EFFECT OF LEAF CUTTING ON GROWTH AND YIELD OF MORDERN *AMAN* RICE VARIETIES

A THESIS

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*This is to certify that the thesis entitled **"EFFECT OF LEAF CUTTING ON GROWTH AND YIELD OF MORDERN AMAN RICE VARIETIES"** 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 **MD.JAHID HOSSAIN**, Registration No.**10-0**3984 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: 08.05.2018

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Dedicated to

My

Beloved Parents

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ABSTRACT

An experiment was carried out in the Experimental Field of the Agricultural Botany Department, Sher-e-Bangla Agricultural University, Dhaka during 2016 -2017, to assess the effect of leaf cutting on plant growth and yield of selected BRRI released *Aman* varieties. The experiment consisted of five rice varieties namely BRRI dhan32, BRRI dhan33, BRRI dhan39, BRRI dhan62, BRRI dhan56 and two treatments *viz* .i.) variety, ii) leaf cutting. RCBD with four replications was used in this experiment. Irrespective of all studied varieties, the highest leaf length, leaf width, leaf area, plant height, leaf numbers at heading, numbers of tillers hill^{-1}, grains panicle, grain yield, straw yield, 1000 grain weight, chlorophyll content and harvest index were obtained in no leaf cutting (control). The yield and yield contributing characters is decreased by leaf cutting as compared to the control. Among the varieties, BRRI dhan33 gave the significantly higher yield in control (control 6.75t ha^{-1} ,treated 4.75t ha^{-1}) The highest grain yield was obtained in no leaf cutting(6.75 t ha^{-1}). Cutting of leaf led to a decline in the number. of panicles hill^{-1} which eventually reduced the grain yield. The leaf cutting (except flag leaf and penultimate leaves) reduced about 10 to 28% loss of grain yield. Besides this, 1000 grains weight was significant reduced in leaves cut plant observed compared to that of the control plant. Remarkable variation in grain filling duration was also noticed in the different varieties due to leaf cutting. Reduction of grain yield was minimum (10%) in BRRI dhan39 (control 5.75t ha^{-1},treated 5.15t ha^{-1}) with leaf cutting than that of the rest varieties.

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LIST OF ABBREVIATIONS

BARI	=	Bangladesh Agricultural Research Institute
BCR	=	Benefit Cost Ratio
cm	=	Centimeter
^{0}C	=	Degree Centigrade
DAS	=	Days after sowing
et al.	=	and others
Kg	=	Kilogram
Kg ha^{-1}	=	Kilogram per hectare
g	=	gram (s)
LER	=	Land Equivalent Ratio
LSD	=	Least Significant Difference
MP	=	Muriate of Potash
m	=	Meter
P^{H}	=	Hydrogen ion conc.
RCBD	=	Randomized Complete Block Design
TSP	=	Triple Super Phosphate
t ha^{-1}	=	ton per hectare
%	=	Percent

CHAPTER I

INTRODUCTION

Rice occupies about 75 percent of agricultural land in Bangladesh and keeps contribution of 14.23 percent in GDP. It is currently the world's sixth largest producer. The cultivation of rice in Bangladesh varies according to seasonal changes in the water supply. More than half of the total production (55.5%) is obtained in *Boro* season occurring in December-May and second largest production in *Aman* season (37.9%); occurring in November and December (Asia and pacific commission on agricultural statistics, 2016). Potential for increased rice production strongly depends on the ability to integrate a better crop management for the different varieties into the existing cultivation. Variety itself is a genetic factor which contributes a lot in producing yield and yield components of a particular crop (Mahmud *et al*. 2013). In the year 2015, among *Aman* rice varieties high yielding modern varieties covered 73.08% and de-husked yield was 2.69 t ha^{-1} and local varieties covered 20.99% and de-husked yield was 1.65 t ha^{-1} (BBS, 2015). It is the farmers who have gradually replaced the local indigenous low yielding rice varieties by high yielding ones and modern varieties of rice developed by Bangladesh Rice Research Institute (BRRI) and Bangladesh Institute of Nuclear Agriculture (BINA) only because of getting 20 to 30% more yield per unit land area (Shahjahan, 2007). Among the three hill tract districts; Khagrachari occupies about one fifth (2,700 m^2) of the total area (Ullah *et al.*, 2012). Currently 37.18% of this area is under irrigation and cropping intensity (CI) is 1.56% (BBS, 2015). Due to unavailability of ground water and extreme irrigation limitation rainfed *Aman* rice is the only hope here; as a result 62.54% of total rice is grown and maximum production is obtained in this season (DAE, 2016). Less input requirement, short-durated, high yielding and pest resistance varieties have key advantage over local and hybrid. To increase production, there is no alternative for cultivation of short duration variety and adoption of modern agricultural practices. Most of the farmers cultivate BRRI and local varieties; and a few produce Bangladesh Institute of

Nuclear Agriculture (BINA) released varieties here. Total area of *Aman* rice cultivation was 28,225 hectare; among them BRRI released varieties were under 22,700 hectare, local varieties under 5,414 hectare and BINA released varieties were under 111 hectare land. Average production was 4.07, 4.04 and 2.58 t ha^{-1} of BRRI, BINA and local varieties respectively (DAE, 2016). Mahmud *et al*. (2013) concluded that, rice varieties differed significantly in all growth characters, such as plant height, tillers number, chlorophyll content, dry matter weight of different plant parts, panicle length, filled grain, unfilled grain, filled grain percentage, 1000-grain weight, grain yield and straw yield. Numbers of seedling(s) per hill had remarkable influence on number of total tillers per hill and total dry matter production. The yield of rice depends on its different growth parameters, i.e. leaf area index, dry matter production and its partitioning, tillering, etc. (Shams, 2002). There are several important factors those have tremendous influence on the growth and development, tiller production, grain formation and other yield contributing characters i.e., age of seedling (Islam and Ahmed, 1981), spacing (Miah *et al.,* 1990). A number of reports showed that indigenous rice varieties possess a wide diversity in ecological, morphological and physiological characteristics (Jahan *et al.,* 2003). The yield contributing characters especially number of effective tillers $hill^{-1}$, number of grains $panicle^{-1}$, grain yield and straw yield were significantly affected when compared to late transplanting.

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). By increasing rice canopy photosynthesis had greater yields. 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 (Mae, 1997). Liu *et al*. (1986) found that both economic and biological yields were closely correlated with optimum leaf area index (LAI) of plant community of different rice varieties. Jiang *et al*. (1988) have also reported that high grain yield in rice was due to high total dry matter (TDM, g plant^{-1}). Agata and Kawamitsu (1990) have found high grain yield in hybrids was released by high TDM which was based on high leaf area rather than leaf photosynthetic rate. Niranjanamurthy *et al*. (1990) found that leaf area at 45 days from sowing was positively associated with TDM and grain yield, while the leaf area at flowering showed either with TDM or grain yield.

The flag leaf contributed maximum to the yield of rice grains. Flag leaf contributed to 45% of grain yield and is the single most component for yield loss. The contribution of leaf removal in different rice cultivar was the minimum, suggesting the probability of maximum translocation of photosynthesis from stem to the grain during grain feeling stage of rice after leaf removal. Since the productivity of a plant depends on the efficiency of its photosynthetic processes and therefore on the extent of its photosynthetic surface, the growth and development of leaves have a profound impact on the yield of the plant. In addition, leaves also play a vital part in controlling water loss by plants. Excess leaf growth of long duration rice plants is grazed at the early vegetative stage. In some deep water areas of Bangladesh, Badal, a traditional deep water rice variety is grown as fodder (Magor, 1986). Cutting long duration rice leaves at the vegetative phase is also practiced in India (Copeland, 1972) and is now more frequently done in Thailand (Kupkanchanakul *et al*., 1991). If leaf cutting really has no effect on the production of grains, it may become one of the most economical ways of increasing the yield, with the added advantage that it will provide the farmers with green feeding materials for their work animals. The success of rice cultivation as dual purpose is mostly dependent on different improved agronomic techniques and cutting time. Time of cutting rice leaves and selection of suitable variety seems to be very important for obtaining enough forage without sacrificing grain yield. Whatever, the present experiment was therefore, undertaken with following objectives.

1. To assess the effect of leaf removal (except flag and penultimate leaves) on plant growth and yield of selected modern *Aman* varieties.

2. To compare the growth and yield parameters of the studied varieties in *Aman* season.

CHAPTER II

REVIEW OF LITERATURE

Rice is widely adaptable crop in different environmental condition. The growth and development of rice may be influenced due to varietal performance and systems of cultivation. Yield potentiality also depends on physiological parameters like leaf area index, dry matter accumulation, translocation of assimilate etc. The available literatures under the heads of the objectives of the study were reviewed in the following paragraphs.

2.1 Effect of leaf cutting on yield and yield contributing characters rice

Agata and Kawamitsu (1990) have found high grain yield in hybrids was realized by high TDM which was based on high leaf area rather than leaf photosynthesis. Bardhan and Mondal (1988) observed that panicle length decreased due to leaf cutting. It is concluded that increasing day of leaf cutting gradually decrease the panicle length. Das and Mukherjee (1992) reported that late leaf cutting reduce the grain yield and this was also true for present experiment.

Experiments about artificial leaf removal were conducted on other plants such as sugarcane (Singh and Singh, 1984), peanut (Jones *et al*., 1982), chickpea (Pandey, 1984), sorghum (Rajewski *et al*., 1991), soybean (Diogo *et al*., 1997) and it was stated that leaf removal affects the yield.

G. Slack (2015) conducted a first experiment, six levels of leaf removal were imposed on January-sown tomatoes and de-leafing was continued so that the length of stem with leaves attached was constant for a given treatment. Flower opening on de-leafed plants was delayed but only significantly so in the most severe treatment. There was no effect on stem elongation. Yield decreased with severity of leaf removal but the rate of fruit ripening was enhanced. In a second experiment, three levels of de-leafing were used but treatment was delayed until the fruits began to ripen. The treatments were combined factorialy with three planting densities and three contrasting varieties. There were no effects of de-leafing on flower opening or stem elongation. Total yield was reduced by leaf removal in the most severe treatment but there was no effect on fruit numbers or quality. Large and significant effects of plant density were recorded but there were no interactions between density, leaf removal and cultivar. The effects of de-leafing and density were similar in all three varieties. Crop yield was thus affected by both the severity of leaf removal and by the stage of plant development at which removal occurred. Losses in yield are attributed to a reduction in photosynthetic area and a decrease in the availability of mobile mineral elements which are present in the leaves. It is strongly recommended that de-leafing in commercial tomato crops should not exceed the level of ripening fruits.

Ghosh and Sharma (1998) reported higher number of grains panicle^{-1} from early leaf cutting than late leaf cutting. The lowest value for all crop characters were observed when the leaf was cut at 35 DAT. M. Ahmed (2001) also showed the effect of leaf cutting was found to be significant in respect of the crop characters except 1000-grain weight. The highest value of productive tillers hill^{-1} (9.19), panicle length (23.52 cm), sterile grains (18.68) grains panicle (92.69), 1000-grain weight (22.72 81, grain yield (4.71 t ha^{-1}, straw yield (5.60 t ha^{-1}), biological yield (10.31 t ha^{-1} and harvest index (45.59%) were found in control.

Hachiya (1989) concluded that the highest value of number of total tillers hill^{-1} for observations at 28, 35, 42, 48 DAT and at maturity were obtained in control and the lowest at the same date of observations were obtained when leaf cutting was done at 21, 21, 28, 28 and 35 DAT, respectively. These results are in full compliance with those of Ahmed (2001).

Hodgkinson *et al*. (1977) proved that leaf area influences the overall plant growth. No significant differences were observed for the total number of leaves produced, indicating that the leaf production rate was not affected by leaf removal.

In experiments related to this subject it is stated that the effects of leaf removal on sunflower yield and yield components change according to the number of leaf removed (Sackston, 1959), removal time (Schneiter *et al*., 1987) and the position of the removed leaf (Johnson, 1972). It is also stated that reactions differ from one cultivar to another (Pereira, 1978).

M. Ahmed (2001) showed the dry matter yield in different leaf cutting treatments varied significantly. Forage yield in leaf cutting at 35 DAT was 2.40 t ha^{-1} while that was only 1.01 and 1.47 t ha^{-1} in leaf cutting at 21 and 28 DAT, respectively. The dry matter yield was 0.62 t ha^{-1} in leaf cutting at 35 DAT and that was 0.22 and 0.35 t ha^{-1} in leaf cutting at 21 and 28 DAT.

