1 which was statistically similar (2.25, 3.67, 4.99 and 5.43, respectively) with V_3 and followed (2.29, 3.69, 5.16 and 5.50, respectively) by V_2, while the lowest (2.01, 3.27, 4.73 and 5.25, respectively) was observed from V_4.

Leaf area index at 20, 40, 60 and 80 DAT showed significant differences due to different seedling age (Figure 7). At 20, 40, 60 and 80 DAT, the highest leaf area index (2.41, 4.02, 5.33 and 5.87, respectively) was observed from A_2 which was statistically similar (2.30, 3.91, 5.26 and 5.72, respectively) with A_1, whereas the lowest (2.01, 3.04, 4.46 and 4.97, respectively) was found from A_3. Krishna *et al.* (2008) reported that seedling age found to have significant influence on leaf area index.

Statistically significant differences was observed due to the combined effect of variety and seedling age in terms of leaf area index of rice at 20, 40, 60 and 80 DAT (Table 3). At 20, 40, 60 and 80 DAT, the highest leaf area index (2.64, 4.29, 5.63 and 6.28, respectively) was observed from the combination of V_1A_2, whereas the lowest (1.71, 2.65, 3.75 and 4.26, respectively) was recorded from the combination of V_4A_3.

4.4 Number of effective tillers hill^{-1}

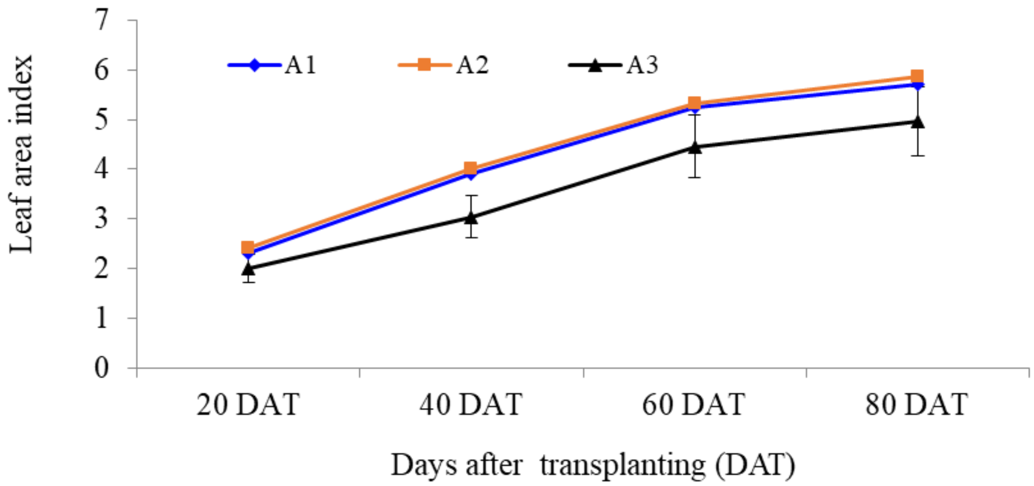
Statistically significant differences was observed in terms of number of effective tillers hill^{-1} due to different rice variety (Table 4). The maximum number of effective tillers hill^{-1} (12.60) was found from V_3 which was statistically similar (12.47) with V_1 and followed (11.76) by V_2, whereas the minimum number (8.98) was observed from V_4. Khalifa (2009) reported that H_1 hybrid rice variety surpassed other varieties in consideration of effective tillers hill^{-1}.



V_1: BRRI hybrid dhan3 V_2: Hera 4

V_3: Moina V_4: BRRI dhan28 (inbred)

Figure 6. Effect of different varieties on leaf area index of rice. (Vertical bars represent LSD value at 5% level of probability)



A_1: Tansplanting of 25 days old seedlings

A_2: Tansplanting of 35 days old seedlings

A_3: Tansplanting of 45 days old seedlings

Figure 7. Effect of different seedling age on leaf area index of rice. (Vertical bars represent LSD value at 5% level of probability)

Table 3. Combined effect of different varieties and seedling age on leaf area index of rice

Treatment	Leaf area index at			
	20 DAT	40 DAT	60 DAT	80 DAT
V_1A_1	2.50 ab	4.25 a	5.46 ab	6.11 a-c
V_1A_2	2.64 a	4.29 a	5.63 a	6.28 a
V_1A_3	2.12 cd	3.43 c	4.48 e	5.24 de
V_2A_1	2.29 bc	4.04 ab	5.37 a-c	5.49 b-d
V_2A_2	2.61 a	4.25 a	5.54 ab	6.24 ab
V_2A_3	1.85 ef	2.71 d	4.06 f	4.57 ef
V_3A_1	2.07 d	3.60 c	4.92 d	5.39 cd
V_3A_2	2.43 ab	4.14 ab	4.99 cd	5.31 d
V_3A_3	2.37 b	3.34 c	5.57 a	5.79 a-d
V_4A_1	2.33 bc	3.76 bc	5.30 a-d	5.87 a-d
V_4A_2	1.98 de	3.41 c	5.15 b-d	5.63 a-d
V_4A_3	1.71 f	2.65 d	3.75 f	4.26 f
$LSD_{(0.05)}$	0.203	0.399	0.368	0.673
CV(%)	5.04	6.37	4.26	7.12

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: BRRI hybrid dhan3 A_1: Tansplanting of 25 days old seedlings

V_2: Hera 4 A_2: Tansplanting of 35 days old seedlings

V_3: Moina A_3: Tansplanting of 45 days old seedlings

V_4: BRRI dhan28 (inbred)

Table 4. Effect of different varieties and seedling age on number of effective, non-effective, total tillers hill^{-1} and panicle length of rice

Treatment	Effective tillers hill^{-1} (No.)	Non-effective tillers hill^{-1} (No.)	Total tillers hill^{-1} (No.)	Length of panicle (cm)
Rice varieties				
V_1	12.47 a	3.16 a	15.62 a	23.05 a
V_2	11.76 b	3.07 a	14.82 a	22.11 a
V_3	12.60 a	2.27 b	14.87 a	22.68 a
V_4	8.98 c	3.09 a	12.07 b	20.57 b
$LSD_{(0.05)}$	0.688	0.285	0.804	1.133
CV(%)	6.15	10.06	5.74	5.49
Seedling age				
A_1	12.37 a	3.12 a	15.48 a	23.70 a
A_2	12.13 a	2.90 ab	15.03 a	22.84 a
A_3	9.85 b	2.67 b	12.52 b	19.76 b
$LSD_{(0.05)}$	0.596	0.247	0.697	0.981
CV(%)	6.15	10.06	5.74	5.49

