EFFECT OF FLAG LEAF CLIPPING ON GROWTH, YIELD AND YIELD ATTRIBUTES OF HYBRID RICE IN *BORO* SEASON

A THESIS

BY

SUMYA FATIMA

DEPARTMENT OF AGRICULTURAL BOTANY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
DHAKA -1207

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BY

SUMYA FATIMA

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Approved by:

Prof. Dr. Md. Moinul Haque
Department of Agricultural Botany
SAU, Dhaka
Supervisor

Prof. Dr. Nasima Akhter
Department of Agricultural Botany
SAU, Dhaka
Co-Supervisor

Assoc. Prof. Dr. Kamrun Nahar
Chairman
Examination Committee

DEPARTMENT OF AGRICULTURAL BOTANY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207
Phone: 9134789

CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF FLAG LEAF CLIPPING ON GROWTH, YIELD AND YIELD ATTRIBUTES OF HYBRID RICE IN *BORO* SEASON"** submitted to the Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTERS OF SCIENCE** in **AGRICULTURAL BOTANY**, embodies the result of a piece of bona-fide research work carried out by **SUMYA FATIMA**, Registration No. **17-08272** 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: 17 June, 2019
Dhaka, Bangladesh

Prof. Dr. Md. Moinul Haque
Department of Agricultural Botany
SAU, Dhaka
Supervisor

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Dated: June, 2019 **The Author**

EFFECT OF FLAG LEAF CLIPPING ON GROWTH, YIELD AND YIELD ATTRIBUTES OF HYBRID RICE IN *BORO* SEASON

Abstract

The experiment was conducted at the Experimental Field of Agricultural Botany Department, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh, during October, 2017 to May, 2018 to study the effect of flag leaf clipping on growth, and yield attributes of hybrid rice. Six hybrid rice varieties (viz. BRRI Hybrid dhan1, BRRI hybrid dhan2, Heera2, Heera4, Nobin and Moyna) were used for this study. The experiment was laid out in split plot Design with three replications. All the test varieties exhibited superiority in control condition. The tallest plant (115.2) cm was recorded from Moyna at harvest stage and higher individual flag leaf area (81.61cm^2) was observed from Heera4. Penultimate leaf area and third leaf area (78.98 cm^2 and 46.95cm^2, respectively) were obtained from BRRI hybrid dhan2. The highest number of leaves (67.33) and spikelet panicle^{-1} (219) were observed from Heera4. Among test rice varieties, higher grain yield (6.01t ha^{-1}) and biological yield (13.45 t ha^{-1}) were also observed from Heera4. Days to maturity was significantly varied from 123 (Nobin) to 145 (BRRI Hybrid dhan1) among the studied varieties. Chlorophyll content (SPAD value) in penultimate leaf after 15 days after heading, grain filling duration, yield contributing characters and yield were collected after cutting of flag leaf. Regardless of variety, all the studied parameters were exhibited superiority in compared to control treatment. Chlorophyll and nitrogen content (1.35% to 17.27%) in penultimate and grain filling duration were increased (4.5 to 6.25 days) due to clipping of flag leaf. The highest number of effective tillers hill^{-1}, filled grains panicle^{-1}, weight of 1000 grains, grain yield, straw yield, biological yield were recorded from Heera4 under control condition. The clipping of the flag leaf reduced grain yield from 15.69 % to 29.43 % in the test hybrid rice varieties.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-ecological Zone
Agric.	=	Agricultural
ANOVA	=	Analysis of Variance
BARI	=	Bangladesh Agricultural Research Institute
Biol.	=	Biology
CV	=	Coefficient Variance
DAT	=	Days after Transplanting
EPB	=	Export Promotion Bureau
et al.	=	And others
FAO	=	Food and Agriculture Organization
GDP	=	Gross Domestic Product
i.e.	=	That is
J.	=	Journal
LSD	=	Least Significance difference
mm	=	Millimeter
oz	=	Ozone
RCBD	=	Randomized Complete Blocked Design
Res.	=	Research
SAU	=	Sher-e-Bangla Agricultural University
Sci.	=	Science
Technol.	=	Technology
Viz.	=	Namely

Chapter I

INTRODUCTION

Rice (*Oryza sativa* L.) is the primary food of about 65% of the world's population (Akter *et al.*, 2014). Asia accounts for 90% of the world's production of rice. Bangladesh is an over populated country. Rice occupies its 77% of the total cropped area, contributes about 70 to 80 percent of total food grain production and continues to play a vital role in the national food and livelihood security system. Rice is the main staple food and the main source of energy for the population of Bangladesh that covers 80% of the total cropped area. Now the position of Bangladesh is 4th in both area and production, and 6th for the production of per hectare yield of rice. Rice that is grown in more than hundred of countries that covers total area of about 160 million hectares and also producing more than 700 million tons every year. It is also known as a main staple food for over half of the world's population, especially in South-east Asia along with rapidly growing populations (Grist, 1988; IRRI, 2009). It is reported that, more than 90% of all produced rice has been consumed in Asia (FAO, 2006). It is rice that covers on an average of 20% apparent calorie intake in the world and also 30% for the Asian people (Hien *et al.,* 2006).Rice is the main staple food and also the source of major energy for Bangladeshi people that covers 80% of the total cropped area as about 12 million hectares (BRRI 1999). It is strongly reported that about 10.4 million hectares of land in Bangladesh is used for the cultivation of rice which is about 85% of total cropped area and the annual production of rice is 30.42 million tons (BBS, 2014).

The demand of rice is constantly increasing in Bangladesh with nearly three million people are being added each year to the total population of the country (BBS, 2014). To meet the food demand of the growing population and to achieve food security, the present production level needs to be increased. The recent yield level of modern rice varieties has reached to its plateau. Hybrid rice cultivation in Bangladesh has been gaining quick ground since then due to its higher yield over conventional inbred varieties. Hybrid rice has higher seedling dry matter content, thicker leaves, larger leaf area and long root system. Hybrid rice can give yield advantage over modern inbred varieties through vigorous growth, extensive root system, efficient and greater sink size, greater carbohydrate translocation from vegetative parts to spikelets and larger leaf area index during the grain filling stage (Lafarge and Bueno, 2009). Dry matter production at different stages show different patterns for hybrid and inbred rice. Hybrid rice has more dry matter accumulation in the early and middle growth stages while inbred has more in the late growth stages (Yan,1988). So, the growth patterns of hybrid rice have been found to be different from that of conventional inbred varieties in several ways.

In Bangladesh there are three distinct growing seasons for Rice. They are *Aus*, *Aman* and *Boro*. The average yield of rice in Bangladesh is about 2.92 tha^{-1} that is very low than the other rice growing countries of the world, such as China (6.30 tha^{-1}), Japan (6.60 tha^{-1}) and Korea (6.30 tha^{-1}). In this condition, the crop production has to be increased at least 60% by 2020 so that we can meet up our food demand for the growing population. Over population and their demand for the grain have been increasing day by day while crop cultivating area is showing negative trend. Now-a-days, soil fertility has decreased because of shorter fallow periods and the latter has not been compensated for by use of chemical fertilizer or organic manure. For these reasons yields have been fluctuating than before with an overall negative trend. The result of food shortages haveled to increase rice importation that leads to drain the country's foreign exchange.

Economic implicationsinclude high consumer prices, problems for the balance of payments,and the burden of external debt. One of the important aims for the cultivation of rice is yield. However, grain yield which is a complex trait and the genetic control of grain yield is a series of biochemical and physiological processes that is also very complex (Ashraf *et al.*, 1994). The primary source of grain yield for rice is photosynthesis of carbohydrate. Grain filling that is sustained by current photosynthesis of the upper parts of the plant, i.e. the flag leaf, penultimate leaves and the ear (Tambussi *et al.*, 2007). Plant leaves are the main organ of photosynthesis that isconsidered as the important determinant and they are also characterized for higher photosynthetic capacities (Asana, 1968).

Flag leaves that play an important role in synthesis and also help for the translocation of photo-assimilates to the rice grains that affects grain yield. The uppermost leaf which is situated below the panicle is called flag leaf that provides the most important source of photosynthetic energy during reproduction. There are many evidence that Flag leaf is metabolically active than the other parts and has proved that the flag leaf, stem and head are the closest source of food to the grain (Asana, 1968; Ramadas and Rajendrudu, 1977). Flag leaf is assigned as an important role for the supply of photosynthates to the grains (Asana, 1968), for grain yield (Sheela *et al.,* 1990; Raj and Tripathi, 2000) and for enhancing productivity (Padmaja and Rao, 1991). The yield of grain and yield related traits have positive relation to the area of flag leaf (Ashrafuzzaman *et al.,* 2009). The top three leaves have most contribution for the yield of grain (Yoshida, 1981; Misra, 1987). Intensive study was done on rice yield after clipping of flag leaf and nearby leaf (Aboukhalifa *et al.,* 2008). Byconsidering the importance of leaves for grain yield, it is necessary to analyze the morphological and the physiological characteristics of functional leaves to improve grain yield in rice (Yue *et al.,* 2006). Clipping of the flag leaf from rice at any stage after the emergence of panicle was the main cause of significant reduction in grain yield (Singh and Ghosh, 1981). In another report it has shown that the contribution of flag leaf is as much as 45% on rice grain yield and, when it was removed, then it was the major component for the loss of rice yield (Abou-Khalifa *et al.,* 2008). In accordance with Mae (1997), 60-90% of total carbon in thepanicles during harvest is derived from photosynthesis after heading, and 80% or more of nitrogen (N) in the panicles during harvest is absorbed before heading which isremobilized from vegetative organs. On the other hand, incase of wheat, above 34.5% grain yield reduction was reported after the clipping of flag leaf during the stage of heading (Mahmood and Chowdhury, 1997), while Birsin (2005) showed that removal of flag leaf which resulted in approximately 13, 34, 24% reduction in grain per spike, grain weight per spike and 1000-grain weight, respectively, and also increase 2.8% protein contents in grain. Similarly,it is believed that rice flag leaves are also a major source of remobilized minerals that is essential for the grains, and recent reports have tried to correlate the expression of gene levels on flag leaves with the concentration of mineral nutrients in rice grains (Narayanan *et al.,* 2007, Sperotto *et al.,* 2009). However, research work on the role of flag and penultimate leaves (individually or combined) in yield formation of hybrid rice is limited in Bangladesh. But it is very essential to elucidate the contribution of different leaves in the formation of rice yield.Under these circumstances, the present research work was undertaken to achieve the following objectives-

Objectives

- To observe the growth behaviour of hybrid rice varieties in *Boro* season.
- To assess the effect of flag leaf clipping on the penultimate leaf chlorophyll content, days to grain filling, yield and yield components of the hybrid rice varieties in *Boro* season.