M. Ahmed *et al*. (2001), conducted an experiment consisted of four varieties namely Latishail, BR 10, BR11 and BRRIdhan32 and four leaf cuttings viz., no leaf cutting (T1), leaf cutting at 21 DAT (T2), leaf cutting at 28 DAT(TJ, leaf cutting at 35 DAT(T4). The effect of leaf cutting was significant on growth parameters namely plant height, total number of tillers and leaves hill' at different days after transplanting. In respect of all studied varieties, the highest plant height, total tillers $hill^{-1}$, productive tillers $hill^{-1}$, non bearing tillers $hill^{-1}$, panicle length, grains $panicle^{-1}$, sterile grains $panicle^{-1}$, grain yield, straw yield, cumulative straw yield, biological yield and harvest index were obtained in no leaf cutting (control). The yield and yield contributing characters are decreased by leaf cutting as compared to control. Latishail leaf cutting at 35 DAT gave the significantly higher forage yield. The highest grain yield was obtained in no leaf cutting which was statistically identical to leaf cutting at 21 and 28 DAT. It may be concluded that leaf cutting at early stage of crop growth could produce almost similar grain or seed yield of control crops with the additional forage yield.

Mannan (1996) stated that panicle length differed among the varieties. In respect of modem varieties, the highest grains $panicle^{-1}$ (97.21), 1000-grain weight (22.11g), grain yield (4.84 t ha^{-1}) biological yield (10.16 t ha^{-1}) and harvest index (46.80./0) were observed in BR11 as compared to BR10 and BRRldhan32 (Table 3).

Martinez Garnica (1984) also found that at least eight leaves at flowering were required to ensure normal plant development of plantains.

Martinez Garnica (1984) conducted a experiment on banana leaf and suggested the the plant size and bunch weight of Musa spp. directly depends on the number and size of functional leaves. Turner (1980), Swennen and De Langhe (1985), Stover and Simmonds (1987) also concluded that leaf area can be used to estimate the photosynthetic capacity and to predict the performance of a banana crop.

Misra (1986) showed that leaf area (cm^2) $plant^{-1}$, chlorophyll content (SPAD units), total dry matter (TDM) production, panicle length, spikelet number, number of grains per panicle, test weight (1000 grain weight) and grain yield (ton/ ha) of hybrid rice cultivar H5 and inbred Egyptian local cultivar Sakha 103 was affected significantly by leaf cuttings. All the parameters showed maximum value under control condition without any leaf cutting.

Misra (1986, 1987, 1995) reported that the harvest index (HI) is the ultimate determinant for grain yield in cereals, and the cultivar differences or other factors affecting crop yield regulates grain yield through the TDM. High grain yield in rice was reported due to high TDM - total dry matter per plant (Yoshida, 1981; Ray *et al*., 1983; Jiang *et al*., 1988).

Misra (1995) & Mitsuru (1992) found that the flag leaf contributed to 45% of grain yield and is the single most component for yield loss. Sugar and starch percentage was the maximum in the control, followed by L3. While L5 and L1 (cutting of flag leaf) reduced both sugar and starch content to the maximum followed by L4 and L2. In both L5 and L1 the flag leaf is cut.

Osunkoya *et al.* (1994) showed, removal of all leaves except the most apical expanded leaf caused a reduction in all parameters recorded, total biomass being about 20% of the control value. Although leaf dry mass of seedlings with only three leaves or with one third of all leaves (average of 7.8 leaves) was reduced compared with control values, total biomass was significantly higher for seedlings in the one-third leaf treatment, whereas it was not significantly different from the control value in seedlings in the three-leaf treatment. In response to the three-leaf and one-third leaf treatments, root dry mass increased significantly, whereas stem dry mass was not affected. Height of seedlings with one third of all leaves did not differ from control values, but a significant reduction in height.

Ray *et al.* (1983) and Makino *et al.* (1983) suggested that the leaf senescence during reproductive and ripening stages is directly related to biomass production and grain yield of rice crop. Also, during leaf senescence, chlorophyll content also decline but the rate of the decline is much slower than Rubisco content.

Robinson *et al.* (1992) found that maximum yield and finger length could be achieved in the dessert banana ‘Williams’ with eight leaves retained at flower emergence, due to a compensatory increase in CO2 uptake by up to 35% on the pruned plants.

Roy and Pradhan (1992) found that the highest value of plant height was obtained from no leaf cutting treatment at all the observation dates. The lowest value of plant height was recorded for 28, 34, 42, 49 DAT and at maturity when the leaf cutting was done at 21, 28, 35, 35 and 35 DAT, respectively. Similar results were also found by M. Ahmed (2001).

Satyanarayana (1986) concluded that no fewer than 12 leaves were required during the vegetative stage to achieve maximum yields in the dessert banana ‘Dwarf Cavendish’. Several studies have been conducted to estimate the smallest number of leaves needed for maximum yield.

Valio (1999) demonstrated that the effects of artificial shading and removal of plant parts on growth of *Trema micrantha* (L.) Blume (Ulmaceae) seedlings were studied. Seedlings were grown in pots in a greenhouse in 45, 30, 10.6, 4.8 and 1.8% of full sunlight. Shading for 60 days had no effect on survival, but it influenced all growth parameters measured. Total biomass decreased with decreasing irradiance, reflecting reductions in dry mass of leaves, stems and roots. In response to shading, allocation of biomass to leaves increased, while allocation of biomass to roots decreased. Specific leaf area, leaf area ratio and leaf mass ratio increased with decreasing irradiance. Decreases in relative growth rate were caused by reductions in net assimilation rate rather than leaf area ratio. Photosynthetic efficiency, as determined by the Fv/Fm ratio (Fv = variable fluorescence, Fm = maximal fluorescence), was unaffected by the shading treatments. Partial removal of leaves, stem or roots did not affect seedling survival. Seedlings responded to removal of plant parts by compensatory growth.

2.2 Correlation of Yield and flag leaf

Abu-khalifa *et al*. (2008) conducted an intensive study on rice yield after cutting flag leaf and nearby leaf 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).

Asana, (1968); Ramadas and Rajendrudu, (1977) conducted different experiment on yield of rice correlated with flag leaf and they concluded that 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 (198) also concluded that flag leaf assigned an important role in terms of supply of photosynthates to the grains where Sheela *et al*. (1990); Raj and Tripathi, (2000) added that the importance of flag leaf in grain yield enhancement.

Jun XUE *at al.* (2017) reported that the distributions of PAR within the canopies of two maize varieties (Zhongdan 909 and Xinyu 41) were altered by removing whole leaves or half leaves in different canopy layers. The results showed that removing whole leaves or half leaves above the three-ear-leaves (RAE and RAE/2) at flowering significantly increased PAR at the ear and interception of PAR (IPAR) from the ear to middle of the ear and soil surface. These changes increased the structural carbohydrate content and rind penetration strength (RPS) of the third basal internode by 5.4–11.6% and reduced lodging by 4.2-7.8%. Removal of the first three leaves below the three-ear-leaves (RBE) before flowering significantly reduced IPAR from the ear to half way below the ear. This reduced the structural carbohydrate content and the RPS of the third basal inter-node by 9.1-17.4% and increased lodging by 7.0–11.2%. Removal of the three lowest green leaves (RB) in the canopy before flowering increased PAR at the bottom of the canopy, but had no effect on the structural carbohydrate content of the basal inter-node, the RPS, and the lodging rate. Overall, the results indicated that the key factors affecting the basal inter-node strength formation and lodging were PAR at the ear and IPAR from the ear to halfway below the ear. Increasing PAR at the ear and IPAR from the ear to halfway below the ear could enhance lodging resistance by increasing the structural carbohydrate content and mechanical strength of the basal inter-node.

Md. Asadur Rahman *et al*. (2013a) showed the flag leaves were excised after the emergence of panicle from some of the selected plants of all the examined varieties and let it to grow. Phenotypic observation indicated various defects existed in the leaf cut plants throughout maturation including late maturation, decaying, shrunken and reduced grain size, as well as increased sterility. Moreover, panicle length and branching were reduced. As a whole, those deformities acted as potential factors for the reduction of yield of the rice varieties. After harvesting 100 grains weight from leaf cut plant was measured and significant reduction of weight was observed compare to 100 grains weight of the control plant. Among varieties the 100 grain weight of leaf cut plants was reduced about two fold in the BR3 and BRRI dhan34 from those of uncut plants.

Md. Asadur Rahman *et al*. (2013b), Chlorophyll content of FL and PL from the studied five varieties was measured. Results indicated that FL contained increased amount of total chlorophyll than that of PL for all of the studied varieties. The difference was more than two fold in BRRI dhan34. Among the varieties, BRRI dhan34 showed the highest (54.22 mg/g) FL chlorophyll content than the others, whereas, BR3 showed maximum PL chlorophyll content. Chlorophyll content among the varieties varied significantly suggesting that the studied genotypes were genetically variable regarding chlorophyll content. Chlorophyll content had the strong and positive correlation with yield. Increased grain yield was observed when chlorophyll was higher as found in the BRRI dhan34, whereas, lower grain yield was observed at lower chlorophyll content as found in the cv.BR11.

Shen (1980); Ohno (1976) and Chen *et al.* (1995) expressed that the photosynthetic pigment chlorophyll is another important molecule associated with photosynthesis in plant leaves that directly affects the biomass and grain yield of crops. Chlorophyll is positively correlated with photosynthetic rate. Ohno (1976) also reported significant differences with photosynthetic rate in rice and suggested high yielding rice could be developed by selecting varieties with high photosynthesis.

2.3 Effect of different varieties of BRRI rice on yield and yield contributing characters

AEF (2006) stated that planting 2 clonal tillers hill^{-1} showed significantly higher grain yield (4.24 t ha^{-1}) compared two other plant densities along with nursery seedlings. The higher yield in clonal tillers compared to nursery seedlings might be due to the higher filled grains per panicle. Clonal tillers gave significantly higher number of filled grains per panicle than nursery seedlings irrespective of variety.

Akbar (2004) reported that variety, seedling age and their interaction exerted significant influence on almost all the crop characters. Among the varieties, BRRI dhan41 performed the best in respect of number of bearing tillers hill^{-1}, panicle length, total spikelet's panicle^{-1} and number of grains panicle^{-1}. BRRI dhan41 also produced the maximum grain and straw yields. Sonarbangla-1 ranked first in respect of total tillers hill^{-1} and 1000-grain weight but produced highest number of non-bearing tillers hill^{-1} and sterile spikelet's panicle^{-1}. Grain, straw and biological yields were found highest in the combination of BRRI dhan41 with 15 day-old seedlings. Therefore, BRRI dhan4l may be cultivated using 15 day-old seedlings in *Aman* season following the SRI technique to have better grain and straw yields.

Anwar and Begum (2010) reported that time of tiller separation of rice significantly influenced plant height, total number of tiller hill^{-1}, number of bearing tillers and panicle length but grain and straw yields were unaffected. Therefore, Sonarbangla-1 appeared to be tolerant to tiller separation and separation should be done between 20 to 40 DAT without hampering grain yield.

Ashrafuzzaman *et al*. (2008) conducted a field experiment at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka during the period from June 2006 to November 2006 to study the growth and yield of inbred and hybrid rice with tiller separation at different growth periods. The experiment was conducted with two levels of treatments viz. a) Variety: BRRI dhan32 and Sonarbangla-1; and b) tiller separation days: 20, 25, 30, 35 and 40 days after mother plant transplantation. Maximum filled grains panicle^{-1} panicle^{-1} (144.28) was observed from the tiller separation at 20 DAT. Total and effective tillers hill^{-1} was affected by tiller separation beyond 30 DAT. Delayed tiller separation extended the flowering and maturity duration. Therefore, it was concluded that earlier tiller separation (20-30 DAT) resulted higher grain yield in hybrid variety but no such variations was observed in inbred variety.

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) and filled grains panicle^{-1} (111.0) than other varieties, whereas IR36 gave the highest 1000-grain weight (21.07 g) and number of panicles m-2 than other tested varieties. In a trial, varietal differences in harvest index and yield examined using 60 Japanese varieties and 20 high yielding varieties bred in Asian countries. It was reported that harvest index varied from 36.8% to 53.4%. Mean values of harvest index were 43.5% in the Japanese group and 48.8% in high yielding group. Yield ranged from 22.6 g plant-1 to 40.0 g plant^{-1}.

Bikash *et al.* (2013) conducted to study morphological, yield and yield contributing characters of four Boro rice varieties of which three were local viz., Bashful, Poshursail and Gosi; while another one was a high yielding variety (HYV) BRRI dhan28. The BRRI dhan8 were significantly superior among the varieties studied. The BRRI dhan28 was shorter in plant height, having more tillering capacity, higher leaf number which in turn showed superior growth character and yielded more than those of the local varieties. The HYV BRRI dhan28 produced higher number of grains panicle^{-1} and bolder grains resulted in higher grain yield over the local varieties. Further, BRRI dhan28 had erect leaves and more total dry mass than those of local varieties. The BRRI dhan28 produced higher grain yield (7.41 t ha^{-1}) and Bashful, Poshurshail and Gosi yielded ha^{-1}, respectively. Among the local rice varieties, Gosi showed the higher yielding ability than Bashful and Poshursail.