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: BRRI hybrid dhan3

V_2: Hera 4

V_3: Moina

V_4: BRRI dhan28 (inbred)

A_1: Tansplanting of 25 days old seedlings

A_2: Tansplanting of 35 days old seedlings

A_3: Tansplanting of 45 days old seedlings

Number of effective tillers hill^{-1} showed significant differences due to different seedling age (Table 4). The maximum number of effective tillers hill^{-1} (12.37) was recorded from A_1 which was statistically similar (12.13) with A_2, whereas the minimum number (9.85) was found from A_3. Touhiduzzaman (2011) also recorded similar increment of number of effective tillers hill^{-1} having variety BRRI dhan50.

Combined effect of different rice variety and seedling age showed statistically significant differences in terms of number of effective tillers hill^{-1} (Table 5). The maximum number of effective tillers hill^{-1} (13.87) was recorded from the combination of V_3A_1, whereas the minimum number (8.27) was found from the combination of V_4A_3.

4.5 Number of non-effective tillers hill^{-1}

Number of non-effective tillers hill^{-1} showed statistically significant differences due to different rice variety (Table 4). The maximum number of non-effective tillers hill^{-1} (3.16) was recorded from V_1 which was statistically similar (3.09 and 3.07, respectively) by V_4 and V_2, whereas the minimum number (2.27) was found from V_3.

Different seedling age varied significantly in terms of number of non-effective tillers hill^{-1} (Table 4). The maximum number of non-effective tillers hill^{-1} (3.12) was found from A_1 which was statistically similar (2.90) with A_2, whereas the minimum number (2.67) was recorded from A_3.

Combined effect of different rice variety and seedling age showed statistically significant differences in terms of number of non-effective tillers hill^{-1} (Table 5). The maximum number of non-effective tillers hill^{-1} (3.73) was recorded from the combination of V_4A_1 which was statistically similar with V_1A_1, whereas the minimum number (2.13) was observed from the combination of V_3A_1.

Table 5. Combined effect of different varieties and seedling age on number of effective, in-effective, total tillers hill^{-1} and length of panicle of rice

Treatment	Effective tillers hill^{-1} (No.)	Non-effective tillers hill^{-1} (No.)	Total tillers hill^{-1} (No.)	Length of panicle (cm)
V_1A_1	13.60 ab	3.60 a	17.20 a	24.64 ab
V_1A_2	13.47 ab	3.07 bc	16.53 ab	25.59 a
V_1A_3	10.33 cd	2.80 bcd	13.13 c	18.91 e
V_2A_1	12.40 b	3.00 bc	15.40 b	23.48 bc
V_2A_2	12.40 b	3.27 ab	15.67 ab	21.79 cd
V_2A_3	10.47 c	2.93 bc	13.40 c	23.45 bc
V_3A_1	13.87 a	2.13 e	16.00 ab	21.09 d
V_3A_2	13.60 ab	2.33 de	15.93 ab	21.06 d
V_3A_3	10.33cd	2.33 de	12.67 c	23.51 bc
V_4A_1	9.60 cd	3.73 a	13.33 c	22.22 cd
V_4A_2	9.07 de	2.93 bc	12.00 cd	21.49 cd
V_4A_3	8.27 e	2.60 cde	10.87 d	17.99 e
$LSD_{(0.05)}$	1.191	0.494	1.393	1.962
CV(%)	6.15	10.06	5.74	5.49

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: BRRI hybrid dhan3 A_1: Tansplanting of 25 days old seedlings

V_2: Hera 4 A_2: Tansplanting of 35 days old seedlings

V_3: Moina A_3: Tansplanting of 45 days old seedlings

V_4: BRRI dhan28 (inbred)

4.6 Number of total tillers hill^{-1}

Statistically significant differences was observed in terms of number of total tillers hill^{-1} due to different rice variety (Table 4). The maximum number of total tillers hill^{-1} (15.62) was found from V_1 which was statistically similar (14.87 and 14.82, respectively) with V_3 and V_2, whereas the minimum number (12.07) was recorded from V_4. Khalifa (2009) reported that H_1 hybrid rice variety surpassed other varieties in consideration of total tillers hill^{-1}.

Number of total tillers hill^{-1} showed significant differences due to different seedling age (Table 4). The maximum number of total tillers hill^{-1} (15.48) was observed from A_1 which was statistically similar (15.03) with A_2, whereas the minimum number (12.52) was recorded from A_3.

Combined effect of different rice variety and seedling age showed statistically significant differences in terms of number of total tillers hill^{-1} (Table 5). The maximum number of total tillers hill^{-1} (17.20) was recorded from the combination of V_1A_1, whereas the minimum number (10.87) was found from the combination of V_4A_3.

4.7 Length of panicle

Statistically significant differences was observed in terms of length of panicle due to different rice variety (Table 4). The longest panicle (23.05 cm) was recorded from V_1 which was statistically similar (22.68 and 22.11 cm, respectively) with V_3 and V_2, whereas the shortest panicle (20.57 cm) was observed from V_4. Wang *et al*. (2006) reported that compared with conventional cultivars, the hybrids had larger panicles.

Length of panicle showed significant differences due to different seedling age (Table 4). The longest panicle (23.70 cm) was observed from A_1 which was statistically similar (22.84 cm) with A_2, whereas the shortest panicle (19.76 cm) was recorded from A_3. Thakur *et al*. (2010) observed measurable changes in longer panicles with transplanting single, young (10 days old) seedlings.

Combined effect of different rice variety and seedling age showed statistically significant differences in terms of length of panicle (Table 5). The longest panicle (25.59 cm) was recorded from the combination of V_1A_2, whereas the shortest panicle (17.99 cm) was found from the combination of V_4A_3.