Chapter II

REVIEW OF LITERATURE

Hybrid rice made a significant impact in China and Vietnam in the 20^{th} century. In Bangladesh, Hybrid rice technology has been introduced through IRRI, BRRI and commercial seed companies of India and China during last 12 years. It should contribute significantly toward food security, environmental protection and poverty alleviation in tropical rice-growing countries like Bangladesh in the 21^{th} century. Hybrid rice varieties are vastly cultivated at *Boro* season. The genetical factor of variety contributes a lot for producing yield components and yield. Different scientists have reported about the effect of rice varieties that contributes yield component and grain yield. However, some of the informative and important works and findingsrelevant related to flag leaf clipping of rice in the recent past have been discussed and presented under the following headings:

2.1 Growth parameters

Vegetative growth of indica rice is more affected by the time of transplanting than the other type of rice (Langfield and Basinski, 1960). Transplanting time has profound influence on the performance of different cultivars of thermo and photo-sensitive in nature (Takahashi *et al.,* 1967). The time between July 15 and August 15 is the best time for transplanting of high yielding cultivars of transplant *Boro* rice in Bangladesh. However, better results can be obtained from early transplanting than the late transplanting (Alim *et al.,* 1993; Hedayetullah *et al.,* 1994). It was reported that mildly photoperiod-sensitive cultivars had a reduced likelihood of encountering low temperature than that of photoperiod-insensitive cultivars.

The experiment which was carried out in BINA (1998) for finding out the performance of variety in advance line (BINA 8-110-2-6) for three check varieties such as- IRRATOM 24, BR26 and BRRI Dhan27. The result has indicated that BINA 8-110-2-6 appeared similar plant height to BRRI Dhan27.

Munoz *et al*. (1996) has observed that IR8025A which is a hybrid rice cultivar has produced 16 % longer plant than that of commercial variety ORYZICA Yacu-9. In 1993, BINA evaluated about the performance of four rice varieties (IRAATOM 24, BR14, BINA13 and BINA19) and the findings revealed that the varieties showed difference significantly in respect of plant height of rice.

BRRI (1991) has recorded about the performance of plant height that has shown difference significantly among the varieties of BR3, BR11, BR14, Pajam and Zagaliin in the *Boro* season. Hosain and Alam (1991)has found that the height of plants in modern rice varieties BR3, BR11, BR14 and Pajam were 90.4, 94.5, 81.3 and 100.7 cm, respectively.

Son *et al.* (1998) reported that the production of dry matter of four inbred lines of rice (large panicle type low tillering), YR15965ACP33, YR16510-B-B-B-9,YR1704ACP5 and YR16512-B-B-B-10, and cv. Daesanbyeo and Namcheonbyeo, which were evaluated for the densities of plant of 10 to 300 plants m^{-2} and also reported that the production of dry matter of large panicle low tillering type rice was lower than that of Namcheonbyeo, regardless of plant density.

Amin *et al.* (2006) has conducted an experiment in the field for finding out about the influence of different doses of N fertilizer on tillering, growth and yield of three rice varieties which are traditional (viz. Jharapajam, Lalmota, Bansful, Chikon) and compared with that of a modern rice variety (viz. KK-4) and has also reported that varieties that are traditional can accumulate higher amount of vegetative dry matter than the modern rice varieties..

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

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

The beneficial effect of photoperiod sensitivity includes greater sowing flexibility and also reduced water because growth duration is shortened when sowing is delayed (Farrell *et al.*, 2006).

In rice, the optimum crop growth rate(CGR) during panicle initiation and optimum leaf area index (LAI) at flowering has been identified as the main determinants of yield. A combination of these growth variables which explains variation of yield better than any individual growth variable.

Hossain and Alam (1991) has reported that the characters of growth like total tillers $hill^{-1}$, plant height and the number of grains $panicle^{-1}$ has showed significant difference among BR11, BR3, BR14 and Pajam varieties of rice in *Boro* season. It has conducted an experiment with six varieties and observed that panicle length has showed difference among varieties and it was greater in IR 20 than high yielding and indigenous varieties.

Baloch *et al.* (2002) who has carried out an experiment with three mutant strains Basmati 370-32, Jajai 77-30 and Sonahri Sugdasi-6 along with their respective mother varieties Basmati 370, Jajai 77, Sonahri Sugdasi and check variety Basmati 385 that were evaluated under different plant population for grain yield and yield contributing parameters. An increase in spacing induced vigorous plant growth as well as increased the number of panicles $hill^{-1}$, grain yield $hill^{-1}$, 1000 grain weight and filled grains $panicle^{-1}$. The mutant strains Jajai 77-30 that produced significantly higher grain yield at all spacing and that is compared with all other entries.

It has reported that leaf area index, dry matter production, crop growth rate (CGR), net assimilation rate (NAR), leaf area duration (LAD) and relative growth rate (RGR) are ultimately reflected in higher grain yield of rice. Crop growth rate which is the most critical attributes of growth for yield of rice under the intensive management during the latter half of the reproductive period. At this stage the CGR critically affects final spikelet number by regulating potential single-grain weight by determining husk size, spikelet degeneration and grain filling by forming active sinks and by determining endosperm cell number at the stage of initial grain filling. Early plating of hybrid rice has exhibited the maximum total and effective tillers per hill, leaf area duration, leaf-area index, relative growth rate, dry-matter accumulation, 1000 grains weight, fertile spikelets per panicle, and straw yields.

It was observed that the significant exponential and linear relationships between aboveground biomass and leaf area index and yield of rice. It has reported that planting time has direct influenced on above attributes.

If the varieties which are photosensitive are transplanted a little early, their vegetative growth has extended that has resulted more leafy growth and plant height. Due to increasing plant height, such type of varieties is lodge badly when they are transplanted early. For this reason, the yield of grain from such kind of crop is reduced drastically. On the other hand, if transplanting is delayed beyond normal period, the grain development is very poor that results in more quantity of under developed grains and cause severe reduction in yield (Kainth and Mehra, 1985).

2.2 Significance of flag leaf

Leaf position on the plant is one of the main factors that affect the efficiency of leaf photosynthesis. For most of the cereals, the flag leaf is the most active part. Flag leafstay the longest on the plant and make a major contribution to the yield of grain in cereals.

In case of rice 60 to 90% of the total carbon in panicles during harvest is derived from photosynthesis after heading, while 80% or more of nitrogen is absorbed in the panicles at harvest before heading and it is also remobilized from the vegetative organs (Mae, 1997). Leaf senescence during maturity and reproductive stages is directly related to the production of biomass and yield of grain in rice.

The flag leaf plays an important role for grain filling in small grain crops such as rice, barley, wheat, oats, etc because of its culm position. It is the topmost leaf and it intercepts a lot of radiation.Moreover, the translocation of assimilates from the flag leaf (source) to the panicle (reproductive sink) is increased by the proximity of the flag leaf to the sink. For this reason, flag leaf is considered as the most active leaf during the period of grain filling. Thusarea of flag leaf could be a choosing factor for increasing yield of rice grain. Flag leaves that are characterized by long-term photosynthetic activity and it is particularly important during grain filling when the older leaves die off. Under the favourable conditions, about 70 to 90% of the total grain yield is produced from the photosynthates which are accumulated during grain filling period.

Mahmood and Chowdhry (1997) who reported that incase of wheat 34.5% grain yield reduction was reported after the removal of flag leaf during the heading stage. It is revealed that flag leaf is the most active part during the period of grain filling and could be chosen as a factor for enhancing grain yield of rice.

Flag leaf which plays an important role in the assimilation and translocation of assimilates in the rice plant, and thus it ultimately influences the grain yield (Singh and Ghosh, 1981). The top three leaves, especially the flag leaf contributes most to the yield of rice grain (Ray *et al.*, 1983; Misra, 1986). Flag leaf plays an important role in rice yield by increasing the grain weight by 41 to 43%. Experiments that were conducted to study the effect of leaf clipping on the rice yield and revealed that flag leaf contributed most to the yield of rice grain and its contribution was as high as 45% (Abou-Khalifa *et al.*, 2008).

Flag leaf has utmost importance in cereals like wheat which provides maximum amount of photosynthesis assimilates that is stored in grains. It was observed that poor grain filling of indica-japonica hybrids rice are related to poor translocation and partitioning of assimilates to the grains, that results in more resources for vegetative growth.

It was observed that there was a positive correlation between translocation of photosynthesis material and flag leaf angle, and the fertility of spikelets increases also for increasing yield of rice grain. A flag leaf area which is greater will actually help to increase photosynthetic efficiency by increasing production of photosynthesis that is then translocated into grains and also increase their weight. Thus flag leaf has a direct relationship on the yield of grain.

Birsin (2005) showed that clipping of flag leaf resulted for reduction in grain per spike, 1000 grain weight and grain weight per spike and also increase protein contents in grain. Narayan *et al.* (2007) has reported that it is believed thatflag leaves are the major source of minerals that are remobilized for the seeds. Khalifa *et al.* (2008) has reported that flag leaf which contributes to 45%

yield of rice grain and has also served as the main source for remobilized minerals for grains. In case of rice 60-90% of the total carbohydrates in the panicles during harvest are derived from the photosynthesis after panicle initiation. It was also identified that flag leaf soluble protein is one of the substances that is produced by the source which plays an important role for increasing dry matter of the grain.

2.3 Yield and yield parameters

It was showed that during development and growth of wheat, soluble protein content level is not only reflected the level of plant nitrogen metabolism, but it was also regarded as an major indicator of the degree of leaf senescence, especially in case of wheat grain filling stage by increasing soluble protein content of flag leaf that was conducive for the maintenance of the flag leaf growth and also extend the photosynthetic function, so as to lay the substances basis for the accumulation of carbohydrates in the grain.