BINA (1993) stated that number of non-bearing tillers hill^{-1} was significantly influenced by varieties. M. Ahmed (2001) showed the varieties showed significant variations on plant height, non-bearing tillers hill^{-1}, panicle length, sterile grains panicle^{-1}, grain yield, straw yield, biological yield, total straw yield and harvest index.

Biswas and Salokhe (2002) conducted an experiment in a Bangkok clay soil to investigate the influence of N rate, light intensity, tiller separation, and plant density on the yield and yield attributes of parent and clone plants of transplanted rice. Application of 75 kg N and 120 kg N ha^{-1} resulted in similar yields. The 50% reduction of light intensity reduced grain yield to 43.5% compared with normal light intensity. Separation of more than 4 tillers hill^{-1} had an adverse effect on the mother crop. Nitrogen fertilizer had no influence on grain weight, per cent filled grains, and panicle size of the mother crop, but increased N produced a higher number of tillers. Reduction of light intensity and higher tiller separation adversely affected grain weight and panicle number. Variation of N rate and light intensity of the mother crop had no influence on grain yield, grain weight, and panicle number of clonal tillers transplanted with 75 kg N ha^{-1} and with normal light intensity.

BRRI (1994) also reported that among the four varieties viz. BRRI dhan14, Pajam, BRRI dhan 5 and Tulsimala, BRRI dhan 14 produced the highest tillers hill^{-1} and the lowest number of spikelet panicle^{-1} respectively. They also observed that the finer the grain size, the higher was the number of spikelet panicle^{-1}.

BRRI (1995) conducted three experiments to find out the performance of different rice varieties. Results of the first experiment indicated that BR4, BR10, BR11, Challish and Nizersail produced grain yield of 4.38, 3.12, 3.12, 3.12 and 2.70 t ha^{-1}, respectively. Challish cultivar flowered earlier than all other varieties. BR22 and BR23 showed poor performance. Second experiment with rice cv. BR10, BR22, BR23 and Rajasail at three locations in *Aman* season. It was found that BR23 yielded the highest (5.17 t ha^{-1}), and Rajasail yielded the lowest (3.63 t ha^{-1}). Growth duration of BR22, BR23 and Rajasail were more or less similar (152-155 days). Third experiment with BR22, BR23, BR25 and Nizersail during Aman season at three locations-Godagari, Noahata, and Putia where BR25 yielded the highest and farmer preferred it due to its fine grain and desirable straw qualities.

Chowdhury *et al*. (2005) conducted an experiment with 2, 4 and 6 seedlings hill^{-1} to study their effect on the yield and yield components of rice varieties BR23 and Pajam during the *Aman* season. They reported that the cv. BR23 showed superior performance over Pajam in respect of yield and yield contributing characters i.e. number of productive tillers hill^{-1}, length of panicle, l000-grain weight, grain yield and straw yield. On the other hand, the cultivar Pajam produced significantly the tallest plant, total number of grains panicle^{-1}, number of filled grains panicle^{-1} and number of unfilled grains panicle^{-1}.

Devaraju *et al*. (1998) in a study with two rice hybrids such as Karnataka Rice Hybrid 1 (KRH1) and Karnataka Rice Hybrid-2 (KRI42) using HYV IR20 as the check variety and found that KRH2 out yielded than IR20. In IR20, the tiller number was higher than that of KRH2.

Hossein and Alam (1991) reported variable number of grains panicle^{-1} among the varieties. The highest 1000-grain (25.09 g) weight was found in Latishail. Again, Latishail produced the lowest panicle length (20.24 cm), sterile grains (11.06) grains panicle^{-1}160.59), grain yield (3.60 t ha^{-1}) and harvest index (37.32).

Islam *et al*. (2009) conducted pot experiments during T. *Aman* 2001 and 2002 (wet season) at Bangladesh Rice Research Institute (BRRI) in net house. Hybrid variety Sonarbangla-1 and inbred modern variety BRRI dhan31 were used in both the seasons and BRRI hybrid dhan-l was used in 2002. The main objective of the experiments was to compare the growth and yield behavior of hybrid and inbred rice varieties under controlled condition. In 2001, BRRI dhan3l had about 10-15% higher plant height, very similar tillers/plant, 15-25% higher leaf area at all days after transplanting (DAT) compared to Sonarbangla-1. Sonarbangla-1 had about 40% higher dry matter production at 25 DAT but had very similar dry matter production at 50 and 75 DAT, 4-11% higher rooting depth at all DATs, about 22% higher root dry weight at 25 DAT, but 5-10% lower root dry weight at 50 and 75 DAT compared to BRRI dhan31. The photosynthetic rate was higher (20 μ mol m-2 sec-1) in BRRI dhan3l at 35 DAT (maximum tillering stage) but at 65 DAT, Sonarbangla-l had higher photosynthetic rate of 19.5 μ mol m-2 sec-1. BRRI dhan3l had higher panicles plant-1 than Sonarbangla-1, but Sonarbangla-1 had higher number of grains panicle^{-1}, 1000-grain weight and grain yield than BRRI dhan31. In 2002, BRRI dhan31 had the highest plant height at 25 DAT, but at 75 DAT, BRRI hybrid dhanl had the highest plant height. Sonarbangla-1 had the largest leaf area at 25 and 50 DAT followed by BRRI dhan31, but at 75 DAT, BRRI dhan31 had the largest leaf area. The highest shoot dry matter was observed in BRRI dhan31 followed by Sonarbangla-1 at all DATs. Sonarbangla-1 had the highest rooting depth and root dry weight at all DATs. BRRI dhan31 gave the highest number of panicles plant-1 followed by Sonarbangla-1, BRRI hybrid dhan-l had the highest grains panicle^{-1} followed by BRRI dhan31 and Sonarbangla-1 had the highest 1000-grain weight followed by BRRI dhan31. The highest amount of grains plant^{-1} (34.6 g) was obtained from BRRI dhan31.

Julfiquar *et al*. (1998) reported that BRRI evaluated 23 hybrids along with three standard checks during *Boro* season 1994-95 as preliminary yield trial at Gazipur and it was reported that five hybrids (IR58025A/IR54056, IR54883, PMS8A/IR46R) out yielded the check varieties (BR14 and BR16) with significant yield difference. They also reported that thirteen rice hybrids were evaluated in three locations of BADC farm during *Boro* season of 1995-96. Two hybrids out yielded the check variety of same duration by more than 1 t ha^{-1}.

M. Ahmed (2001) showed that the forage and dry matter yield were significantly influenced by varieties. Latishail was superior to all other studied varieties in respect of forage and dry matter yield. The highest forage (1.37 t ha^{-1}) and dry matter yield (0.32 t ha^{-1}) were obtained in Latishail. While lowest forage (1.10 t ha^{-1}) and corresponding dry matter yield were obtained in BR10.

Main *et al*. (2007) stated that in south and Southeast Asia, floodwater may remain for more than a month during the period of *Aman* rice grown with maximum submergence reaching to about 50-400 cm in depth. Comparative submergence by flash floods has been reported as a major production constraint in about 25 million ha of low land in this region. Although rice is adapted to lowland, complete submergence for more than 2-3 days killed most of the rice varieties. This type of damage would be rather serious for dwarf and semi dwarf varieties, which cause total crop losses. Horizontal expansion of *Aman* rice area is not possible due to high human population pressure on land. Therefore, it is an urgent need of the time to increase rice production through increasing the yield of *Aman* rice at farmers level using inbreed and hybrid varieties. There are different methods of planting such as direct seedlings (haphazard and line sowing), transplanting of seedlings (haphazard and line sowing), transplanting of clonal tillers. The vegetative propagation of using clonal tillers separated from previously established transplanted crop was beneficial for restoration of a damaged crop of *Aman* rice where maximum number of filled grain per panicle (173.67), the highest grain yield (4.96 t ha^{-1}) was obtained with the clonal tillers followed by nursery seedlings the highest harvest index (49.04%) was found from the clonal tillers those were statistically similar with nursery seedlings.

Malik *et al*. (1992) observed differences in forage yield among the varieties.

Mallick (1994) carried out a pot experiment at the Institute of Postgraduate Studies in Agriculture (IPSA), Salna, Gazipur during the wet season, 1993 to evaluate the varietal differences in panicle characteristics, spikelet ripening, and special distribution of filled and unfilled grains within a panicle as influenced by tiller removal and double transplanting. The two varieties- Nizersail and BR 22 representing old and modern rice were taken as variables. Removal of tillers from the mother shoot and double transplanting increased panicle formation by about 10% in both the varieties. Tiller removal increased grain yield $panicle^{-1}$ by 27% in Nizersail and 21% in BR 22. Double transplanting increased the number of spikelet's $panicle^{-1}$ in both the varieties. Tiller removal also increased grains but not as much as was in the double transplanted rice.

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

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

Rahman *et al*. (2002) carried out an experiment with 4 varieties of transplant Aman rice viz., BR1l, BR22, BR23 and Tuishimala and 6 structural arrangement of rows viz., 25 cm + 25 cm, 30 cm + 20 cm, 35 cm + 1 5 cm, 40 cm + 10 cm) 45 cm + 05 cm and haphazard planting at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh. Thousand grains weight and grain yield were highest in BR23 and these were lowest in Tulshirnaia.

Siddiquee *et al*. (2002) conducted a study to evaluate the difference between hybrid and inbred rice in respect of their growth duration, yield and quality in Boro season, 1999. Among the varieties, Aalok 6201 had the highest grain yield followed by BRRI dhan29 and IR68877H but statistically they were similar. BRRI dhan28 had the lowest grain yield, which was statistically similar to Loknath503. BRRI dhan28 and the tested hybrid rice had lower growth duration than BRRI dhan29. Milling out turn varied from 67 to 70% among the tested varieties. Loknath 503 had the lowest milling out turn (70%) and, BRRI dhan28 and BRRI dhan29 had the highest milling out turn (70%) for unparboiled but parboiled rice the highest milling out turn(73%) were found in BRRI dhan28 and IR68877H . All tested hybrid rice were medium bold, whereas BRRI dhan29 and BRRI dhan28 were medium slender and long slender, respectively in both parboiled and unparboiled condition. Among the varieties, amylose content (%) was higher in BRRI dhan29 and protein content (%) was higher in IR68877H for both under parboiled and unparboiled condition.

Sumit *et al*. (2004) worked with newly released four commercial rice hybrids (DRRH 1, PHB 71, Pro-Agro 6201, KHR 2, ADTHR 1, UPHR 1010 and Pant Sankar dhan1) and two high yielding varieties (HYV) as controls (Pant dhan4 and Pant dhan12) and reported that KHR 2 gave the best yield (7.0 t ha^{-1}) among them.

Swain *et al*. (2006) evaluated in a field experiment the performance of rice hybrids NRH1, NRH3, NRH4, NRH5, PA6111, PA6201, DRRH1, IR64, CR749-20-2 and Lalat conducted in Orissa, India during 1999-2000. Among the hybrids tested, PA 6201 recorded the highest leaf area index.

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 varieties of rice. Compared with conventional varieties, the hybrids had larger panicles, heavier seeds, resulting in an average yield increase of 7.27%.

Xia *et al.* (2007) in experiment found that Shanyou63 variety gave the higher yield (12 t ha^{-1}) compared to Xieyou46 variety (10 t ha^{-1}).

Yuni Widyastuti *et al.* (2015) established since early 1990's at the Indonesia Center for Rice Research (ICRR). Twenty-four experimental hybrid rice varieties which have been developed were tested in lowland rice fields in Sukamandi (West Java) and Batang (Central Java) during the dry season and the rainy season of 2012. Randomized complete block design (RCBD) with three replications was used in each location. The results showed that grains yields were affected by locations, seasons, and genotypes. The genotypes x locations x seasons interaction effect was significant; therefore, the best hybrid was different for each location and season. A7/PK36 hybrid has the best performance in Batang during the dry season, while A7/PK40 and A7/PK32 are the best hybrids in the rainy season. In Sukamandi, nine hybrids were identified as better yielder than that of the check cultivar in the dry season, but not so in the rainy season.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the research farm of Sher-e-Bangla Agricultural University, Dhaka from July 2016 to December 2016 to study the physiological behavior and yield performance of hybrid rice varieties in aerobic and anaerobic conditions. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations, data recording and their analysis.

3.1 Experimental site

The study was conducted at the Sher-e-Bangla Agricultural University farm, Dhaka, under the Agro-ecological zone of Modhupur Tract, AEZ-28. The location of the site is 23074/N latitude and 90035/E longitude with an elevation of 8.2 meter from sea level (Appendix I).