4.8 Filled grains panicle^{-1}

Statistically significant differences was observed in terms of number of filled grains panicle^{-1} due to different rice variety (Table 6). The maximum number of filled grains panicle^{-1} (85.66) was found from V_1 which was statistically similar (84.31 and 83.44, respectively) with V_2 and V_3, whereas the minimum number (72.09) was recorded from V_4. Obulamma *et al.* (2004) recorded highest number of filled grains panicle^{-1} in hybrid APHR 2 than hybrid DRRH 1.

Number of filled grains panicle^{-1} varied significantly due to different seedling age (Table 6). The maximum number filled grains panicle^{-1} (87.64) was observed from A_1 which was statistically similar (85.51) with A_2, whereas the minimum number (70.97) was found from A_3. Touhiduzzaman (2011) also recorded similar increment of number of filled grain with variety BRRI dhan50.

Combined effect of different rice variety and seedling age showed statistically significant differences in terms of number of filled grains panicle^{-1} (Table 7). The maximum number of filled grains panicle^{-1} (94.73) was observed from the combination of V_1A_1, whereas the minimum number (62.83) was recorded from the combination of V_4A_3.

4.9 Unfilled grains panicle^{-1}

Statistically significant differences was observed in terms of number of unfilled grains panicle^{-1} due to different rice variety (Table 6). The maximum number of unfilled grains panicle^{-1} (8.74) was recorded from V_4 which was followed (6.19 and 5.99, respectively) by V_3 and V_2, whereas the minimum number (4.91) was observed from V_1. Hosain *et al*. (2014) reported that hybrid varieties Heera2 and Aloron gave the higher spikelet sterility.

Table 6. Effect of different varieties and seedling age on length of panicle, filled, unfilled and total grains panicle^{-1} of rice

Treatment	Filled grains panicle^{-1} (No.)	Unfilled grains panicle^{-1}	Total grains panicle^{-1}	Grain sterility (%)
Rice varieties				
V_1	85.66 a	4.91 c	90.57 a	5.61 d
V_2	84.31 a	5.99 b	90.30 a	6.74 c
V_3	83.44 a	6.19 b	89.63 a	7.01 b
V_4	72.09 b	8.74 a	80.83 b	10.96 a
$LSD_{(0.05)}$	5.416	0.376	5.450	0.231
CV(%)	6.81	5.96	6.35	4.25
Seedling age				
A_1	87.64 a	5.78 b	93.43 a	8.45 a
A_2	85.51 a	5.44 c	90.95 a	6.15 c
A_3	70.97 b	8.15 a	79.13 b	8.14 b
$LSD_{(0.05)}$	4.690	0.326	4.720	0.201
CV(%)	6.81	5.96	6.35	4.25

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: BRRI hybrid dhan3 — A_1: Tansplanting of 25 days old seedlings

V_2: Hera 4 — A_2: Tansplanting of 35 days old seedlings

V_3: Moina — A_3: Tansplanting of 45 days old seedlings

V_4: BRRI dhan28 (inbred)

Table 7. Combined effect of different varieties and seedling age on length of panicle, filled, unfilled and total grains panicle^{-1} of rice

Treatment	Number of filled grains panicle^{-1}	Number of unfilled grains panicle^{-1}	Number of total grains panicle^{-1}	Grain sterility (%)
V_1A_1	94.73 a	4.40 ef	99.13 a	4.44 e
V_1A_2	92.23ab	4.23 f	96.47 a	4.38 e
V_1A_3	70.00 de	6.10 c	76.10 cd	8.02 c
V_2A_1	75.63 cd	8.17 b	83.80 bc	9.75 b
V_2A_2	88.13 ab	4.70 def	92.83 ab	5.06 de
V_2A_3	89.17 ab	5.10 de	94.27 ab	5.41 d
V_3A_1	75.43 cd	8.57 b	84.00 bc	10.20 b
V_3A_2	88.13 ab	4.77 def	92.90 ab	5.13 d
V_3A_3	86.77 ab	5.23 d	92.00 ab	5.68 d
V_4A_1	82.40 bc	8.57 b	90.97 ab	9.42 b
V_4A_2	71.03 de	7.90 b	78.93 cd	10.01 b
V_4A_3	62.83 e	9.77 a	72.60 d	13.46 a
$LSD_{(0.05)}$	9.381	0.651	9.440	0.621
CV(%)	6.81	5.96	6.35	4.25

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: BRRI hybrid dhan3 — A_1: Tansplanting of 25 days old seedlings

V_2: Hera 4 — A_2: Tansplanting of 35 days old seedlings

V_3: Moina — A_3: Tansplanting of 45 days old seedlings

V_4: BRRI dhan28 (inbred)

Number of unfilled grains panicle^{-1} varied significantly due to different seedling age (Table 6). The maximum number unfilled grains panicle^{-1} (8.15) was observed from A_3, whereas the minimum number (5.44) from A_2 which was statistically similar (5.78) with A_1. Touhiduzzaman (2011) also recorded similar increment of number of filled grain having variety BRRI dhan50.

Combined effect of different rice variety and seedling age showed statistically significant differences in terms of number of unfilled grains panicle^{-1} (Table 7). The maximum number of unfilled grains panicle^{-1} (9.77) was recorded from the combination of V_4A_3, whereas the minimum number (4.23) was found from the combination of V_1A_2.

4.10 Total grains panicle^{-1}

Statistically significant differences was observed in terms of number of total grains panicle^{-1} due to different rice variety (Table 6). The maximum number of total grains panicle^{-1} (90.57) was found from V_1 which was statistically similar (90.30 and 89.63, respectively) with V_2 and V_3, whereas the minimum number (80.83) was observed from V_4. Guilani *et al.* (2003) observed that grain number panicle^{-1} was not significantly different among cultivars.

Number of total grains panicle^{-1} showed significant differences due to different seedling age (Table 6). The maximum number total grains panicle^{-1} (93.43) was observed from A_1 which was statistically similar (90.95) with A_2, whereas the minimum number (79.13) was recorded from A_3.

Combined effect of different rice variety and seedling age showed statistically significant differences in terms of number of total grains panicle^{-1} (Table 7). The maximum number of total panicle^{-1} (99.13) was recorded from the combination of V_1A_1, whereas the minimum number (72.60) from V_4A_3.