Birsin (2005) showed that the removal of flag leaf resulted in approximately 13, 34, 24% reduction in grain per spike,1000 grain weight and grain weight per spike, respectively, and also increase protein contents 2.8% in grain.

The vegetative growth of indica rice is more influenced by the time of transplanting than that of other type of rice varieties (Langfield and Basinski, 1960). Time of transplanting has much influence on the performance of different cultivars that are thermo and photo-sensitive in nature (Takahashi *et al.*, 1967). In Bangladesh the best time for transplantation is between July 15 and August 15 for high yielding cultivars of transplanted *Boro* rice. Moreover, better results can be obtained from early transplanting than late transplanting (Alim *et al.*, 1993; Hedayetullah *et al.*, 1994).

It was conducted an experiment on Africa Rice at 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. There were many effects on cultivar that are significant for all traits. The grain yield of hybrid rice (bred by the International Rice Research Institute) was not significantly higher than that of the check cultivar that is widely grown in Senegal.

Moreover, flag leaf that has a direct relationship to the yield of grain. They also reported that fertilization of high nitrogen level enhances the carotenoid and chlorophyll content of leaves.

An experiment that was conducted by Haque and Biswash (2014) along with five hybrid rice varieties and one hybrid and two checks from Bangladesh Rice Research Institute (BRRI). Varieties were Sonarbangla-1,Heera, Jagoron, Richer, Aloron, BRRI hybrid dhan1 and two checks were BRRI dhan28 and BRRI dhan29.At this time the highest plant height was 101.5 cm was recorded from BRRI dhan28 and the lowest plant height from Richer (82.5 cm).

Jisan *et al.* (2014) who carried out an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh to examine the yield performance of some transplant *Boro* rice varieties that were influenced by different nitrogen levels. The experiment consisted of four rice varieties viz. BRRI dhan49, BRRI dhan52, BRRI Nobin, BRRI dhan57 and four N levels. Data revealed that among the varieties, BRRI dhan52 showed the tallest plant (117.20 cm), whereas BRRI dhan57 showed the lowest plant height.

Murthy *et al.* (2004) has also conducted an experiment along with six varieties of rice genotypes such as Mangala, Madhu, J-13, Sattari, CR 666-16 and Mukti. They observed that Mukti produced the longest plant compared to the others.

BINA (1993) evaluated the performance among four rice varieties IRATOM 24, BR14, BINA13 and BINA19. They found that varieties showed significant difference on panicle length and sterile spikelets panicle^{-1}. However, it was also reported that varieties BINA13and BINA19 each had better morphological characters such as more grains panicle^{-1} compared to their better parents that contributed to improvement of yield in these hybrid lines of rice.

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

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

Xie*et al.* (2007) found that Shanyou-63 variety which produced higher yield (12 t/ha) compared to Xieyou46 variety (10 tha^{-1}). Amin *et al.* (2006) also conducted a field experiment for finding out the influence of different types of doses of N fertilizer on tillering, growth and yield of three rice varieties which are traditional (*viz*. Jharapajam, Lalmota, Bansful-Chikon) were compared with that of a modern variety (viz. KK-4) and the report showed that traditional rice varieties accumulated higher amount of vegetative dry matter than the modern rice variety.

It was revealed that the cultivars that were mildly photoperiod-sensitive had a reduced likelihood of encountering low temperature compared with cultivars that were photoperiod-insensitive. The benefits of photoperiod sensitivity include greater sowing flexibility and reduced water use because growth duration is shortened when sowing is delayed (Farrell *et al.*, 2006).

Wang *et al.* (2006) also studied that 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 components and yield of conventional cultivars and hybrids of rice. Compared with conventional cultivars, the hybrids showed larger panicles and heavier seeds that caused in an average yield increase of 7.27%.

It was also reported that Pro-Agro6201 (hybrid) gave a significant higher yield than IET4 (86 (HYV), because of more mature panicles m^{-2}, higher number of filled grains $panicle^{-1}$ and greater seed weight.

Kamal *et al.* (1998) who conducted an experiment along with 9 modern varieties (MV) and 6 local improved varieties (LIV) and they observed that modern variety BR11 showed the highest grain yield than that of BR10, BR23, Binasail and BR4.

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

Nematzadeh *et al.* (1997) also reported that local high quality rice cultivars Hassan Sarai and Sang-Tarom were crossed with improved high yielding cultivars Amol 3, PND160-2-1 and RNR1446 in all possible combinations and it was released in 1996 under the name of Nemat that produced an average grain yield of 8 tha^{-1}, twice as much as local cultivars.

Islam (1995) carried out an experiment along with four rice cultivars viz. BR10, BR11, BR22 and BR23. He observed that the highest number of non bearing tillers $hill^{-1}$ was showed by cultivar BR11 and the lowest number was showed by BR10. Chowdhury *et al.* (1993) also reported that the cultivar BR23 had superior performance over Pajam in case of number of productive tillers $hill^{-1}$.

Julfiquar *et al.* (1998) has reported that BRRI evaluated 23 hybrids with three standard checks in *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 one t ha^{-1}.

Chapter III

MATERIALS AND METHODS

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2017 to May 2018 to theeffect of flag leaf clipping on growth and yield of hybrid rice varieties. The details of the materials and methods *i.e.* experimental period, location, climatic and soil condition of the experimental area, materials that were used for the experiment, treatment and design of the experiment, growing of crops, data collection procedure and procedure of data analysis that were followed in this experiment has been presented under the following headings:

3.1 Description of the experimental site

3.1.1 Period

The experiment was conducted at the period of November 2017 to May 2018.

3.1.2 Location

The present research work which 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 $88^0 35^/$ E longitude with an elevation of 8.2 meter from sea level. Experimental location has presented in Appendix I.

3.1.3 Soil

The soil belonged to “The Modhupur Tract”, AEZ-28 (FAO, 1988).The texture of top soilwas silty clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 6.2 and it had 0.43%organic carbon. The experimental area was flat which had available irrigation and drainage system and above flood level. The details have been presented in Appendix II.

3.1.4 Climate

The geographical location of the experimental site was under the subtropical climate which was characterized by three distinct seasons, winter season from Novemberto February and hot season or the pre-monsoon period from March to April and monsoon period from May to October. Details of the meteorological data of rainfall, air temperature, relative humidity, and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e Bangla Nagar, Dhaka and has been presented in Appendix II.

3.2 Experimental details

3.2.1 Treatments

The experiment comprised of two factors.

Factor A: Flag leaf clipping (Main plot)

a. Clipping at heading

b. Control (without clipping)

Factor B: Hybrid rice variety (Sub-plot)

1. V_1 = BRRI hybriddhan1
2. V_2 = BRRI hybriddhan2
3. V_3 = Heera2
4. V_4 = Heera4
5. V_5 = Nobin
6. V_6 = Moyna

3.2.2 Experimental design and layout

The experiment was laid out in a Split-plot Design with three replications. There were 36 plots for 12 treatment combinations each of 3 replications. A set of 12 treatment combinations were assigned at random in 12 plots of each replication. The layout of the experiment presented in (Figure 1).

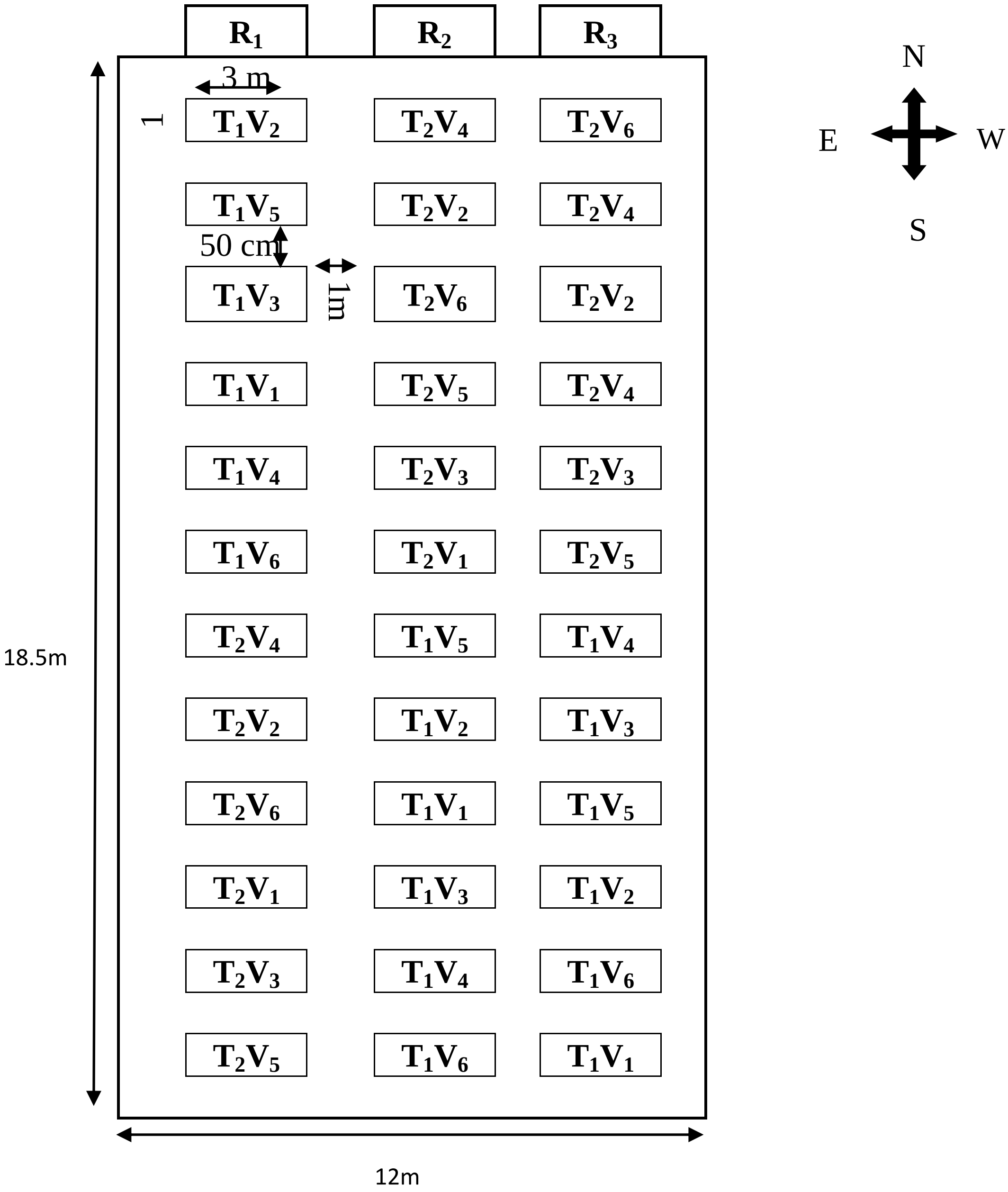

Figure 1. Layout of the experimental field

3.3 Crop growing

3.3.1 Seed collection

The seeds of BRRI hybrid dhan1, BRRI hybrid dhan2, Heera-2, Heera-4, Nobinand Moyna were collected from Bangladesh Rice Research Institute (BRRI), Joydevpur, Gazipur and respective Seed Company, Dhaka. The seeds were collected just 20 days ahead of the sowing of seeds in seed bed.

