EFFECT OF LEAF CUTTING ON MORPHO-PHYSIOLOGY AND YIELD OF SELECTED RICE VARIETIES

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CERTIFICATE

*This is to certify that the thesis entitled **"EFFECT OF LEAF CUTTING ON MORPHO-PHYSIOLOGY AND YIELD OF SELECTED RICE VARIETIES"** submitted to the **Faculty of Agriculture,** Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS) IN AGRICULTURAL BOTANY** embodies the result of a piece of bona fide research work carried out by **TONUSREE BARMAN, Registration no. 18-09133** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

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TO

MY BELOVED

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EFFECT OF LEAF CUTTING ON MORPHO-PHYSIOLOGY AND YIELD OF SELECTED RICE VARIETIES

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ABSTRACT

The present investigation entitled "Effect of leaf cutting on morpho-physiology and yield of selected rice varieties" was conducted from February to June, 2019 at the Research Farm of SAU, Dhaka, Bangladesh. The experiment comprised of two factors; viz. Factors A: Two rice varieties(BRRI dhan29 and BRRI hybrid dhan2) and Factor B: Leaf cutting (Flag leaf cutting, Flag leaf + 3rd leaf cutting, Penultimate leaf + 3rd leaf cutting, all leaves cutting without flag leaf, all leaves cutting and Untreated control). The experiment was laid out in spilt plot with three replications. Different treatment combinations showed significant differences due to their interaction effect on morphological parameters, physiological parameters, yield attributes and yield. Considering all leaf cutting treatments the tallest plant (98.22 cm), maximum number of tillers hill^{-1} (20.56g), leaves hill^{-1} (22.78g), total dry mater (13.64 g), leaf area index (2.34 cm^{-2}), stomatal conductance (0.49 mmol CO_2 m^{-2} s^{-1}), SPAD (45.62), total spikelet panicle^{-1} (174.9), weight of 1000 grain (27.19 g), grain yield (5.81 t ha^{-1}), straw yield (6.48 t ha^{-1}) and harvest index (46.83%) were found in BRRI dhan29 variety. Whereas, maximum sterile spikelet panicle^{-1} (35.50) and spikelet sterility (21.15%) were found in BRRI hybrid dhan2 variety. Considering both varieties the tallest plant (99.50 cm), maximum total number of tillers hill^{-1} (25.00), number of leaves hill^{-1} (26.17g), total dry mater (20.42 g), leaf area index (2.95 cm^{-2}), stomatal conductance (0.55 mmol CO_2 m^{-2} s^{-1}), SPAD (46.17), grain panicle^{-1} (147.50), total spikelet panicle^{-1} (175.5), effective tillers hill^{-1} (8.33g), spikelet panicle^{-1} (149.8g), weight of 1000 grains (28.97 g), grain yield (7.73 t ha^{-1}), straw yield (9.35 t ha^{-1}) and harvest index (48.60%) were found in L_0 (Untreated control). Whereas, maximum sterile spikelet panicle^{-1} (47.50g) and spikelet sterility (45.72%) were found in L_5 (All leaves cutting).Consiering the combination of varieties and leaf cutting the tallest plant (104.3 cm), maximum number of tillers hill^{-1} (26.67g), number of leaves hill^{-1} (27.67g), total dry mater (21.50 g), leaf area index (2.95 cm^{-2}), stomatal conductance (0.57 mmol CO_2 m^{-2} s^{-1}), SPAD (46.67), number of grain padnicle^{-1} (151.67g), total number of spikelet panicle^{-1} (241.7g), weight of 1000 grain (29.63 g), number of grain panicle^{-1} (8.13g) and straw yield (9.47 t ha^{-1}) were found in BRRI dhan29 + Untreated control. Whereas, the maximum number of sterile spikelet panicle^{-1} (47.67) and spikelet sterility (42.45%) were found in BRRI dhan29 +Untreated control. From this study it can be concluded that, BRRI dhan29 performed well in case of leaf cutting treatments than BRRI hybrid dhan2. Beside this, Untreated control treatment performed great than the other treatments.

LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Full meaning
%	Percent
°C	Degree Celsius
AEZ	Agro-ecological Zone
AVOVA	Analysis of variance
AS	Aroma Scoring
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BRRI	Bangladesh Rice Research Institute
CD	Cooking Duration
cm	Centimeter
CV	Coefficient of variation
DAS	Days after sowing
DAT	Days after transplanting
d.f.	Degrees of freedom
et al.	And others
ER	Elongation ratio
FAO	Food and Agriculture Organization
G	Gram
Ha	Hectare
J.	Journal
Kg	Kilogram
L/B	Length-breadth ratio
LSD	Least Significant Difference
Mg	Milligram
Ml	Milliliter
MP	Muriate of Potash
SAU	Sher-e-Bangla Agricultural University
SPAD	The Soil Plant Analysis Development
TSP	Triple Super Phosphate

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Rice is the seed of the grass species *Oryza sativa* (Asian rice) or *Oryza glaberrima* (African rice). As a cereal grain, it is the most widely consumed staple food for a large part of the world's human population, especially in Asia. 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. 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). Bangladesh Rice Research Institute (BRRI) released BRRI dhan29 and BRRI hybrid dhan2 whose planting season is Boro, Rabi, late October to Mid-November and Rabi, Boro, Mid November to Mid-December respectively and harvesting time is Mid-April to early May.

Variety itself is a genetic factor which contributes a lot in producing yield and yield components of a particular crop (Mahmud *et al*., 2013). 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). 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 durated variety and adoption of modern agricultural practices. Most of the farmers cultivate BRRI and local varieties; and have a few produce BINA released varieties. Total area under Boro crop has been estimated at 118,32,309 acres

(47,88,276 hectares) in this year (2018-19) as compared to 120,07,983 acres (48,59,367 hectares) of the last year (2017-18). The harvested area has decreased by 1.46 % (BBS, 2019).

Total area of Boro rice cultivation was 47,88,276 hectare; among them local boro varieties were under 45,332 hectare, high yielding varieties under 38,89,889 hectare and hybrid varieties were under 8,53,055 hectare land. Average production was 4.0851, 1.87, 3.95 and 4.82 t ha^{-1} of total boro rice, local boro varieties, high yielding varieties and hybrid varieties respectively (BBS 2019).

The flag leaf contribute maximum to the yield of rice grains. Flag leaf contributes to about 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 filling stage of rice after leaf removal (Hossain, 2017). 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 through transpiration. Excess leaf growth of long durated rice plants is grazed at the early vegetative stage (Magor, 1986).

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). 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.

If the leaf cutting really has no effect on the production of rice grains, it may become one of the most economical way of increasing the yield, with the additional advantage that it will provide green feeding material leaves for their animals. The success of rice cultivation with leaf cutting is mostly dependent on different improved rice varieties, improved agronomic techniques types of leaves that would be cut and cutting time. Selection of specific leaf for cutting and suitable rice varieties seem to be very important for obtaining enough forage without sacrificing grain yield in rice. Considering the above statements the present investigation is carried out with the following objectives:

1. To study the effect of leaf cutting on morphology, physiology and yield of rice.
2. To evaluate the varietal performance due to leaf cutting.

CHAPTER II

REVIEW OF LITERATURE

Rice is mostly grown cereal crops in Bangladesh. The growth and development of rice may be influenced due to varietal performance and morpho-physiological performance. 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 and given in following headings:

2.1. Effect of varieties on rice production

A number of reports showed that indigenous rice varieties possess a wide diversity in ecological, morphological and physiological characteristics (Jahan *et al*., 2003).

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.

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.

Ashrafuz zaman *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} (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. Ahmed *et al*., (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 dhan5 and Tulsimala, BRRI dhan14 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 Putiawhere 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 Hybrid1 (KRH1) and Karnataka Rice Hybrid2 (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, Sonar bangla-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}.

Ahmed *et al*., (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.

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.

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. 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.

2.2. Effect of leaf on rice production

Leaf length was positively correlated with panicle length thereby was correlated with the grain yield which showed the similarity with the results of Li *et al*., (1998), where found that large leaf length, leaf width, and leaf area contributed to increased spikelet number panicle^{-1}.

Bing *et al.*, (2006) found that potential yield and spikelet number were positively correlated with length, width and area of flag leaf. Thereby indicating, it is possible to improve grain yield by genetic improvement of length, width and area of flag leaf.

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).

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*., (1991) 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.

Yield was significantly and positively associated with panicle length (Yadav *et al*., 2010). It also found that flag leaf length was positively associated with panicle length, thereby indicating associated with grain yield (Rahman *et al*., 2013).

Prakash *et al*., (2011) found that the grain yield was positively related with flag leaf area in rice cultivars. Roy and Kar, (1992), Gupta *et al*., (1999) also reported significant positive association between boot leaf length plant^{-1} and grain yield plant^{-1}.

High grain yield in rice was reported due to high TDM plant^{-1} (Yoshida, 1981; Ray *et al*., 1983; Jiang *et al*., 1988). 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. Misra, (1986, 1987 & 1995) and Misra and Misra, (1986) 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.

Flag leaf contributed to 45% of grain yield (Misra, 1995) 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).

2.3. Effect of leaf on morpho-physiological characteristics of rice

Genetic analysis of the morphological and physiological characteristics of functional leaves, especially flag leaf is found important for rice improvement program (Yue *et al*., 2006).

It is noticed that when FL length is high the panicle length is also high. In case of BR11 when the average FL length was 21.33, 25.90, 28.19, 37.33, 18.28, 37.84, 37.59, 25.90, 24.13, 35.50 cm, then the average panicle length was 18.03, 18.54, 20.32, 34.98, 17.52, 33.87, 33.36, 19.85, 22.60, 31.65 cm, respectively and in case of correlation analysis, a significant correlation was found between them (Rahman *et al*., 2013).

2.4. Effect of leaf cutting on yield of rice in different cultivars

The growth and yield parameters studied e.g. leaf area (cm^2) $plant^{-1}$, chlorophyll content (SPAD units), total dry matter (TDM) production (g) $mainstem^{-1}$, Spikelets unit leaf $area^{-1}$ –ratio, panicle length, spikelet number, number of grains $panicle^{-1}$, test weight (1000 grain weight) and grain yield (t ha^{-1}) 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 (Khalifa *et al*., 2008).

Misra, 1986, 1987, 1995 and Misra and Misra, 1991b also showed that the corroboration with the effect of leaf cutting on chlorophyll content, leaf area, spikelet number and yield parameters in pearl millet.

Cutting long duration rice leaves at the vegetative phase is also practiced in India (Copeland, 1972) and is now more frequently done in Thailand (Kupkan chanakul *et al*., 1991).

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.

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. Ahmed *et al*., (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 gm), 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 *et al*., (2001).

Hodgkinson and Becking, (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).

Ahmed *et al*., (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.

Ahmed *et al*., (2001), conducted an experiment consisted of four varieties namely Latishail, BR10, BR11 and BRRIdhan32 and four leaf cuttings viz., no leaf cutting (T_1), leaf cutting at 21 DAT (T_2), leaf cutting at 28 DAT(T_3), leaf cutting at 35 DAT(T_4). 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) were observed in BR11 as compared to BR10 and BRRI dhan32.

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 an experiment on banana leaf and suggested 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), TDM production, panicle length, spikelet number, number of grains panicle^{-1}, 1000 grain weight and grain yield (t ha^{-1}) 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 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 plant^{-1} (Yoshida, 1981; Ray *et al*., 1983; Jiang *et al*., 1988).

Misra, (1995) 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 CO_2 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 Ahmed *et al*., (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 *Tremamicrantha* (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.

CHAPTER III

MATERIALS AND METHOD

The experiment was conducted to find out the effect of leaf cutting on morpho-physiology and yield of selected rice varieties. The details of the materials and methods i.e. experimental period, location, soil and climatic condition of the experimental area, materials used, treatments and design of the experiment, growing of crops, data collection and data analysis procedure that followed in this experiment has been presented under the following headings:

3.1 Experimental period

The field experiments were conducted during the period of February to June 2019.

3.2 Description of the experimental site

3.2.1 Location of the experimental field

The experiment was carried out on the farm of Sher-e-Bangla Agricultural University, Dhaka. The location of the site is 23º74'N latitude and 90º35'E longitude with an elevation of 8.2 meter from sea level.

3.2 2 Characteristics of the soil

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

3.2.3 Climate

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

3.3 Plant material

In this research, two rice varieties namely BRRI dhan29 and BRRI hybrid dhan2 were used. The seeds were collected from the Bangladesh Rice Research Institution (BRRI), Joydeppur, Gazipur.

3.4 Experimental design

The experiment followed a split plot design with three replications and it laid out following unit plot size of 3 m x 3 m.