3.2 Climate and weather

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 (Idris *et al*., 1979). Details of the meteorological data of air temperature, relative humidity and rainfall during the period of the experiment were collected from the Weather Station of Bangladesh, Sher-e Bangla Nagar, presented in Appendix II.

3.3 Soil

The soil belongs 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 5.6 and has organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land. The details were presented in Appendix.

3.4 Plant material

In this research work, five samples of BRRI rice varieties were used as plant materials. The rice varieties used in the experiments were BRRI dhan32, BRRI dhan33, BRRI dhan39, BRRI dhan62, BRRI dhan56. The seeds were collected from the Bangladesh Rice Research Institute (BRRI) at Joydebpur.

3.5 Experimental details

Sowing Date: 22.7.2016

Transplanting Date: 17.8.2016

Fertilizer Applied: Urea, TSP, MP, Zinc sulphate

Spacing: 20 cm x 25 cm

Two Factors:

A. Variety (5)

V1=BRRI dhan32
V2=BRRI dhan33
V3=BRRI dhan39
V4=BRRI dhan62
V5=BRRI dhan56

B. Leaf Cutting

T1= Leaf cutting (except flag and penultimate leaves)
T2= Control

3.5.1 Treatment combinations

This two factor experiments were included 10 treatment combinations.

V1 T1 = BRRI dhan32 x Leaf cutting
V2 T1 = BRRI dhan33 x Leaf cutting
V3 T1 = BRRI dhan39 x Leaf cutting
V4 T1 = BRRI dhan62 x Leaf cutting
V5 T1 = BRRI dhan56 x Leaf cutting
V1 T2 = BRRI dhan32 x Control
V2 T2 = BRRI dhan33 x Control
V3 T2 = BRRI dhan39 x Control
V4 T2 = BRRI dhan62 x Control
V5 T2 = BRRI dhan56 x Control

3.5.2 Experimental design

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The layout of the experiment was prepared for distributing the variety. There were 30 plots of size 2.5 m × 4 m in each of 3 replications.

The treatments of the experiment were assigned at random into each replication following the experimental design. Seedlings were sown in the seed bed. When age of seedling was 23 days then up rooted and transplanted maintaining line to line distance 25 cm and hill to hill distance 20 cm. Two seedlings hill^{-1} were used during transplanting.

3.6 Growing of crops

3.6.1 Raising seedlings

3.6.1.1 Seed sprouting

Healthy seeds were selected by specific gravity method and then immersed in water bucket for 24 hours(19th July) and then it was kept tightly in gunny bags(20th July). The seeds started sprouting after 48 hours (22nd July).

3.6.1.2 Preparation of nursery bed and seed sowing

As per BRRI recommendation seedbed was prepared with 1 m wide adding nutrients as per the requirements of soil. Seed were sown in the seed bed @ 70 g m^{-2} on 23th July, 2016.

3.6.2 Preparation of the main field

The plot selected for the experiment was opened in 10th August, 2016 with a power tiller, and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good condition. Weeds and stubble were removed, and finally obtained a desirable tilth of soil for transplanting of seedlings.

3.6.3 Fertilizers and manure application

The following doses of manure and fertilizers (BRRI, 2013) were used.

1) Cow-dung : 5 t ha^{-1}
2) Urea (N) : 220 kg ha^{-1}
3) TSP (P_2O_5) : 165 kg ha^{-1}
4) MP (K_2O) : 180 kg ha^{-1}
5) Gypsum : 70 kg ha^{-1}
6) Zinc : 10 kg ha^{-1}

Whole amount of cow-dung, TSP, MP, Gypsum and Zinc and one third of urea were applied at the time of final land preparation at broadcasting method. Half of the rest two third of urea was applied at 25 DAT and the rest amount of urea was applied at 45 DAT.

3.6.4 Uprooting seedlings

The nursery bed was made wet by application of water one day before uprooting the seedlings. The seedlings were uprooted on August 17, 2016 without causing much mechanical injury to the roots.

3.6.5 Transplanting of seedlings in the field

The seedlings were transplanted in the main field on August 17, 2016 and the rice seedlings were transplanted in lines each having a line to line distance of 25 cm and plant to plant distance was 20 cm for all test varieties in the well prepared plot.

3.6.6 Cultural operations

The details of different cultural operations performed during the course of experimentation are given below:

3.6.6.1 Irrigation and drainage

Three water regimes namely, low land transplant, raised upland, raised transplant were used as main plot treatment.

3.6.6.2 Gap filling

Gap filling was done for all of the plots at 7-10 days after transplanting (DAT) by planting same aged seedlings.

3.6.6.3 Weeding

First weeding was done from each plot at 15 DAT and second weeding was done from each plot at 40 DAT. Mainly hand weeding was done from each plot.

3.6.6.4 Plant protection

Furadan 57 EC was applied at the time of final land preparation .

3.7 Harvesting, threshing and cleaning

The rice plant was harvested depending upon the maturity of grains and harvesting was done manually from each plot. Maturity of crop was determined when 80-90% of the grains become golden yellow in color. Ten pre-selected hills per plot from which different data were collected and 3 m^2 areas from middle portion of each plot was separately harvested and bundled, properly tagged and then brought to the threshing floor. Enough care was taken for harvesting, threshing and also cleaning of rice seed.

Fresh weight of grain and straw were recorded plot wise. Finally the weight was adjusted to a moisture content of 13%. The straw was sun dried and the yields of grain and straw $plot^{-1}$ were recorded and converted to t ha^{-1}.

3.8 Data recording

3.8.1 Plant height

The height of plant was recorded in centimeter (cm) at the time of 55 DAT (days after transplanting) and at harvest. Data were recorded as the average of same 10 hills selected at random from the outer side rows (started after 2 rows from outside) of each plot. The height was measured from the ground level to the tip of the plant.

3.8.2 Leaves $hill^{-1}$

The number of leaves $hill^{-1}$ was recorded at 55 DAT and at harvest by counting total leaves as the average of same 5 hills pre-selected at random from the inner rows of each plot.

3.8.3 Leaf area index

Leaf area index (LAI) was estimated manually at the time of 55, 75 DAT and at harvest. Data were collected as the average of 5 plants selected. Final data were calculated multiplying by a correction factor 0.75

3.8.4 Chlorophyll content

Flag leaves were sampled at 6 days after flowering and a segment of 20 mg from middle portion of leaf was used for chlorophyll analysis. Chlorophyll content was measured on fresh weight basis extracting with 80 % acetone and used doubled beam spectrophotometer (Model: U-2001, Hitachi, Japan) according to Witham *et al.* (1986). Amount of chlorophyll was calculated using following formulae.

Chlorophyll a (mg g^{-1}) = $[12.7\ (OD_{663}) - 2.69\ (OD_{645})] \times \frac{V}{1000\ W}$

Chlorophyll b (mg g^{-1}) = $[12.9\ (OD_{663}) - 4.68\ (OD_{645})] \times \frac{V}{1000\ W}$

Where,

OD = Optical density of the chlorophyll extract at the specific wave length.

V = Final volume of the 80% acetone chlorophyll extract (ml)

W = Fresh weight in gram of the tissue extracted.

The total chlorophyll content was estimated by adding chlorophyll a and chlorophyll b.

3.8.5 Tillers hill^{-1}

The number of tillers hill^{-1} was recorded at 55 DAT (days after transplanting) and at harvest by counting total tillers as the average of same 5 hills pre-selected at random from the inner rows of each plot.

3.8.6 Dry matter hill^{-1}

Total dry matter hill^{-1} was recorded at the time of 55 DAT (days after transplanting) and at harvest by drying plant sample. Data were recorded as the average of 3 sample hill plot^{-1} selected at random from the outer rows of each plot leaving the border line and expressed in gram.

3.8.7 Grains panicle^{-1}

The total number of grains was collected from the randomly selected 10 panicles from each plot and then average number of grains panicle^{-1} was calculated.

3.8.8 Weight of 1000 grains

One thousand grains were counted randomly from the total cleaned harvested grains of each individual plot and then weighed with an electric balance in grams and recorded.

3.8.9 Grain yield

The central 5 lines from each plot were harvested, threshed, dried, weighed and finally converted to t ha^{-1} basis.

3.8.10 Straw yield

The dry weight of straw of central 5 lines were harvested, threshed, dried and weighed and finally converted to t ha^{-1}.

3.8.11 Harvest index (%)

Harvest index was calculated dividing the grain yield by the total biological yield (grain and straw) of the same area and multiplying by 100.

3.9 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among the treatment. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatment means were estimated by the Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULT AND DISCUSSION

The effect of leaf cutting of different variety of rice showed significant effect on maximum growth parameters. The analysis of variance (ANOVA) of the data on growth behaviour, yield and yield contributing parameters are presented in Appendix III- XIII. The findings have been presented and discussed by using tables, graphs and possible interpretations given under following headings:

4.1 Plant height

The plant height of different lines exhibited wide variation. The plant height was maximum (108 cm) in BRRI dhan39, which was identical (107.3 cm) with BRRI dhan32. The shortest plant (97.00 cm) was found from BRRI dhan32. The remaining varieties were intermediate in this regard (Figure 1). Statistically BRRI dhan39 produced tallest plants than rest of the line. Confalonieri *et al.* (2011) detected plant height as a key factor to predict rice yield potential and established a model to estimate the plant height increase. Suprio *et al.* (2010) also found effective grains per panicle revealed significant positive relationship with plant height. It indicated that increasing plant height caused to increase effective panicles per plant.

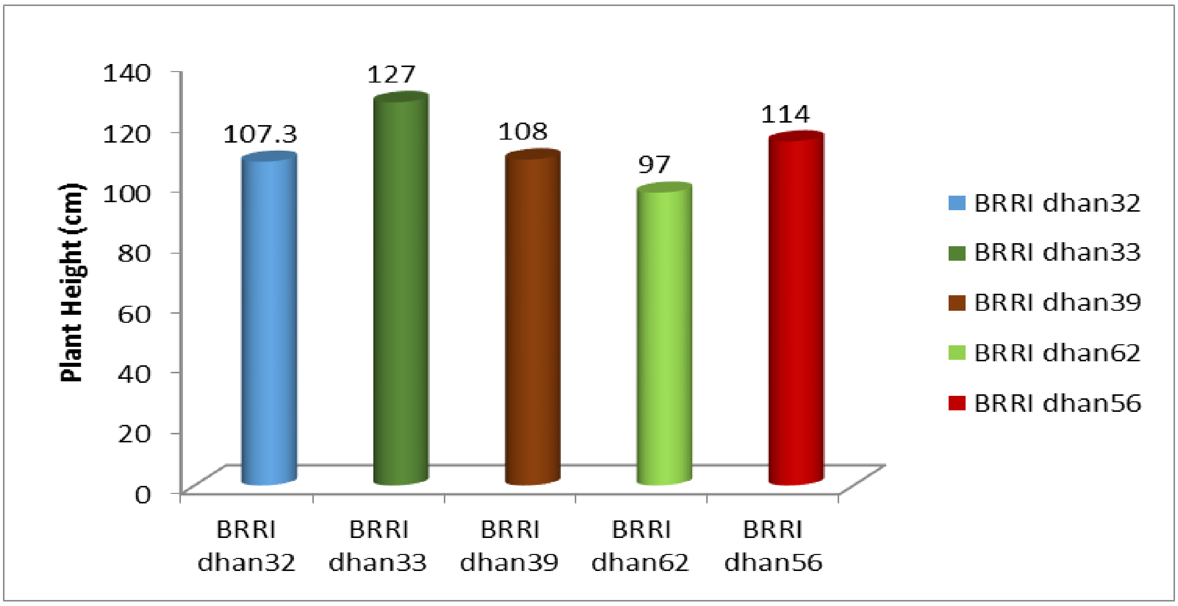

Figure 1: Effect of different modern *Aman* rice varieties on plant height

4.2 Leaf length

The average marked difference on length of flag leaf of rice was observed among five varieties (Figure 2). Plants with grater flag leaf length had elongated panicle length, thus producing increased number of primary and secondary rachis resulted in increased number of grain in the panicle that ultimately improved the yield of the variety. Flag leaf contributed to 45% of grain yield and is the single most component for yield loss. 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). The longest flag leaf (64.13 cm) and penultimate leaf (64.30 cm) was found from BRRI dhan39 and BRRI dhan56 produces longest third leaf, whereas the shortest flag leaf (31.13cm) and penultimate leaf (31.13cm) was recorded from BRRI dhan62 and shortest third leaf from (23.42cm) from BRRI dhan39 (Table 2). Roy and Kar (1992), Gupta *et al.* (1999) also reported significant positive association between boot leaf length and grain yield per plant.