3.3.2 Seed sprouting

Healthy seeds were selected by specific gravity method and then immersed in water bucket for 24 hours and then they were kept tightly in gunny bags. The seeds started sprouting after 48 hours and were sown after 72 hours.

3.3.3 Seed bed preparation and seed sowing

As per BRRI recommendation seed bed was prepared with 1 m wide adding nutrients as per the requirements of soil. Seeds were sown in the seed bed on November 12, 2017 in order to transplant the seedlings in the plot as per experimental design.

3.3.4 Land preparation

The plot selected for conducting the experiment was opened in the 12^{th} December 2018 with a power tiller, and left exposed to the sun for a week. After three days 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 in 2.3.4 were mixed with the soil of each unit plot.

3.3.5 Fertilizers and manure application

The fertilizers N, P, K, S, Zn and B in the form of urea, TSP, MP, Gypsum, zinc sulphate and borax, respectively were applied @ 80 kg, 60 kg, 90 kg, 12 kg, 2.0 kg and 10 kg (BRRI, 2013). The entire amount of TSP, MP, 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.

3.3.6 Uprooting of seedlings

The nursery bed was made wet by application of water one day before uprooting of the seedlings. The seedlings were uprooted on December 12, 2017and January 18, 2018 for transplant without causing much mechanical injury to the roots.

3.3.7 Transplanting of seedlings in the field

On the scheduled dates as per experiment the rice seedlings were transplanted in lines each having a line to line distance of 30 cm and plant to plant distance 25 cm in the well prepared plots.

3.3.8 Intercultural operations

After establishment of seedlings, various intercultural operations were accomplished for better growth and development of the rice seedlings. First gap filling was done for all of the plots at 10 days after transplanting (DAT) by planting same aged seedlings.

3.3.9 Irrigation and drainage

Flood irrigation was provided to maintain a constant level of standing water upto 6 cm in the early stages to enhance tillering and 10-12 cm in the later stage to discourage late tillering. The field was finally dried out at 15 days before harvesting.

3.3.10 Gap filling

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

3.3.11 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 tillering stage and at panicle initiation stage by mechanical means.

3.3.12 Top dressing

After basal dose, the remaining doses of urea were top-dressed in 2 equal installments and were applied on both sides of seedlings rows in the soil.

3.3.13 Plant protection

Furadan 57 EC was applied at the time of final land preparation and later on other insecticides were applied as and when necessary.

3.3.14 Harvesting, threshing and cleaning

The rice was harvested depending upon the maturity of plant and harvesting was done manually from each plot. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken during harvesting, threshing and also cleaning of rice seed. Fresh weight of grain and straw were recorded plot wise. The grains were cleaned and finally the weight was adjusted to a moisture content of 14%. The straw was sun dried and the yields of grain and straw plot^{-1} were recorded and converted to t ha^{-1}.

3.4 Data collection

Three hills were selected randomly from the net plot area of each plot and tagged as sample plants. Two rows from all sides of the plot were left as border rows. The following observations were recorded from the sample plants and the mean values were worked out.

3.4.1 Panicle Initiation (PI)

Panicle initiation was determined when the panicle premordia initiate the production of a panicle in the uppermost node of the culm. At this point, the panicle is not visible to the naked eye.

3.4.2 Booting stage

This stage isdetermined as that period characterized by a swelling of the flag leaf sheath which is caused by an increase in the size of the panicle as it grows up the leaf sheath. Full or late boot occurs when the flag leaf has completely extended.

3.4.3 Heading stage

This is the time when the panicle begins to exsert from the boot. Heading may take over 10 to 14 days due to variations within tillers on the same plant and between plants in the field.

3.4.4 Flowering stage (Anthesis)

The flowering stage begins with the emergence of the first anthers from the 'uppermost spikelets on each panicle.

3.4.5 The Milk stage

The endosperm first begins to form as a milky liquid. Rice at the milk stage is very susceptible to attack by sucking insect pests.

3.4.6 The Dough Stage

The milky liquid begins to solidify into a sticky white pas tot Bird pests generally begin to be a serious problem.

3.4.7 The Maturity stage

The grain is mature, or ripe, when the endosperm becomes hard and opaque. While the grains ripen, the leaves of the plant begin to turn yellow as nitrogen is transferred from the leaves to the seed. The full maturity stage is reached when more than 90% of the grains in the panicles have ripened.

3.4.8 Plant height

Plant height was recorded at panicle initiation, booting, flowering and at harvest stages using the method described by Gomez (1972). The height wasmeasured from the base of the plant to the tip of the longest leaf or tip of the longest ear head, whichever was longer and the average was recorded in centimeters.

3.4.9 Leaf area

Individual area of flag leaf, penultimate leaf and third leaf at heading, were determined by leaf product method. The correction factor (k) used were 0.75.

Individual leaf area (cm^2) = Length x maximum width x k

3.4.10 Tillers hill^{-1}

Tiller count was taken from three tagged observation hills at panicle initiation, booting, flowering and harvest stages and the mean value was recorded as number of tillers per hill.

3.4.11Panicles hill^{-1}

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

3.4.12 Spikelets panicle^{-1}

The number of spikelets per panicle was recorded by counting the spikelets separated from the three randomly selected panicles.

3.4.13 SPAD value

SPAD reading was taken from penultimate leaf 15 days after heading stage using SPAD (chlorophyll) meter (Minolta-52, Japan).

3.4.14 Duration of grain filling

Duration of grain filling was determined counting days from heading to maturity for each treatment.

3.4.15 Filled grain panicle^{-1}

The total number of filled grains was collected randomly from selected 3 plants of a plot on the basis of grain in the spikelet and then average number of filled grains panicle^{-1} was recorded.

3.4.16 Unfilled grains panicle^{-1}

The total number of unfilled grains was collected randomly from selected 3 plants of a plot on the basis of no grain in the spikelet and then average number of unfilled grains panicle^{-1} was recorded.

3.4.17 Weight of 1000 seeds

One thousand grains were counted from the cleaned and dried produce from the net plot area of each plot and the weight of the grains was recorded in grams.

3.4.18 Yield

Rice obtained from each unit plot was sun-dried and weighed carefully. The dry weight of rice of central 1 m^2 area and five sample plants were added to the respective straw yield m^{-2} and finally converted to t ha^{-1} at 14% moisture.

3.4.18.1 Grain yield

Grains obtained from each unit plot were sun-dried and weighed carefully. The dry weight of grains of central 1 m^2 area and five sample plants were added to the respective grain yield m^{-2} and converted to t ha^{-1}.

3.4.18.2 Straw yield

Straw obtained from each unit plot were sun-dried and weighed carefully. The dry weight of straw of central 1 m^2 area and five sample plants were added to the respective straw yield m^{-2} and finally converted to t ha^{-1}.

3.4.18.3 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 Statistical analysis

The data obtained for different characters were statistically analyzed using MSTAT software to observe the significant difference among the different rice variety. The mean values of all the characters were calculated and factorial analysis of variance was performed. The significance of difference among the treatment means was estimated by the Least Significant Difference (LSD) at 5% level of probability.

Chapter IV

RESULTS AND DISCUSSION

An experiment was carried out to assess the effect of flag leaf clipping on growth and yield of some rice varieties viz. BRRIhybriddhan1, BRRI hybriddhan2, Heera2, Heera4, Nobin and Moyna. The analyses of variance (ANOVA) of the data on different parameters are presented in Appendix III-VIII. With the help of tables and graphs, the results are presented and discussed and also possible interpretations given under the following headings:

4.1 Plant height

Plant height at different days after transplanting showed statistically significant variation in studied hybrid rice varieties (Table 1). At harvest, the tallest plant (115.2cm) was recorded from Moyna which was statistically similar to BRRI hybrid dhan1. The shortest plant (99.43 cm, respectively) at harvest was found from Nobin (Table 1).

Table 1. Effect of variety on plant height of the six rice hybrid varieties in *Boro* season

Treatment	Plant height (cm)								
	40 DAT		55 DAT		70 DAT		85 DAT	At harvest	
BRRI hy. dhan1	25.46	a	48.27	ab	63.41	abc	84.70	110.40	ab
BRRI hy. dhan2	20.88	bc	45.22	b	55.19	c	83.10	103.80	cd
Heera2	19.03	c	44.00	b	65.42	ab	79.00	108.50	bc
Heera4	21.21	bc	44.71	ab	58.83	bc	85.80	109.10	bc
Nobin	20.43	bc	47.79	ab	70.00	a	92.30	99.43	d
Moyna	22.50	ab	49.64	a	64.93	abc	86.00	115.20	a
$LSD_{(0.05)}$	3.41		4.19		10.12		NS	5.44	
CV(%)	10.75		7.21		6.65		7.34	5.79	

The values with same letters(s) in a column are not significantly different as per LSD test.