4.11 Grain sterility

Statistically significant differences was observed in terms of grain sterility due to different rice variety (Table 6). The highest grain sterility (10.96%) which was followed (7.01%) by V_3, whereas the lowest (5.61%) was recorded from V_1. Obulamma *et al.* (2004) recorded similar results in earlier study.

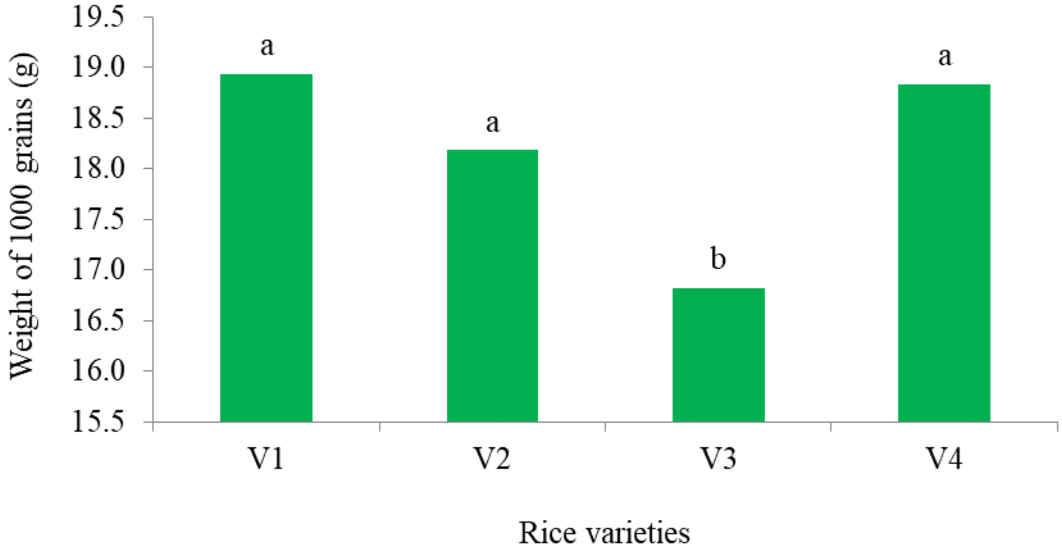
Grain sterility showed significant differences due to different seedling age (Table 6). The highest grain sterility (8.45%) was observed from A_1 which was followed (8.14%) with A_3, whereas the lowest (6.15%) was recorded from A_2. Touhiduzzaman (2011) also recorded lowest grain sterility by using different aged seedlings of BRRI dhan50.

Combined effect of different rice variety and seedling age showed statistically significant differences in terms of grain sterility (Table 7). The highest grain sterility (13.46%) was observed from the combination of V_4A_3, whereas the lowest (4.38%) was recorded from the combination of V_1A_2.

4.12 Weight of 1000 grains

Statistically significant differences was observed in terms of weight of 1000 grains due to different rice variety (Figure 8). The highest weight of 1000 grains (18.93 g) was observed from V_1 which was statistically similar (18.83 and 18.18 g, respectively) with V_4 and V_2, whereas the lowest weight (16.82 g) was found from V_3. Wang *et al*. (2006) reported that compared with conventional cultivars, the hybrids had heavier seeds.

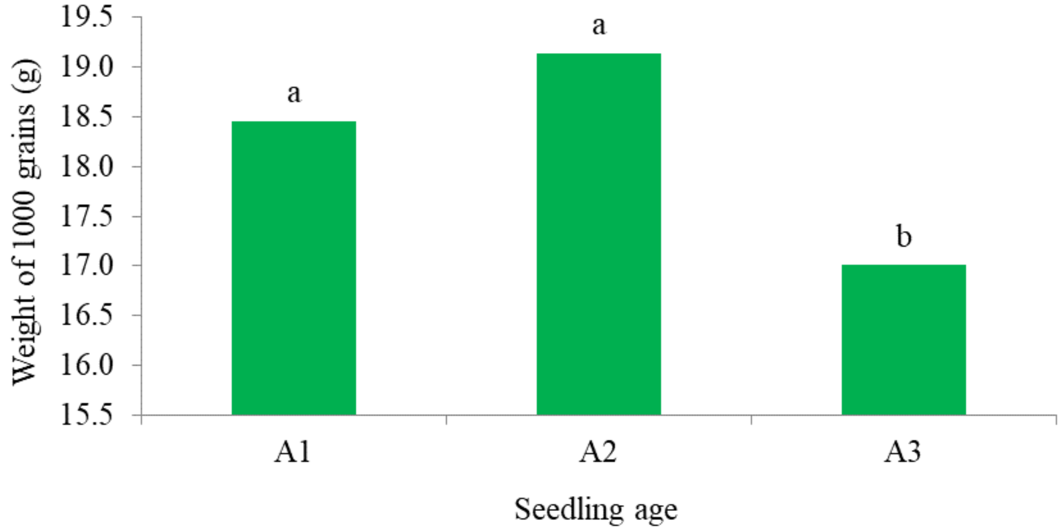
Weight of 1000 grains showed significant differences due to different seedling age (Figure 9). The highest weight of 1000 grains (19.13 g) was observed from A_2 which was statistically similar (18.45 g) with A_1, whereas the lowest weight (17.00 g) was recorded from A_3. Datta and Goutam (1988) reported that 1000 grain weight were significantly higher with 30 and 40 days old seedlings than with 50 days old ones during the wet season.



V_1: BRRI hybrid dhan3 V_2: Hera 4

V_3: Moina V_4: BRRI dhan28 (inbred)

Figure 8. Effect of different varieties on weight of 1000 grains of rice



A_1: Tansplanting of 25 days old seedlings

A_2: Tansplanting of 35 days old seedlings

A_3: Tansplanting of 45 days old seedlings

Figure 9. Effect of different seedling age on weight of 1000 grains of rice

Combined effect of different rice variety and seedling age showed statistically significant differences in terms of weight of 1000 grains (Figure 10). The highest weight of 1000 grains (20.35 g) was recorded from the combination of V_1A_2, whereas the lowest weight (16.25 g) was observed from V_3A_3.