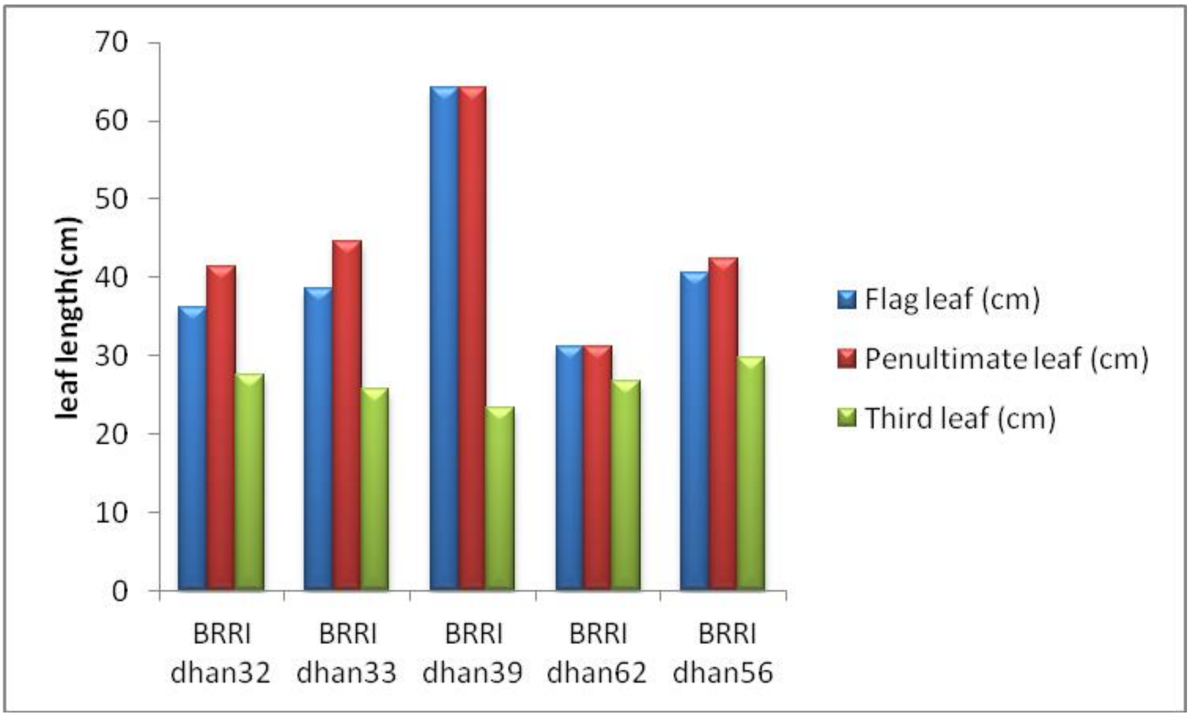

Figure 2: Effect of different modern *Aman* rice varieties on leaf length

4.3 Leaf breadth

Breadth of leaf of rice varied significantly for different varieties (Figure 3). BRRI dhan39 produces the highest breadth of flag leaf (1.90 cm), penultimate leaf (1.90 cm) and third leaf (1.47cm), whereas the lowest breadth of flag leaf (1.60cm), penultimate leaf (1.15 cm) and third leaf (0.70cm), was attained from BRRI dhan56 (Table 3). Bing *et al*. (2006) found that potential yield and Grain number were positively correlated with length, breadth and area of flag leaf.

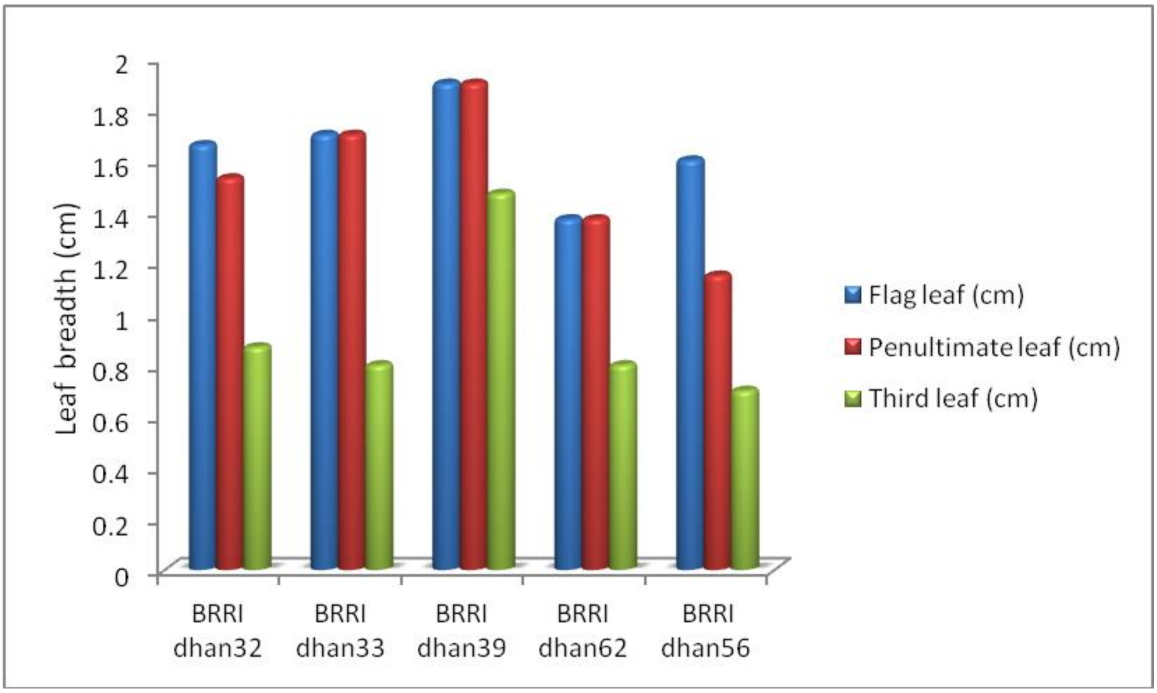

Figure 3: Effect of different modern *Aman* rice varieties on leaf breadth

4.4 Leaf numbers at heading

The number of leaves produced at heading of different rice cultivers were recorded and presented in Figure 4. It was revealed that the maximum numbers of leaves at heading (66.00) were produced by BRRI dhan62 which were statistically superior to the rest of the varieties. BRRI dhan32 produced second highest number of fruit per plant (63.00), which was also statistically different from the rest of the lines. The least number of leaves (56.00) produced by BRRI dhan56 while the other varieties took intermediate positions and they were statistically different among themselves.

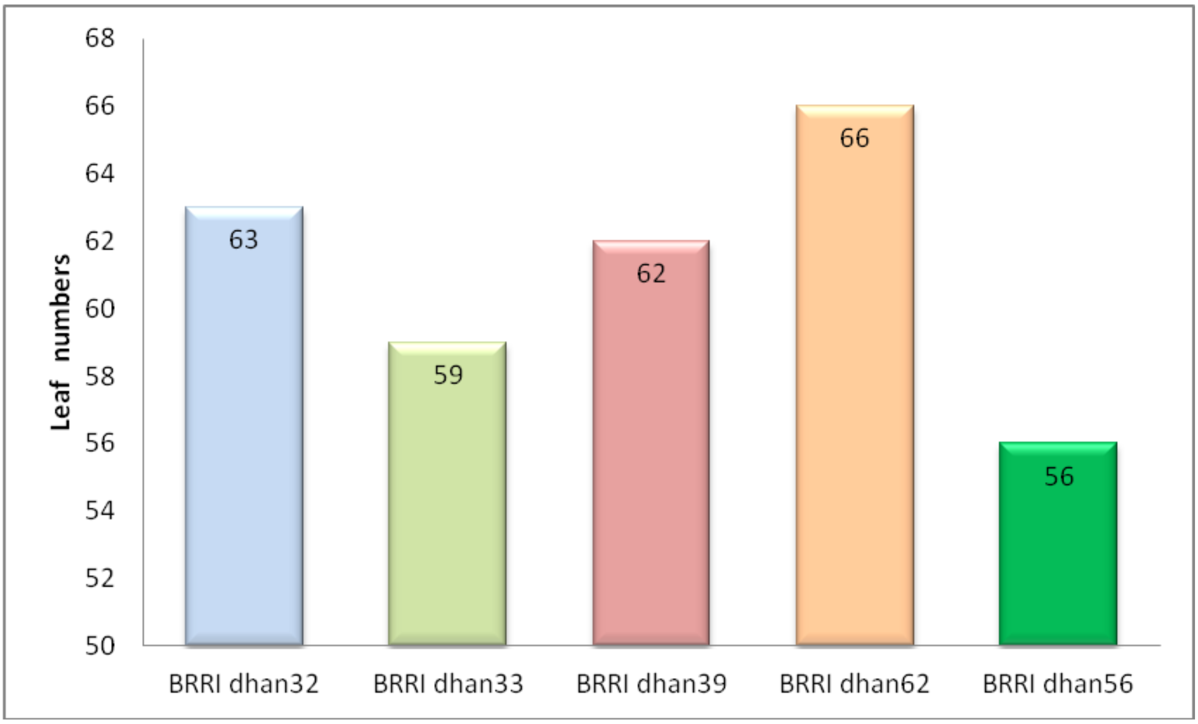

Figure 4: Effect of different modern *Aman* rice varieties on leaf numbers at heading

4.5 Leaf area

Statistically significant variation was recorded for different variety on leaf area of Rice (Figure 5). Leaf area is used to predict photosynthetic primary production, evapo-transpiration and as a reference tool for crop growth. It can help to a breeder to know the information on photosynthesis rate. The highest flag leaf area of rice (70.80 cm^2) was recorded from BRRI dhan39 where BRRI dhan33 produce highest penultimate leaf area (80.35 cm^2) and third leaf area (26.88 cm^2) and the lowest flag leaf area (42.52 cm^2), penultimate leaf area (51.87 cm^2) and third leaf area (20.66 cm^2) was found from BRRI dhan62 .The Grains yield and yield related traits were positively related to flag leaf area (Ashrafuzzaman *et al*., 2009). Prakash *et al*. (2011) found that the Grains yield was positively related with flag leaf area in rice varieties.

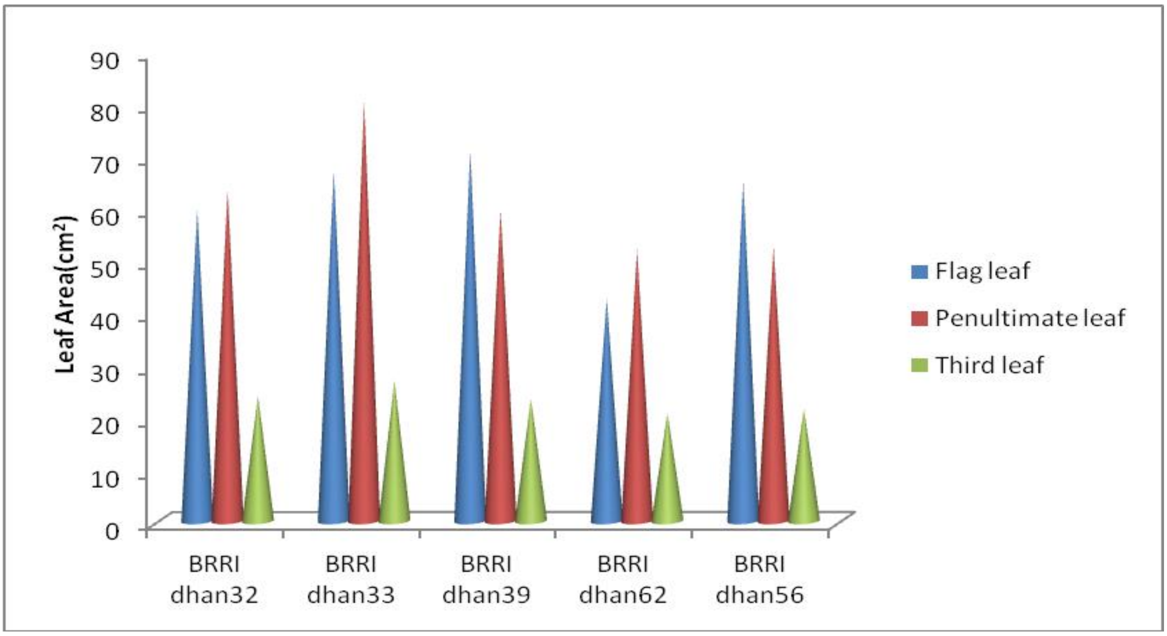

Figure 5: Effect of different modern *Aman* rice varieties on leaf area

4.6 Chlorophyll Contain in flag Leaf

Chlorophyll content of flag leaf at 12 days and at maturity from the study of five BRRI released rice varieties was measured. Different rice varieties under study showed variations in their flag leaf chlorophyll content. Results indicated that flag leaf contained increased amount of total chlorophyll at 12 days than that of at maturity for all of the studied varieties (Fig. 6).

