EFFECT OF FLAG LEAF REMOVAL ON GROWTH AND YIELD OF SIX MODERN RICE VARIETIES IN *AMAN* SEASON

A THESIS

BY

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CERTIFICATE

This is to certify that the thesis entitled **"EFFECT OF FLAG LEAF REMOVAL ON GROWTH AND YIELD OF SIX MODERN RICE VARIETIES IN AMAN 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 **SALMA AKTER**, Registration No. **11-04518** 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: June, 2017

Dhaka, Bangladesh

Prof. Dr. Md. Moinul Haque

Supervisor

Dedicated to

My

Beloved Parents

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Salma Akter

Abstract

The experiment was conducted at the Experimental Field of Agricultural Botany Department, Sher-e-Bangla Agricultural University, Dhaka-1207, Bangladesh, during July to November, 2016 to study effect of flag leaf removal on physiological characteristics and yield of six modern rice varieties in *Aman* season. The six varieties are BARI Dhan32, BARI Dhan33, BARI Dhan39, BARI Dhan54, BARI Dhan56 and BARI Dhan62. The experiment was laid out in Randomized Complete Block Design with four replications. All the test varieties exhibited superiority in control condition. At harvest, the tallest plant (130.2) was recorded from BARI dhan54 and higher individual flag leaf area (81.61cm^2) was observed from BARI dhan54. Penultimate leaf area and third leaf area (78.98 cm^2 and 46.95 cm^2, respectively) were obtained from BARI dhan33. The highest number of leaves and spikelet panicle^{-1} were observed from BARI dhan54. Among test *Aman* rice varieties, higher grain yield and biological yield were also achieved from BARIdhan54. Chlorophyll content (SPAD value) in penultimate leaf after 15 days after heading, grain filling duration, yield contributing characters and yield were investigated after removal of flag leaf. Irrespective of variety, all the studied parameters were exhibited superiority in control treatment. Chlorophyll content in penultimate (1.18 % to 16.72 %) and grain filling duration was increased (4.6 to 6.2 days) due to removal 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 BARIdhan54 under control condition. The removal of the flag leaf reduced grain yield from 17.00 % to 27.70 % in the test *Aman* rice varieties.

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ABBREVIATIONS AND ACCORONYMS

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
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 one of the leading cereal crops in the world and staple food crop in Bangladesh. It is life for more than 60% of the world's population (Akter *et al*., 2014). It is grown in more than hundred countries with a total area of about 160 million hectares, producing more than 700 million tons every year. It is also a staple food for over half the world's population, particularly in South-east Asia with rapidly growing populations (Grist, 1988; IRRI, 2009). In Asia, more than 90% of all produced rice has been consumed (FAO, 2006). Rice contributes on an average 20% of apparent calorie intake of the world and 30% of Asian populations (Hien *et al.*, 2006).

Rice is the main food and major energy source for the population of Bangladesh which covers 80% of the total cropped area as about 12 million hectares (BRRI 1999). In Bangladesh, 10.4 million hectares of land is used for rice production which is about 85% of total cropped area, with annual production of 30.42 million tons (BBS, 2014). Bangladesh ranks 4th in both area and production and 6th in the production of per hectare yield of rice (Sarkar *et al.*, 2016). Rice is grown in Bangladesh in three distinct growing seasons namely Aus, Aman and Boro and Aman rice covers the area of 5.66 million hectares with a production of 13.3 million tons. According to FAO (2014) in Bangladesh, the average yield of rice is about 2.92 t ha^{-1} which is very low compared to other rice growing countries of the world, like China (6.30 t ha^{-1}), Japan (6.60 t ha^{-1}) and Korea (6.30 t ha^{-1}). The crop production has to be increased at least 60% by 2020 to meet up food requirement of the increasing population (Masum, 2009). Population and demand for the grain have been on the increase while area cultivated to the crop showing negative trend. Soil fertility has decreased because of shorter fallow periods and the latter has not been compensated for by use of fertilizer or organic manure. Therefore yields have been fluctuating with an overall negative trend. The resulting food shortages have led to increased rice importation that in turn has drained the country's foreign exchange.

Economic implications include high consumer prices, balance of payments problems, and external debt burden. One of the important aims for growing rice is the yield. However, grain yield is a complex trait and genetic control of grain yield is a series of complex biochemical and physiological processes (Ashraf *et al.*, 1994). Photosynthesis of carbohydrate is the primary source of grain yield in rice. Grain filling is sustained by current photosynthesis of the upper parts of the plant, i.e. the flag leaf and penultimate leaves and the ear (Tambussi *et al.,* 2007). Plant leaves being the organ of photosynthesis is considered to be the important determinant and characterized for higher photosynthetic capacities (Asana, 1968).

Flag leaves play a major role in synthesis and translocation of photo-assimilates to the rice grains and affecting grain yield. The uppermost leaf below the panicle is the flag leaf that provides the most important source of photosynthetic energy during reproduction. Flag leaf is metabolically active and has proved that the flag leaf, stem and head are the closest source food to the grain (Asana, 1968; Ramadas and Rajendrudu, 1977). Flag leaf assigned an important role in terms of supply of photosynthates to the grains (Asana, 1968), in grain yield (Sheela *et al.*, 1990; Raj and Tripathi, 2000) and in enhancing productivity (Padmaja and Rao, 1991). The grain yield and yield related traits were positively related to flag leaf area (Ashrafuzzaman *et al.,* 2009). The top three leaves contribute most to grain yield (Yoshida, 1981; Misra, 1987). Intensive study was done on rice yield after cutting flag leaf and nearby leaf (Abou khalifa *et al.,* 2008). Considering the importance of leaf on grain yield it is prerequisite to analyze the morphological and the physiological characteristics of functional leaves to improve grain yield in rice (Yue *et al.,* 2006). Removal of the rice flag leaf at any stage after panicle emergence was reported to cause significant reduction in grain yield (Singh and Ghosh 1981). Another report showed that flag leaf contributed to as much as 45% rice grain yield and, when removed, was the major component for yield loss

(Abou-Khalifa *et al.*, 2008). According to Mae (1997), 60–90% of total carbon in the panicles at harvest is derived from photosynthesis after heading, while 80% or more of nitrogen (N) in the panicles at harvest is absorbed before heading and remobilized from vegetative organs. In wheat, up to 34.5% grain yield reduction was reported after flag leaf removal at the heading stage (Mahmood and Chowdhury 1997), while Birsin (2005) showed that flag leaf removal resulted in approximately 13, 34, 24% reduction in grain per spike, grain weight per spike and 1000-grain weight, respectively, and 2.8% increase in grain protein contents. Similarly, rice flag leaves are also believed to be a major source of remobilized minerals for the grains, and recent reports tried to correlate gene expression levels on flag leaves with concentration of mineral nutrients in rice grains (Narayanan *et al.*, 2007, Sperotto *et al.*, 2009). However, research work on the effect of flag and penultimate leaves (individually or combined) removal in yield formation of rice is still meagre in Bangladesh. But it is very important to elucidate the contribution of different leaves in yield formation of rice. Keep in mind the above circumstances, the present research work was carried out to achieve the following objectives-

Objectives

- To compare the morphological and physiological characteristics of six selected rice varieties in *Aman* season.
- To study the effect of flag leaf removal on penultimate leaf chlorophyll content, duration of grain filling, yield contributing characteristics and yield of the six rice varieties in *Aman* season.