4.13 Grain yield

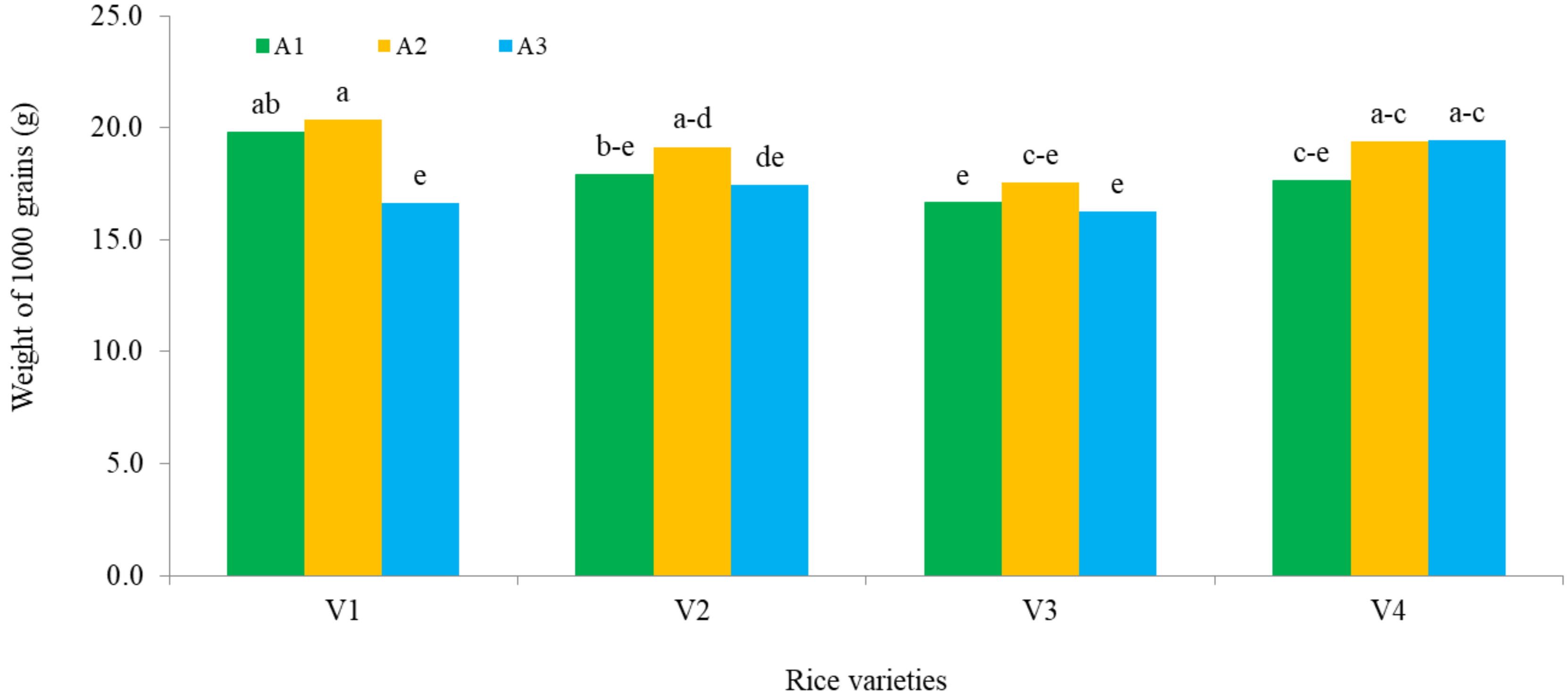
Statistically significant differences was observed in terms of grain yield due to different rice variety (Table 8). The highest grain yield (6.44 t ha^{-1}) was observed from V_1 which was followed (5.97 and 5.89 t ha^{-1}, respectively) with V_2 and V_3 and they were statistically similar, whereas the lowest grain yield (3.51 t ha^{-1}) was found from V_3. Kanfany *et al*. (2014) reported that grain yield of rice hybrids (bred by the International Rice Research Institute) was not significantly higher than that of the check cultivar.

Grain yield of rice showed significant differences due to different seedling age (Table 8). The highest grain yield (5.91 t ha^{-1}) was recorded from A_2 which was followed (5.32 t ha^{-1}) by A_1, whereas the lowest grain yield (5.12 t ha^{-1}) was found from A_3. Touhiduzzaman (2011) also recorded similar increment of grain yield having variety BRRI dhan50.

Combined effect of different rice variety and seedling age showed statistically significant differences in terms of grain yield (Table 9). The highest grain yield (6.81 t ha^{-1}) was recorded from the combination of V_1A_2, whereas the lowest grain yield (3.21 t ha^{-1}) was found from the combination of V_4A_3.

4.14 Straw yield

Statistically significant differences was observed in terms of straw yield due to different rice variety (Table 8). The highest straw yield (7.40 t ha^{-1}) was recorded from V_3 which was statistically similar (7.27 t ha^{-1}) with V_1 and followed (6.99 t ha^{-1}) by V_2, while the lowest straw yield (5.26 t ha^{-1}) was observed from V_4. Patel (2000) observed significantly higher grain and straw yield from Kranti than IR36.



V_1: BRRI hybrid dhan3 V_2: Hera 4 A_1: Tansplanting of 25 days old seedlings A_2: Tansplanting of 35 days old seedlings

V_3: Moina V_4: BRRI dhan28 (inbred) A_3: Tansplanting of 45 days old seedlings

Figure 10. Combined effect of different varieties and seedling age on weight of 1000 grains of rice

Table 8. Effect of different varieties and seedling age on grain, straw, biological yield and harvest index of rice

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index %)
<u>Rice varieties</u>				
V_1	6.44 a	7.27 a	13.70 a	46.93 a
V_2	5.97 b	6.99 b	12.96 c	46.12 a
V_3	5.89 b	7.40 a	13.29 b	44.35 b
V_4	3.51 c	5.26 c	8.76 d	39.80 c
$LSD_{(0.05)}$	0.072	0.048	0102	2.452
CV(%)	6.72	8.44	7.12	6.56
<u>Seedling age</u>				
A_1	5.32 b	6.52 b	11.84 b	44.45 a
A_2	5.91 a	7.19 a	13.10 a	44.73 a
A_3	5.12 c	6.48 b	11.60 c	43.72 b
$LSD_{(0.05)}$	0.059	0.048	0.075	1.021
CV(%)	6.72	8.44	7.12	6.56