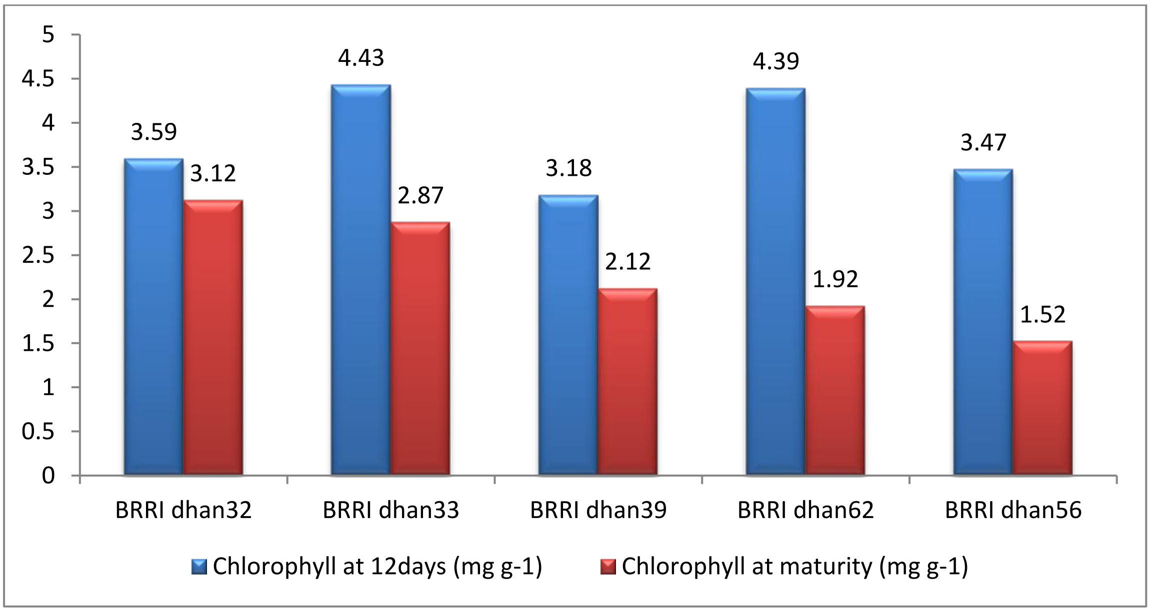

Figure 6: Effect of different modern *Aman* rice varieties on chlorophyll content

Chlorophyll is positively correlated with photosynthetic rate (Davis *et al*., 1979). Ohno (1976) also reported significant differences with photosynthetic rate in rice and suggested high yielding rice could be developed by selecting varieties with high photosynthesis.

Leaf cutting increases chlorophyll in the remaining flag leaf (Table 1). This point to 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.

Table 1: Chlorophyll Contents in flag Leaf at 12 days after heading and maturity of rice

Treatment	Chlorophyll contain in flag leaf (mg g^{-1})	
	12days	At maturity
Control	3.15 b	2.04 b
Leaf cutting	3.79 a	2.31 a
LSD	0.13	0.08
CV%	4.97	4.89

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at .05 level of probability.

Table 2 shows that among the rice varieties in leaf cutting treatment, BRRI dhan33 showed the highest (4.43 mg g^{-1}) flag leaf chlorophyll content at 12 days than the others, whereas BRRI dhan32 showed maximum (3.12 mg/g) flag leaf chlorophyll content at maturity (Table 2).

On the other hand in control condition BRRI dhan62 gives the maximum (4.10 mg g^{-1}) flag leaf chlorophyll content at 12 days and BRRI dhan33 showed maximum (3.10 mg g^{-1}) flag leaf chlorophyll content at maturity. Study showed that mean chlorophyll content among the varieties varied significantly suggesting that the studied genotypes were genetically variable regarding chlorophyll content. Chlorophyll content had the strong and positive correlation with yield. Increased grains yield was observed when chlorophyll was higher as found in the BRRI dhan33, whereas, lower Grains yield was observed at lower chlorophyll content as found in the BRRI dhan56.

Table 2: Combined effect of leaf cutting and varieties on Chlorophyll Contents in flag leaf at 12 days after heading and maturity of rice

Treatment	Chlorophyll contain in flag leaf (mg g^{-1})	
	12days	**At maturity**
Leaf cutting		
BRRI dhan32	3.59 d	3.12 a
BRRI dhan33	4.43 a	2.87 b
BRRI dhan39	3.18 e	2.12 c
BRRI dhan62	4.39 ab	1.92 d
BRRI dhan56	3.47 de	1.52 e
Controlled		
BRRI dhan32	3.28 e	2.15 c
BRRI dhan33	3.90 c	3.10 a
BRRI dhan39	2.70 f	1.70 e
BRRI dhan62	4.10 bc	2.15 c
BRRI dhan56	1.78 g	1.10 f
CV%	0.30	0.18
LSD	4.97	4.89

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at .05 level of probability.

4.7 Tillers hill^{-1}

Number of tillers per hill is an important morphological character which is related to yield of rice. The number of tillers per each hill was recorded and their average mean was calculated (Figure 7). It was observed that the maximum numbers of tillers per hill (14.00) were produced by both BRRI dhan32 and BRRI dhan33 which were statistically better from the rest of the variety. The least number of tillers (10.00) was recorded from BRRI dhan32.

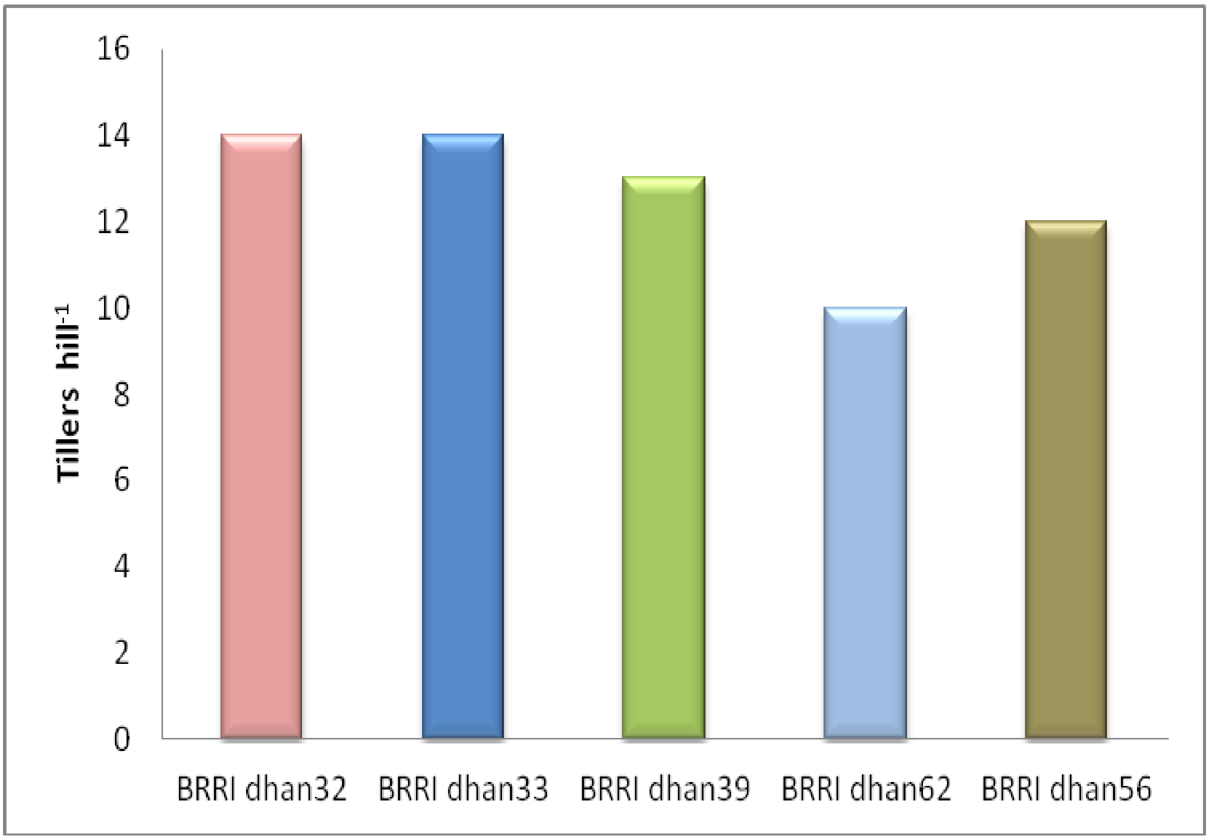

Figure 7: Effect of different modern *Aman* rice on tillers hill^{-1}

4.8 Grains panicle^{-1}

Distinct variation was observed in Grains panicle^{-1} in five BRRI released rice varieties and presented in Figure 8. It was revealed that the maximum numbers of Grains per panicle (112.33) were produced by BRRI dhan33 which was statistically superior to the rest of the varieties. BRRI dhan56 produced second highest number of Grains per plant (105.78), which was also statistically different from the rest of the lines. BRRI dhan62 had the lowest (71.67) Grains panicle^{-1} while the other varieties took intermediate positions and they were statistically different among themselves. Virmani *et al.* (1981), Ponnuthurai *et al.*, (1984); Song *et al.*, (1990b); Patnaik *et al.*, (1994) also found that the greater sink size was the result of a higher number of Grains panicle^{-1}. The highest value of Grain per panicle was obtained from no leaf cutting treatment (control) which was 146.81 and leaf cutting treatment showed lowest value of grain per panicle which was 60.17. All 2 means are significantly different from one another. (Figure 8)

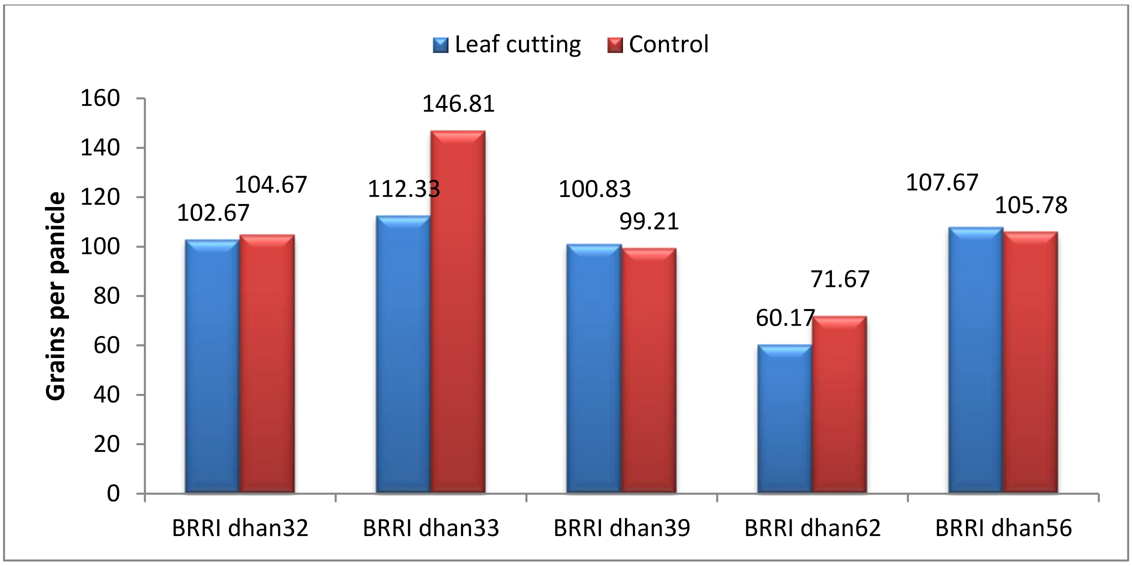

Figure 8: Effect of different modern *Aman* rice on grains panicle^{-1}

4.9 Duration of grain filling

Among the varieties the maximum days required for Grains filling (33.5 days) was recorded from BRRI dhan33 whereas the minimum days required for Grains filling was attained from BRRI dhan39 which was 26.5 days (Figure 9). The difference among the varieties might be related to the genetically characteristics of the varieties, influence of day length and temperature.