Different varieties produced different plant height on the basis of their varietal characters and improved varieties is the first and foremost requirement for initiation and accelerated production. Growth of rice is strongly influenced by genotype as well as environmental factors (BRRI, 2003). Jisan *et al.* (2014) reported that Hybrid Tiaproduced the tallest plant (117.20 cm). Haque and Biswash (2014) also found the highest plant height was 101.5 cm from BRRI dhan28 and the lowest plant height from Richer (82.5 cm).

4.2 Leaf number at heading

Leaf number at heading of different rice variety showed statistically significant variation under the present trial (Figure 1). The maximum number of leaf (67.33) was observed from Heera4 which were following (66.67and 65.67) with BRRI hybrid dhan1 and BRRI hybriddhan2, whereas the minimum number of leaf (57.67) from Moyna (Figure 1).

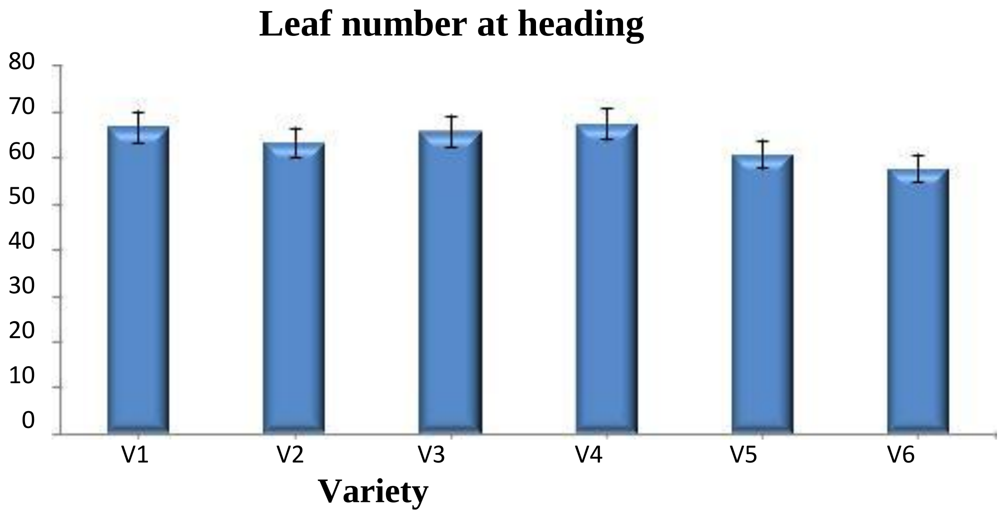

Figure 2. Effect of variety on leaf number at heading in the six rice hybrid varieties in *Boro* season [Vertical bar represents LSD values at 5% level.] V_1 =BRRI hybriddhan1, V_2= BRRI hybriddhan2, V_3= Heera2, V_4= Heera4, V_5= Nobin, V_6= Moyna.

4.3 Leaf area

Flag leaf,penultimate leaf and third leaf area of six hybrid rice varieties varied significantly in the *Boro* season (Figure 2). The highest flag leaf area index (81.61cm^2) was observed from Heera4, penultimate leaf and third leaf are index (78.98 cm^2 and 46.95 cm^2, respectively) was observed from BRRI hybriddhan2, while the lowest leaf area (48.37 cm^2, 52.42 cm^2 and 20.55 cm^2, respectively) was found from Moyna (Figure 2).

Probably delayed planted crop prevailed lesser time in favor of growing environment which might have lowest leaf area of flag leaf. Jisan*et al*. (2014) reported that BRRI dhan29 produced the leaf area, while the lowest values of these parameters were produced by BRRI dhan45. Similar results also reported by Amin *et al.* (2006), Son *et al.* (1998) and Shaloie *et al.* (2014) from their earlier study.

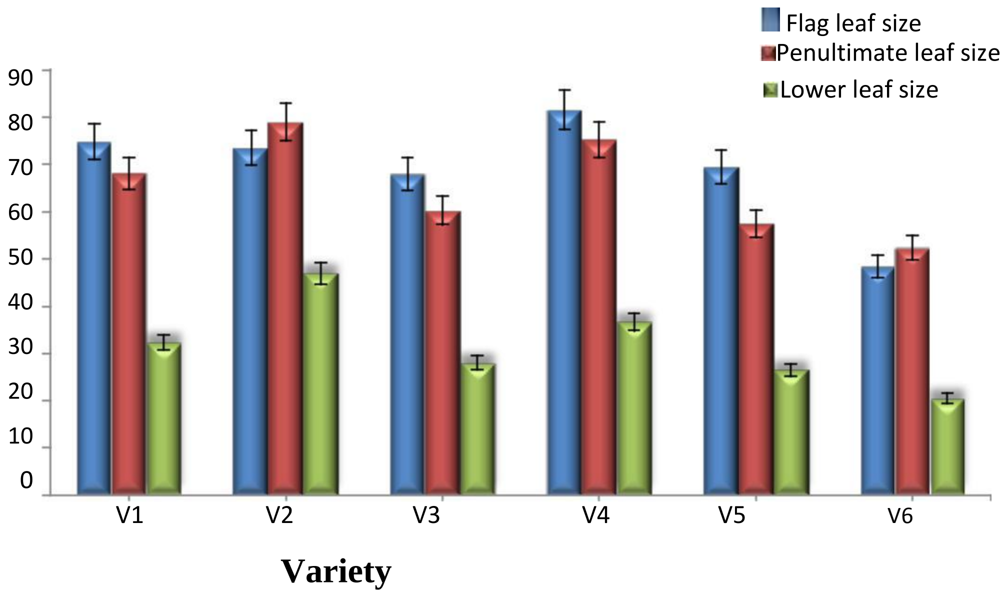

Figure 3. Effect of variety on leaf area of six rice hybrid varieties in *Boro* season[Vertical bars indicate LSD values at 5% level.] V_1 = BRRI hybriddhan1, V_2= BRRI hybriddhan2, V_3= Heera2, V_4= Heera4, V_5= Nobin, V_6= Moyna.

4.4 Days of panicle initiation

Days of panicle initiation (PI) significantly affected due to variety to variety. Nobin takes the minimum days (75)for the panicle initiation while the maximum days(92) requires for panicle initiation in BRRI hybriddhan2 (Table 2a).

4.5 Booting stage

The booting stage of rice significantly influenced due to varietal effect (Table 2a). The highest days (104) require for the booting of rice plant in BRRI hybriddhan2 while the shortest days (85) was recorded in Nobin among all rice varieties.

4.6 Panicle emergence

The emergence of panicle in rice was progressively influenced by hybrid rice varieties (Table 2a). Nobin and Heera2 takes the minimum days (89) and maximum time days (111), respectively for the emergence of panicle among all genotypes.

4.7 Days to 50% flowering

Flowering in rice progressively varied due to varietal effect. The earliest 50% flowering (95 days) was recorded in Nobin while the maximum delaying flowering (116 days) was recorded by BRRI hybrid dhan2 among all of the hybrid rice varieties (Table 2b)

Table 2a. Different growth stages of the hybrid rice varieties in *Boro* season

Variety	PI stage (days)	Booting stage (days)	PEstage (days)
BRRI hybrid dhan1	88ab	95bc	102c
BRRI hybrid dhan2	92a	104a	107b
Heera2	91ab	103a	111a
Heera4	85bc	99ab	103c
Nobin	75d	85d	89d
Moyna	83c	92c	101c
$LSD_{(0.05)}$	6.72	5.12	2.94
CV(%)	3.53	2.38	1.29

The values with same letters(s) in a column are not significantly different as per LSD test.

4.8 Milky stage

Different hybrid rice varieties significantly varied in respect of the milky stage attended (Table 2b).Nobin took103 days and BRRI hybriddhan2maximum days (124) for milky stage among all the hybrid rice varieties.

4.9 Dough stage

In case of dough stage of rice progressively varied by varietal effect (Table 2b). Among all genotypes, Nobin produced earlier (112 days) and BRRI hybrid dhan2 and Heera2 achieved dough stage late (132 days).

4.10 Maturity stage

Maturity stage was significantly varied among the studied varieties. BRRI hybrid dhan2 and Heera2 took the maximum days (145) to reach maturity. Nobin (123 days) reached the maturity earlier compared to the rest of the hybrid varieties (Table 2b).

Table 2b. Different growth stages of the hybrid rice varieties in *Boro* season

Variety	50% flowering (days)	Milky stage (days)	Dough stage (days)	Maturity stage (days)
BRRI hybrid dhan1	105b	111b	122b	133b
BRRI hybrid dhan2	116a	124a	132a	145a
Heera2	115a	123a	132a	145a
Heera4	105 b	112b	123b	135b
Nobin	95 c	103c	112c	123c
Moyna	104 b	111b	122b	133b
$LSD_{(0.05)}$	4.29	4.98	4.88	6.37
CV(%)	11.74	8.88	9.75	4.52

The values with same letter(s) in a column are not significantly different as per LSD test.

4.11 SPAD Value of penultimate leaf

Statistically significant variation was recorded for chlorophyll content (SPAD value) of at 15 days after heading (Appendix VII). The highest chlorophyll content (SPAD value) in amount (46.62) was found from T_1, whereas the lowest weight (43.41) was recorded from T_2 (Table 3). Leaf cutting increases chlorophyll (SPAD value) in the penultimate leaf. These points indicated a compensatory increase in photosynthetic efficiency in the remaining leaves. Similarly, It was reported that defoliation of young apple trees caused an increased photosynthetic rate in the remaining leaves.

Chlorophyll content of penultimate leaf at 15 days and at maturity stage varied significantly for different rice varieties (Table 3). The highest Chlorophyll content (46.52) was recorded from V_2, which was statistically similar with V_5 and V4 On the other hand, the lowest weight (43.29) was observed from V_6 which were statistically similar with V_1 and V_3 (Table 3). Study showed that mean chlorophyll content among the cultivars varied significantly and suggested that the studied genotypes were genetically variable regarding chlorophyll content.

Combined effect of flag leaf cutting and rice varieties showed significant variation in chlorophyll content in penultimate leaves (Table 4). The highest SPAD value (48.25) was found from treatment combination of T_1V_5 treatment combination and which was statistically similar with (47.72 and 47.20) was found T_1V_4 and T_1V_2, the lowest (41.29) was recorded from treatment combination of T_2V_3.