CHAPTER II

REVIEW OF LITERATURE

Rice is the staple food more than three billion people in the world and around ninety per cent 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 and eating quality for regular consumption. Most of the high yielding rice varieties of Bangladesh have been developed by IRRI and BINA. Variety itself is the genetical factor which contributes a lot for producing yield and yield components. Different researcher reported the effect of rice varieties on yield contributing component and grain yield. However, some of the important and informative works and research findings to the available relevant reviews related to flag leaf cutting and varieties in the recent past have been presented and discussed under the following headings:

2.1 Growth parameters

An experiment was carried out at BINA (1998) to find out varietal performance of advance line (BINA 8-110-2-6) along with three check varieties - Iratom 24, BR26 and BRRI Dhan27. The result indicated that BINA 8-110-2-6 appeared similar to BRRI Dhan27 in terms of plant height.

Munoz et al. (1996) observed that IR8025A hybrid rice cultivar produced 16% longer plant than the commercial variety Oryzica Yacu-9. BINA (1993) evaluated the performance of four rice varieties (IRAATOM 24, BR14, BINA13 and BINA19) and the findings revealed that the varieties differed significantly in respect of plant height of rice.

BRRI (1991) recorded the plant height differed significantly among BR3, BR11, BR14, Pajam and Zagali varieties in the Boro season. Hosain and Alam (1991) found that the plant height in modern rice varieties BR3, BR11, BR14 and Pajam were 90.4, 94.5, 81.3 and 100.7 cm, respectively.

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, BansfulChikon) 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.

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, were 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.

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 were significantly affected in terms of dry matter and mentioned trait was more in hybrid Hb_2 than Hb_1.

An experiment was conducted by Hosain *et al.* (2014) at the research farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during Ausseason (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}).

Vegetative growth of Indica rice is more affected by time of transplanting than that of other type of rice (Langfield and Basinski, 1960). Time of transplanting has profound influence on the performance of different cultivars of photo and thermo-sensitive in nature (Takahashi *et al.*, 1967). The time between July 15 and August

15 is the best for transplantation of high yielding cultivars of transplant Aman rice in Bangladesh. However, better results are obtained from early transplanting than late transplanting (Alim *et al.,* 1993; Hedayetullah *et al.,* 1994). It was revealed that mildly photoperiod-sensitive cultivars had a reduced likelihood of encountering low temperature compared with photoperiod-insensitive cultivars. The benefits of photoperiod sensitivity include greater sowing flexibility and reduced water use as growth duration is shortened when sowing is delayed (Farrell *et al.,* 2006).

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

Hosain *et al.* (2014) reported that dry matter production, leaf area index, leaf area duration (LAD), crop growth rate (CGR), net assimilation rate (NAR) and relative growth rate (RGR) are ultimately reflected in higher grain yield of rice. Crop growth rate is the most critical growth attributes for rice yield under intensive management during the latter half of the reproductive period (Horie, 2001). The CGR at this stage critically affects final spikelet number by regulating spikelet degeneration, potential single-grain weight by determining husk size, and grain filling by forming active sinks and determining endosperm cell number at initial grain filling. Early plating of hybrid rice, exhibited the maximum total and effective tillers per hill, leaf-area index, leaf-area duration, dry-matter accumulation, relative growth rate, fertile spikelets per panicle, 1000 grains weight and straw yields.

Hundal *et al.* (2005) observed the significant linear and exponential relationships between leaf area index and aboveground biomass and yield of rice. Planting time had direct influenced on above attributes.

If photosensitive varieties are transplanted a little early, their vegetative growth extended which resulted more plant height and leafy growth. Due to increased plant height, such varieties lodge badly when transplanted early. As a result, the grain yield from such a crop is reduced drastically. On the other hand, 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 (Kainth and Mehra, 1985).

Hossain and Alam (1991) reported that the growth characters like plant height, total tillers hill^{-1} and the number of grains panicle^{-1} differed significantly among BR3, BRll, BR14 and Pajam varieties of rice in *Boro* season. Idris Matin (1990) conducted an experiment with six varieties and observed that panicle length differed among varieties and it was greater in IR 20 than in indigenous and high yielding varieties.

Baloch *et al.* (2002) 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 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}, filled grains panicle^{-1} and 1000 grain weight. The mutant strains Jajai 77-30 produced significantly higher grain yield at all spacing as compared with all other entries.

2.2 Significance of flag leaf

Leaf position on the plant is one of the major factors affecting the efficiency of leaf photosynthesis. In most of the cereals, the flag leaf is most active. The flag leaf stays longest on the plant and makes a major contribution to the grain yield in cereals.

The flag leaf plays a very important role in grain filling in small grain crops such as rice, wheat, barley, oats, etc. because of its position on the culm. It is the topmost leaf and as such it intercepts lot of radiation. Further, the translocation of assimilates from the flag leaf (source) to the panicle (reproductive sink) is enhanced by the proximity of the flag leaf to the sink. Thus flag leaf is considered as an activist leaf during the grain filling period. Thus flag leaf area could be a choosing factor for increasing rice grain yield. Flag leaves are characterized by long-term photosynthetic activity, which is particularly important during grain filling when the older leaves die off. Under favourable conditions, approximately 70 to 90 per cent of the total grain yield is derived from the photosynthates accumulated during grain filling period (Inoue *et al.,* 2004)

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

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

Mahmood and Chowdhry (1997) reported that in wheat 34.5 per cent grain yield reduction was reported after flag leaf removal at the heading stage. Revealed that flag leaf is the activist leaf at grain filling period and could be chosen as a factor for increasing grain yield of rice.

Flag leaf is of utmost importance in cereals like wheat it provides maximum amount of photosynthesis assimilates to be stored in grains. Yang *et al.* (2002) observed that poor grain filling of indica-japonica rice hybrids is related to poor translocation and partitioning of assimilates to the grains, resulting in more resources for vegetative growth.

Dutta *et al.* (2002) observed that there was a positive correlation between flag leaf angle and photosynthesis material translocation, and spikelets fertility increases also for increasing grain yield in rice. A greater flag leaf area will eventually help to increase photosynthetic efficiency by increasing production of photosynthesis which is then translocated into grains increasing their weight. Therefore flag leaf has a direct relationship to grain yield.

Birsin (2005) showed that flag leaf removal resulted in reduction in grain per spike, grain weight per spike and 1000 grain weight and increase in grain protein contents. Narayan *et al.* (2007) reported that flag leaves are believed to be a major source of remobilized minerals for the seeds. Khalifa *et al.* (2008) reported that flag leaf contributed to 45per cent rice grain yield and served as a major source for remobilized minerals for grains. In rice 60-90 per cent of the total carbohydrates in the panicles at harvest are derived from the photosynthesis after panicle initiation. Yan and Shi (2013) identified flag leaf soluble protein as one of the substances produced by the source which plays an important role in increasing the grain dry matter.

2.3 Yield and yield parameters

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. There were significant cultivar effects for all traits. 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.

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

Minjun *et al. (*2002) showed that during growth and development of wheat, the level of soluble protein content not only reflected the level of plant nitrogen metabolism, but also was regarded as an important indicator of the degree of leaf senescence, especially in wheat grain filling stage, increasing soluble protein content of flag leaf was conducive to the maintenance of the flag leaf growth and extending the photosynthetic function, so as to lay the substances basis for the accumulation of grain carbohydrates.