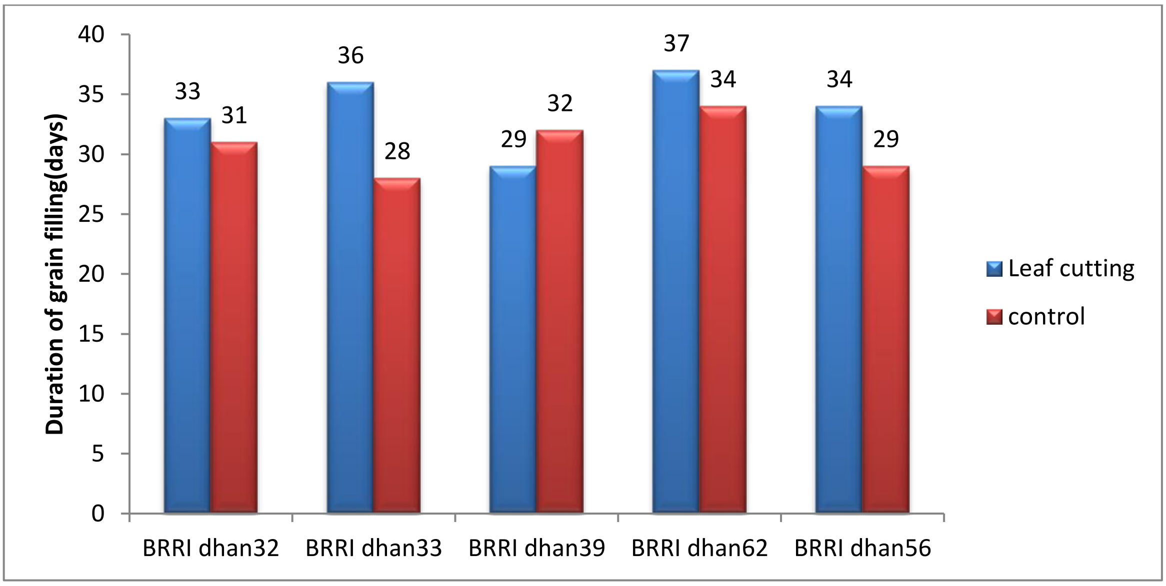

Figure 9: Effect of different varieties on the on duration of Grains filling of rice

Table 3: Effect leaf cutting on grain panicle^{-1} and duration of grains filling of different *Aman* rice varieties

Treatment	Grain panicle^{-1}	Duration of grains filling (days)
Control	105.63 a	33.80
Leaf cutting	94.73 b	27.00
LSD(0.05)	9.45	1.78(ns)
CV%	7.33	6.14

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at .05 level of probability.

Table 3 showed that duration of Grains filling was significantly different in both controls and leaf cuttings. Rice plant requires about 33 days in leaf cutting treatment and around 27 days in control to fill the Grains. All the rice varieties in this experiment showed maximum value of Grain per panicle under control condition without any leaf cutting except BRRI dhan62. There are 6 groups (a, b, etc.) in which the means are not significantly different from one another). Among them BRRI dhan33 gives higher Grains (146.81) and BRRI dhan62 gives lower Grains per panicle (71.67) in controlled environment.

Table 4: Combined effect of leaf cutting grain panicle^{-1} and duration of grains filling of different *Aman* rice varieties

Variety	Grain per panicle		Duration of grain filling	
	Treated	control	Leaf cutting	Control
BRRI dhan32	102.67 d	104.67bcd	33 cd	31 de
BRRI dhan33	112.33 bc	146.81a	36 ab	28 e
BRRI dhan39	100.83d	99.21b	29 ef	32 cd
BRRI dhan62	60.17e	71.67f	37 a	34 cde
BRRI dhan56	107.67cd	105.78b	34 ab	29 e
LSD	21.12		2.16	
CV%	7.33		4.15	

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at .05 level of probability.

Wide range of variability was observed in respect of Grains filling time among five selected BRRI rice varieties (Table 4). Rice varieties *viz.* BRRI dhan32, BRRI dhan33, BRRI dhan39, BRRI dhan62 and BRRI dhan56 plants took 31, 28, 32, 34 and 29 days, respectively for grain maturity under in control condition whereas it takes 33, 36, 29, 37 and 34 days under in leaf cutting condition. In control BRRI dhan62 took maximum days and BRRI dhan33 took minimum days of Grains filling. And in leaf cutting, BRRI dhan62 and BRRI dhan39 needed maximum days minimum days respectively for grains filling among the test varieties.

4.10 Yield Component

The major yield components in rice are number of panicles per unit area, number of Grains panicle^{-1}, Grains filling percentage and individual Grains weight normally expressed as 1000-Grains weight. Different variety showed statistically significant variation in terms of yield of rice (Figure 10).

Among the four major component of yield BRRI dhan33 produces highest filled Grains panicle^{-1} (15.39) and BRRI dhan56 gives lowest value (11.8), BRRI dhan32 gives highest filled Grains percentage (92.05%) and BRRI dhan62 gives lowest value (76.525), BRRI dhan39 shows highest 1000 Grains weight (43.85g) and BRRI dhan33 shows lowest value (26.84g) and BRRI dhan33 produces maximum number of panicle per hill (15.39) and BRRI dhan56 gives minimum number of panicle per hill (11.8) while the other varieties took intermediate positions and they were statistically different among themselves. Tambussi *et al.* (2007) also found the similar result and stated that Grains filling is sustained by current photosynthesis of the upper parts of the plant, i.e. the flag leaf and penultimate leaves and the ear.

Table 5: Comparisons Test of yield components of rice for treatment

Treatment	No. of panicles hill^{-1}	Filled Grains panicle^{-1}	Filled Grains %	1000 grains wt. (g)
Control	15.38 a	105.63 a	85.87 a	29.36 a
Leaf cutting	12.28 b	94.73 b	84.98 b	27.52 b
LSD	0.58	13.03	4.16	0.93
CV%	7.45	9.35	6.47	11.09

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at .05 level of probability.

Table 5 revealed that highest value of all the yield component of no. of panicles hill^{-1} (15.38), filled Grains panicle^{-1} (105.63), filled Grains % (85.87) and 1000-Grains weight (29.36g) were found in control condition. On the other hand the lowest values were obtained when leaf cutting was done, respectively where all 2 means are significantly different from one another. These results are in full compliance with those of Hachiya (1989).

Table 6: Combined effect of leaf cutting and varieties on yield components of rice

Treatments	No. of panicles hill^{-1}	Filled grains panicle^{-1}	Filled grain %	1000 grain weight (g)
Leaf cutting				
BRRI dhan32	14.20 bc	102.67 c	90.50 ab	23.38 g
BRRI dhan33	13.16 cde	112.33 bc	86.84 abcd	22.08 h
BRRI dhan39	11.66 f	100.83 bc	78.15 de	26.50 bc
BRRI dhan62	12.83 def	60.17 d	81.05 cde	24.58 cd
BRRI dhan56	9.55 g	107.67 bc	88.34 abc	22.22 e
Control				
BRRI dhan32	16.55 a	104.67 b	93.60 a	24.50 f
BRRI dhan33	17.62 a	146.81 a	89.06 abc	23.60 fg
BRRI dhan39	12.34 ef	99.21 bc	82.65 bcd	28.20 a
BRRI dhan62	14.87 b	71.67 d	72.00 e	26.00 ab
BRRI dhan56	14.05 bcd	105.78 bc	92.02 a	24.50 d
LSD	1.3	29.13	9.3	2.08
CV%	5.54	10.28	6.35	0.93

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at .05 level of probability.

Table 6 showed that all the yield parameters studied e.g. no. of panicles hill^{-1} , filled Grains panicle^{-1}, filled Grains % and 1000-Grains weight of five rice varieties were affected significantly by leaf cuttings. All the parameters showed maximum value under control condition without any leaf cutting. In controlled condition filled Grains panicle^{-1} (146.81) was the highest in BRRI dhan33 owing to the larger number of panicles hill^{-1} (17.62). On the other hand BRRI dhan32 and BRRI dhan56 showed greater result in terms of filled Grains % (93.60) and 1000grain weight (24.50g) respectively in controlled condition.

4.11 Grain yield

Grains yield (Table. 7) was in the order of BRRI dhan33 (5.75 t ha^{-1}) > BRRI dhan39 (5.45 t ha^{-1}) > BRRI dhan62 (5.2917 t ha^{-1})> BRRI dhan32 (4.975 t ha^{-1}) > BRRI dhan32 (4.865 t ha^{-1}). The total straw yield was in the order of BRRI dhan33 > BRRI dhan62 > BRRI dhan39> BRRI dhan32 > BRRI dhan56 (Fig. 11). And for harvest index percentage BRRI dhan56 revealed maximum and BRRI dhan33 showed minimum value than others varieties. Likely, Das and Mukherjee (1992) reported that late leaf cutting reduce the Grains yield and this was also true for present experiment.

Table 7: Effect of leaf cutting on yield of five modern *Aman* rice varieties

Treatment	Grains yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
Control	5.89 a	6.09 a	98.43 b
Leaf cutting	4.65 b	4.39 b	109.65 a
LSD	0.33	0.38	7.35
CV%	8.18	9.49	9.21

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at .05 level of probability.

Table 7 shows that in both control and leaf cutting treatments the Grains yield, straw yield and harvest index was 5.89 t ha^{-1}, 6.09 t ha^{-1}, 98.43% and 4.65 t ha^{-1}, 4.39 t ha^{-1}, 109.65% respectively. The yield components in control were least affected relative to leaf cutting condition except harvest index.

Table 8: Combined effect of leaf cutting and variety on yield of five modern *Aman* rice varieties

Treatments	Grains yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
Leaf cutting			
BRRI dhan32	3.95 g	4.02 ef	45.44 c
BRRI dhan33	4.75 ef	6.13 b	40 .88 e
BRRI dhan39	5.15 cde	4.08 ef	49.27 ab
BRRI dhan62	4.98 def	4.44 de	44.94 bc
BRRI dhan56	4.39 fg	3.32 f	49.70 a
Control			
BRRI dhan32	6.00 b	5.47 bc	48.87 bc
BRRI dhan33	6.75 a	8.24 a	43.72 de
BRRI dhan39	5.75 bc	5.95 b	47.58 cd
BRRI dhan62	5.60 bcd	5.79 bc	45.97 cd
BRRI dhan56	5.33 bcde	5.02 cd	49.99 c
LSD	0.74	0.85	16.44
CV%	8.18	9.49	9.21

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at .05 level of probability.

Yield comparisons among various traits of five selected BRRI varieties indicated significant differences among entries (Table 8). Varieties in controlled condition produced more Grains yield (t ha^{-1}), straw yield (t ha^{-1}) and Harvest index (%) than in leaf cutting condition. Among the varieties BRRI dhan33 and BRRI dhan56 produced the highest (6.75 t ha^{-1}) and the lowest (5.33 t ha^{-1}) Grains yield respectively across the control condition. The same trend was observed in case of straw yield (t ha^{-1}) where BRRI dhan33 produces maximum straw (8.24 t ha^{-1}) and BRRI dhan56 produces minimum straw (5.02 t ha^{-1}). The Straw yield (t ha^{-1}) of both leaf cutting (6.13 t ha^{-1}) and control condition (8.24 t ha^{-1}) was higher in BRRI dhan33 than others but lower in case of harvest index percentage.

For the harvest index percentage counted, BRRI dhan32 had the highest percentage (49.70%) while the lowest was from BRRI dhan33 at 40.88%. A drastic reduction of all yield components was observed in the leaf cutting treatment as compared to the control.

CHAPTER V

SUMMARY AND CONCLUSION

In order to evaluate the effect of leaf cutting on plant growth and yield of selected BRRI released *Aman* varieties, an experiment was conducted with five rice varieties in RCBD with three replication during the period from July 2016 to December 2016 in the experimental area of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka.

In the study the highest plant height was obtained in BRRI dhan56 and the lowest was found in BRRI dhan32 at all dates of observations. The highest value of breadth of leaf and leaf area was found in BRRI dhan39 (except observations at Penultimate leaf size and Third leaf). Results indicated that leaf cutting treatment showed significant effect on all growth parameters. The highest value of grains panicle^{-1} was obtained from no leaf cutting treatment at all the observation dates. The Grain yield, Straw yield and Harvest index were significantly influenced by treatments.

The longest flag leaf (64.13 cm) and penultimate leaf (64.30 cm) was found from BRRI dhan39 and BRRI dhan56 produces longest third leaf. Leaf length is very important in rice because leaf length is positively correlated with panicle length thereby was correlated with the grain yield of rice. Thereby indicating, it is possible to improve grain yield by genetic improvement of length of flag leaf. Genetic analysis of the morphological and physiological characteristics of functional leaves, especially flag leaf is found important for rice improvement program. It is noticed that when leaf length is high the panicle length is also high.