4.12Grain filling duration

Table 3 showed that duration of grains filling was significantly different in both control and flag leaf removal treatment regardless of variety. Rice plant required 31.83 days for grain filling in flag leaf clipping treatment and around 28.40 days in control, respectively to fill the grains. It might be happened due to slow supply of assimilate to the grain.

Table 3. Effect of flag leaf cutting and variety on yield components in the six rice varieties

Treatment /variety	SPAD value		Days tograin filling	
T1	46.62	a	31.83	b
T2	43.41	b	28.40	a
LSD(0.05)	2.17		2.73	
V_1	44.31	b	28.53	c
V_2	46.52	a	31.34	a
V_3	43.73	b	29.25	bc
V_4	45.01	a	31.12	a
V_5	46.31	a	27.57	c
V_6	43.29	b	30.55	ab
LSD(0.05)	0.65		1.63	
CV%	5.73		5.81	

In a column, mean values having same letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05 level of significance. T_1= Flag leaf cutting, T_2= Control, V_1= BRRI hybriddhan1, V_2= BRRI hybriddhan2, V_3= Heera2, V_4= Heera4, V_5= Nobin, V_6= Moyna

Among the varieties the maximum days required for grains filling (31.34 days) was recorded from BRRI hybriddhan2 whereas the minimum days required for Grains filling was attained from Nobin which was 27.57 days (Table 3). The difference among the varieties might be related to the genetically characteristics of the varieties. Wide range of variability was observed in respect of grains filling duration among six selected hybrid rice varieties (Table 3). Rice varieties viz. BRRI hybriddhan1, BRRI hybriddhan2, Heera2, Heera4, Nobin and Moyna plants took 26.37, 28.23, 28.83, 28.67, 28.30 and 27.87days, respectively for grain maturity under in control condition whereas it takes 31.28, 34.41, 29.63, 33.34, 32.34 and 33.13 days under flag leaf clipping condition.

Table 4.Combined effect of flag leaf cutting and variety on SPAD value in penultimate leaf & days to grain filling of six hybrid rice varieties

Treatment combination	SPAD value	Days to grain filling
T_1V_1	44.42 ef	31.28 d
T_1V_2	47.20 b	34.41 a
T_1V_3	46.31 c	29.63 e
T_1V_4	47.72 ab	33.34 b
T_1V_5	48.25 a	32.34 c
T_1V_6	45.18 de	33.13 b
T_2V_1	44.23 f	26.37 h
T_2V_2	45.82 cd	28.25 f
T_2V_3	41.29 h	28.83 ef
T_2V_4	42.35 g	28.62 fg
T_2V_5	44.24 ef	26.33 h
T_2V_6	42.50 g	27.81 g
$LSD_{(0.05)}$	0.89	0.91
CV%	1.52	4.86

In a column, mean values having same letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05 level of significance. V_1 =BRRI hybriddhan1, V_2=BRRI hybriddhan2, V_3= Heera2, V_4= Heera4, V_5= Nobin, V_6= Moyna T_1= Flag leaf cutting, T_2= Control.

4.13 Filled grain panicle^{-1}

Statistically significant variation was recorded for filled grains panicle^{-1} due to flag leaf removal (Table 5). The highest filled grains panicle^{-1} (169.10) was recorded from T_2, whereas the lowest (134.00) was obtained from T_1.

Filled grains panicle^{-1} varied significantly for different rice varieties (Appendix VI). The highest filled grains panicle^{-1} (179.70) was recorded from V_4, which was statistically different (169.70) to V_2, whereas the lowest (136.30) was found from V_6 (Table 5). Murthy *et al.* (2004) recorded different number of filled spikelets for different variety.

Interaction effect of flag leaf removal and rice varieties showed significant variation on filled grains panicle^{-1}. The highest filled grains panicle^{-1} (227.30) was recorded from treatment combination of T_2V_2, while the lowest (124.00) was found from treatment combination of T_1V_1 (Table 6).

4.14 Unfilled grains panicle^{-1}

Statistically significant variation was recorded for unfilled grains penicle^{-1} due to flag leaves removal (Table 5). The highest unfilled grains panicle^{-1} (52.00) was recorded from T_1, whereas the lowest (23.00) was recorded from T_2. Unfilled grains panicle^{-1} varied significantly for different rice varieties (Table 5). The highest unfilled grains panicle^{-1} (60.33) was observed from V_3, while the lowest (19.50) was observed from V_5 (Table 5). BINA (1993) conducted an experiment with four varieties/advance lines and reported significant variation in unfilled spikelets panicle^{-1}. Combined effect of flag leaf removal and rice varieties showed significant variation on unfilled grains panicle^{-1} (Table 6). The highest unfilled grainspanicle^{-1} (101.70) was observed from treatment combination of T_1V_3 again the lowest (17.67) was recorded from treatment combination of T_1V_5.

4.15 Weight of 1000 grains

Statistically significant variation was recorded for weight of 1000 seeds due to flag leaf removal (Table 5). The highest weight of 1000 seeds (27.40 g) was found from T_2, whereas the lowest weight (23.83 g) was recorded from T_1 (Table 5). Alim*et al.*,(1993) reported that better results are obtained from early transplanting than late transplanting. Weight of 1000 seeds varied significantly for different rice varieties (Table 5). The highest weight of 1000 seeds (28.55 g) was recorded from V_4, On the other hand, the lowest weight (21.56 g) was observed from V_6 (Table 5). 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 and observed that IR36 gave the highest 1000 grain weight (21.07g). Wang *et al.* (2006) reported that compared with conventional cultivars, the hybrids had heavier seeds. Combined effect of flag leaf removal and rice varieties showed significant variation on weight of 1000 seeds (Table 6). The highest weight of 1000 seeds (30.27 g) was found from treatment combination of T_2V_4 and the lowest (22.62 g) was recorded from treatment combination of T_1V_6.

After harvesting 1000 grains weight from leaf cut plant was measured and significant reduction of weight was observed compare to 1000 grains weight of the control plant.

Table 5. Effect of flag leaf clipping and variety on yield in the six rice varieties

Treatment /variety	Effective tillers $hill^{-1}$		Filled grain $panicle^{-1}$		Unfilled grains $panicle^{-1}$		Weight of 1000 grains	
T1	11.56	B	134.00	b	52.00	a	23.83	b
T2	12.50	A	169.10	a	23.00	b	27.40	a
$LSD_{(0.05)}$	0.75		12.23		5.21		0.33	
V_1	12.83	B	138.00	cd	27.50	d	27.43	b
V_2	11.33	C	169.70	b	41.00	b	24.60	d
V_3	11.00	C	139.70	cd	60.33	a	24.82	d
V_4	15.17	A	179.70	a	39.00	bc	28.55	a
V_5	12.67	B	146.00	c	19.50	e	26.74	c
V_6	9.17	D	136.30	d	37.67	c	21.56	e
$LSD_{(0.05)}$	0.69		9.32		2.28		0.40	
CV%	4.78		4.29		5.08		2.01	

In a column, mean values having same letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05 level of significance. V_1 =BRRI hybriddhan1, V_2=BRRI hybriddhan2, V_3= Heera2, V_4= Heera4, V_5= Nobin, V_6= Moyna; T_1= Flag leaf cutting, T_2= Control.

Table 6. Interaction effect of flag leaf clipping and variety on yield in the six rice varieties

Treatment combination	Effective tillers $hill^{-1}$		Filled grain $panicle^{-1}$		Unfilled grains $panicle^{-1}$		Weight of 1000 grains	
T_1V_1	12.67	C	124.00	gh	37.00	e	25.73	e
T_1V_2	11.33	D	142.00	h	52.67	c	22.73	h
T_1V_3	10.33	E	145.70	de	101.70	a	23.05	gh
T_1V_4	15.00	Ab	158.30	cd	47.00	d	26.83	d
T_1V_5	11.00	De	126.00	fg	17.67	h	24.97	f
T_1V_6	9.00	F	138.00	ef	56.00	b	22.62	h
T_2V_1	13.00	C	152.00	d	18.00	h	29.12	b
T_2V_2	11.33	D	227.30	a	29.33	f	26.47	d
T_2V_3	11.67	D	133.70	efg	19.00	gh	26.55	d
T_2V_4	15.33	A	201.00	b	31.00	f	30.27	a
T_2V_5	14.33	B	166.00	c	21.33	g	28.48	c
T_2V_6	9.33	F	134.70	efg	19.33	gh	23.47	g
$LSD_{(0.05)}$	0.97		13.19		3.23		0.56	
CV%	4.78		4.29		5.08		2.01	

In a column, mean values having same letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05 level of significance. V_1 = BRRI hybriddhan1, V_2= BRRI hybriddhan2, V_3= Heera2, V_4= Heera4, V_5= Nobin, V_6= Moyna; T_1= Flag leaf cutting, T_2= Control.

4.16 Dry weight

Statistically significant variation was recorded for dry weight of rice due to removal (Table 7). The highest dry weight of rice (4.57 tha^{-1}) was recorded from T_2, whereas the lowest (3.67 tha^{-1}) was recorded from T_1.

Dry weight of rice varied significantly for different rice varieties (Table 7). The highest dry weight of rice (4.83 tha^{-1}) was observed from V_4, On the other hand, the lowest (3.06 tha^{-1}) was observed from V_6.

Interaction effect of flag leaf cutting and rice varieties showed significant variation on dry weight of rice yield (Table 8). The highest dry weight of rice (5.25 tha^{-1}) was observed from treatment combination of T_2V_4, while the lowest (2.55 tha^{-1}) was recorded from treatment combination of T_1V_6.

4.17 Grain yield

Statistically significant variation was recorded for grain yield due to removal (Table 7). The highest grain yield (5.70 t ha^{-1}) was observed from T_2, whereas the lowest (4.73 t ha^{-1}) was recorded from T_1 (Table 7). These results agrees with the results of Nafziger (1994), in that an optimum planting date exists and the planting before or after that optimum results in yield reduction of crops. Singh *et al*., 1995; Patel *et al*., 1987 reported that grain yield of rice markedly declined with delayed planting. These results are in agreement with earlier reports on the contribution of flag leaf and top three leaves to grain yield (Yoshida, 1981; Ray *et al.*, 1983; Misra, 1986; 1987, Misra and Misra, 1991).