Therefore flag leaf has a direct relationship to grain yield (Riaz and Chowdhry, 2003). They also opined that high nitrogen fertilization level enhances the chlorophyll and carotenoid content of leaves.

An experiment was conducted by Haque and Biswash (2014) with five varieties of hybrid rice 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 and 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) carried out and 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 among the varieties, BRRI dhan52 produced the tallest plant (117.20 cm), whereas the lowest plant height by BRRI dhan57.

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 longest plant compared to the others.

BINA (1993) evaluated the performance of four varieties IRATOM 24, BR14, BINA13 and BINA19. They found that varieties differed significantly on panicle length and sterile spikelets panicle^{-1}. It was also reported that varieties BINA13 and BINA19 each had better morphological characters like more grains panicle^{-1} compared to their better parents which contributed to yield improvement in these hybrid lines of rice.

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.

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 t ha^{-1} that was statistically similar to the hybrid line PA6201.

Xie *et al.* (2007) found that Shanyou-63 variety gave the higher yield (12 t/ha) 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, BansfulChikon) 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.

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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, heavier seeds, resulting in an average yield increase of 7.27%.

Molla (2001) reported that Pro-Agro6201 (hybrid) had a significant higher yield than IET4 (86 (HYV), due to more mature panicles m^{-2}, higher number of filled grains panicle^{-1} and greater seed weight.

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 were 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 were crossed with improved high yielding cultivars Amol 3, PND160-2-1 and RNR1446 in all possible combinations and released in 1996 under the name Nemat, which gave an average grain yield of 8 t ha^{-1}, twice as much as local cultivars.

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. Chowdhury *et al.* (1993) reported that the cultivar BR23 showed superior performance over Pajam in respect of number of productive tillers hill^{-1}

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}.

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 July to November 2016 to effect of flag leaf cutting on growth and yield of some rice cultivars. The details of the materials and methods i.e. experimental period, location, soil and climatic 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 followed in this experiment has been presented under the following headings:

3.1 Description of the experimental site

3.1.1 Experimental period

The experiment was conducted at the period of July to November 2016.

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

3.1.3 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 details have been presented in Appendix II.

3.1.4 Climate condition

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

a. Removal at heading
b. Control (without removal)

Factor B: Different rice varieties: 6 rice varieties

SL. No	Treatment	Name
1	V_1	BARI Dhan-32
2	V_2	BARI Dhan-33
3	V_3	BARI Dhan-39
4	V_4	BARI Dhan-54
5	V_5	BARI Dhan-56
6	V_7	BARI Dhan-62

3.2.2 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. There were 36 plots for12 treatment combinations each of 3 replications. A set of 12 treatment combinations were assigned at random in 12 pots of each replication. The layout of the experiment presented in (Figure 1).

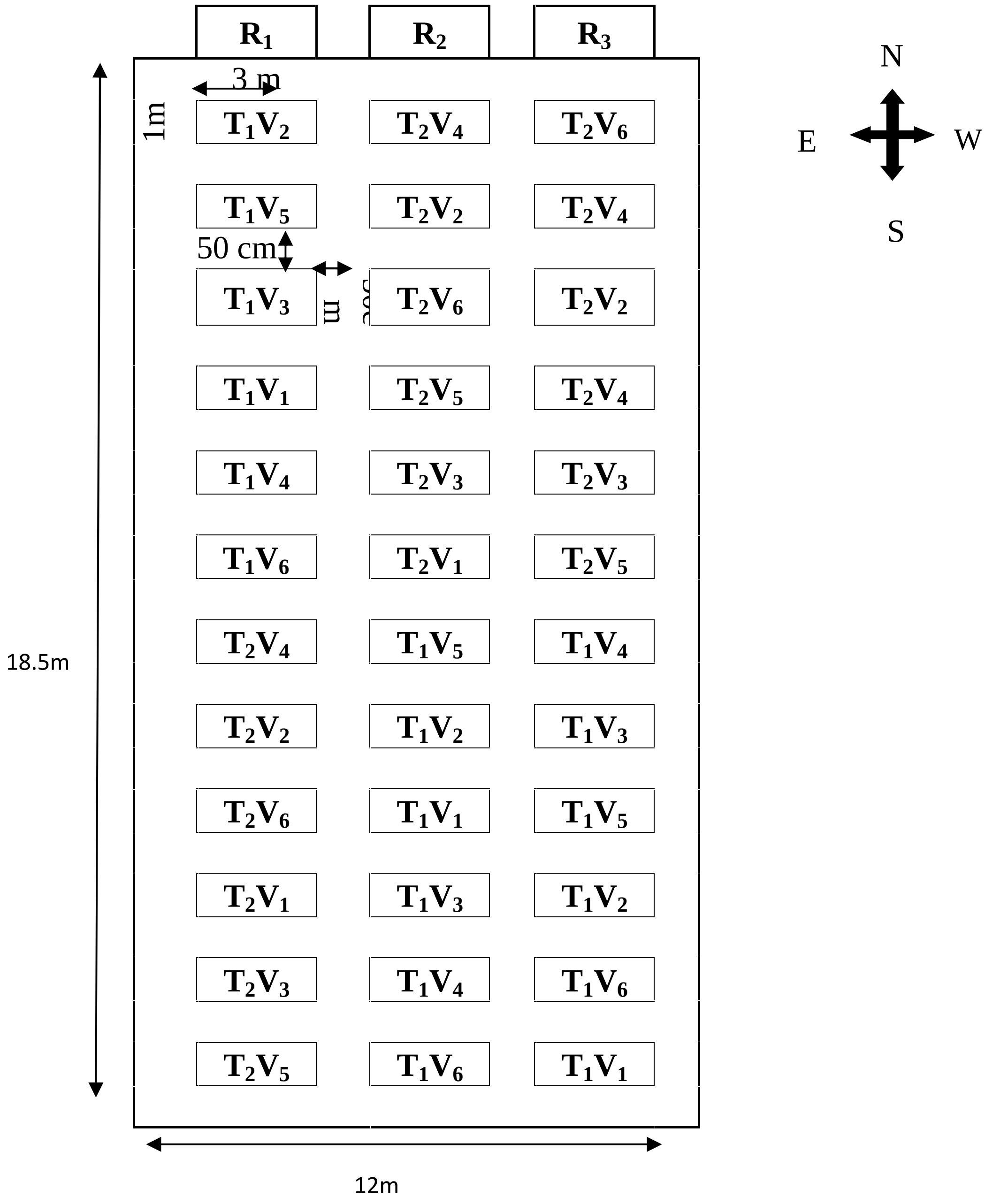

Figure 1. Layout of the experimental field

3.3 Growing of crops

3.3.1 Seed collection

The seeds of BRRI dhan-32, BRRI dhan-33, BRRI dhan-39, BRRI dhan-54, BRRI dhan-56 and BRRI dhan-62 were collected from Bangladesh Rice Research Institute (BRRI), Joydevpur, Gazipur. 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 Preparation of seedling nursery bed and seed sowing

As per BRRI recommendation seed bed was prepared with 1 m wide seed bed adding nutrients as per the requirements of soil. Seeds were sown in the seed bed on March 12, 2016 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 12th August 2016 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 February 28, 2015 and March 31, 2016 for transplant on the date of 12st March, 2016 and 12st April, 2016 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 Aftercare

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 pot 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 Observations

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 Plant height

Plant height was recorded at panicle initiation, booting, flowering and at harvest stages using the method described by Gomez (1972). The height was measured 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.