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: BRRI hybrid dhan3

V_2: Hera 4

V_3: Moina

V_4: BRRI dhan28 (inbred)

A_1: Tansplanting of 25 days old seedlings

A_2: Tansplanting of 35 days old seedlings

A_3: Tansplanting of 45 days old seedlings

Table 9. Combined effect of different varieties and seedling age on grain, straw, biological yield and harvest index of rice

Treatment	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index %)
V_1A_1	6.53 ab	7.19 cd	13.72 bc	47.59 a
V_1A_2	6.81 a	7.62 ab	14.43 a	47.19 ab
V_1A_3	5.96 cd	7.01 de	12.96 de	45.99 ab
V_2A_1	5.62 de	6.61 f	12.21 f	46.03 ab
V_2A_2	6.56 ab	7.55 ab	14.12 ab	46.46 ab
V_2A_3	5.76 de	6.80 ef	12.56 ef	45.86 ab
V_3A_1	5.90 c-e	7.37 bc	13.27 cd	44.46 bc
V_3A_2	6.22 bc	7.75 a	13.97 ab	44.52 bc
V_3A_3	5.57 e	7.07 de	12.64 ef	44.07 bc
V_4A_1	3.24 g	4.92 h	8.16 h	39.71 d
V_4A_2	4.02 f	5.84 g	9.87 g	40.73 cd
V_4A_3	3.21 g	5.03 h	8.24 h	38.96 d
$LSD_{(0.05)}$	0.117	0.095	0.149	2.052
CV(%)	6.72	8.44	7.12	6.56

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability

V_1: BRRI hybrid dhan3 — A_1: Tansplanting of 25 days old seedlings

V_2: Hera 4 — A_2: Tansplanting of 35 days old seedlings

V_3: Moina — A_3: Tansplanting of 45 days old seedlings

V_4: BRRI dhan28 (inbred)

Straw yield of rice showed significant differences due to different seedling age (Table 8). The highest straw yield (7.19 t ha^{-1}) was observed from A_2 which was followed (6.52 t ha^{-1}) by A_1, whereas the lowest straw yield (6.48 t ha^{-1}) was recorded from A_3.

Combined effect of different rice variety and seedling age showed statistically significant differences in terms of straw yield (Table 9). The highest straw yield (7.75 t ha^{-1}) was recorded from the combination of V_3A_2, whereas the lowest straw yield (4.92 t ha^{-1}) was found from the combination of V_4A_1.

4.15 Biological yield

Statistically significant differences was observed in terms of biological yield due to different rice variety (Table 8). The highest biological yield (13.70 t ha^{-1}) was observed from V_1 which was followed (13.29 t ha^{-1}) by V_3, while the lowest biological yield (8.76 t ha^{-1}) was found from V_4.

Biological yield of rice showed significant differences due to different seedling age (Table 8). The highest biological yield (13.10 t ha^{-1}) was observed from A_2 which was followed (11.84 t ha^{-1}) by A_1, whereas the lowest biological yield (11.60 t ha^{-1}) was found from A_3.

Combined effect of different rice variety and seedling age showed statistically significant differences in terms of biological yield (Table 9). The highest biological yield (14.43 t ha^{-1}) was observed from the combination of V_1A_2, whereas the lowest biological yield (8.16 t ha^{-1}) was recorded from the combination of V_4A_1.

4.16 Harvest index

Statistically significant differences was observed in terms of harvest index due to different rice variety (Table 8). The highest harvest index (46.93%) was recorded from V_1 which statistically similar (46.12%) with V_2 and followed (44.35%) by V_3, while the lowest harvest index (39.80%) was observed from V_4. Similar results also reported by Amin *et al*. (2006) from an experiment.

Harvest index of rice showed significant differences due to different seedling age (Table 8). The highest harvest index (44.73%) was observed from A_2 which was statistically similar (44.45%) by A_1, whereas the lowest harvest index (43.72%) was recorded from A_3.

Combined effect of different rice variety and seedling age showed statistically significant differences in terms of harvest index (Table 9). The highest harvest index (47.59%) was recorded from the combination of V_1A_1, whereas the lowest harvest index (38.96%) was found from the combination of V_4A_3.

Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka from December, 2017 to April 2018 to study the tillering behavior, grain sterility and yield of HYV rice varieties as influenced by seedling age. The experiment comprised of two factors: Factor A: Rice variety (4 varieties) e.g., V_1 = BRRI hybrid dhan3, V_2 = Hera 4, V_3 = Moina, V_4 = BRRI dhan28 (inbred) and Factor B: Seedling age (3 levels) e.g., A_1 = Tansplanting of 25 days old seedlings; A_2 = Tansplanting of 35 days old seedlings and A_3 = Tansplanting of 45 days old seedlings. The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different growth characters, yield components and yield were recorded and statistically significant differences was observed for different treatments.

In case of different rice variety, at 20, 40, 60, 80 DAT and harvest, the tallest plant (31.66, 56.51, 84.40, 105.66 and 112.00 cm, respectively) was recorded from V_1 (BRRI hybrid dhan3), whereas the shortest plant (29.16, 53.12, 80.69, 98.53 and 102.97 cm, respectively) from V_4. At 20, 40, 60 and 80 DAT, the maximum number of tillers hill^{-1} (4.44, 9.25, 14.31 and 15.79, respectively) was found from V_1, while the minimum number (3.83, 6.81, 10.48 and 12.56, respectively) from V_4. At 20, 40, 60 and 80 DAT, the highest leaf area index (2.42, 3.99, 5.19 and 5.88, respectively) was found from V_1, while the lowest (2.01, 3.27, 4.73 and 5.25, respectively) from V_4. The maximum number of effective tillers hill^{-1} (12.60) was found from V_3, whereas the minimum number (8.98) was observed from V_4. The maximum number of non-effective tillers hill^{-1} (3.16) was recorded from V_1, whereas the minimum number (2.27) from V_3. The maximum number of total tillers hill^{-1} (15.62) was found from V_1, whereas the minimum number (12.07) from V_4. The longest panicle (23.05 cm) was recorded from V_1, whereas the shortest panicle (20.57 cm) from V_4. The maximum number of filled grains panicle^{-1} (85.66) was found from V_1, whereas the minimum number (72.09) from V_4. The maximum number of unfilled grains panicle^{-1} (8.74) was recorded from V_4, whereas the minimum number (4.91) from V_1. The maximum number of total grains panicle^{-1} (90.57) was found from V_1, whereas the minimum number (80.83) from V_4. The highest grain sterility (10.96%) was recorded from V_4, whereas the lowest (5.61%) from V_1. The highest weight of 1000 grains (18.93 g) was observed from V_1, whereas the lowest weight (16.82 g) from V_3. The highest grain yield (6.44 t ha^{-1}) was observed from V_1, whereas the lowest grain yield (3.51 t ha^{-1}) from V_3. The highest straw yield (7.40 t ha^{-1}) was recorded from V_3, while the lowest straw yield (5.26 t ha^{-1}) from V_4. The highest biological yield (13.70 t ha^{-1}) was observed from V_1, while the lowest (8.76 t ha^{-1}) from V_4. The highest harvest index (46.93%) was recorded from V_1, while the lowest (39.80%) from V_4.