3.5 Treatments

The experiment were conducted in two factors split plot design with three replications. It consisted of two factors as mentioned below:

Factor A: Variety (2)

(i) BRRI dhan29 (V_1)

(ii) BRRI hybrid dhan2 (V_2)

Factor B: Leaf cutting (6)

1. Untreated control (L_0)
2. Flag leaf cutting (L_1)
3. Flag leaf + 3rd leaf cutting (L_2)
4. Penultimate leaf + 3rd leaf cutting (L_3)
5. All leaves cutting without flag leaf (L_4)
6. All leaves cutting (L_5)

Treatment Combinations (12):

1. V_1L_1: BRRI dhan29 + Flag leaf cutting
2. V_1L_2: BRRI dhan29 + Flag leaf + 3rd leaf cutting
3. V_1L_3: BRRI dhan29 + Penultimate leaf + 3rd leaf cutting
4. V_1L_4: BRRI dhan29 + All leaves cutting without flag leaf
5. V_1L_5: BRRI dhan29 + All leaves cutting

6. V_1L_0: BRRI dhan29 + Untreated control

7. V_2L_1: BRRI hybrid dhan2 + Flag leaf cutting

8. V_2L_2: BRRI hybrid dhan2 + Flag leaf + 3rd leaf cutting

9. V_2L_3: BRRI hybrid dhan2 + Penultimate leaf + 3rd leaf cutting

10. V_2L_4: BRRI hybrid dhan2 + All leaves cutting without flag leaf

11. V_2L_5: BRRI hybrid dhan2 + All leaves cutting

12. V_1L_0: BRRI hybrid dhan2 + Untreated control

3.6 Procedure of experiment

3.6.1 Raising seedling

3.6.1.1 Seed collection

Vigorous and healthy seeds of BRRI dhan29 and BRRI hybrid dhan2 were collected from BRRI, Gazipur, Bangladesh.

3.6.1.2 Seed sprouting

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

3.6.1.3 Preparation of nursery bed and seed sowing

As per BRRI recommendation seedbed was prepared with 1 m wide adding nutrients as per the requirements of soil. Seeds were sown in the seed bed on 20 February, 2019 in order to transplant the seedlings in the main field.

3.6.2 Preparation of the main field

The plot selected for the experiment was opened in the 2nd week of March, 2019 with a power tiller and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross ploughed several times followed by laddering to obtain a good tilt. Weeds and stubble were removed and finally obtained a desirable tilth of soil for transplanting of seedlings.

3.6.3 Fertilizers and manure application

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

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

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

3.6.4 Uprooting of seedlings

The nursery bed was made wet by application of water one day before uprooting the seedlings. The seedlings were uprooted on 15 March, 2019 without causing much mechanical injury to the roots.

3.6.5 Transplanting of seedlings in the field

Thirty (30) days old seedlings were transplanted in the experimental plots using three seedlings hill^{-1} on 15 March, 2019.

3.6.6 Intercultural operations

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

3.6.6.1 Irrigation and drainage

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

3.6.6.2 Gap filling

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

3.6.6.3 Weeding

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

3.6.6.4 Top dressing

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

3.6.6.5 Plant protection

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

3.7 Harvesting, threshing and cleaning

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

3.8 Data recording

The following data were collected during the study period:

Growth characteristics

1. Plant height

2. Total tillers hill^{-1}

3. Leaves hill^{-1}

Morphological parameters

1. Leaf area index

Physiological parameters

1. SPAD Value

2. Stomatal conductance

3. Total dry matter hill^{-1}

4. Dry matter distribution

Yield contributing parameters

1. Total grainpanicle^{-1}

2. Filled grain panicle^{-1}

3. Unfilled grain panicle^{-1}

4. Spikelet sterility (%)

5. 1000 seed weight

Yield parameters

1. Grain yield

2. Straw yield

3. Biological yield

4. Harvest index

3.9 Procedure of recording data

3.9.1 Plant height

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

3.9.2 Number of total tillers hill^{-1}

Total tillers which had at least one leaf visible were counted. It includes both productive and unproductive tillers. The effective, ineffective and total number of tillers hill^{-1} were counted from 5 selected hills at harvest and average value was recorded.

3.9.3 Number of leaves hill^{-1}

The total number of leaves hill^{-1} was counted from 5 selected hills at harvest and average value was recorded.

3.9.4 Leaf area index

Leaf area index (cm^2) 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.

Leaf area index = Leaf length × leaf breadth × 0.75

3.9.5 SPAD Value

SPAD readings were taken at three locations: (a) 1/3 of the distance from the leaf base, (b) 1/2 of the distance from the leaf base, and (c) 2/3 of the distance from the leaf base. In the meanwhile, (ab), (ac), (bc) and (abc) mean the combination of the corresponding (a), (b) and (c) positions. Ten randomly selected plants from each plot were measured in the field. For the sake of illustration, Sa, Sb, and Sc represent SPAD readings at leaf locations (a), (b), and (c), respectively. Sabc represents the average SPAD readings of the whole leaf.

3.9.6 Stomatal conductance

Leaf Porometer is a battery-operated, menu-driven device used to measure stomatal conductance of leaves. The Leaf Porometer measures stomatal conductance by putting the conductance of a leaf in series with two known conductance elements, and comparing the humidity measurements between them.

3.9.7 Total dry matter hill^{-1}

Total dry matter per hill was measured in gram (g) at 25, 50, 75 DAT and at harvest from 5 randomly selected plant of each plot from inner rows leaving the boarder row.

Collected plant were oven dried at 70°C for 72 hours then transferred into desecrator and allowed to cool down at room temperature, then final weight was taken.

3.9.8 Total grains panicle^{-1}

The total number of grains was calculated by adding filled and unfilled grains from randomly selected ten panicles per plot and then average number of grains panicle^{-1} was recorded.

3.9.9 Filled grainspanicle^{-1}

The total number of filled grains was collected from the randomly selected 5 panicles from each plot and then average number of filled grains panicle^{-1} was calculated.

3.9.10 Unfilled grains panicle^{-1}

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

3.9.11 Spikelet sterility (%)

The grain sterility percentage was calculated by dividing number of unfilled grains with number of total grains and multiply by 100.

Grain sterility percentage= (Number of unfilled grains/ Number of total grains) x 100

3.9.12 1000 seed weight

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

3.9.13 Grain yield ha^{-1}

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

3.9.14 Straw yield ha^{-1}

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

3.9.15 Biological yield

The biological yield was calculated by adding total grain yield and straw yield.

Biological yield = Grain yield + Straw yield

3.9.16 Harvest index (%)

The harvest index was calculated with the following formula:

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

3.10 Statistical Analysis

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

CHAPTER IV

RESULTS AND DISCUSSION

The present investigation entitled "Effect of leaf cutting on morpho-physiology and yield of selected rice varieties". The findings obtained from the study have been presented, discussed and compared in this chapter through different tables and figures. The analyses of variance (ANOVA) and other table on different parameters have been presented in Appendices. The results have been presented and discussed with the help of tables and graphs and possible interpretations have been given under the following sub-headings.

4.1 Growth performances

4.1.1 Plant height (cm) at harvesting stage

4.1.1.1 Effect of variety

Plant height is an important morphological and developmental phenotype that directly indicates overall plant growth and is widely predictive of final grain yield and biomass. Plant height is a central part of plant ecological strategy. It is strongly correlated with life span, seed mass and time to maturity, and is a major determinant of a species' ability to compete for light. In case of plant height (cm) at harvesting stage, there was statistically significant variations among the rice cultivars (Figure 1). Data revealed that the tallest plant (98.22 cm) was observed from BRRI dhan29, which was statistically different from the other variety, whereas the shortest plant (90.33 cm) was recorded from BRRI hybrid dhan2. This confirms the report of Jahid, (2017) that plant height differed from variety to variety. Plant height was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

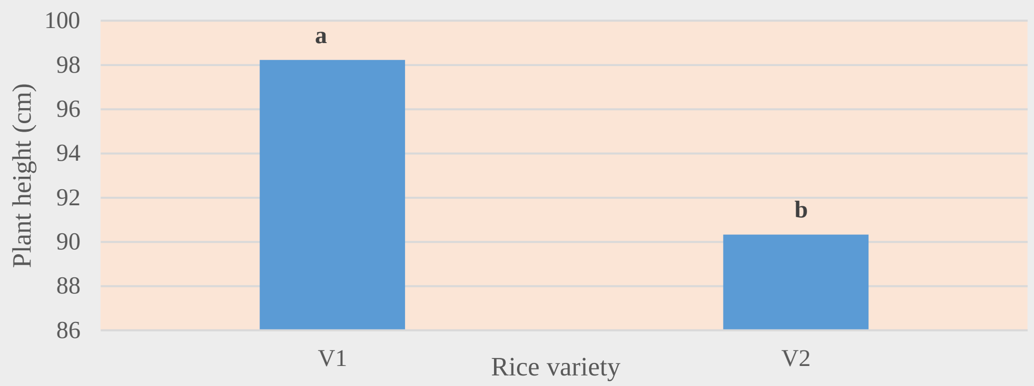

Figure 1: Varietal effect of leaf cutting on plant height (cm) of rice plant at harvesting stage.

Here, V_1= BRRI dhan29 and V_2= BRRI hybrid dhan2

4.1.1.2 Effect of leaf cutting

In case of plant height (cm) at harvesting stage, there was statistically significant variations among the different leaf cuttings of rice plant (Figure 2). Among the different leaf cutting, the maximum plant height (99.50 cm) was observed from L_0 (Untreated control) which was significantly similar with L_4 (All leaves cutting without flag leaf) followed by others and minimum plant height (87.50 cm) was recorded from L_5 (All leaves cutting). It might be due to the fact that lack of chlorophyll effect on the development of rice plant. Similar results were also reported (Abu-Khalifa *et al*.,2008).

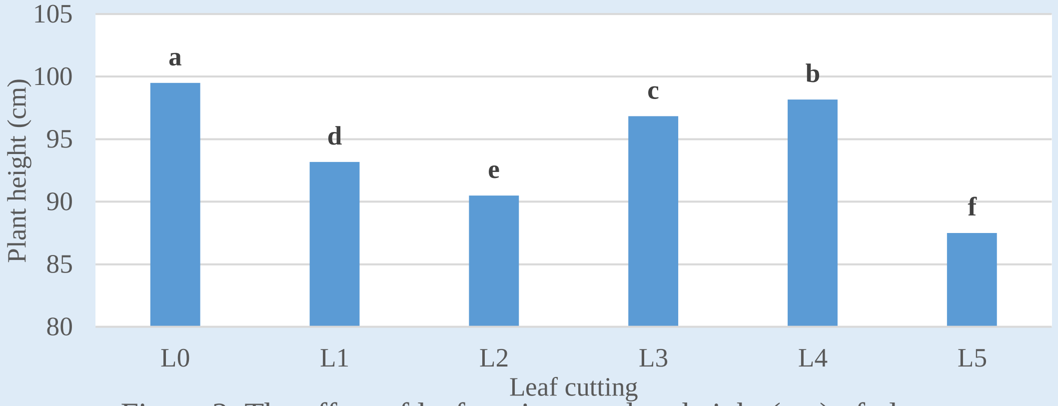

Figure 2: The effect of leaf cutting on plant height (cm) of plants at harvesting stage.

Here, L_1= Flag leaf cutting; L_2= Flag leaf + 3rd leaf cutting; L_3= Penultimate leaf + 3rd leaf cutting; L_4= All leaves cutting without flag leaf; L_5= All leaves cutting; L_0= Untreated control.

4.1.1.3 Interaction effect of different varieties and leaf cutting

Different varieties and leaf cutting expressed significant differences due to their interaction effect on plant height of rice at harvesting stage (Table 2). The maximum plant height (104.3 cm) was recorded from the V_1L_0 (BRRI dhan29 + Untreated control) which was statistically different from others and followed by V_1L_4, V_2L_0, V_1L_3, V_2L_4, V_1L_1 and V_1L_2. The shortest plant (85.33 cm) was obtained from the V_2L_5 (BRRI hybrid dhan2 + All leaves cutting) which was statistically similar with V_1L_5 and followed byV_2L_2, V_2L_1, and V_2L_3 (Appendix 3).

Table 2: Interaction effect of varieties and leaf cutting on plant height of rice at harvesting stage.

Varieties	Leaf cuttings	Plant height (cm)
BRRI dhan29 (V_1)	L_0	104.3 a
	L_1	94.67 d
	L_2	93.67 de
	L_3	96.67 c
	L_4	102.7 b
	L_5	86.33 g
BRRI hybrid dhan2 (V_2)	L_0	101.3 b
	L_1	89.67 f
	L_2	89.67 f
	L_3	92.33 e
	L_4	94.67 d
	L_5	85.33 g
CV (%)		0.94
LSD $_{(0.05)}$		1.46

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, L_1= Flag leaf cutting; L_2= Flag leaf + 3rd leaf cutting; L_3= Penultimate leaf + 3rd leaf cutting; L_4= All leaves cutting without flag leaf; L_5= All leaves cutting; L_0= Untreated control.

4.1.2 Tillers hill^{-1} at anthesis stage

4.1.2.1 Effect of variety

In case of total number of tillers hill^{-1} at anthesis stage, there was statistically significant variations among the rice cultivars (Figure 3). Data revealed that, the maximum tiller hill^{-1} (20.56) was observed from BRRI dhan29, which was statistically different from the other variety, whereas the minimum tiller hill^{-1} (18.33) was recorded from BRRI hybrid dhan2. This confirms the report of Jahid, (2017) that the number of tillers hill^{-1} differed from variety to variety. Number of tillers hill^{-1} was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

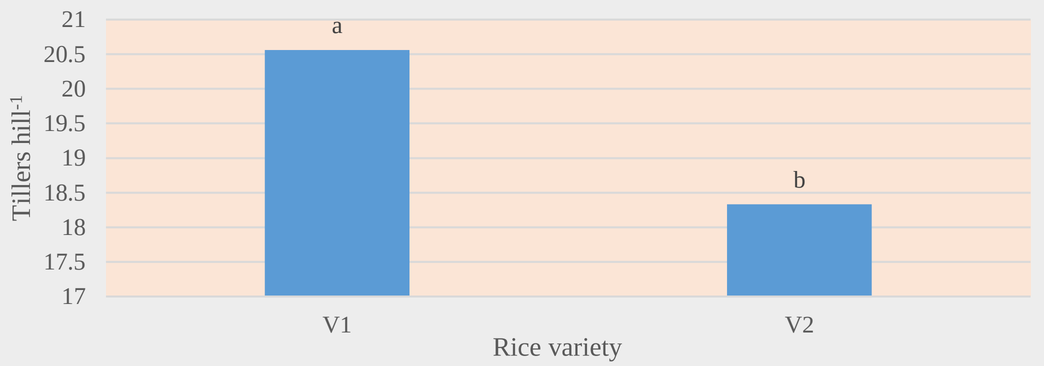

Figure 3: Varietal effect of leaf cutting on tillers hill^{-1} of rice plants at anthesis stage.