3.4.2 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

3.4.3 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.

3.4.4 Effective tillers 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.

3.4.5 Spikelets panicle^{-1}

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

3.4.6 SPADE value

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

3.4.7 Duration of grain filling

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

3.4.8 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.

3.4.9 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.

3.4.10 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.

3.4.11 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.

3.4.12 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}.

3.4.13 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}.

3.4.14 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.

3.6 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 conducted to study the effect of flag leaf removal on growth and yield of some rice varieties viz. BRRI dhan32, BRRI dhan33, BRRI dhan39, BRRI dhan54, BRRI dhan56 and BRRI dhan62. 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 of different rice variety showed statistically significant variation at harvest (Appendix V). At harvest, the tallest plant (130.2) was recorded from BARI dhan54 which was statistically similar (128.7 cm respectively) with BARI dhan33, whereas the shortest plant (99.43 cm, respectively) was found from BRRI dhan62 (Figure 2).

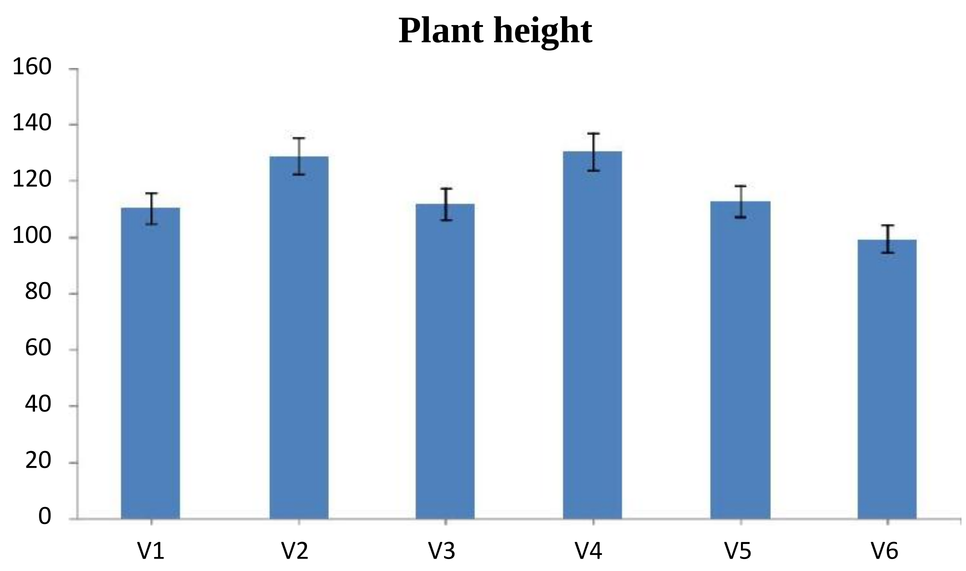

Figure 2. Effect of variety on plant height in the six rice varieties [Vertical bars indicate LSD values at 5% level.] V_1 =BARI Dhan32, V_2=BARI Dhan33, V_3=BARI Dhan39, V_4=BARI Dhan54, V_5=BARI Dhan56, V_6=BARI Dhan62.

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 program. Growth of rice is strongly influenced by genotype as well as environmental factors (BRRI, 2003). Jisan et al. (2014) reported that BRRI dhan52 produced 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 area

Leaf area of different rice varieties varied significantly of flag leaf, penultimate leaf and lower leaf, (Appendix IV). The highest flag leaf area index (81.61cm^2) was observed from BARI dhan54, penultimate leaf and third leaf are index (78.98 cm^2 and 46.95 cm^2, respectively) was observed from BARI dhan33, while the lowest leaf area (48.37 cm^2, 52.42 cm^2 and 20.55 cm^2, respectively) was found from BRRI dhan62 (Figure 3).

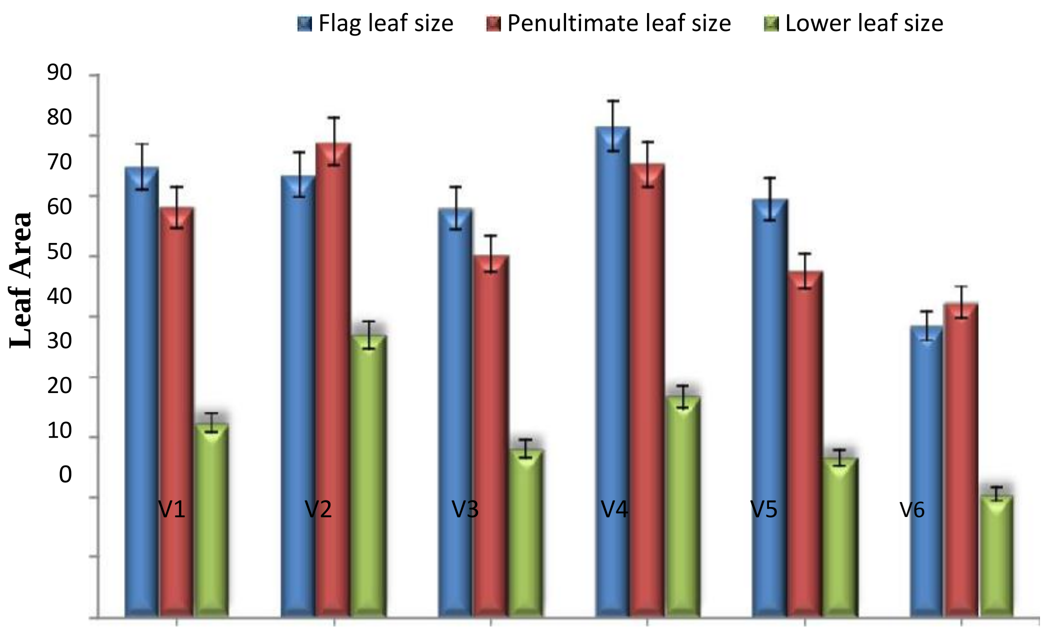

Figure 2. Effect of variety on leaf area in the six rice varieties [Vertical bars indicate LSD values at 5% level.] V_1 =BARI Dhan32, V_2=BARI Dhan33, V_3=BARI Dhan39, V_4=BARI Dhan54, V_5=BARI Dhan56, V_6=BARI Dhan62.

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 dhan52 produced the leaf area, while the lowest values of these parameters were produced by BRRI dhan57. Similar results also reported by Amin *et al.* (2006), Son *et al.* (1998) and Shaloie *et al.* (2014) from their earlier study.

4.3 Leaf number at heading

Leaf number at heading of different rice variety showed statistically significant variation under the present trial (Appendix V). The maximum number of leaf (67.33) was observed from BARI dhan 54 which were following (66.67and 65.67) with BARI dhan32 and BARI dhan33, whereas the minimum number of leaf (57.67) from BRRI dhan62 (Figure 4).