For different seedling age, at 20, 40, 60, 80 DAT and harvest, the tallest plant (31.35, 55.93, 84.33, 103.47 and 110.00 cm, respectively) was observed from A_2, while the shortest plant (28.32, 52.85, 78.22, 98.97 and 103.04 cm, respectively) from A_3. At 20, 40, 60 and 80 DAT, the maximum number of tillers hill^{-1} (4.44, 8.90, 13.90 and 15.29, respectively) from A_2, whereas the minimum number (3.77, 7.72, 11.92 and 13.29, respectively) was observed from A_3. At 20, 40, 60 and 80 DAT, the highest leaf area index (2.41, 4.02, 5.33 and 5.87, respectively) was observed from A_2, whereas the lowest (2.01, 3.04, 4.46 and 4.97, respectively) was found from A_3. The maximum number of effective tillers hill^{-1} (12.37) was recorded from A_1, whereas the minimum number (9.85) was found from A_3. The maximum number of non-effective tillers hill^{-1} (3.12) from A_1, whereas the minimum number (2.67) was recorded from A_3. The maximum number of total tillers hill^{-1} (15.48) was observed from A_1, whereas the minimum number (12.52) from A_3. The longest panicle (23.70 cm) was observed from A_1, whereas the shortest panicle (19.76 cm) from A_3. The maximum number filled grains panicle^{-1} (87.64) was observed from A_1, whereas the minimum number (70.97) from A_3. The maximum number unfilled grains panicle^{-1} (8.15) was observed from A_3, whereas the minimum number (5.44) from A_2. The maximum number total grains panicle^{-1} (93.43) was observed from A_1, whereas the minimum number (79.13) from A_3. The highest weight of 1000 grains (19.13 g) was observed from A_2, whereas the lowest weight (17.00 g) from A_3. The highest grain sterility (8.45%) was observed from A_1, whereas the lowest (6.15%) was recorded from A_2. The highest grain yield (5.91 t ha^{-1}) was recorded from A_2, whereas the lowest grain yield (5.12 t ha^{-1}) from A_3. The highest straw yield (7.19 t ha^{-1}) was observed from A_2, whereas the lowest straw yield (6.48 t ha^{-1}) was recorded from A_3. The highest biological yield (13.10 t ha^{-1}) from A_2, whereas the lowest biological yield (11.60 t ha^{-1}) from A_3. The highest harvest index (44.73%) was observed from A_2, whereas the lowest (43.72%) from A_3.

Due to the combined effect of different rice variety and seedling age, at 20, 40, 60, 80 DAT and harvest, the tallest plant (32.80, 59.49, 87.72, 107.48 and 113.15 cm, respectively) was recorded from the combination of V_1A_2 and the shortest plant (25.34, 49.92, 75.88, 95.80 and 97.80 cm, respectively) from the V_4A_3. At 20, 40, 60 and 80 DAT, the maximum number of tillers hill^{-1} (4.75, 9.95, 15.34 and 17.07, respectively) was found from the combination of V_1A_1, whereas the minimum number (3.57, 6.62, 10.50 and 11.23, respectively) was observed from the combination of V_4A_3. At 20, 40, 60 and 80 DAT, the highest leaf area index (2.64, 4.29, 5.63 and 6.28, respectively) was observed from the combination of V_1A_2, whereas the lowest (1.71, 2.65, 3.75 and 4.26, respectively) from V_4A_3. The maximum number of effective tillers hill^{-1} (13.87) was recorded from the combination of V_3A_1, whereas the minimum number (8.27) from V_4A_3. The maximum number of non-effective tillers hill^{-1} (3.73) was recorded from the combination of V_4A_1, whereas the minimum number (2.13) from V_3A_1. The maximum number of total tillers hill^{-1} (17.20) was recorded from the combination of V_1A_1, whereas the minimum number (10.87) from V_4A_3. The longest panicle (25.59 cm) was recorded from the combination of V_1A_2, whereas the shortest panicle (17.99 cm) from V_4A_3.The maximum number of filled grains panicle^{-1} (94.73) was observed from the combination of V_1A_1, whereas the minimum number (62.83) from V_4A_3. The maximum number of unfilled grains panicle^{-1} (9.77) was recorded from the combination of V_4A_3, whereas the minimum number (4.23) from V_1A_2. The maximum number of total grains panicle^{-1} (99.13) was recorded from the combination of V_1A_1, whereas the minimum number (72.60) from V_4A_3. The highest grain sterility (13.46%) was observed from the combination of V_4A_3, whereas the lowest (4.38%) was recorded from the combination of V_1A_2. The highest weight of 1000 grains (20.35 g) was recorded from the combination of V_1A_2, whereas the lowest weight (16.25 g) from V_3A_3. The highest grain yield (6.81 t ha^{-1}) was recorded from the combination of V_1A_2, whereas the lowest grain yield (3.21 t ha^{-1}) from V_4A_3. The highest straw yield (7.75 t ha^{-1}) was recorded from the combination of V_3A_2, whereas the lowest straw yield (4.92 t ha^{-1}) was found from V_4A_1. The highest biological yield (14.43 t ha^{-1}) was observed from the combination of V_1A_2, whereas the lowest biological yield (8.16 t ha^{-1}) from V_4A_1. The highest harvest index (47.59%) was recorded from the combination of V_1A_1, whereas the lowest (38.96%) from the combination of V_4A_3.