Here, V_1= BRRI dhan29 and V_2= BRRI hybrid dhan2

4.1.2.2 Effect of leaf cutting

In case of number of total tillers hill^{-1} at anthesis stage, there was statistically significant variations among the different leaf cuttings of rice plants (Figure 4). Among the different leaf cutting, the maximum number of tillers hill^{-1} (25.00) was observed from L_0 (Untreated control) which was significantly different and followed by others. Minimum number of tillers hill^{-1} (14.17) was recorded from L_5 (All leaves cutting). It might be due to the fact that lack of chlorophyll effect on the development of rice plant. Similar results were also reported (Abu-Khalifa *et al*.,2008).

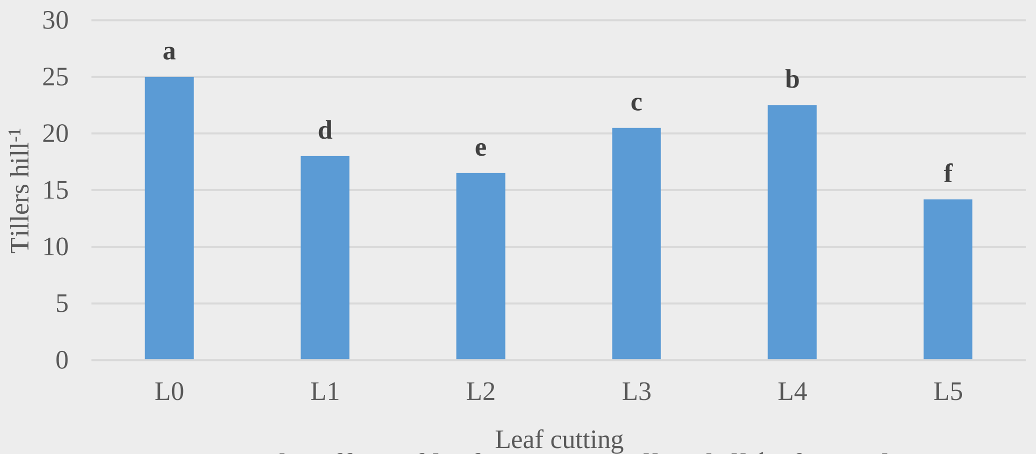

Figure 4: The effect of leaf cutting on tillers hill^{-1} of rice plant at anthesis atage.

Here, L_1= Flag leaf cutting; L_2= Flag leaf + 3rd leaf cutting; L_3= Penultimate leaf + 3rd leaf cutting; L_4= All leaves cutting without flag leaf; L_5= All leaves cutting; L_0= Untreated control.

4.1.2.3 Interaction effect of different varieties and leaf cutting

Different varieties and leaf cutting expressed significant differences due to their interaction effect on number of tillers hill^{-1} of rice at anthesis stage (Table 3). The maximum number of tillers hill^{-1} (26.67) was recorded from the V_1L_0 (BRRI dhan29 + Untreated control) which was statistically different from others and followed by V_1L_4, V_2L_0, V_1L_3, V_2L_4, V_1L_1, V_1L_2, V_2L_1 andV_2L_3. The minimum number of tillers hill^{-1} (13.67) was obtained from the V_2L_5 (BRRI hybrid dhan2 + All leaves cutting) which was statistically similar with V_1L_5 and followed by V_2L_2 (Appendix 4).

Table 3: Interaction effect of varieties and leaf cutting on tillers hill^{-1} of rice at anthesis stage.

Varieties	Leaf cuttings	Tillers hill^{-1}
BRRI dhan29 (V_1)	L_0	26.67 a
	L_1	18.67 e
	L_2	18.33 e
	L_3	22.33 cd
	L_4	23.67 b
	L_5	14.67 fg
BRRI hybrid dhan2 (V_2)	L_0	23.33 bc
	L_1	17.67 e
	L_2	15.33 f
	L_3	17.67 e
	L_4	21.33 d
	L_5	13.67 g
CV (%)		3.62
LSD $_{(0.05)}$		1.17

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, L_1= Flag leaf cutting; L_2= Flag leaf + 3rd leaf cutting; L_3= Penultimate leaf + 3rd leaf cutting; L_4= All leaves cutting without flag leaf; L_5= All leaves cutting; L_0= Untreated control.

4.1.3 Leaves hill^{-1} at anthesis stage

4.1.3.1 Effect of variety

In case of total number of leaves hill^{-1} at anthesis stage, there was statistically significant variations among the rice varieties (Figure 5). Data revealed that, the maximum number of leaves hill^{-1} (22.78) was observed from BRRI dhan29, which was statistically different from other variety, whereas the minimum number of leaves hill^{-1} (19.94) was recorded from BRRI hybrid dhan2. This confirms the report of Jahid, (2017) that the number of leaves hill^{-1} differed from variety to variety. The number of leaves hill^{-1} was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

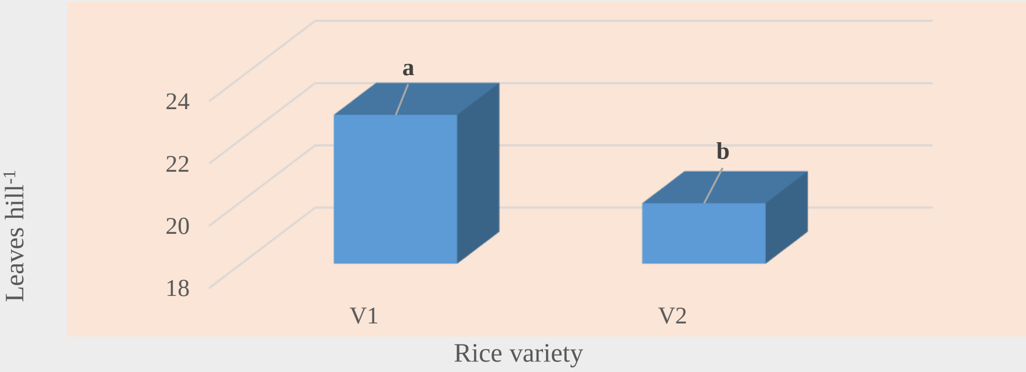

Figure 5: Varietal effect of leaves hill^{-1} of rice plants at anthesis stage before leaf cutting.

Here, V_1= BRRI dhan29 and V_2= BRRI hybrid dhan2

4.1.3.2 Effect of leaf before cutting

In case of number of total leaves hill^{-1} at anthesis stage, there was statistically significant variations among the different leaf before cuttings of rice plants (Figure 6). Among the different leaf before cutting, the maximum number of leaves hill^{-1} (26.17) was observed from L_0 (Untreated control) which was significantly different and followed by others. Minimum number of leaves hill^{-1} (17.17) was recorded from L_5 (All leaves cutting). It might be due to the fact that lack of chlorophyll effect on the development of rice plant. Similar results were also reported (Abu-Khalifa *et al.*, 2008).

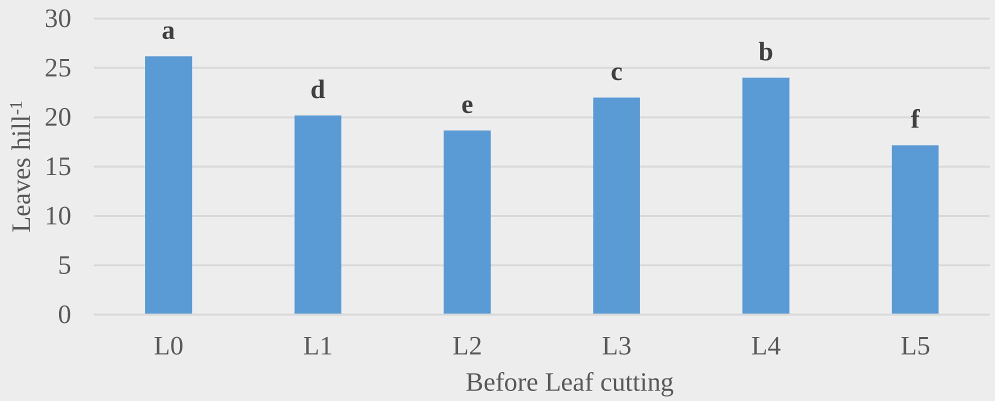

Figure 6: The effect of leaves hill^{-1} of rice plant at anthesis stage before leaf cutting.

Here, L_1= Flag leaf cutting; L_2= Flag leaf + 3rd leaf cutting; L_3= Penultimate leaf + 3rd leaf cutting; L_4= All leaves cutting without flag leaf; L_5= All leaves cutting; L_0= Untreated control.

4.1.3.3 Interaction effect of different varieties before leaf cutting

Different varieties expressed significant differences due to their interaction effect on the number of leaves hill^{-1} of rice at anthesis stage (Table 4). The maximum number of leaves hill^{-1} (27.67) was recorded from the V_1L_0 (BRRI dhan29 + Untreated control) which was statistically different from others and followed by V_1L_4, V_2L_0, V_1L_3, V_2L_4, V_1L_1, V_1L_2, V_2L_1 andV_2L_3. The minimum number of leaves hill^{-1} (16.33) was obtained from the V_2L_5 (BRRI hybrid dhan2 + All leaves cutting) which was statistically similar with V_1L_5 and followed byV_2L_2(Appendix 5).

Table 4: Interaction effect of leaves hill^{-1} of rice at anthesis stage before leaf cutting.

Varieties	Before Leaf cuttings	Leaves hill^{-1}
BRRI dhan29 (V_1)	L_0	27.67 a
	L_1	22.00 d
	L_2	20.67 e
	L_3	23.33 c
	L_4	25.33 b
	L_5	17.00 gh
BRRI hybrid dhan2 (V_2)	L_0	24.67 b
	L_1	18.33 f
	L_2	18.00 fg
	L_3	20.33 e
	L_4	22.67 cd
	L_5	16.33 h
CV (%)		3.16
LSD $_{(0.05)}$		1.12

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, L_1= Flag leaf cutting; L_2= Flag leaf + 3rd leaf cutting; L_3= Penultimate leaf + 3rd leaf cutting; L_4= All leaves cutting without flag leaf; L_5= All leaves cutting; L_0= Untreated control.

4.2 Morphological parameters

4.2.1 Leaf area index (cm^2) at grain filling stage

4.2.1.1 Effect of variety

In case of leaf area index (cm^2) at grain filling stage, there was statistically significant variations among the rice cultivars (Figure 7). Data revealed that, the maximum leaf area index (2.34) was observed from BRRI dhan29, which was statistically different from other variety. Whereas the minimum leaf area index (1.77) was recorded from BRRI hybrid dhan2. This confirms the report of Jahid M.H. (2017) that the leaf area index differed from variety to variety. The leaf area index was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

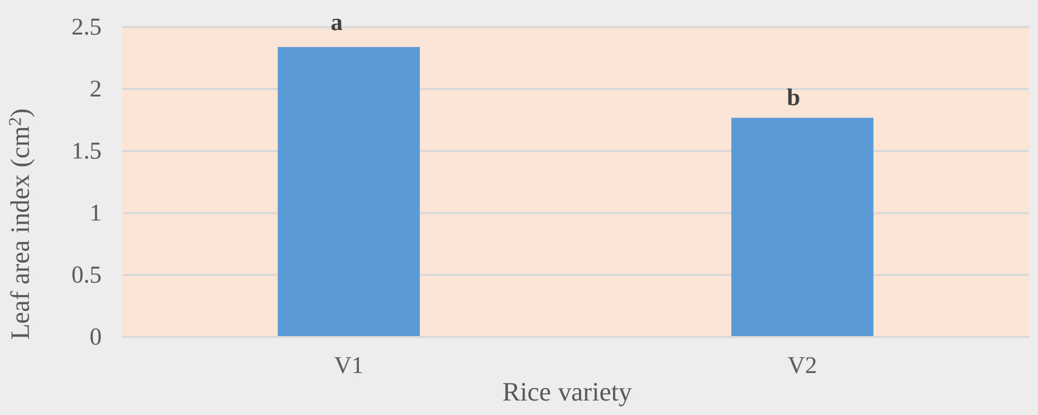

Figure 7: Varietal effect of leaf cutting on leaf area index (cm^2) of rice plants at grain filling stage.

Here, V_1= BRRI dhan29 and V_2= BRRI hybrid dhan2

4.2.1.2Effect of leaf cutting

In case of leaf area index (cm^2) at grain filling stage, there was statistically significant variations among the different leaf cuttings of rice plants (Figure 8). Among the different leaf cutting, the maximum leaf area index (2.95) was observed from L_0 (Untreated control) which was significantly different and followed by the others. Minimum leaf area index (2.50) was recorded from L_5 (All leaves cutting). It might be due to the fact that lack of chlorophyll effect on the development of rice plant. Similar results were also reported (Abu-Khalifa *et al*. 2008).