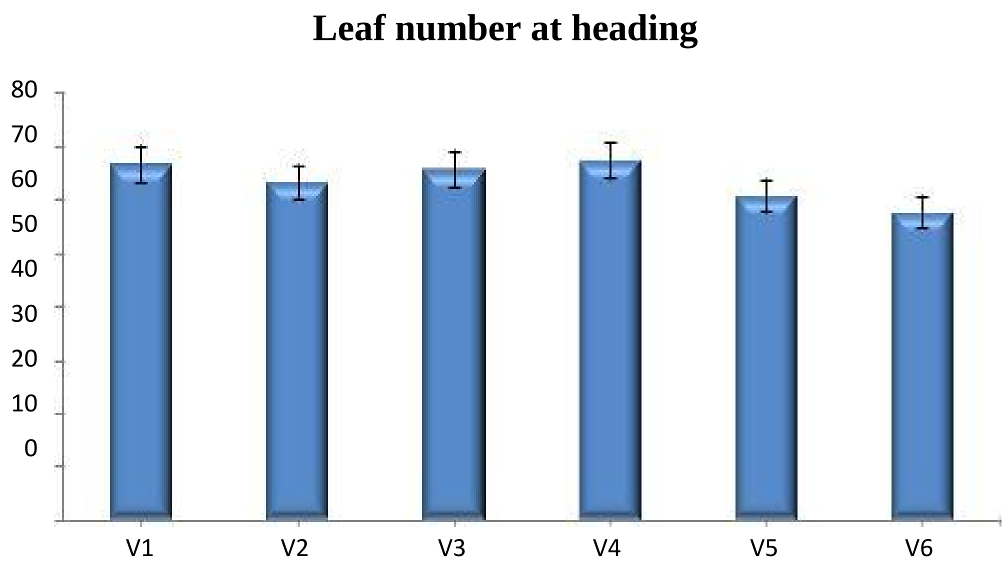

Figure 4. Effect of variety on leaf number of heading in the six rice varieties [Vertical bar represents LSD values at 5% level.] V_1 =BARI Dhan32, V_2=BARI Dhan33, V_3=BARI Dhan39, V_4=BARI Dhan54, V_5=BARI Dhan56, V_6=BARI Dhan62

4.4 Spikelet panicle^{-1}

Spikelet panicle^{-1} of different rice variety showed statistically significant variation under the present trial (Appendix V). The maximum spikelet (12.33) was observed from BARI dhan54 which was similar (9.67) with BARI dhan32 and BARI dhan33, whereas the minimum spikelet (9.33) from BRRI dhan62 (Figure 5).BINA (1993) they found that varieties differed significantly on panicle length and sterile spikelets panicle^{-1}. Bing et al. (2006) also found that potential yield and spikelet number were positively correlated with length, width and area of flag leaf.

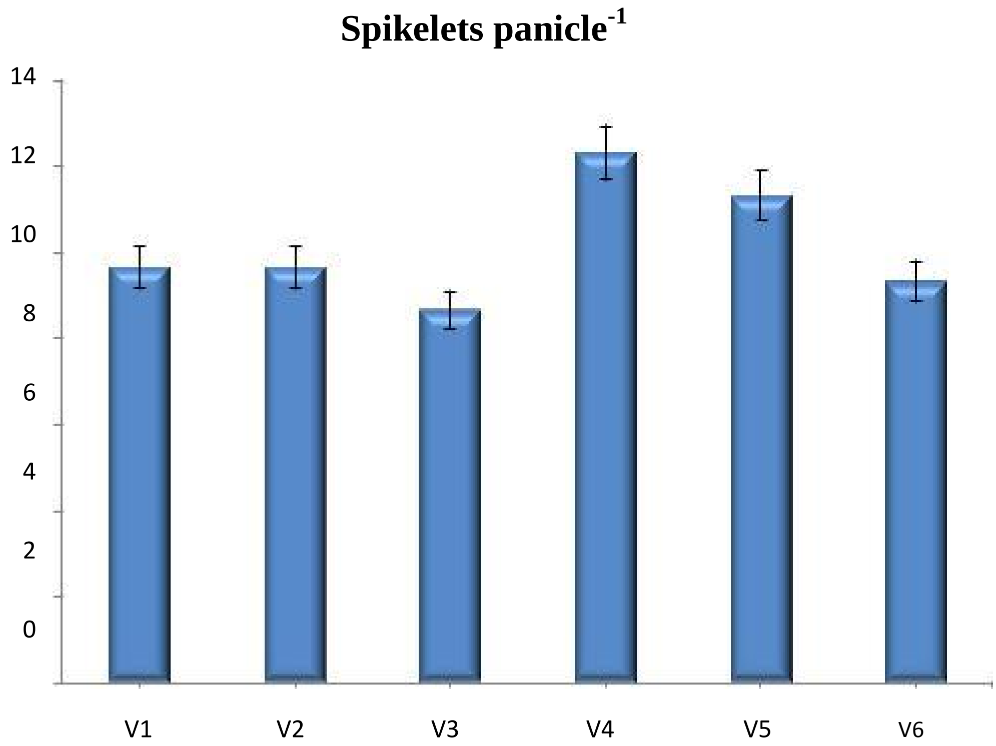

Figure 5. Effect of variety on spikelet panicle^{-1} in the six different rice varieties [Vertical bars are LSD values at 5% level.] V_1 =BARI Dhan32, V_2=BARI Dhan33, V_3=BARI Dhan39, V_4=BARI Dhan54, V_5=BARI Dhan56, V_6=BARI Dhan62

4.5 Effective tillers hill^{-1}

Significant variation was observed for number of effective tillers hill $^{-1}$ due to flag leaf removal (Appendix VI). 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 (Table 1). Probably delayed planted crop prevailed lesser time in favor of growing environment which might have minimum number of effective tillers hill^{-1}.

Number of effective tillers hill^{-1} varied significantly for different rice varieties (Appendix VI). The maximum number of effective tillers hill^{-1} (15.17) was observed from V_4 (BRRI dhan54), and the minimum number (9.16) was observed from V_6 (BRRI dhan62) (Table 1).

Interaction effect of flag leaf removal and rice varieties showed significant variation on number of effective tillers hill^{-1} (Appendix VI). The maximum number of effective tillers hill^{-1} (15.33) was found from treatment combination of. T_2V_4, while the minimum number (9.00) was observed from treatment combination of T_1V_6 (Table 2) The number of tiller per hill decreased rationally irrespective of all transplanting times after peak as tiller survival was negatively correlated to the maximum tiller number (Sarkar and Reddy, 2006) and mutual shading of the crop (Farrell *et al*., 2006).

4.6 Chlorophyll content (SPAD Value)

Statistically significant variation was recorded for chlorophyll content (SPAD value) of penultimate leaf at 15 days after heading (Appendix VII). The highest chlorophyll content (SPAD value) in amount (36.5) was found from T_1, whereas the lowest weight (33.38) was recorded from T_2 (Table 1). Leaf cutting increases chlorophyll (SPAD value) in the penultimate leaf. These points indicated a compensatory increase in photosynthetic efficiency in the remaining leaves as shown by Robinson *et al.* (1992). Similarly, Myers and Ferree (1983) 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 of varied significantly for different rice varieties (Table 2). The highest Chlorophyll content (36.52) was recorded from V_2, which was statistically similar with V_5 On the other hand, the lowest weight (33.83) was observed from V_6. Which were statistically similar with V_1 and V_3 (Table 1). Study showed that mean chlorophyll content among the cultivars varied significantly suggesting 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 (Appendix VI). The highest SPAD value (38.31) was found from treatment combination of T_1V_5 treatment combination and which was statistically similar with (37.7 and 37.22) was found T_1V_4 and T_1V_2, the lowest (32.48) was recorded from treatment combination of T_2V_6 treatment combination and which was statistically similar with (32.3) was recorded from T_2V_4 (Table 2).