Conclusion:

- In case of different rice varieties (BRRI hybrid dhan3, Hera 4, Moina, BRRI dhan28 (inbred); the tallest plant (113.15 cm), maximum number of tillers hill^{-1} (17.20), highest leaf area index was recorded from BRRI hybrid dhan3 in 35 days old seedlings.
- The longest panicle (25.59 cm), maximum number total grains panicle^{-1} (99.13), lowest unfilled grains panicle^{-1} (4.23), lowest grain sterility (4.38%), highest weight of 1000 grains (20.35 g), highest grain yield (6.81 t ha^{-1}), highest biological yield (14.43 t ha^{-1}) was found from BRRI hybrid dhan3 in 35 days old seedlings.
- BRRI hybrid dhan3 with 35 days old seedlings produced the highest number of tillers, lowest grain sterility and also provided best yield contributing characters and yield.

From the above results it can be concluded that BRRI hybrid dhan3 with 35 days old seedlings produced the highest number of tillers, lowest grain sterility and also provided best yield contributing characters and yield. Considering the results obtained from the present experiment, further studies in the following areas might be suggested:

- Other variety (s) with different management practices might be included for future study ,
- Such type of study is needed in different agro-ecological zones (AEZ) of Bangladesh for testing the regional compliance and other quality attributes.

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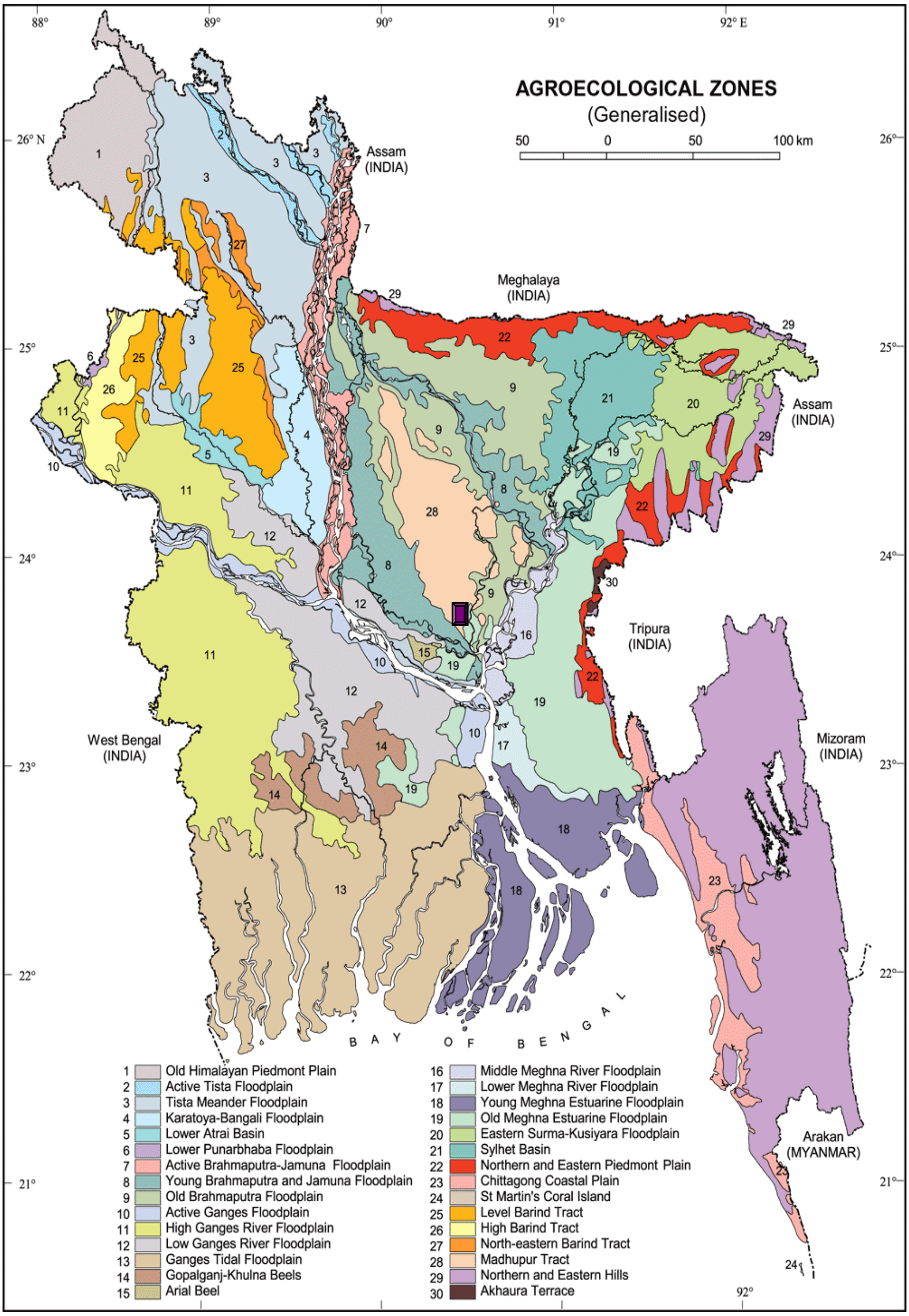
Appendices

APPENDICES

Appendix I. The Map of the experimental site



Appendix II. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from December 2017 to April 2018

Month	Air temperature (ºc)		Relative humidity (%)	Total Rainfall (mm)	Sunshine (hr)
	Maximum	Minimum			
December, 2017	22.6	13.4	78	05	6.6
January, 2018	24.9	12.2	64	00	5.8
February, 2018	27.7	16.9	69	30	6.7
March, 2018	31.4	19.6	67	18	8.4
April, 2018	34.4	23.1	79	128	8.3

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka-1212

Appendix III. Soil characteristics of experimental field as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Horticulture farm field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	26
% Silt	43
% clay	31
Textural class	Sandy loam
pH	5.9
Catayan exchange capacity	2.64 meq 100 g/soil
Organic matter (%)	1.15
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45