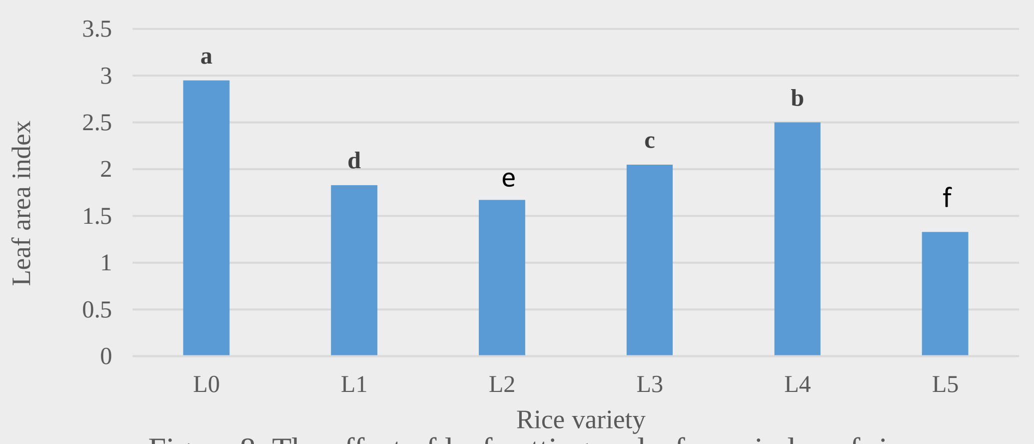

Figure 8: The effect of leaf cutting on leaf area index of rice.

Here, L_1= Flag leaf cutting; L_2= Flag leaf + 3rd leaf cutting; L_3= Penultimate leaf + 3rd leaf cutting; L_4= All leaves cutting without flag leaf; L_5= All leaves cutting; L_0= Untreated control.

4.2.1.3 Interaction effect of different varieties and leaf cutting

Different varieties and leaf cutting expressed no significant differences due to their interaction effect on leaf area index (cm^2) of rice plants at grain filling stage (Table 5). The maximum leaf area index (2.95) was recorded from the V_1L_0 (BRRI dhan29 +Untreated control) which was statistically different from others and followed by V_1L_4, V_2L_0, V_1L_3, V_2L_4, V_1L_1, V_1L_2, V_2L_1 andV_2L_3. The minimum leaf area index (1.33) was obtained from the V_2L_5 (BRRI hybrid dhan2 + All leaves cutting) which was statistically different from others and followed by V_1L_5 and V_2L_2 (Appendix 6).

Table 5: Interaction effect of varieties and leaf cutting on leaf area index (cm^2) of rice plants at grain filling stage.

Varieties	Leaf cuttings	Leaf area index (cm^2)
BRRI dhan29 (V_1)	L_0	3.33 a
	L_1	2.33 b
	L_2	1.70 c
	L_3	2.57 b
	L_4	2.67 b
	L_5	1.33 c
BRRI hybrid dhan2 (V_2)	L_0	2.63 b
	L_1	1.47 c
	L_2	1.40 c
	L_3	1.63 c
	L_4	2.33 b
	L_5	1.27 c
CV (%)		11.28
LSD $_{(0.05)}$		0.39

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, L_1= Flag leaf cutting; L_2= Flag leaf + 3rd leaf cutting; L_3= Penultimate leaf + 3rd leaf cutting; L_4= All leaves cutting without flag leaf; L_5= All leaves cutting; L_0= Untreated control.

4.3 Physiological parameters

4.3.1 SPAD value at grain filling stage

4.3.1.1 Effect of variety

In case of SPAD value at grain filling stage, there was statistically significant variations among the rice cultivars (Table 6). Data revealed that, the maximum SPAD value (45.62) was observed from BRRI dhan29, which was statistically similar with other variety. Whereas the minimum SPAD value (44.51) was recorded from BRRI hybrid dhan2. This confirms the report of Jahid M.H. (2017) that the SPAD value differed from variety to variety. The SPAD value was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

Table 6: Varietal effect on SPAD value of rice leaf at grain filling stage.

Varieties	SPAD value
V_1	45.62 a
V_2	44.51 a

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, V_1= BRRI dhan29; V_2= BRRI hybrid dhan2.

4.3.1.2 Effect of leaf cutting

In case of SPAD value at grain filling stage, there was statistically significant variations among the different leaf cuttings of rice plants (Table 7). Among the different leaf cutting, the maximum SPAD value (46.17) was observed from L_0 (Untreated control) which was statistically similar with others. Minimum SPAD value (43.40) was recorded from L_5 (All leaves cutting). It might be due to the fact that lack of chlorophyll effect on the development of rice plant. Similar results were also reported (Abu-Khalifa *et al*., 2008).

Table 7: The effect of leaf cutting on SPAD value of rice leaf at grain filling stage.

Leaf cuttings	SPAD value
L_0	46.17 a
L_1	45.03 a
L_2	44.80 a
L_3	45.03 a
L_4	45.93 a
L_5	43.40 a

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, L_1= Flag leaf cutting; L_2= Flag leaf + 3rd leaf cutting; L_3= Penultimate leaf + 3rd leaf cutting; L_4= All leaves cutting without flag leaf; L_5= All leaves cutting; L_0= Untreated control.

4.3.1.3 Interaction effect of different varieties and leaf cutting

Different varieties and leaf cutting expressed significant differences due to their interaction effect on SPAD value of rice leaf at grain filling stage (Table 8). The maximum SPAD value (46.67) was recorded from the V_1L_0 (BRRI dhan29 + Untreated control) which was statistically similar with V_1L_4, V_2L_0, V_1L_3, V_2L_4, V_1L_1, V_1L_2, V_2L_1, V_2L_3, V_1L_5 and V_2L_2. The minimum SPAD value (41.67) was obtained from the V_2L_5 (BRRI hybrid dhan2 + All leaves cutting) which was statistically different from others (Appendix 13).

Table 8: Interaction effect of varieties and leaf cutting on SPAD value of rice leaf at grain filling stage.

Varieties	Leaf cuttings	SPAD value
BRRI dhan29 (V_1)	L_0	46.67 a
	L_1	45.67 a
	L_2	45.27 ab
	L_3	46.30 a
	L_4	46.60 a
	L_5	43.60 ab
BRRI hybrid dhan2 (V_2)	L_0	46.40 a
	L_1	43.77 ab
	L_2	43.67 ab
	L_3	45.13 ab
	L_4	46.00 a
	L_5	41.67 b
CV (%)		4.53
LSD $_{(0.05)}$		3.39

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, L_1= Flag leaf cutting; L_2= Flag leaf + 3rd leaf cutting; L_3= Penultimate leaf + 3rd leaf cutting; L_4= All leaves cutting without flag leaf; L_5= All leaves cutting; L_0= Untreated control.

4.3.2 Stomatal conductance (mmol CO_2 m^{-2} s^{-1}) at grain filling stage

4.3.2.1 Effect of variety

In case of stomatal conductance (mmol CO_2 m^{-2} s^{-1}) at grain filling stage, there was statistically significant variations among the rice cultivars (Table 9). Data revealed that, the maximum stomatal conductance (0.49 mmolCO_2 m^{-2} s^{-1}) was observed from BRRI dhan29, which was statistically similar with other variety. Whereas the minimum stomatal conductance (0.46 mmolCO_2 m^{-2} s^{-1}) was recorded from BRRI hybrid dhan2. This confirms the report of Jahid, (2017)) that the stomatal conductance differed from variety to variety. The stomatal conductance was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

Table 9: Varietal effect on stomatal conductance of rice leaf at grain filling stage.

Varieties	Stomatal conductance (mmol CO_2 m^{-2} s^{-1})
V_1	0.49 a
V_2	0.46 a

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, V_1= BRRI dhan29; V_2= BRRI hybrid dhan2.

4.3.2.2 Effect of leaf cutting

In case of stomatal conductance (mmol CO_2 m^{-2} s^{-1}) at grain filling stage, there was statistically significant variations among the different leaf cuttings of rice plants (Figure 10). Among the different leaf cutting, the maximum stomatal conductance (0.55 mol CO_2 m^{-2} s^{-1}) was observed from L_0 (Untreated control) which was significantly different and followed by the others. Minimum stomatal conductance (0.44 mol CO_2 m^{-2} s^{-1}) was recorded from L_5 (All leaves cutting). It might be due to the fact that lack of chlorophyll effect on the development of rice plant. Similar results were also reported (Abu-Khalifa *et al*.,2008).

Table 10: The effect of leaf cutting on stomatal conductance of rice leaf at grain filling stage.

Leaf cuttings	Stomatal conductance (mmol CO_2 m^{-2} s^{-1})
L_0	0.55 a
L_1	0.45 b
L_2	0.44 b
L_3	0.48 b
L_4	0.49 b
L_5	0.44 b

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, L_1= Flag leaf cutting; L_2= Flag leaf + 3rd leaf cutting; L_3= Penultimate leaf + 3rd leaf cutting; L_4= All leaves cutting without flag leaf; L_5= All leaves cutting; L_0= Untreated control.

4.3.2.3 Interaction effect of different varieties and leaf cutting

Different varieties and leaf cutting expressed significant differences due to their interaction effect on stomatal conductance of rice at grain filling stage (Table 11). The maximum stomatal conductance (0.57mmol CO_2 m^{-2} s^{-1}) was recorded from the V_1L_0 (BRRI dhan29 + Untreated control) which was statistically different from others and followed by V_1L_4, V_2L_0, V_1L_3, V_2L_4, V_1L_1, V_1L_2, V_2L_1 and V_2L_3. The minimum stomatal conductance (0.41 mmol CO_2 m^{-2} s^{-1}) was obtained from the V_2L_5 (BRRI hybrid dhan2 + All leaves cutting) which was statistically different from others and followed by V_1L_5 and V_2L_2 (Appendix 8).

Table 11: Interaction effect of varieties and leaf cutting on stomatal conductance (mmol CO_2 m^{-2} s^{-1}) of rice at grain filling stage.

Varieties	Leaf cuttings	Stomatal conductance (mmol CO_2 m^{-2} s^{-1})
BRRI dhan29 (V_1)	L_0	0.57 a
	L_1	0.47 cde
	L_2	0.46 de
	L_3	0.49 bcd
	L_4	0.53 ab
	L_5	0.43 e
BRRI hybrid dhan2 (V_2)	L_0	0.53 abc
	L_1	0.44 de
	L_2	0.43 e
	L_3	0.45 de
	L_4	0.47 cde
	L_5	0.41 e
CV (%)		1.69
LSD $_{(0.05)}$		0.05

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, L_1= Flag leaf cutting; L_2= Flag leaf + 3rd leaf cutting; L_3= Penultimate leaf + 3rd leaf cutting; L_4= All leaves cutting without flag leaf; L_5= All leaves cutting; L_0= Untreated control.

4.3.3 Total dry mater (g) at harvesting stage

4.3.3.1 Effect of variety

The dry matter of plant includes carbohydrates, fats, proteins, vitamins, minerals, and antioxidants (e.g., thiocyanate, anthocyanin, and quercetin).In case of total dry matter (g) at harvesting stage, there was statistically significant variations among the rice cultivars (Figure 9). Data revealed that, the maximum dry mater hill^{-1} (13.64 g) was observed from BRRI dhan29, which was statistically different from other variety, whereas the minimum dry mater hill^{-1} (12.43 g) was recorded from BRRI hybrid dhan2. This confirms the report of Jahid, (2017) that the total dry mater hill^{-1} differed from variety to variety. The total dry mater hill^{-1} was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

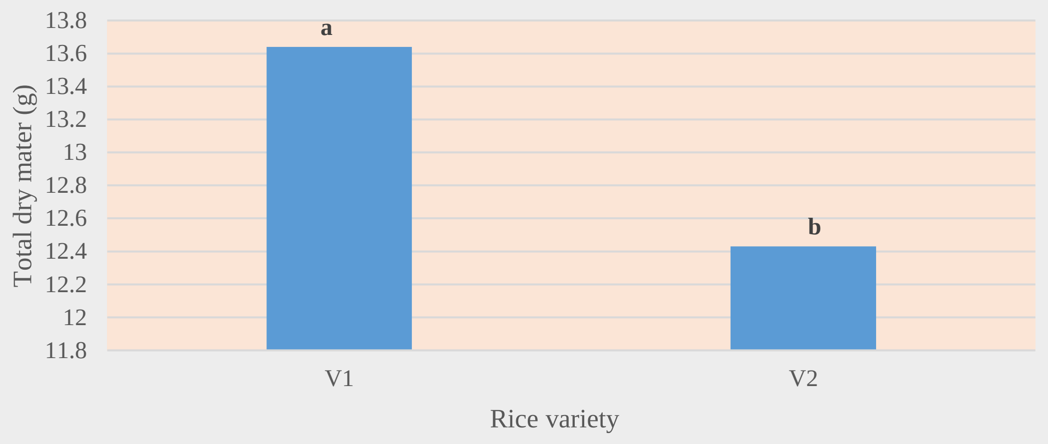

Figure 9: Varietal effect of leaf cutting on total dry mater (g) of rice at harvesting stage.

Here, V_1= BRRI dhan29 and V_2= BRRI hybrid dhan2

4.3.3.2Effect leaf cutting

In case of total dry matter (g) at harvesting stage, there was statistically significant variations among the different leaf cuttings of rice plants (Figure 10). Among the different leaf cutting, the maximum dry mater hill^{-1} (20.42 g) was observed from L_0 (Untreated control) which was significantly different and followed by the others. Minimum dry mater hill^{-1} (5.95 g) was recorded from L_5 (All leaves cutting). It might be due to the fact that lack of chlorophyll effect on the development of rice plant. Similar results were also reported (Abu-Khalifa *et al*.,2008).