From the experiment it was observed highest weight of 1000 grains was from BRRI dhan39 which was 26.50 g and 28.20 g for control and treated, respectively. Similarly, highest value of all yield components *e.g.* number of panicles hill^{-1} (15.38), filled grains panicle^{-1} (146.81), filled grain % (92.02%) and 1000-grain weight (28.20g) were found in control condition rather than leaf cutting treatment. Results indicating yield was always significantly reduced when leaf was removed from the plant at panicle initiation stage. This is might be due to the inappropriate food supply to sink that mostly leaf does and thus the effect was observed as various defects in the floral identity. Therefore, it is worth mentioning that leaf has a great contribution on yield. In the study of the duration of grain filling of different rice varieties BRRI dhan39 took minimum (28) days than others. On the other hand leaf cutting affected the duration of grain filling of rice that takes lengthy time than control.

Chlorophyll content of flag leaf from the studied five varieties was measured. Results indicated that flag leaf contained increased amount of total chlorophyll than that of all of the studied varieties. Among the varieties, BRRI dhan33 showed the highest (4.43 mg g^{-1}) flag leaf chlorophyll content at 12 days than the others in leaf cutting treatment and BRRI dhan62 gives the maximum (4.10 mg g^{-1}) flag leaf chlorophyll content at 12 days in control. Variable amount of chlorophyll content was observed in the rice varieties where flag leaf contained increased amount of total chlorophyll at 12 days than that of at maturity for all of the studied varieties. That means photosynthesis occurs mostly in flag leaves at 12 days and contributes mostly in panicle development.

In rice, the leaf is metabolically active and critically important in determining yield. It has been assigned an important role in terms of supply of photosynthates to the grains. Any damage done to that leaf will have a direct and dramatic impact on crops potential. Therefore, it is important to protect the flag leaf in the early stages of crop. In the leaf cutting treatment, the leaves were excised after the emergence of panicle from some of the selected plants of all the examined varieties. Phenotypic observation indicated various defects existed in the leaf cut plants throughout maturation including late maturation, decaying, shrunken and reduced grain size, as well as increased sterility. Moreover, panicle length and branching were reduced. As a whole, those deformities acted as potential factors for the reduction of yield of the rice varieties. 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.

Conclusion

i) Chlorophyll content in flag and penultimate leaves was increased 20% due to lower leaf removal.

ii) The yield and yield contributing characters were adversely affected by leaf cutting.

iii) Based on the comparison of five rice varieties, BRRI dhan39 was found to be highest yielder because of greater flag leaf length, leaf breadth, flag leaf area, 1000 grain weight etc in control condition.

iv) Leaf cutting at heading (except flag leaf and penultimate leaves) reduced avarage10-28% loss of grain yield.

v) BRRI dhan32 affected severely by lower leaf cutting. On the other hand BRRI dhan39 had the recovery potential minimizing the detrimental effect by lower leaf removal

Recommendation

- . BRRI dhan39 should be cultivated for achieving higher grain yield in *Aman* season.
- Further trials at different agro-ecological zones of Bangladesh are needed for the conformation of the results.

CHAPTER V

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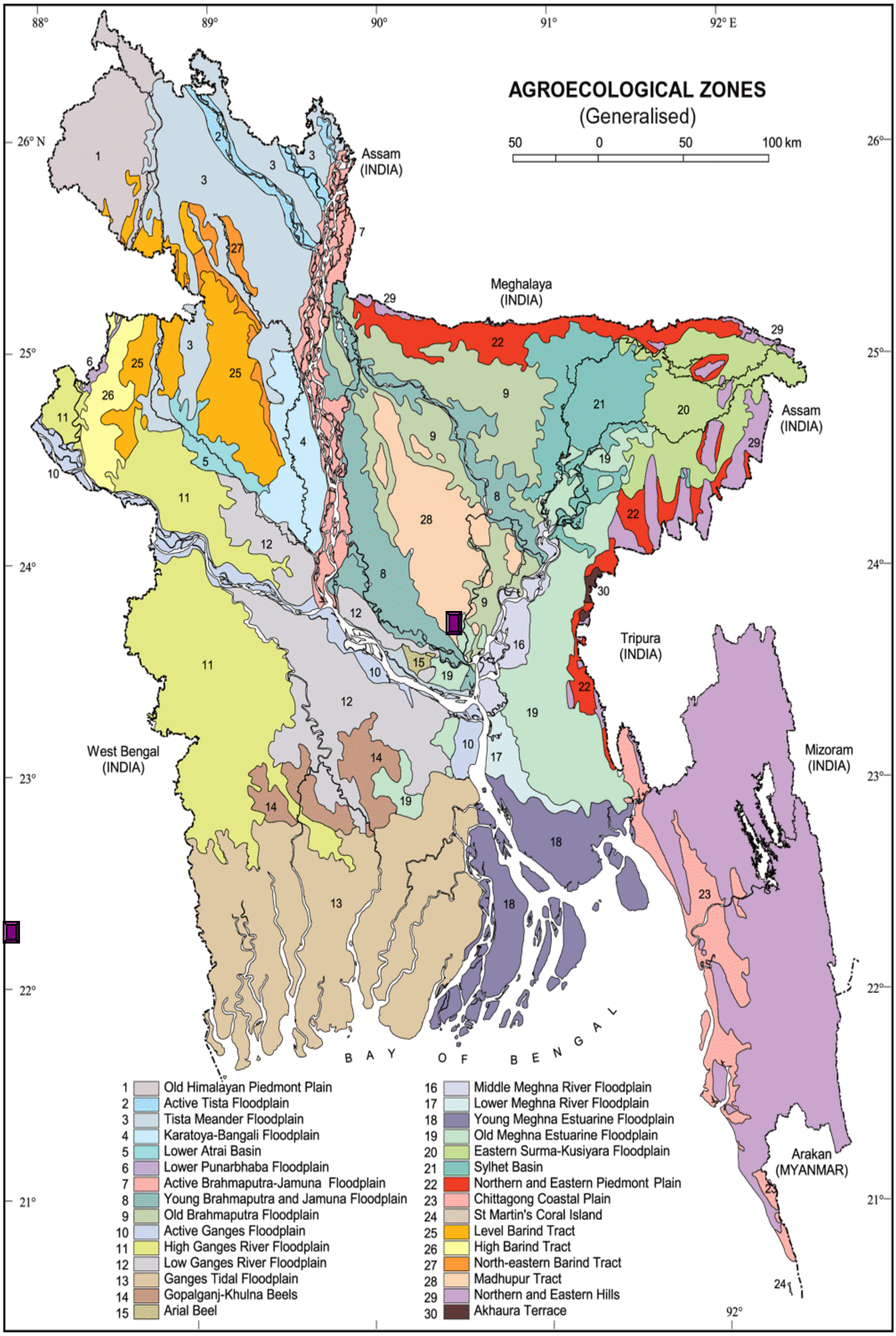
APPENDICES

Appendix I: Map showing the experimental sites under study



Appendix II: Characteristics of soil of experimental is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka-1207

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy Field laboratory, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	Medium hHigh 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 (SRD)

ANOVA Tables

Appendix III : Analysis of variance of the data on chlorophyll contain in flag leaf (mg g^{-1}) at 12days of rice as influenced by leaf cutting

Source	Degrees of freedom	Sum of Square	Mean square	F	P
Replication	2	1.6327	0.81633		
Treated	1	3.0083	3.00833	101.40	0.0000
Control	4	13.1814*	3.29535*	111.08	0.0000
Treated × Control	4	1.6637	0.41593	14.02	0.0000
Error	18	0.5340	0.02967		
Total	29	20.0201			

*Significant at 5% level of probability

Appendix IV: Analysis of variance of the data on chlorophyll contain in flag leaf (mg g^{-1}) at maturity of rice as influenced by leaf cutting

Source	Degrees of freedom	Sum of Square	Mean square	F	P
Replication	2	0.5360	0.26800		
Treated	1	0.5468	0.54675	48.24	0.0000
Control	4	10.2345*	2.55862*	225.76	0.0000
Treated × Control	4	1.5525	0.38812	34.25	0.0000
Error	18	0.2040	0.01133		
Total	29	13.0738			

*Significant at 5% level of probability

Appendix V: Analysis of variance of the data on yield contributing character (panicle hill^{-1})of rice as influenced by leaf cutting

Source	Degrees of freedom	Sum of Square	Mean square	F	P
Replication	2	24.200	12.1000		
Treated	1	59.052	59.0523	102.60	0.0000
Control	4	73.097*	18.2742*	31.75	0.0000
Treated × Control	4	16.380	4.0950	7.11	0.0013
Error	18	10.360	0.5756		
Total	29	183.089			

*Significant at 5% level of probability

Appendix VI: Analysis of variance of the data on yield contributing character (filled grain panicle^{-1}) of rice as influenced by leaf cutting

Source	Degrees of freedom	Sum of Square	Mean square	F	P
Replication	2	8.6	4.29		
Treated	1	3273.8	3273.78	11.35	0.0034
Control	4	25775.8*	6443.96*	22.35	0.0000
Treated × Control	4	4225.3	1056.33	3.66	0.0237
Error	18	5189.8	288.32		
Total	29	38473.3			

*Significant at 5% level of probability

Appendix VII: Analysis of variance of the data on yield contributing character (grain panicle^{-1}) of rice as influenced by leaf cutting on

Source	Degrees of freedom	Sum of Square	Mean square	F	P
Replication	2	818.1	409.03		
Treated	1	1493.5	1493.47	9.85	0.0057
Control	4	34884.6*	8721.14*	57.53	0.0000
Treated×Control	4	4871.7	1217.92	8.03	0.0007
Error	18	2728.6	151.59		
Total	29	44796.4			

*Significant at 5% level of probability

Appendix VIII: Analysis of variance of the data on yield contributing character (% filled grains) of rice as influenced by leaf cutting

Source	Degrees of freedom	Sum of Square	Mean square	F	P
Replication	2	832.20	416.100		
Treated	1	5.94	5.941	0.20	0.6586
Control	4	1064.02*	266.005*	9.04	0.0003
Treated×Control	4	189.41	47.352	1.61	0.2153
Error	18	529.80	29.433		
Total	29	2621.37			

*Significant at 5% level of probability

Appendix IX: Analysis of variance of the data on duration of grain filling of rice as influenced by leaf cutting

Source	Degrees of freedom	Sum of Square	Mean square	F	P
Replication	2	137.400	68.700		
Treated	1	346.800	346.800	218.27	0.0000
Control	4	187.200*	46.800*	29.45	0.0000
Treated×Control	4	19.200	4.800	3.02	0.0454
Error	18	28.600	1.589		
Total	29	719.200			

*Significant at 5% level of probability

Appendix X: Analysis of variance of the data on 1000 -grain weight of rice as influenced by leaf cutting

Source	Degrees of freedom	Sum of Square	Mean square	F	P
Replication	2	148.95	74.475		
Treated	1	67.86	67.860	46.01	0.0000
Control	4	1372.57*	343.143*	232.64	0.0000
Treated×Control	4	2.08	0.521	0.35	0.8384
Error	18	26.55	1.475		
Total	29	1618.01			

*Significant at 5% level of probability

Appendix XI: Analysis of variance of the data on grain yield (t ha^{-1}) of rice as influenced by leaf cutting

Source	Degrees of freedom	Sum of Square	Mean square	F	P
Replication	2	2.8887	1.4443		
Treated	1	11.5568	11.5568	62.32	0.0000
Control	4	3.1097*	0.7774*	4.19	0.0143
Treated×Control	4	3.1828	0.7957	4.29	0.0130
Error	18	3.3380	0.1854		
Total	29	24.0759			

*Significant at 5% level of probability

Appendix XII: Analysis of variance of the data on straw yield (t ha^{-1}) of rice as influenced by leaf cutting

Source	Degrees of freedom	Sum of Square	Mean square	F	P
Replication	2	0.4380	0.2190		
Treated	1	21.5731	21.5731	87.03	0.0000
Control	4	31.4341*	7.8585*	31.70	0.0000
Treated×Control	4	0.5729	0.1432	0.58	0.6825
Error	18	4.4620	0.2479		
Total	29	58.4801			

*Significant at 5% level of probability

Appendix XIII: Analysis of variance of the data on harvest index (%) of rice as influenced by leaf cutting

Source	Degrees of freedom	Sum of Square	Mean square	F	P
Replication	2	248.4	124.19		
Treated	1	944.3	944.28	10.28	0.0049
Control	4	5357.6*	1339.40*	14.58	0.0000
Treated×Control	4	1970.5	492.62	5.36	0.0050
Error	18	1653.4	91.85		
Total	29	10174.1			

*Significant at 5% level of probability

Appendix XIV: Pictorial of experimental field

Plate-1: Prepararred main field

Plate-2: Field after transplantaion

Plate-3: Field at tillering stage in main field

Plate-4: Field at panicle initiation stage in main field

Plate-5: Field at maturing stage in main field

Plate-6: Field at maturing stage in main field

Plate-7: Author, in main field