Grain yield varied significantly for different rice varieties (Table 7). The highest grain yield (6.01 t ha was observed from V_4, whereas the lowest (4.12 tha^{-1}) was observed from V_6 (Table 7). Swain *et al.* (2006) reported that the control cultivar IR64, with high translocation efficiency and 1000-grain weight and lowest spikelet sterility recorded a grain yield of 5.6 tha^{-1} that was statistically similar to the hybrid line PA6201. Xie *et al.* (2007) reported different yield for different variety.

Interaction effect of removal and rice varieties showed significant variation on grain yield (Table 8). The highest grain yield (6.47 tha^{-1}) was found from treatment combination of T_2V_4 and the lowest (3.61 tha^{-1}) was recorded from treatment combination of T_1V_6.

4.18 Straw yield

Statistically significant variation was recorded for dry straw yield due to removal (Table 7). The highest dry straw yield (7.29 t ha^{-1}) was recorded from T_2, whereas the lowest (5.84 t ha^{-1}) was recorded from T_1.

Straw yield varied significantly for different rice varieties (Table 7). The highest straw yield (7.44 t ha^{-1}) was observed from V_4, which were statistically identical (6.50 and 6.48 t ha^{-1}) to V_2 and $V_{3,}$ which were statistically followed (6.41 and 6.44 t ha^{-1}) by V_1 and V_5. On the other hand, the lowest (6.11 t ha^{-1}) was observed from V_6.

Interaction effect of flag leaf cutting and rice varieties showed significant variation on straw yield (Table 8). The highest straw yield (8.01 t ha^{-1}) was observed from treatment combination of T_2V_4, while the lowest (5.19 t ha^{-1}) was recorded from treatment combination of T_1V_2.

4.19 Biological yield

Statistically significant variation was recorded for biological yield due to flag leaf cutting (Table 7). The highest biological yield (12.98 t ha^{-1}) was observed from T_2, while the lowest (10.57 t ha^{-1}) was found from T_1.Kainth and Mehra, 1985 reported that when transplanting is delayed beyond normal period, the grain development is very poor which results in more quantity of under developed grains and ultimately severe reduction in yield.

Biological yield varied significantly for different rice varieties. The highest biological yield (13.45 t ha^{-1}) was recorded from V_4, which were statistically identical (12.11 t ha^{-1}) to V_1 and followed (11.95 t ha^{-1}) by V_5, whereas the lowest (10.23 t ha^{-1}) was found from V_6.

Combined effect of flag leaf clipping and rice varieties showed significant variation on biological yield (Table 8). The highest biological yield (14.48 t ha^{-1}) was attained from treatment combination of T_2V_4 again the lowest (8.89 t ha^{-1}) was found from treatment combination of T_1V_6.

Table 7. Effect of flag leaf clipping and variety on yield of the six rice hybrid varieties in *Boro* season

Treatment /variety	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
T1	4.73 B	5.84 b	10.57 b
T2	5.70 A	7.29 a	12.98 a
LSD(0.05)	0.18	0.24	0.26
V_1	5.71 b	6.41 bc	12.11 b
V_2	4.94 d	6.50 b	11.44 c
V_3	5.00 d	6.48 b	11.48 c
V_4	6.01 a	7.44 a	13.45 a
V_5	5.52 c	6.44 bc	11.95 b
V_6	4.12 e	6.11 c	10.23 d
LSD(0.05)	0.11	0.34	0.37
CV%	2.34	4.36	2.83

In a column, mean values having same letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05 level of significance. V_1 = BRRI hybriddhan1, V_2= BRRI hybriddhan2, V_3= Heera2, V_4= Heera4, V_5= Nobin, V_6= Moyna; T_1= Flag leaf cutting, T_2= Control.

Table 8. Interaction effect of flag leaf removal and variety on yield of the six rice hybrid varieties in *Boro* season

Treatment combination	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
T_1V_1	5.25 e	6.06 c	11.31 de
T_1V_2	4.43 h	5.19 e	9.63 g
T_1V_3	4.52 gh	5.79 cd	10.31 f
T_1V_4	5.54 d	6.87 b	12.41 c
T1V_5	5.05 f	5.82 cd	10.87 ef
T_1V_6	3.61 i	5.28 de	8.89 h
T_2V_1	6.16 b	6.75 b	12.91 bc
T_2V_2	5.45 d	7.80 a	13.25 b
T_2V_3	5.48 d	7.17 b	12.65 bc
T2V4	6.47 a	8.01 a	14.48 a
T_2V_5	5.99 c	7.05 b	13.04 bc
T_2V_6	4.61 g	6.93 b	11.57 d
LSD (0.05)	0.15	0.59	0.63
CV%	2.34	4.63	2.83

In a column, mean values having same letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05 level of significance. V_1 = BRRI hybriddhan1, V_2= BRRI hybriddhan2, V_3= Heera2, V_4= Heera4, V_5= Nobin, V_6= Moyna; T_1= Flag leaf cutting, T_2= Control.

Chapter V

SUMMARY AND CONCLUSION

The experiment was conducted at the Experimental Field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during *Boro* season (November 2017 to May, 2018) to effect of flag leaf clipping on growth and yield of six hybrid rice varieties. The experiment comprised of two factors. Factor (main plot) A: 1. Flag leaf removal, 2. Control, and Factor (sub-plot) B: V_1 = BRRI hybriddhan1, V_2= BRRI hybriddhan2, V_3= Heera2, V_4= Heera4, V_5= Nobin, V_6= Moyna. The experiment was laid out in factorial Split-plot Design with three replications. Data on different physiological characters, yield components and yield were recorded and significant variation was observed.

At harvest, the tallest plant (115.20 cm) was recorded from Moyna which was statistically similar (128.7 cm) with BRRI hybriddhan2, whereas the shortest plant (99.43 cm, respectively) was found from Nobin. The maximum number of leaf (67.33) was observed from Heera4 which were following (66.67and 65.67) with BRRI hybrid dhan1 and BRRI hybriddhan2, whereas the minimum number of leaf (57.67) from Moyna. The highest flag leaf area (81.61 cm^2) was observed from Heera4, penultimate leaf and lower leaf are (78.98 cm^2 and 46.95 cm^2, respectively) was observed from BRRI hybriddhan2, while the lowest leaf area (48.37 cm^2, 52.42 cm^2 and 20.55 cm^2 respectively) was found from Moyna.

Nobin takes the minimum days (75) for the panicle initiation while the maximum days (92) requires for panicle initiation in BRRI hybriddhan2. The highest days (104) require for the booting of rice plant in BRRI hybriddhan2 while the shortest days (85) was recorded in Nobin among all rice varieties. Nobin and Heera2 took the minimum days (89) and maximum time days (111), respectively for the emergence of panicle among all genotypes. Flowering in rice progressively varied due to varietal effect. The earliest 50% flowering (98 days) was recorded in Heera4 while the maximum delaying flowering (116 days) was recorded by BRRI hybrid dhan2 among all of the hybrid rice varieties.

Heera4 took 103 days and BRRI hybriddhan2maximum days (124) for milky stage among all the hybrid rice varieties.Among all genotypes, Heera4 produced earlier (112 days) and BRRI hybrid dhan2 and Heera2 achieved milky stage late (132 days).

BRRI hybrid dhan2 and Heera2 took the maximum days (145) to reach maturity. Heera4 (123 days) reached the maturity earlier compared to the rest of the hybrid varieties.

The maximum tillers hill^{-1}(12.33) was observed from Heera4 which was similar (9.67) with BRRIhybriddhan1 and BRRIhybriddhan2, whereas the minimum spikelet (9.33) from Moyna. The maximum number of effective tillers hill^{-1} (12.5) was found from T_2, whereas the minimum number (11.56) was found from T_1. The maximum number of effective tillers hill^{-1} (15.17) was observed from V_4 (Nobin), and the minimum number (9.16) was observed from V_6 (Moyna). The maximum number of effective tillers hill^{-1} (15.33) was found from treatmentcombination of T_2V_4, while the minimum number (9.00) was observed from treatment combination of T_1V_6.

Significant variation was recorded for chlorophyll content (SPAD value) of penultimate leaf at 15 days after heading. The highest chlorophyll content (SPAD value) in amount (46.5) was found from T_1, whereas the lowest weight (43.38) was recorded from T_2. Duration of grains filling was significantly different in both controls and flag leaf removal treatment regardless of variety. Rice plant required 31.83 days for grain filling in flag leaf clipping treatment and around 28.40 days in control, respectively to fill the grains. It might be happened due to slow supply of assimilate to the grain.

The highest filled grains panicle^{-1} (169.10) was recorded from T_2, whereas the lowest (134.05) was obtained from $T_{1.}$ The highest filled grains panicle^{-1} (179.70) was recorded from V_4, which were statistically identical (169.65) to V_2, whereas the lowest (136.35) was found from V_6. The highest filled grains panicle^{-1} (227.30) was recorded from treatment combination of T_2V_2, while the lowest (112.91) was found from treatment combination of T_1V_2.

The highest unfilled grains panicle^{-1} (52.00) was recorded from T_1, whereas the lowest (23.00) was recorded from T_2. The highest unfilled grains panicle^{-1}(60.33) was observed from V_3, while the lowest (27.50) was observed from V_1. The highest unfilled grains panicle^{-1} (101.70) was observed from treatment combination of T_1V_3 again the lowest (17.67) was recorded from treatment combination of T_1V_5.

The highest weight of 1000 grains (27.57 g) was found from T_2, whereas the lowest weight (23.80 g) was recorded from T_1. The highest weight of 1000 grains (28.58 g) was recorded from V_4, On the other hand, the lowest weight (11.56 g) was observed from V_6. The highest weight of 1000 grains (30.27 g) was found from treatment combination of T_2V_4 and the lowest (22.62 g) was recorded from treatment combination of T_1V_6.