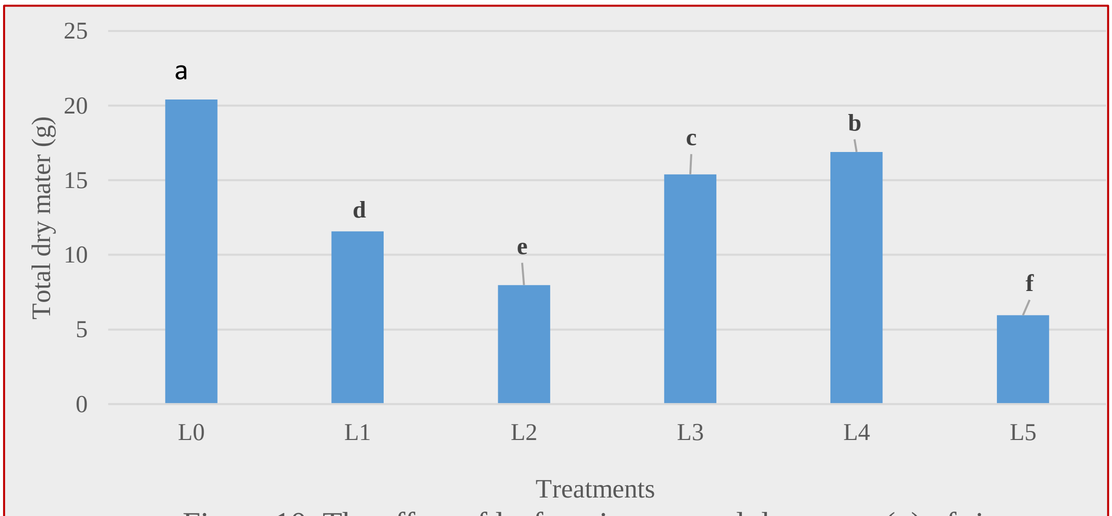

Figure 10: The effect of leaf cutting on total dry mater (g) of rice.

Here, L_1= Flag leaf cutting; L_2= Flag leaf + 3rd leaf cutting; L_3= Penultimate leaf + 3rd leaf cutting; L_4= All leaves cutting without flag leaf; L_5= All leaves cutting; L_0= Untreated control.

4.3.3.3 Interaction effect of different varieties and leaf cutting

Different varieties and leaf cutting expressed significant differences due to their interaction effect on total dry mater hill^{-1} of rice (Table 12). The maximum dry mater hill^{-1} (21.50 g) was recorded from the V_1L_0 (BRRI dhan29 + Untreated control) which was statistically different from others and followed by V_1L_4, V_2L_0, V_1L_3, V_2L_4, V_1L_1, V_1L_2, V_2L_1 andV_2L_3. The minimum dry mater hill^{-1} (5.23 g) was obtained from the V_2L_5 (BRRI hybrid dhan2 + All leaves cutting) which was statistically different from others and followed by V_1L_5 and V_2L_2 (Appendix 9).

Table 12: Interaction effect of varieties and leaf cutting on total dry mater (g) of rice at harvesting stage.

Varieties	Leaf cuttings	Total dry matter (g)
BRRI dhan29 (V_1)	L_0	21.50 a
	L_1	15.37 e
	L_2	12.57 f
	L_3	16.43 d
	L_4	19.33 b
	L_5	6.67 j
BRRI hybrid dhan2 (V_2)	L_0	17.37 c
	L_1	8.33 h
	L_2	7.63 i
	L_3	10.57 g
	L_4	15.43 e
	L_5	5.23 k
CV (%)		1.72
LSD $_{(0.05)}$		0.37

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, L_1= Flag leaf cutting; L_2= Flag leaf + 3rd leaf cutting; L_3= Penultimate leaf + 3rd leaf cutting; L_4= All leaves cutting without flag leaf; L_5= All leaves cutting; L_0= Untreated control.

4.3.4 Dry matter distribution (g) at harvesting stage

4.3.4.1 Effect of variety

In case of dry matter distribution (g) at harvesting stage, there was statistically significant variations among the rice cultivars (Table 13). In case of total dry grain weight (g), there was statistically significant variations among the rice cultivars. The maximum weight (10.21 g) was observed from BRRI dhan29, which was statistically different from other variety. Whereas the minimum weight (9.27 g) was recorded from BRRI hybrid dhan2 (Table 13).

On the other hand, dry straw weight (g), there was statistically significant variations among the rice cultivars. The maximum weight (3.43 g) was observed from BRRI dhan29, which was statistically similar with other variety. Whereas the minimum weight (3.16 g) was recorded from BRRI hybrid dhan2 (Table 13).

This confirms the report of Jahid, (2017) that the dry matter distribution differed from variety to variety. The dry matter distribution was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

Table 13: Varietal effect of leaf cutting on dry matter distribution of rice plants at harvesting stage.

Varieties	Dry matter distribution (g)		
	Total dry matter	**Total grain dry weight**	**Dry straw weight**
V_1	13.64 a (100%)	10.21 a (74.85%)	3.43 a (25.15%)
V_2	12.43 b (100%)	9.27 b (74.58%)	3.16 a (25.42%)

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, V_1= BRRI dhan29; V_2= BRRI hybrid dhan2.

4.3.4.2 Effect of leaf cutting

In case of dry mater distribution (g) at harvesting stage, there was statistically significant variations among the different leaf cuttings of rice plants (Table 14). In case of total dry grain weight (g), there was statistically significant variations among the rice cultivars. The maximum weight (16.27 g) was observed from L_0 (Untreated control), which was statistically different from others. Whereas the minimum weight (4.16 g) was recorded from L_5 (All leaves cutting) (Table 14).

On the other hand, dry straw weight (g), there was statistically significant variations among the rice cultivars. The maximum weight (4.15 g) was observed from L_0 (Untreated control), which was statistically different from others. Whereas the minimum weight (1.79 g) was recorded from L_5 (All leaves cutting) (Table 14).

It might be due to the fact that plant height effect on the development of rice plant. Similar results were also reported (Abu-Khalifa *et al*.,2008).

Table 14: The effect of leaf cutting on dry matter distribution of rice plant at harvesting stage.

Leaf cuttings	Dry matter distribution (g)		
	Total dry matter	Total grain dry weight	Dry straw weight
L_0	20.42 a (100%)	16.27 a (79.68%)	4.15 a (20.32%)
L_1	11.57 c (100%)	8.83 c (76.32%)	2.74 b (23.68%)
L_2	7.98 d (100%)	6.11 d (76.57%)	1.87 d (23.43%)
L_3	15.40 b (100%)	13.33 b (86.56%)	2.07 c (13.44%)
L_4	16.90 b (100%)	13.81 b (81.72%)	3.09 b (18.28%)
L_5	5.95 e (100%)	4.16 e (69.92%)	1.79 d (30.08%)

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, L_1= Flag leaf cutting; L_2= Flag leaf + 3rd leaf cutting; L_3= Penultimate leaf + 3rd leaf cutting; L_4= All leaves cutting without flag leaf; L_5= All leaves cutting; L_0= Untreated control.

4.3.4.3 Interaction effect of different varieties and leaf cutting

Different varieties and leaf cutting expressed significant differences due to their interaction effect on dry matter distribution (g) of rice plant at harvesting stage (Table 15). In case of total dry grain weight (g), there was statistically significant variations among the interaction effect of different varieties and leaf cutting. The maximum weight (16.38 g) was observed from V_1L_0 (BRRI dhan29 + Untreated control), which was statistically different from others. Whereas the minimum weight (3.82 g) was recorded from V_2L_5 (BRRI hybrid dhan2 + All leaves cutting) (Table 15).

On the other hand, dry straw weight (g), there was statistically significant variations among the interaction effect of different varieties and leaf cutting. The maximum weight (5.12 g) was observed from V_1L_0 (BRRI dhan29 + Untreated control), which was statistically different from others. Whereas the minimum weight (1.41 g) was recorded from V_2L_5 (BRRI hybrid dhan2 + All leaves cutting) (Table 15).

Table 15: Interaction effect of varieties and leaf cutting on dry matter distribution of rice plant at harvesting stage.

Varieties	Leaf cuttings	Total dry matter (g)	Total grain dry weight (g)	Dry straw weight (g)
BRRI dhan29 (V_1)	L_0	21.50 a (100%)	16.38 a (76.19%s)	5.12 a (23.81%)
	L_1	15.37 e (100%)	12.25 d (79.70%)	3.12 d (20.30%)
	L_2	12.57 f (100%)	10.01 e (79.63%)	2.56 d (20.37%)
	L_3	16.43 d (100%)	12.67 d (77.12%)	3.76 c (22.88%)
	L_4	19.33 b (100%)	14.90 b (77.08%)	4.43 b (22.92%)
	L_5	6.67 j (100%)	4.80 i (71.96%)	1.87 f (28.04%)
BRRI hybrid dhan2 (V_2)	L_0	17.37 c (100%)	13.06 c (75.19%)	4.31 b (24.81%)
	L_1	8.33 h (100%)	6.20 g (74.43%)	2.13 e (25.57%)
	L_2	7.63 i (100%)	5.54 h (72.61%)	2.09 e (27.39%)
	L_3	10.57 g (100%)	8.31 f (78.62%)	2.26 e (21.38%)
	L_4	15.43 e (100%)	12.22 d (79.20%)	3.21 cd (20.80%)
	L_5	5.23 k (100%)	3.82 j (73.04%)	1.41 g (26.96%)
CV (%)		1.72	1.13	0.87
LSD $_{(0.05)}$		0.37	0.21	0.16

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, L_1= Flag leaf cutting; L_2= Flag leaf + 3rd leaf cutting; L_3= Penultimate leaf + 3rd leaf cutting; L_4= All leaves cutting without flag leaf; L_5= All leaves cutting; L_0= Untreated control.

4.4. Yield contributing parameters

4.4.1 Effect of variety

4.4.1.1 Total spikelet panicle^{-1} at harvesting stage

Different varieties expressed no significant differences due to the effect on the number of spikelet panicle^{-1} of rice at harvesting stage (Table 16). The maximum number of spikelet panicle^{-1} (174.9) was recorded from the BRRI dhan29 which was statistically different from other. Whereas the minimum number of spikelet panicle^{-1} (164.7) was obtained from the BRRI hybrid dhan2. This confirms the report of Jahid, (2017)) that the number of spikelet panicle^{-1} differed from variety to variety. The number of spikelet panicle^{-1} was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

4.4.1.2 Filled spikeletpanicle^{-1} at harvesting stage

Different varieties expressed significant differences due to the effect on the number of filled spikelet panicle^{-1} of rice at harvesting stage (Table 16). The maximum number of filled spikelet panicle^{-1} (140.07) was recorded from the BRRI dhan29 which was statistically different from other. Whereas the minimum number of filled spikelet panicle^{-1} (129.20) was obtained from the BRRI hybrid dhan2. This confirms the report of Jahid, (2017) that the number of filled spikelet panicle^{-1} differed from variety to variety. The number of filled spikelet panicle^{-1} was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

4.4.1.3 Unfilled spikelet panicle^{-1} at harvesting stage

Different varieties expressed significant differences due to the effect on the number of unfilled spikelet panicle^{-1} of rice at harvesting stage (Table 16). The maximum number of unfilled spikelet panicle^{-1} (35.50) was recorded from the BRRI Hybrid dhan2 which was statistically similar with other. Whereas the minimum number of unfilled spikelet panicle^{-1} (34.83) was obtained from the BRRI dhan29. This confirms the report of Jahid, (2017) that the number of unfilled spikelet panicle^{-1} differed from variety to variety. The number of unfilled spikelet panicle^{-1} was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

4.4.1.4 Spikelet sterility (%) at harvesting stage

Different varieties expressed significant differences due to the effect on spikelet sterility of rice at harvesting stage (Table 16). The maximum grain sterility (21.15%) was recorded from BRRI hybrid dhan2 which was statistically different from other. Whereas the minimum grain sterility (20.30%) was obtained from BRRI dhan29. This confirms the report of Jahid, (2017) that grain sterility differed from variety to variety. The grain sterility was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

Table 16: Varietal effect of leaf cutting on yield attribution characteristics of rice at harvesting stage.

Varieties	Total spikelet panicle^{-1}	Filled spikelet panicle^{-1}	Unfilled spikelet panicle^{-1}	Spikelet sterility (%)
V_1	174.9 a	140.07 a	34.83 a	20.30 b
V_2	164.7 b	129.20 b	35.50 a	21.15 a

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, V_1= BRRI dhan29; V_2= BRRI hybrid dhan2.

4.4.2 Effect of leaf cutting

4.4.2.1 Total spikelet panicle^{-1} at harvesting stage

Different leaf cutting expressed significant differences due to the effect on the number of spikelet panicle^{-1} of rice at harvesting stage (Table 17). The maximum number of total spikelet panicle^{-1} (175.5) was recorded from L_0 (Untreated control) which was statistically different from others. Minimum number of total spikelet panicle^{-1} (103.9) was recorded from L_5 (All leaves cutting). It might be due to the fact that lack of chlorophyll effect on the development of rice plant. Similar results were also reported (Abu-Khalifa *et al*.,2008).

4.4.2.2 Filled spikelet panicle^{-1} at harvesting stage

Different leaf cutting expressed significant differences due to the effect on the number of filled spikelet panicle^{-1} of rice at harvesting stage (Table 17). The maximum number of filled spikelet panicle^{-1} (150.67) was recorded from the L_0 (Untreated control) which was statistically similar with L_4 and followed by others. Minimum number of filled spikelet panicle^{-1} (56.40) was recorded from L_5 (All leaves cutting). It might be due to the fact that lack of chlorophyll effect on the development of rice plant. Similar results were also reported (Abu-Khalifa *et al*.,2008).