4.7 Duration of grain filling

Table 1 showed that duration of grains filling was significantly different in both controls and flag leaf removal treatment regardless of variety. Rice plant requires about 33.75 days in flag leaf removal treatment and around 30.38 days in control, respectively to fill the grains. It might be happened duo to slow supply of assimilate to the grain.

Among the varieties the maximum days required for grains filling (33.34 days) was recorded from BRRI dhan33 whereas the minimum days required for Grains filling was attained from BRRI dhan39 which was 29.65 days (Table 1). 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 BRRI rice varieties (Table 2). Rice varieties viz. BRRI dhan32, BRRI dhan33, BRRI dhan39, BRRI dhan54, BRRI dhan56 and BRRI dhan62 plants took 28.37, 30.23, 30.83, 30.67, 28.30 and 29.87days, respectively for grain maturity under in control condition whereas it takes 33.00, 36.45, 31.67, 35.34, 34.33 and 35.13 days under flag leaf removal condition.

Table 1. Effect of flag leaf removal and variety on SPAD value in penultimate leaf and days to grain filling of the six rice varieties

Treatment /variety	Chlorophyll content (SPAD value)		Grain filling duration (days)	
T1	36.50	a	33.75	b
T2	33.38	b	30.38	a
LSD(0.05)	2.17		2.73	
V_1	34.20	b	30.67	c
V_2	36.52	a	33.34	a
V_3	33.73	b	31.25	bc
V_4	35.00	a	33.00	a
V_5	36.36	a	29.65	c
V_6	33.83	b	32.50	ab
LSD(0.05)	0.69		1.65	
CV%	4.78		4.29	

In a column, mean values having similar 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 =BARI Dhan32, V_2=BARI Dhan33, V_3=BARI Dhan39, V_4=BARI Dhan54, V_5=BARI Dhan56, V_6=BARI Dhan62

Table 2. Combined effect of flag leaf removal and variety on SPAD value in penultimate leaf and days to grain filling of the six rice varieties

Treatment combination	Chlorophyll content (SPAD value)		Days to grain filling	
T_1V_1	34.40	ef	33.00	d
T_1V_2	37.22	b	36.45	a
T_1V_3	36.16	c	31.67	e
T_1V_4	37.70	ab	35.34	b
T_1V_5	38.31	a	34.33	c
T_1V_6	35.18	de	35.13	b
T_2V_1	34.00	f	28.37	h
T_2V_2	35.82	cd	30.23	f
T_2V_3	31.29	h	30.83	ef
T_2V_4	32.30	g	30.67	fg
T_2V_5	34.40	ef	28.30	h
T_2V_6	32.48	g	29.87	g
LSD(0.05)	0.87		0.94	
CV%	1.48		4.78	

In a column, mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05 level of significance. V_1 =BARI Dhan32, V_2=BARI Dhan33, V_3=BARI Dhan39, V_4=BARI Dhan54, V_5=BARI Dhan56, V_6=BARI Dhan62; T_1= Flag leaf cutting, T_2=Control.

4.8 Filled grain panicle^{-1}

Statistically significant variation was recorded for filled grains panicle^{-1} due to flag leaf removal (Appendix VI). The highest filled grains panicle^{-1} (199.10) was recorded from T_2, whereas the lowest (164.00) was obtained from $T_{1.}$ (Table 3).

Filled grains panicle^{-1} varied significantly for different rice varieties (Appendix VI). The highest filled grains panicle^{-1} (209.70) was recorded from V_4, which were statistically identical (199.70) to V_2, whereas the lowest (166.30) was found from V_6 (Table 3). 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} (Appendix VI). The highest filled grains panicle^{-1} (257.30) was recorded from treatment combination of T_2V_2, while the lowest (142.00) was found from treatment combination of T_1V_2 (Table 4).

4.9 Unfilled grains panicle^{-1}

Statistically significant variation was recorded for unfilled grains penicle^{-1} due to flag leaf removal (Appendix VI). The highest unfilled grains panicle^{-1} (52.00) was recorded from T_1, whereas the lowest (23.00) was recorded from T_2 (Table 3).

Unfilled grains panicle^{-1} varied significantly for different rice varieties (appendix VI). The highest unfilled grains panicle^{-1} (60.33) was observed from V_3, while the lowest (27.50) was observed from V_1 (Table 3). 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} (Appendix VI).

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 (Table 4).

4.10 Weight of 1000 grains

Statistically significant variation was recorded for weight of 1000 seeds due to flag leaf removal (Appendix VII). The highest weight of 1000 seeds (17.40 g) was found from T_2, whereas the lowest weight (13.83 g) was recorded from T_1 (Table 3). 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 (Figure 12). The highest weight of 1000 seeds (18.55 g) was recorded from V_4, On the other hand, the lowest weight (11.56 g) was observed from V_6 (Table 3). 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 (Figure 13). The highest weight of 1000 seeds (20.27 g) was found from treatment combination of T_2V_4 and the lowest (12.62 g) was recorded from treatment combination of T_1V_6 (Table 4).

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 3. Effect of flag leaf removal and variety on number of effective tillers hill $^{-1}$, filled grain panicle^{-1}, unfilled grains panicle^{-1} in the six rice varieties

Treatment /variety	Effective tillers hill^{-1}		Filled grain panicle^{-1}		Unfilled grains panicle^{-1}		Weight of 1000 grains	
					1			
T1	11.56	b	164.00	b	52.00	a	13.83	b
T2	12.50	a	199.10	a	23.00	b	17.40	a
LSD(0.05)	0.75		12.23		5.21		0.33	
V_1	12.83	b	168.00	cd	27.50	d	17.43	b
V_2	11.33	c	199.70	b	41.00	b	14.60	d
V_3	11.00	c	169.70	cd	60.33	a	14.82	d
V_4	15.17	a	209.70	a	39.00	bc	18.55	a
V_5	12.67	b	176.00	c	19.50	e	16.74	c
V_6	9.17	d	166.30	d	37.67	c	11.56	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 similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05 level of significance. V_1 =BARI Dhan32, V_2=BARI Dhan33, V_3=BARI Dhan39, V_4=BARI Dhan54, V_5=BARI Dhan56, V_6=BARI Dhan62; T_1= Flag leaf cutting, T_2=Control.

Table 4. Interaction effect of flag leaf removal and variety on number of effective tillers hill $^{-1}$, filled grain panicle^{-1}, unfilled grains panicle^{-1} 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	154.00	gh	37.00	e	15.73	e
T_1V_2	11.33	d	142.00	h	52.67	c	12.73	h
T_1V_3	10.33	e	175.70	de	101.70	a	13.05	gh
T_1V_4	15.00	ab	188.30	cd	47.00	d	16.83	d
T_1V_5	11.00	de	156.00	fg	17.67	h	14.97	f
T_1V_6	9.00	f	168.00	ef	56.00	b	12.62	h
T_2V_1	13.00	c	182.00	d	18.00	h	19.12	b
T_2V_2	11.33	d	257.30	a	29.33	f	16.47	d
T_2V_3	11.67	d	163.70	efg	19.00	gh	16.55	d
T_2V_4	15.33	a	231.00	b	31.00	f	20.27	a
T_2V_5	14.33	b	196.00	c	21.33	g	18.48	c
T_2V_6	9.33	f	164.70	efg	19.33	gh	13.47	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 similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05 level of significance. V_1 =BARI Dhan32, V_2=BARI Dhan33, V_3=BARI Dhan39, V_4=BARI Dhan54, V_5=BARI Dhan56, V_6=BARI Dhan62; T_1= Flag leaf cutting, T_2=Control.