The highest grain yield (4.70 t ha^{-1}) was observed from T_2, whereas the lowest (3.73 tha^{-1}) was recorded from T_1. The highest grain yield (5.01 tha was observed fromV_4, which were statistically followed (4.00 and 3.94 t ha^{-1}) by V_3 and V_4, whereas the lowest (3.12 tha^{-1}) was observed from V_6. The highestgrain yield (5.47 tha^{-1}) was found from treatment combination of T_2V_4 and the lowest (2.61 tha^{-1}) was recorded from treatment combination of T_1V_6.

The highest straw yield (7.29 tha^{-1}) was recorded from T_2, whereas the lowest (5.84 tha^{-1}) was recorded from T_1. The highest straw yield (7.44 tha^{-1}) was observed from V_4, which were statistically identical (6.50 and 6.48 t ha^{-1}) to V_2 and $V_{3,}$ which were statistically followed (6.41 and 6.44 t ha^{-1}) by V_1 and V_5. On the other hand, the lowest (6.11 t ha^{-1}) was observed from V_6. The highest straw yield (8.01 tha^{-1}) was observed from treatment combination of T_2V_4, while the lowest (5.28 tha^{-1}) was recorded from treatment combination of T_1V_6.

The highest biological yield (11.98 tha^{-1}) was observed from T_2, while the lowest (9.57 tha^{-1}) was found from T_1. The highest biological yield (12.45 tha^{-1}) was recorded from V_4, which were statistically identical (11.11 tha^{-1}) to V_1 and followed (10.95 tha^{-1}) by V_5, whereas the lowest (9.23 tha^{-1}) was found from V_6. The highest biological yield (13.48 tha^{-1}) was attained from treatment combination of T_2V_4 again the lowest (7.87 tha^{-1}) was found from treatment combination of T_1V_6.

Conclusion

- Heera4 provided the highest yield (5.54 and 6.49 tha^{-1}) at leaf cutting and control condition among the studied hybrid varieties.On an average, grain yield reduced average 22.5% due to cutting of flag leaf.
- SPAD value (chlorophyll and nitrogen content) in penultimate leaveswere increased from 1.35% to 17.27% and grain filling duration increased 4.5 day to 6.25 days due to removal of flag leaf in the studied varieties.

Recommendation

- Heera4 can be cultivated to get higher yield in *Boro* season.
- For wider acceptability, the same experiment should be repeated at different agro-ecological zones of the country

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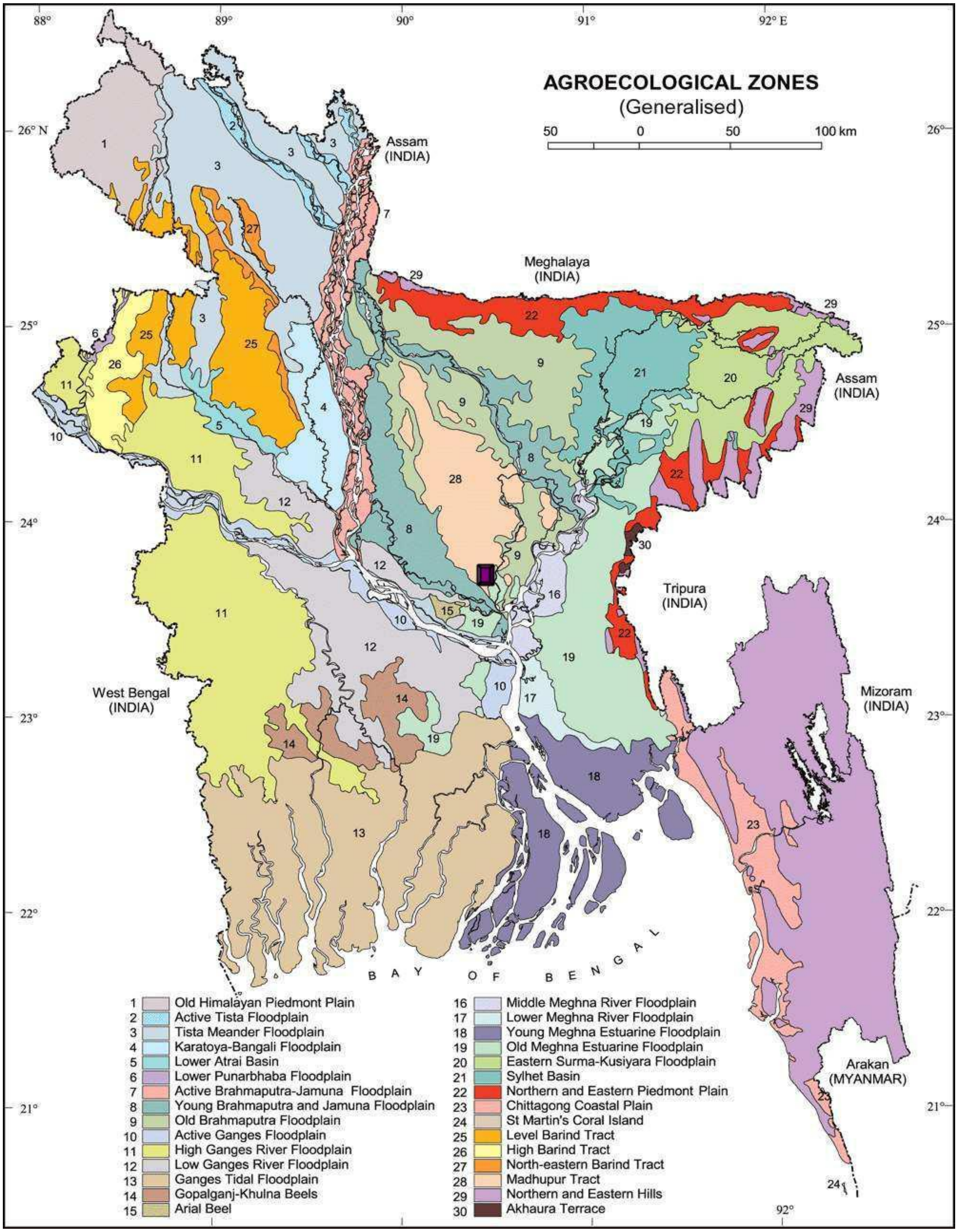
APPENDICES

Appendix I. The Map of the experimental site



■ **The experimental site under study**

Appendix II. Monthly records of air temperature, relative humidity, rainfall Andsunshine during the period from November 2017 to February, 2018

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)	Sunshine (Hours)
		Max.	Min.	Avg.			
2017	December	28.2	13.5	20.9	79	8	3.8
2018	January	24.5	11.5	18.0	72	6	5.7
2018	February	33.1	12.9	23.0	55	10	8.1
2018	March	33.6	15.3	24.5	63	43	7.5
2018	April	36.0	21.20	28.6	65	86	9.5
2018	May	35.8	24.6	30.2	72	92	9.6

Source: Bangladesh Meteorological Department (Climate division), Agargaon, 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 experimentalfield

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

B. Physical and chemical properties of the initialsoil

Characteristics	Value
% Sand	26
% Silt	43
% clay	31
Textural class	Sandy loam
pH	5.9
Cation 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

Appendix IV. Analysis of variance of the data leaf area index of different rice varieties

Source of variation	df	Mean square		
		Leaf area index		
		Flag leaf size	Penultimate leaf size	lower leaf size
Replication	2	167.774	180.634	5.167
Factor (Variety)	5	384.060*	329.211*	253.419*
Error	10	34.689	30.475	30.701

Appendix V. Analysis of variance of the data on plant height, leaf number of heading, spikelet panicle^{-1} of different rice varieties

Source of variation	df	Mean square		
		Plant height	leaf number of heading	Spikelet panicle^{-1}
Replication	2	22.341	88.389	282.167
Factor (Variety)	5	418.868*	42.889*	6457.600*
Error	10	21.667	3.522	17.767

Appendix VIa. Analysis of variance of the days to different stages in hybrid rice varieties

Source of variation	df	Mean square		
		PI stage (days)	Booting stage (days)	PE stage (days)
Replication	2	2.099	0.122	1.087
Factor A	1	18.777*	26.283*	32.624*
Error	30	0.116	1.126	2.544

Appendix VIb. Analysis of variance of the days to different stages in hybrid rice varieties

Source of variation	df	Mean square			
		50% flowering (days)	Milky stage (days)	Dough stage (days)	Maturity stage (days)
Replication	3	0.120	0.591	1.051	1.022
Factor A	8	7.770*	9.40**	8.300*	10.684*
Error	24	2.266	10.012	13.107	2.871

Appendix VII. Analysis of variance of the data on chlorophyll content (SPAD Value) and yield components of different hybrid rice varieties

Source of variation	df	Mean square			
		Chlorophyll content (SPAD Value)	Number of effective tillers hill $^{-1}$	Filled grain panicle-[1]	Unfilled grains panicle -[1]
Replication	2	19.996	35.028	649.694	235.083
Treatment (A)	1	87.298*	8.028*	11095.11*	7569.000*
Variety (B)	5	9.329*	24.76*	2047.11*	1151.867*
Interaction (A×B)	5	5.814*	2.361*	3079.37*	1292.13*
Error	22	0.266	0.331	60.634	3.629

Appendix VIII. Analysis of variance of the data on yield components of different hybrid rice varieties

Source of variation	df	Mean square		
		Weight of 1000 seeds	Weight of rice yield	Dry weight of rice yield
Replication	2	7.250	0.260	0.260
Treatment (A)	1	114.633*	7.290*	7.290*
Variety (B)	5	37.469*	2.416*	2.416*
Interaction (A×B)	5	0.043*	0.024*	0.024*
Error	22	0.110	0.008	0.008

Appendix VIII. Analysis of variance of the data on grain yield, weight of straw yield, dry weight of straw yield and biological yield of different rice varieties

Source of variation	df	Mean square			
		Grain yield	Weight of Straw yield	Dry weight of Straw yield	Biological yield
Replication	2	0.530	21.908	2.081	4.680
Treatment (A)	1	8.362*	74.132*	18.922*	52.442
Variety (B)	5	2.733*	14.007*	1.238*	6.651
Interaction (A×B)	5	0.003*	5.033*	0.634*	0.708
Error	22	0.008	0.577	0.082	0.093

** and *significant at 5% and 1% level of probability, respectively