4.4.2.3 Unfilled spikelet panicle^{-1} at harvesting stage

Different leaf cutting expressed significant differences due to the effect on the number of unfilled spikelet panicle^{-1} of rice at harvesting stage (Table 17). The maximum number of unfilled spikelet panicle^{-1} (47.50) was recorded from the L_5 (All leaves cutting) which was statistically different from others. Minimum number of unfilled spikelet panicle^{-1} (24.83) was recorded from L_0 (Untreated control). It might be due to the fact that lack of chlorophyll effect on the development of rice plant. Similar results were also reported (Abu-Khalifa *et al*.,2008).

4.4.2.4 Spikelet sterility (%) at harvesting stage

Different leaf cutting expressed significant differences due to the effect on spikelet sterility of rice (Table 17). The maximum spikelet sterility (45.72%) was recorded from the L_5 (All leaves cutting) which was statistically different from others. Minimum spikelet sterility (14.15%) was recorded from L_0 (Untreated control). It might be due to the fact that lack of chlorophyll effect on the development of rice plant. Similar results were also reported (Abu-Khalifa *et al.*, 2008).

Table 17: The effect of leaf cutting on yield attribution characteristics of rice at harvesting stage.

Leaf cuttings	Total spikelet panicle^{-1}	Filled spikelet panicle^{-1}	Unfilled spikelet panicle^{-1}	Spikelet sterility (%)
L_0	175.5 a	150.67 a	24.83 e	14.15 e
L_1	153.5 c	116.00 c	37.50 c	24.43 c
L_2	141.8 d	98.30 d	43.50 b	30.68 b
L_3	164.7 b	135.37 b	29.33 d	17.81 d
L_4	174.9 a	149.57 a	25.33 e	14.48 e
L_5	103.9 e	56.40 e	47.50 a	45.72 a

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, L_1= Flag leaf cutting; L_2= Flag leaf + 3rd leaf cutting; L_3= Penultimate leaf + 3rd leaf cutting; L_4= All leaves cutting without flag leaf; L_5= All leaves cutting; L_0= Untreated control.

4.4.3 Interaction effect of different varieties and leaf cutting

4.4.3.1 Total spikelet panicle^{-1} at harvesting stage

Different varieties and leaf cutting expressed significant differences due to their interaction effect on the number of total spikelet panicle^{-1} of rice at harvesting stage (Table 18). The maximum number of total spikelet panicle^{-1} (241.7) was recorded from V_1L_0 (BRRI dhan29 + Untreated control) which was statistically different from others and followed by V_1L_4, V_2L_0, V_1L_3, V_2L_4, V_1L_1, V_1L_2, V_2L_1, V_2L_3, V_1L_5 and V_2L_2. The minimum number of total spikelet panicle^{-1} (112.3) was obtained from the V_2L_5 (BRRI hybrid dhan2 + All leaves cutting) which was statistically different from others.

4.4.3.2 Filled spikelet panicle^{-1} at harvesting stage

Different varieties and leaf cutting expressed significant differences due to their interaction on the number of filled spikelet panicle^{-1} of rice at harvesting stage (Table 18). The maximum number of filled spikelet panicle^{-1} (219.70) was recorded from V_1L_0 (BRRI dhan29 + Untreated control) which was statistically different from others and followed by V_1L_4, V_2L_0, V_1L_3, V_2L_4, V_1L_1, V_1L_2, V_2L_1, V_2L_3, V_1L_5 and V_2L_2. The minimum number of filled spikelet panicle^{-1} (64.63) was obtained from the V_2L_5 (BRRI hybrid dhan2 + All leaves cutting) which was statistically different from others.

4.4.3.3 Unfilled spikelet panicle^{-1} at harvesting stage

Different varieties and leaf cutting expressed significant differences due to their interaction effect on the number of unfilled spikelet panicle^{-1} of rice at harvesting stage (Table 18). The maximum number of unfilled spikelet panicle^{-1} (47.67) was recorded from the V_2L_5 (BRRI hybrid dhan2 + All leaves cutting) which was statistically similar with V_1L_5 and followed byV_2L_2, V_2L_1, V_2L_3, V_1L_2, V_1L_1, V_2L_4,V_1L_3, $V_2L_0$and V_1L_4. The minimum number of unfilled spikelet panicle^{-1} (22.00) was obtained from the V_1L_0 (BRRI dhan29 + Untreated control) which was statistically different from others.

4.4.3.4 Spikelet sterility (%) at harvesting stage

Different varieties and leaf cutting expressed significant differences due to their interaction effect on the percent of spikelet sterility (Figure 11). The maximum spikelet sterility (42.45%) was recorded from the V_2L_5 (BRRI hybrid dhan2 + All leaves cutting) which was statistically different from others and followed by V_1L_5, V_2L_2, V_2L_1, V_2L_3, V_1L_2, V_1L_1, V_2L_4, V_1L_3, V_2L_0 and V_1L_4. The minimum percent of spikelet sterility (9.10) was obtained from the V_1L_0 (BRRI dhan29 + No leaf cutting) which was statistically different from others.

Table 18: Interaction effect of varieties and leaf cutting on yield attribution characteristics of rice at harvesting stage.

Varieties	Leaf cuttings	Total grain panicle^{-1}	Filled grain panicle^{-1}	Unfilled grain panicle^{-1}
BRRI dhan29 (V_1)	L_0	241.7 a	219.70 a	22.00 j
	L_1	172.3 f	140.63 f	31.67 f
	L_2	154.3 g	117.63 g	36.67 e
	L_3	188.3 d	161.30 d	27.00 h
	L_4	226.3 b	202.97 b	23.33 i
	L_5	134.3 j	86.97 j	47.33 a
BRRI hybrid dhan2 (V_2)	L_0	193.3 c	166.97 c	26.33 h
	L_1	147.3 h	104.97 h	42.33 c
	L_2	136.3 i	91.63 i	44.67 b
	L_3	152.7 g	114.37 g	38.33 d
	L_4	178.7 e	150.03 e	28.67 g
	L_5	112.3 k	64.63 k	47.67 a
CV (%)		0.60	1.06	2.17
LSD $_{(0.05)}$		1.68	0.37	1.25

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, L_1= Flag leaf cutting; L_2= Flag leaf + 3rd leaf cutting; L_3= Penultimate leaf + 3rd leaf cutting; L_4= All leaves cutting without flag leaf; L_5= All leaves cutting; L_0= Untreated control.

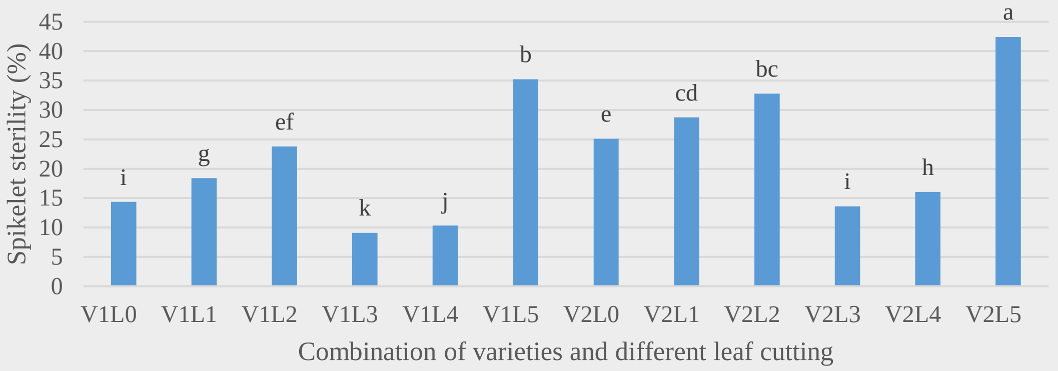

Figure 11: Interaction effect of varieties and different leaf cutting on spikelet sterility of rice at harvesting stage.

Values followed by same letter(s) did not differ significantly at 5% level of probability.Here, V_1= BRRI dhan29; V_2= BRRI hybrid dhan2; L_1= Flag leaf cutting; L_2= Flag leaf + 3rd leaf cutting; L_3= Penultimate leaf + 3rd leaf cutting; L_4= All leaves cutting without flag leaf; L_5= All leaves cutting; L_0= Untreated control.

4.4.4 1000 grain weight (g) at harvesting stage

4.4.4.1 Effect of variety

Different varieties expressed no significant differences due to the effect on 1000 grain weight of rice (Table 19). The maximum weight of 1000 grain (27.19 g) was recorded from the V_1 (BRRI dhan29) which was statistically similar with other. Whereas the minimum weight of 1000 grain (27.13 g) was obtained from the V_2 (BRRI hybrid dhan2). This confirms the report of Jahid, (2017) that 1000 grain weight differed from variety to variety. The weight of 1000 grain was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

Table 19: Varietal effect of leaf cutting on 1000 grain weight of rice at harvesting stage.

Varieties	1000 grain weight (g)	
	Actual	Relative
V_1	27.19 a	100%
V_2	27.13 a	99.78%

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, V_1= BRRI dhan29; V_2= BRRI hybrid dhan2.

4.4.4.2 Effect of leaf cutting

Different leaf cutting expressed significant differences due to the effect on 1000 grain weight of rice at harvesting stage (Table 20). The maximum weight of 1000 grain (28.97 g) was recorded from the L_0 (Untreated control) which was statistically different from others. Minimum weight of 1000 grain (25.53) was recorded from L_5 (All leaves cutting). It might be due to the fact that lack of chlorophyll effect on the development of rice plant. Similar results were also reported (Abu-Khalifa *et al*., 2008).

Table 20: The effect of leaf cutting on yield attribution characteristics of rice at harvesting stage.

Leaf cuttings	1000 grain weight (g)	
	Actual	**Relative**
L_0	28.97 a	100%
L_1	26.67 d	92.06%
L_2	26.10 e	90.09%
L_3	27.50 c	94.93%
L_4	28.20 b	97.34%
L_5	25.53 f	88.13%

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, L_1= Flag leaf cutting; L_2= Flag leaf + 3rd leaf cutting; L_3= Penultimate leaf + 3rd leaf cutting; L_4= All leaves cutting without flag leaf; L_5= All leaves cutting; L_0= Untreated control.

4.4.4.3 Combined effect of varieties and different leaf cutting

Different varieties and leaf cutting expressed significant differences due to their interaction effect on 1000 grain weight of rice at harvesting stage (Table 21). The maximum weight of 1000 grain (29.63 g) was recorded from the V_1L_0 (BRRI dhan29 + Untreated control) which was statistically different from others and followed by V_1L_4, V_2L_0, V_1L_3, V_2L_4, V_1L_1, V_1L_2, V_2L_1 andV_2L_3. The minimum weight of 1000 grains (25.33 g) was obtained from the V_2L_5 (BRRI hybrid dhan2 + All leaves cutting) which was statistically similar with V_1L_5 and V_2L_2 (Appendix 13).

Table 21: Interaction effect of varieties and leaf cutting on 1000 grain weight of rice at harvesting stage.

Varieties	Leaf cuttings	1000 grain weight (g)	
		Actual	Relative
BRRI dhan29 (V_1)	L_0	29.63 a	100%
	L_1	27.43 d	92.58%
	L_2	26.97 e	91.02%
	L_3	27.63 d	93.25%
	L_4	28.77 b	97.10%
	L_5	25.60 g	86.40%
BRRI hybrid dhan2 (V_2)	L_0	28.30 c	95.51%
	L_1	26.37 f	88.99%
	L_2	25.73 g	86.84%
	L_3	26.60 ef	89.77%
	L_4	27.57 d	93.05%
	L_5	25.33 g	85.49%
CV (%)		0.90	-
LSD $_{(0.05)}$		0.40	-

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, L_1= Flag leaf cutting; L_2= Flag leaf + 3rd leaf cutting; L_3= Penultimate leaf + 3rd leaf cutting; L_4= All leaves cutting without flag leaf; L_5= All leaves cutting; L_0= Untreated control.

4.5 Yield parameters

4.5.1 Effect of variety

4.5.1.1 Grain yield (t ha^{-1}) at harvesting stage

Different varieties expressed significant differences due to the effect on the grain yield at harvesting stage (Table 22). The maximum grain yield (5.81 t ha^{-1}) was recorded from the V_1(BRRI dhan29) which was statistically different from other. Whereas the minimum grain yield (5.15 t ha^{-1}) was obtained from the V_2 (BRRI hybrid dhan2). This confirms the report of Jahid, (2017) that the grain yield differed from variety to variety. The yield of grain was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

4.5.1.2 Straw yield (t ha^{-1}) at harvesting stage

Different varieties expressed significant differences due to the effect on the straw yield at harvesting stage (Table 22). The maximum straw yield (6.48 t ha^{-1}) was recorded from the V_1 (BRRI dhan29) which was statistically different from other. Whereas the minimum straw yield (6.04 t ha^{-1}) was obtained from the V_2 (BRRI hybrid dhan2). This confirms the report of Jahid, (2017) that the straw yield differed from variety to variety. The yield of straw was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

4.5.1.3 Biological yield (t ha^{-1}) at harvesting stage

Different varieties expressed significant differences due to the effect on the biological yield at harvesting stage (Table 22). The maximum biological yield (12.29 t ha^{-1}) was recorded from the V_1 (BRRI dhan29) which was statistically different from other. Whereas the minimum biological yield (11.19 t ha^{-1}) was obtained from the V_2 (BRRI hybrid dhan2). This confirms the report of Jahid, (2017) that the biological yield differed from variety to variety. The biological yield was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

Table 22: Varietal effect of leaf cutting on yield of rice at harvesting stage

Varieties	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
V_1	5.81 a	6.48 a	12.29 a
V_2	5.15 b	6.04 b	11.19 b

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, V_1= BRRI dhan29; V_2= BRRI hybrid dhan2.