4.11 Dry weight of Rice yield

Statistically significant variation was recorded for dry weight of rice due to removal (Appendix VII). The highest dry weight of rice (4.57 t ha^{-1}) was recorded from T_2, whereas the lowest (3.67 t ha^{-1}) was recorded from T_1 (Table 3).

Dry weight of rice varied significantly for different rice varieties (Appendix VII). The highest dry weight of rice (4.83 t ha^{-1}) was observed from V_4, On the other hand, the lowest (3.06 t ha^{-1}) was observed from V_6 (Table 3).

Interaction effect of flag leaf cutting and rice varieties showed significant variation on dry weight of rice yield (Appendix VII). The highest dry weight of rice (5.25 t ha^{-1}) was observed from treatment combination of T_2V_4, while the lowest (2.55 t ha^{-1}) was recorded from treatment combination of T_1V_6 (Table 4)

4.12 Rice yield

Statistically significant variation was recorded for grain yield due to removal (Appendix VIII). The highest grain yield (4.70 t ha^{-1}) was observed from T_2, whereas the lowest (3.73 t ha^{-1}) was recorded from T_1 (Table 5). 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 (Appendix VIII). The highest grain yield (5.01 t ha was observed from V_4, which were statistically followed (4.00 and 3.94 t ha^{-1}) by V_3 and V_4, whereas the lowest (3.12 t ha^{-1}) was observed from V_6 (Table 5). 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 t ha^{-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 (Appendix VIII). The highest grain yield (5.47 t ha^{-1}) was found from treatment combination of T_2V_4 and the lowest (2.61 t ha^{-1}) was recorded from treatment combination of T_1V_6 (Table 6).

4.13 Straw yield

Statistically significant variation was recorded for dry straw yield due to removal (Appendix VIII). 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 (Table 5).

Straw yield varied significantly for different rice varieties (Appendix VIII). 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 (Table 5).

Interaction effect of flag leaf cutting and rice varieties showed significant variation on straw yield (Appendix VIII). The highest straw yield (8.01 t ha^{-1}) was observed from treatment combination of T_2V_4, while the lowest (5.28 t ha^{-1}) was recorded from treatment combination of T_1V_6 (Table 6).

4.14 Biological yield

Statistically significant variation was recorded for biological yield due to flag leaf cutting (Appendix VIII). The highest biological yield (11.98 t ha^{-1}) was observed from T_2, while the lowest (9.57 t ha^{-1}) was found from T_1 (Table 5). 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 (Appendix VIII). The highest biological yield (12.45 t ha^{-1}) was recorded from V_4, which were statistically identical (11.11 t ha^{-1}) to V_1 and followed (10.95 t ha^{-1}) by V_5, whereas the lowest (9.23 t ha^{-1}) was found from V_6 (Table 5).

Interaction effect of flag leaf cutting and rice varieties showed significant variation on biological yield (Appendix VIII). The highest biological yield (13.48 t ha^{-1}) was attained from treatment combination of T_2V_4 again the lowest (7.87 t ha^{-1}) was found from treatment combination of T_1V_6 (Table 6).

Table 5. Effect of flag leaf removal and variety on number of grain yield, weight of straw yield, dry weight of straw yield and biological yield in the six rice varieties

Treatment /variety	Grain yield (tha^{-1})	Straw yield (tha^{-1})	Biological yield (t ha^{-1})
T1	3.73 b	5.84 b	9.57 b
T2	4.70 a	7.29 a	11.98 a
LSD$_{(0.05)}$	0.18	0.24	0.26
V_1	4.71 b	6.41 bc	11.11 b
V_2	3.94 d	6.50 b	10.44 c
V_3	4.00 d	6.48 b	10.48 c
V_4	5.01 a	7.44 a	12.45 a
V_5	4.52 c	6.44 bc	10.95 b
V_6	3.12 e	6.11 c	9.23 d
LSD$_{(0.05)}$	0.11	0.34	0.37
CV%	2.34	4.36	2.83

In a column, mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05 level of significance. V_1 =BARI Dhan32, V_2=BARI Dhan33, V_3=BARI Dhan39, V_4=BARI Dhan54, V_5=BARI Dhan56, V_6=BARI Dhan62; T_1= Flag leaf cutting, T_2=Control.

Table 6. Combined effect of flag leaf removal and variety on number of Grain yield, weight of straw yield, dry weight of straw yield and biological yield in the six rice varieties

Treatment combination	Grain yield ($t\ ha^{-1}$)		Straw yield ($t\ ha^{-1}$)		Biological yield ($t\ ha^{-1}$)	
T_1V_1	4.25	e	6.06	c	10.31	de
T_1V_2	3.43	h	5.19	e	8.63	g
T_1V_3	3.52	gh	5.79	cd	9.31	f
T_1V_4	4.54	d	6.87	b	11.41	c
$T1V_5$	4.05	f	5.82	cd	9.87	ef
T_1V_6	2.61	i	5.28	de	7.89	h
T_2V_1	5.16	b	6.75	b	11.91	bc
T_2V_2	4.45	d	7.80	a	12.25	b
T_2V_3	4.48	d	7.17	b	11.65	bc
$T2^V4$	5.47	a	8.01	a	13.48	a
T_2V_5	4.99	c	7.05	b	12.04	bc
T_2V_6	3.61	g	6.93	b	10.57	d
$LSD_{(0.05)}$	0.15		0.59		0.63	
CV%	2.34		4.36		2.83	

In a column, mean values having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 0.05 level of significance. V_1 =BARI Dhan32, V_2=BARI Dhan33, V_3=BARI Dhan39, V_4=BARI Dhan54, V_5=BARI Dhan56, V_6=BARI Dhan62; T_1= Flag leaf cutting, T_2=Control.

CHAPTER V

SUMMARY AND CONCLUSION

Rice (*Oryza sativa* L.) belongs to the family Gramineae, is the most important food in tropical and subtropical regions. The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from July to November 2016 to effect of flag leaf removal on growth and yield of six Aman rice varieties. The experiment comprised of two factors. Factor A: Treatments 1. Flag leaf removal, 2. Control, and Factor B: V_1 =BARI Dhan32, V_2=BARI Dhan33, V_3=BARI Dhan39, V_4=BARI Dhan54, V_5=BARI Dhan56, V_6=BARI Dhan62. The experiment was laid out in factorial Randomized Complete Block Design with four replications. Data on different physiological characters, yield components and yield were recorded and significant variation was observed.

At harvest, the tallest plant (130.2) was recorded from BARI dhan54 which was statistically similar (128.7 cm respectively) with BARI dhan33, whereas the shortest plant (99.43 cm, respectively) was found from BRRI dhan62. The highest flag leaf area (81.61 cm^2) was observed from BARI dhan54, penultimate leaf and lower leaf are (78.98 cm^2 and 46.95 cm^2, respectively) was observed from BARI dhan33, while the lowest leaf area (48.37 cm^2, 52.42 cm^2 and 20.55 cm^2 respectively) was found from BRRI dhan62. The maximum number of leaf (67.33) was observed from BARIdhan54 which were following (66.67and 65.67) with BARI dhan32 and BARI dhan33, whereas the minimum number of leaf (57.67) from BRRI dhan62.The maximum spikelet (12.33) was observed from BARI dhan54 which was similar (9.67) with BARI dhan32 and BARI dhan33, whereas the minimum spikelet (9.33) from BRRI dhan62.