4.5.1.4 Harvest index (%) at harvesting stage

Different varieties expressed non-significant differences due to the effect on the harvest index of rice at harvesting stage (Figure 12). The maximum harvest index (46.83%) was recorded from the V_1 (BRRI dhan29) which was statistically similar with other. Whereas the minimum harvest index (46.25%) was obtained from the V_2 (BRRI hybrid dhan2). This confirms the report of Jahid (2017) that the harvest index differed from variety to variety. The harvest index was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

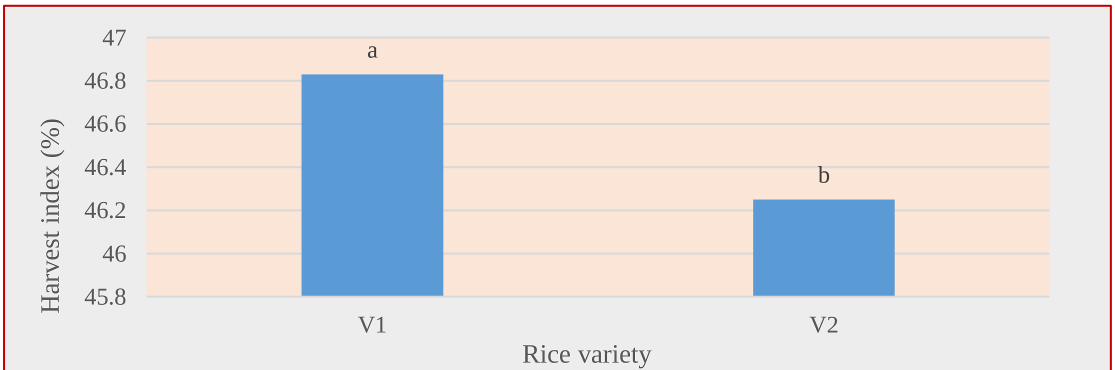

Figure 12: Varietal effect of leaf cutting on harvest index (%) of rice plants at harvesting stage.

Here, V_1= BRRI dhan29 and V_2= BRRI hybrid dhan2

4.5.2 Effect of leaf cutting

4.5.2.1 Grain yield (t ha^{-1}) at harvesting stage

Different leaf cutting expressed significant differences due to the effect on the grain yield of rice at harvesting stage (Table 23). The maximum grain yield (7.73 t ha^{-1}) was recorded from L_0 (Untreated control) which was statistically different from others. Minimum grain yield (3.37 t ha^{-1}) was recorded from L_5 (All leaves cutting). It might be due to the fact that lack of chlorophyll effect on the development of rice plant. Similar results were also reported (Abu-Khalifa *et al*.,2008).

4.5.2.2 Straw yield (t ha^{-1}) at harvesting stage

Different leaf cutting expressed significant differences due to the effect on the straw yield of rice at harvesting stage (Table 23). The maximum straw yield (9.35 t ha^{-1}) was recorded from L_0 (Untreated control) which was statistically different from others. Minimum straw yield (3.95 t ha^{-1}) was recorded from L_5 (All leaves cutting). It might be due to the fact that lack of chlorophyll effect on the development of rice plant. Similar results were also reported (Abu-Khalifa *et al*.,2008).

4.5.2.3 Biological yield (t ha^{-1}) at harvesting stage

Different leaf cutting expressed significant differences due to the effect on the biological yield of rice at harvesting stage (Table 23). The maximum biological yield (17.08 t ha^{-1}) was recorded from L_0 (Untreated control) which was statistically different from others. Minimum biological yield (7.32 t ha^{-1}) was recorded from L_5 (All leaves cutting). It might be due to the fact that lack of chlorophyll effect on the development of rice plant. Similar results were also reported (Abu-Khalifa *et al*., 2008).

Table 23: The effect of different leaf cutting on yield of rice at harvesting stage.

Leaf cuttings	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})
L_1	4.63 d	5.35 d	9.98 d
L_2	3.98 e	4.95 e	8.93 e
L_3	6.05 c	6.38 c	12.43 c
L_4	7.10 b	7.60 b	14.70 b
L_5	3.37 f	3.95 f	7.32 f
L_0	7.73 a	9.35 a	17.08 a

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, L_1= Flag leaf cutting; L_2= Flag leaf + 3rd leaf cutting; L_3= Penultimate leaf + 3rd leaf cutting; L_4= All leaves cutting without flag leaf; L_5= All leaves cutting; L_0= Untreated control.

4.5.2.4 Harvest index (%) at harvesting stage

Different leaf cutting expressed significant differences due to the effect on the harvest index of rice at harvesting stage (Figure 13). The maximum harvest index (48.60%) was recorded from L_0 (Untreated control) which was statistically similar with L_4. Minimum harvest index (44.56%) was recorded from L_5 (All leaves cutting). It might be due to the fact that lack of chlorophyll effect on the development of rice plant. Similar results were also reported (Abu-Khalifa *et al.*, 2008) (Appendix 16).

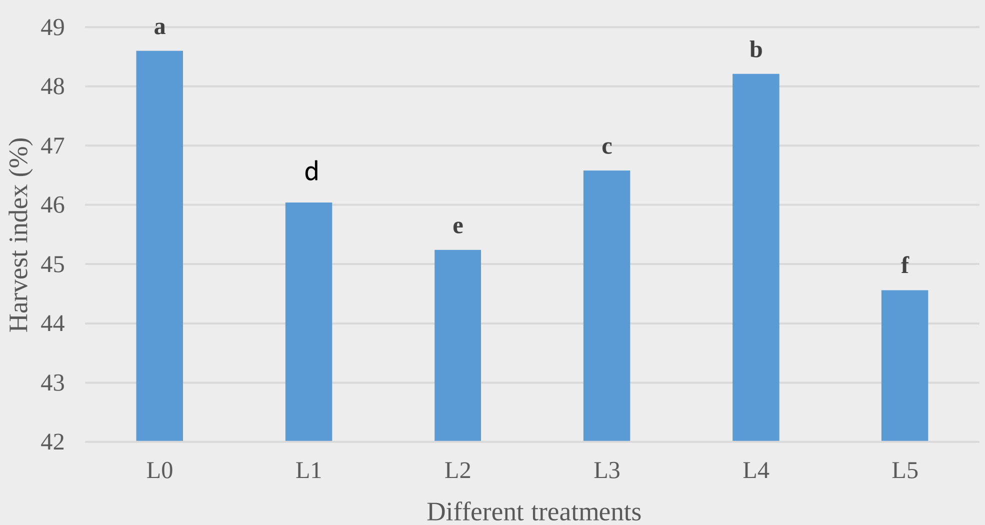

Figure 13: The effect of leaf cutting on harvest index (%) of rice plant at harvesting stage.

Here, L_1= Flag leaf cutting; L_2= Flag leaf + 3rd leaf cutting; L_3= Penultimate leaf + 3rd leaf cutting; L_4= All leaves cutting without flag leaf; L_5= All leaves cutting; L_0= Untreated control

4.5.3 Interaction effect of different varieties and leaf cutting

4.5.3.1 Grain yield (t ha^{-1}) at harvesting stage

Different varieties and leaf cutting expressed significant differences due to their interaction effect on the grain yield of rice at harvesting stage (Table 24). The maximum grain yield (8.13 t ha^{-1}) was recorded from V_1L_0 (BRRI dhan29 + Untreated control) which was statistically similar with V_1L_4 andV_2L_0 and followed byV_1L_3, V_2L_4, V_1L_1, V_1L_2, V_2L_1,V_2L_3, V_1L_5 and V_2L_2. The minimum grain yield (3.37 t ha^{-1}) was obtained from the V_2L_5 (BRRI hybrid dhan2 + All leaves cutting) which was statistically different from others (Appendix 14).

4.5.3.2 Straw yield (t ha^{-1}) at harvesting stage

Straw is an agricultural byproduct consisting of the dry stalks of cereal plants after the grain and chaff have been removed. It makes up about half of the yield of cereal crops such as barley, oats, rice, rye and wheat. Different varieties and leaf cutting expressed significant differences due to their interaction effect on the straw yield of rice at harvesting stage (Table 24). The maximum straw yield (9.47 t ha^{-1}) was recorded from V_1L_0 (BRRI dhan29 + Untreated control) which was statistically similar with V_1L_4 and followed byV_2L_0, V_1L_3, V_2L_4, V_1L_1, V_1L_2, V_2L_1,V_2L_3, V_1L_5 and V_2L_2. The minimum straw yield (3.67 t ha^{-1}) was obtained from the V_2L_5 (BRRI hybrid dhan2 + All leaves cutting) which was statistically different from others (Appendix 15).

4.5.3.3 Biological yield (t ha^{-1}) at harvesting stage

The biological yield refers to the total dry matter accumulation of a plant system. Improved harvest index represents increased physiological capacity to mobilize photosynthates and translocate them into organs having economic yield.Different varieties and leaf cutting expressed significant differences due to their interaction effect on the biological yield of rice at harvesting stage (Table 24). The maximum biological yield (17.60 t ha^{-1}) was recorded from V_1L_0 (BRRI dhan29 +Untreated control) which was statistically different from others and followed by V_1L_4, V_2L_0, V_1L_3, V_2L_4, V_1L_1, V_1L_2, V_2L_1,V_2L_3, V_1L_5 and V_2L_2. The minimum biological yield (7.04 t ha^{-1}) was obtained from the V_2L_5 (BRRI hybrid dhan2 + All leaves cutting) which was statistically different from others.

Table 24: Interaction effect of varieties and leaf cutting on yield of rice at harvesting stage.

Varieties	Leaf cuttings	Grain yield ($t\ ha^{-1}$)		Straw yield ($t\ ha^{-1}$)		Biological yield ($t\ ha^{-1}$)	
		Actual	Relative	Actual	Relative	Actual	Relative
BRRI dhan29 (V_1)	L_0	8.13 a	125.66%	9.47 a	125.10%	17.60 a	125.36%
	L_1	5.63 e	87.02%	6.33 c	83.62%	11.96 d	85.19%
	L_2	4.80 f	74.19%	5.97 d	78.86%	10.77 e	76.71%
	L_3	6.47 d	100%	7.57 b	100%	14.04 c	100%
	L_4	7.73 b	119.48%	9.23 a	121.93%	16.96 b	120.80%
	L_5	3.37 h	52.09%	4.23 g	55.88%	7.60 h	54.13%
BRRI hybrid dhan2 (V_2)	L_0	7.33 c	163.98%	7.63 b	143.15%	14.96 c	152.65%
	L_1	4.33 g	96.87%	4.73 f	88.74%	9.06 f	92.45%
	L_2	3.63 h	81.21%	4.57 f	85.74%	8.20 g	83.67%
	L_3	4.47 fg	100%	5.33 e	100%	9.80 f	100%
	L_4	6.47 d	144.74%	6.43 c	120.64%	12.90 d	131.63%
	L_5	3.37 h	75.39%	3.67 h	68.86%	7.04 h	50.14%
CV (%)		4.06		3.17		3.23	
LSD $_{(0.05)}$		0.37		0.33		2.49	

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, L_1= Flag leaf cutting; L_2= Flag leaf + 3rd leaf cutting; L_3= Penultimate leaf + 3rd leaf cutting; L_4= All leaves cutting without flag leaf; L_5= All leaves cutting; L_0= Untreated control

CHAPTER V

SUMMARY AND CONCLUSION

The present investigation entitled "Effect of leaf cutting on morpho-physiology and yield of selected rice varieties" was conducted during the period from February to June 2019 at the Agricultural research field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The experiment comprised of two factors; viz. Factors A: rice varieties (BRRI dhan29 and BRRI hybrid dhan2) and Factor B: leaf cutting (Flag leaf cutting, Flag leaf + 3rd leaf cutting, Penultimate leaf + 3rd leaf cutting, All leaves cutting without flag leaf, All leaves cutting and Untreated control). The experiment was laid out in a Split plot design with three replications. There were 12 treatment combinations and total numbers of unit plots were 36. The size of unit plot was 9 m^2 (3 m × 3 m). The field was fertilized with nitrogen, phosphate, potash, sulphur and zinc at the rate of 120, 100, 70, 60 and 10 kg/ha, respectively in the form of urea, triple super phosphate, muriate of potash, gypsum and zinc-sulphate. Results revealed that leaf cutting, variety and their interactions had significant effect on plant growth determinants, yield attributing traits and yields detailed below:-

The tallest plant (98.22 cm at harvest), maximum number of tillers per hill (20.56), maximum number of leaves (22.78), maximum total dry mater (13.64 g), maximum leaf area index (2.34), maximum stomatal conductance (0.49 $mmolCO_2m^{-2}s^{-1}$), maximum SPAD (45.62), maximum total spikelet panicle^{-1} (174.9), maximum weight of 1000 grain (27.19 g),maximum grain yield (5.81 t ha^{-1}), maximum straw yield (6.48 t ha^{-1}) and harvest index (46.83%) were observed from BRRI dhan29 variety. Whereas, maximum sterile spikelet panicle^{-1} (35.50) and maximum spikelet sterility (21.15%) were found from BRRI hybrid dhan2 variety.

Among the different leaf cutting, the tallest plant (99.50 cm), maximum total number of tillers $hill^{-1}$ (25.00), maximum number of leaves $hill^{-1}$ (26.17), maximum total dry mater (20.42 g), maximum leaf area index (2.95), maximum stomatal conductance (0.55 mol CO_2 m^{-2} s^{-1}), maximum SPAD (46.17), maximum grain $panicle^{-1}$ (147.50), maximum total spikelet $panicle^{-1}$ (175.5), effective tillers $hill^1$ (8.33), spikelet per panicle (149.8), maximum weight of 1000 grains (28.97 g), maximum grain yield (7.73 t ha^{-1}), maximum straw yield (9.35 t ha^{-1}) and harvest index (48.60%) were recorded from L_0 (Untreat control). Whereas, maximum sterile spikelet $panicle^{-1}$ (47.50) and maximum spikelet sterility (45.72%) were recorded from L_5 (All leaves cutting).

Different combinations of varieties and leaf cutting, the tallest plant (104.3 cm), the maximum number of total tillers per hill (26.67), maximum number of leaves (27.67), maximum total dry mater (21.50 g), maximum leaf area per hill (64.67 cm^{-2}), maximum leaf area index (2.95), maximum flag leaf chlorophyll content (4.47 gm g^{-1}), maximum stomatal conductance (0.57mmol CO_2 m^{-2} s^{-1}), maximum SPAD (46.67), maximum number of grain per panicle (151.67), maximum total number of spikelets per panicle (241.7), maximum weight of 1000 grain (29.63 g),maximum number of grain per panicle (8.13), maximum straw yield (9.47) and harvest index V_1L_0 (BRRI dhan29 + Untreated control). Whereas, the maximum number of sterile spikelets per panicle (47.67) and maximum spikelets sterility (42.45%) were recorded V_2L_5 (BRRI dhan29 + All leaf cutting).

Conclusion

1. Different morphological, physiological and yield attributes were affected due to leaf cutting.
2. The parameters like plant height, number of tiller hill^{1}, number of leaves hill^{-1}, leaf area, number of spikelet panicle^{-1}, SPAD value, dry matter content, stomatal conductance, 1000 grains weight, grain yield, straw yield and harvest index were severely affected due to leaf cutting.
3. The treatment untreated control performed better than the other treatments.
4. The variety BRRI dhan29 was less affected due to leaf cutting compared to BRRI hybrid dhan2.

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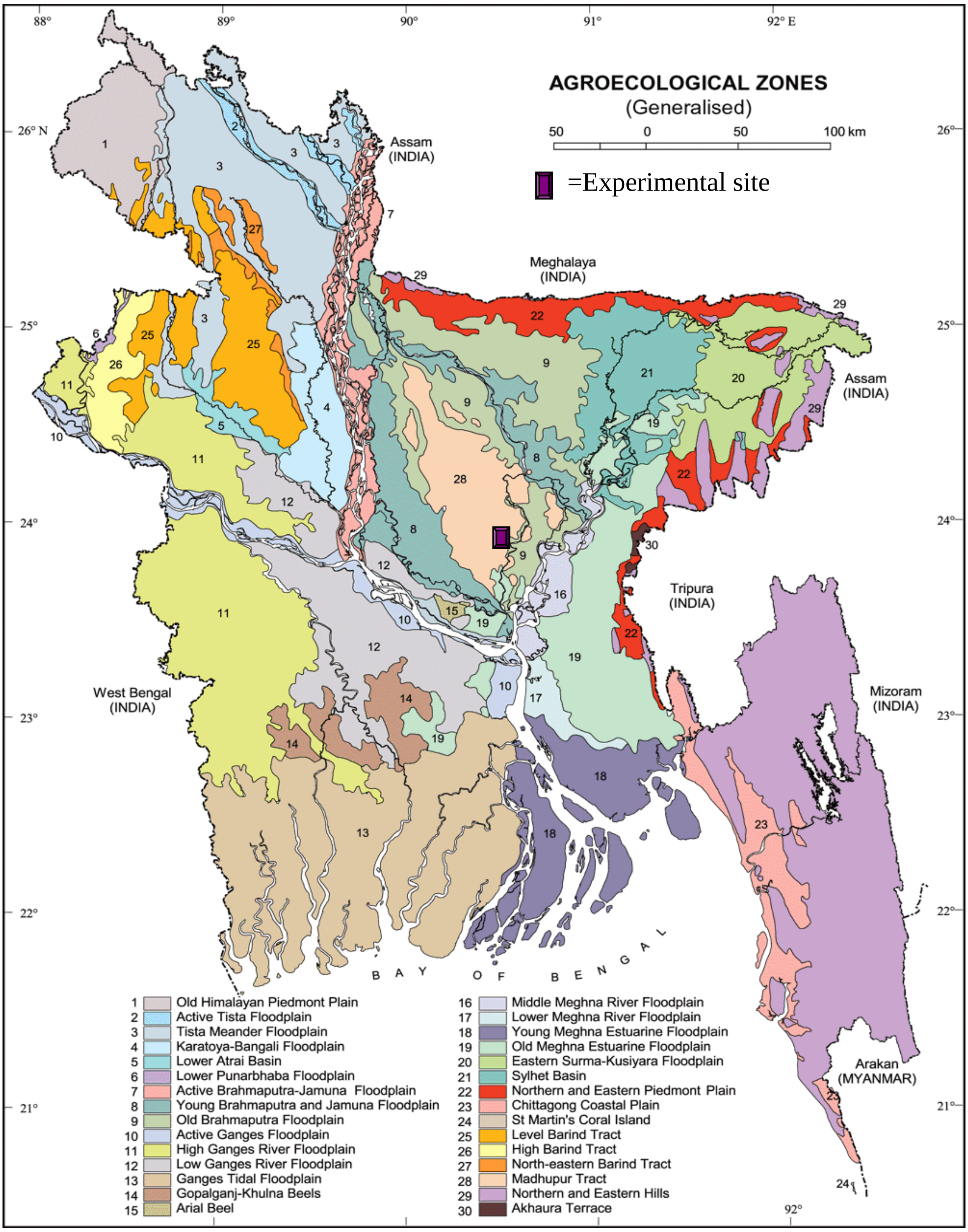
APPENDIXES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix 2. The physical and chemical characteristics of soil of the experimental site as observed prior to experimentation (0-15 cm depth).

Constituents	**Percent**
Sand	26
Silt	45
Clay	29
Textural class	Silty clay

Chemical composition:

Soil characters	**Value**
Organic carbon (%)	0.45
Organic matter (%)	0.54
Total nitrogen (%)	0.027
Phosphorus	6.3 µg/g soil
Sulphur	8.42 µg/g soil
Magnesium	1.17 meq/100 g soil
Boron	0.88 µg/g soil
Copper	1.64 µg/g soil
Zinc	1.54 µg/g soil
Potassium	0.10 meg/100g soil

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

Appendix 3: Analysis of variance of the data on plant height of rice as influenced by varieties and different leaf cutting.

Source of variance	Degrees of freedom	Mean square
Replication	2	0.194NS
Factor A	1	560.111***
Error	2	6.028
Factor B	5	132.444 *
A×B	5	5.778 *
Error	20	0.778

Here, NS= Non-significant; * = Significant at 1% level; ** = Significant at 5% level; *** = Significant at 10% level.

Appendix 4: Analysis of variance of the data on tillers hill^{-1} of rice as influenced by varieties and different leaf cutting.

Source of variance	Degrees of freedom	Mean square
Replication	2	0.861NS
Factor A	1	44.444 **
Error	2	1.194
Factor B	5	95.911 *
A×B	5	2.178 *
Error	20	0.494

Here, NS= Non-significant; * = Significant at 1% level; ** = Significant at 5% level; *** = Significant at 10% level.

Appendix 5: Analysis of variance of the data on leaves hill^{-1} of rice as influenced by varieties and different leaf cutting.

Source of variance	Degrees of freedom	Mean square
Replication	2	0.361NS
Factor A	1	72.250 ***
Error	2	1.083
Factor B	5	68.094 *
A×B	5	0.717 ***
Error	20	0.456

Here, NS= Non-significant; * = Significant at 1% level; ** = Significant at 5% level; *** = Significant at 10% level.

Appendix 6: Analysis of variance of the data on leaf area as varieties and different leaf cutting.

Source of variance	Degrees of freedom	Mean square
Replication	2	0.028NS
Factor A	1	200.694 *
Error	2	0.194
Factor B	5	160.161 *
A×B	5	4.828 *
Error	20	0.978

Here, NS= Non-significant; * = Significant at 1% level; ** = Significant at 5% level; *** = Significant at 10% level.

Appendix 7: Analysis of variance of the data on leaf area of rice as varieties and different leaf cutting.

Source of variance	Degrees of freedom	Mean square
Replication	2	0.004NS
Factor A	1	3.004 ***
Error	2	0.072
Factor B	5	2.064 *
A×B	5	0.324 *
Error	20	0.054

Here, NS= Non-significant; * = Significant at 1% level; ** = Significant at 5% level; *** = Significant at 10% level.

Appendix 8: Analysis of variance of the data on chlorophyll content of rice as influenced by varieties and different leaf cutting.

Source of variance	Degrees of freedom	Mean square
Replication	2	0.037 ***
Factor A	1	0.871 *
Error	2	0.025
Factor B	5	6.07 *
A×B	5	0.014NS
Error	20	0.052

Here, NS= Non-significant; * = Significant at 1% level; ** = Significant at 5% level; *** = Significant at 10% level.

Appendix 9: Analysis of variance of the data on total dry matter of rice as influenced by varieties and different leaf cutting.

Source of variance	Degrees of freedom	Mean square
Replication	2	0.13 ***
Factor A	1	13.322 **
Error	2	0.031
Factor B	5	183.472 *
A×B	5	0.97 *
Error	20	0.051

Here, NS= Non-significant; * = Significant at 1% level; ** = Significant at 5% level; *** = Significant at 10% level.

Appendix 10: Analysis of variance of the data on grain panicle^{-1}of rice as influenced by varieties and different leaf cutting.

Source of variance	Degrees of freedom	Mean square
Replication	2	0.030NS
Factor A	1	779.34 *
Error	2	0.114
Factor B	5	6934.422 *
A×B	5	108.038 *
Error	20	1.378

Here, NS= Non-significant; * = Significant at 1% level; ** = Significant at 5% level; *** = Significant at 10% level.

Appendix 11: Analysis of variance of the data on sterile grain spikelet^{-1} as influenced by varieties and different leaf cutting.

Source of variance	Degrees of freedom	Mean square
Replication	2	0.083NS
Factor A	1	25.00 ***
Error	2	1.583
Factor B	5	555.60 *
A×B	5	20.067 *
Error	20	0.567

Here, NS= Non-significant; * = Significant at 1% level; ** = Significant at 5% level; *** = Significant at 10% level.

Appendix 12: Analysis of variance of the data on percent sterility of rice as influenced by varieties and different leaf cutting.

Source of variance	Degrees of freedom	Mean square
Replication	2	0.028NS
Factor A	1	61.152 **
Error	2	0.857
Factor B	5	714.051 *
A×B	5	10.21 *
Error	20	0.22

Here, NS= Non-significant; * = Significant at 1% level; ** = Significant at 5% level; *** = Significant at 10% level.

Appendix 13: Analysis of variance of the data on 1000 grain weight of rice as influenced by varieties and different leaf cutting.

Source of variance	Degrees of freedom	Mean square
Replication	2	0.004NS
Factor A	1	0.028 *
Error	2	0.034
Factor B	5	10.169 *
A×B	5	1.374 *
Error	20	0.059

Here, NS= Non-significant; * = Significant at 1% level; ** = Significant at 5% level; *** = Significant at 10% level.

Appendix 14: Analysis of variance of the data on grain yield of rice as influenced by varieties and different leaf cutting.

Source of variance	Degrees of freedom	Mean square
Replication	2	0.014 ***
Factor A	1	3.868 **
Error	2	0.009
Factor B	5	18.54 *
A×B	5	0.288 *
Error	20	0.049

Here, NS= Non-significant; * = Significant at 1% level; ** = Significant at 5% level; *** = Significant at 10% level.

Appendix 15: Analysis of variance of the data on straw yield of rice as influenced by varieties and different leaf cutting.

Source of variance	Degrees of freedom	Mean square
Replication	2	0.072 ***
Factor A	1	1.734 ***
Error	2	0.054
Factor B	5	23.087 *
A×B	5	0.403 *
Error	20	0.039

Here, NS= Non-significant; * = Significant at 1% level; ** = Significant at 5% level; *** = Significant at 10% level.

Appendix 16: Analysis of variance of the data on harvest index of rice as influenced by varieties and different leaf cutting.

Source of variance	Degrees of freedom	Mean square
Replication	2	0.597 ***
Factor A	1	3.063 ***
Error	2	0.50
Factor B	5	15.451 *
A×B	5	20.133 *
Error	20	2.257

Here, NS= Non-significant; * = Significant at 1% level; ** = Significant at 5% level; *** = Significant at 10% level.

Appendix 17: Analysis of variance of the data on SPAD value of rice as influenced by varieties and different leaf cutting.

Source of variance	Degrees of freedom	Mean square
Replication	2	2.92NS
Factor A	1	11.111NS
Error	2	21.955
Factor B	5	5.774 ***
A×B	5	8.111 ***
Error	20	4.176

Here, NS= Non-significant; * = Significant at 1% level; ** = Significant at 5% level; *** = Significant at 10% level.