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 (BRRI dhan54), and the minimum number (9.16) was observed from V_6 (BRRI dhan62). The maximum number of effective tillers $hill^{-1}$ (15.33) was found from treatment combination 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 (36.5) was found from T_1, whereas the lowest weight (33.38) 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 requires about 33.75 days in flag leaf removal treatment and around 30.38 days in control, respectively to fill the grains.

The highest filled grains panicle^{-1} (199.10) was recorded from T_2, whereas the lowest (164.00) was obtained from $T_{1.}$ The highest filled grains panicle^{-1} (209.70) was recorded from V_4, which were statistically identical (199.70) to V_2, whereas the lowest (166.30) was found from V_6. The highest filled grains panicle^{-1} (257.30) was recorded from treatment combination of T_2V_2, while the lowest (142.00) 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 (17.40 g) was found from T_2, whereas the lowest weight (13.83 g) was recorded from T_1. The highest weight of 1000 grains (18.55 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 (20.27 g) was found from treatment combination of T_2V_4 and the lowest (12.62 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 t ha^{-1}) was recorded from T_1. The highest grain yield (5.01 t ha was observed from V_4, which were statistically followed (4.00 and 3.94 t ha^{-1}) by V_3 and V_4, whereas the lowest (3.12 t ha^{-1}) was observed from V_6. The highest grain yield (5.47 t ha^{-1}) was found from treatment combination of T_2V_4 and the lowest (2.61 t ha^{-1}) was recorded from treatment combination of T_1V_6.

The highest 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. 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. The highest straw yield (8.01 t ha^{-1}) was observed from treatment combination of T_2V_4, while the lowest (5.28 t ha^{-1}) was recorded from treatment combination of T_1V_6.

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

Conclusion

1) Chlorophyll content (SPAD value) in penultimate leaf was increased from 1.2% (BARI dhan32) to 16.7% (BARI dhan54) and grain filling duration increased 1day (BARI dhan39) to 6 days (BARI dhan33) due to removal of flag leaf in the studied varieties.
2) BARI dhan54 provided the highest yield (5.47 t ha^{-1}) compared to the rest varieties.
3) Irrespective of variety, grain yield was reduced average 21% due to removal of flag leaf at heading.

Recommendation

- BARI dhan54 should be cultivated to get higher yield in *Aman* season.
- Further study is needed for confirmation of the results.

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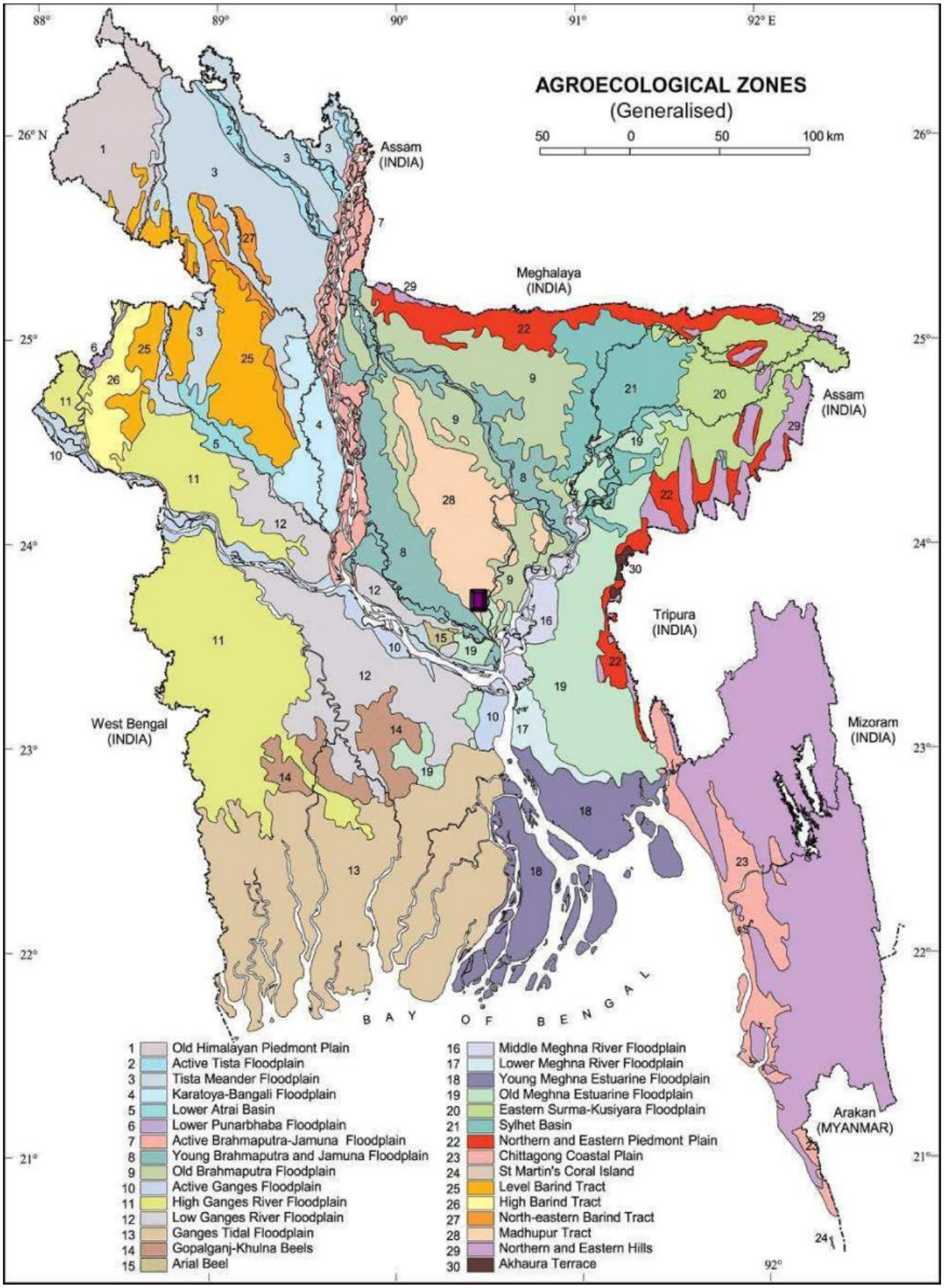
APPENDICES

Appendix I. The Map of the experimental site



Appendix II. Characteristics of the soil of experimental field

A. Morphological characteristics of the soil of experimental field

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

B. Physical and chemical properties of the initial soil

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

Source: Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

Appendix III. Monthly record of air temperature, relative humidity and rainfall of the experimental site during the period from July to November 2016

Month (2016)	Air temperature (^{0}C)		Relative humidity (%)	Rainfall (mm)
	Maximum	Minimum		
July	36.0	24.6	83	563
August	36.0	23.6	81	319
September	34.8	24.4	81	279
October	26.5	19.4	81	22
November	25.8	16.0	78	00

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

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 VI. Analysis of variance of the data on Chlorophyll content (SPAD Value) number of effective tillers hill $^{-1}$, filled grain panicle^{-1}, unfilled grains panicle^{-1} of different 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 VII. Analysis of variance of the data on weight of 1000 seeds, weight of rice yield, dry weight of rice yield of different 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