INFLUENCE OF LEAF CLIPPING ON THE GROWTH AND YIELD OF AUS RICE

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JUNE, 2020

INFLUENCE OF LEAF CLIPPING ON THE GROWTH AND YIELD OF AUS RICE

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REGISTRATION NO: 13-05639

A Thesis

Submitted to the Faculty of Agriculture,
Sher-e-Bangla Agricultural University, Dhaka,
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (M.S.)
IN
AGRONOMY

SEMESTER: JANUARY-JUNE, 2020

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CERTIFICATE

*This is to certify that thesis entitled, "**INFLUENCE OF LEAF CLIPPING ON THE GROWTH AND YIELD OF AUS RICE**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) in AGRONOMY**, embodies the result of a piece of bona-fide research work carried out by **MD. NAYEEM AHSAN** , Registration no. **13-05639** 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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ACKNOWLEDGEMENTS

All praises are putting forward to Allah (SWT) Who is the Supreme Planner and has blessed the author to complete this piece of study as required for the degree Master of Science.

It is a great pleasure for the author to make delighted his respected parents, who had been shouldering all kinds of hardship to establish a favourable platform thereby receiving proper education until today.

The author is happy to express his sincere appreciation and profound gratitude to his respected Supervisor ***Prof. Dr. Md. Fazlul Karim****, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his dynamic guidance, constant encouragement, constructive criticism and valuable suggestions encompassed the research work and thesis writing times.*

It is a great pleasure for the author to express his deep sense of gratitude and sincere regards to his Co-Supervisor ***Prof. Dr. A. K. M. Ruhul Amin****, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his adept guidance, supervision, kind cooperation, and valuable suggestions in preparation of the thesis.*

It is highly appreciating words for ***Prof. Dr. Md. Shahidul Islam****, Chairman, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka along with faculties of the Department of Agronomy, Sher-e-Bangla Agricultural University for their rendered novel services towards me as their student.*

The author also expresses heartfelt thanks to the staff of Department of Agronomy and central farm, SAU, for their valuable suggestions, instructions ordial help and encouragement during the period of research work.

The author wish to extend his special thanks to his classmates and friends Sajadul Islam, Pulak Kumar Sarkar, Md. Mehedi Hasan Sumon and Nasrin Sultana for their keen help as well as heartfelt co-operation and encouragement.

The author express his thanks to own brothers, sisters, uncles, aunts and other relatives who continuously prayed for his success and without whose love, affection, inspiration and sacrifice this work would not have been completed.

May Allah (SWT) bless and protect them all.

The Author
June, 2020

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ABSTRACT

An experiment was conducted during the period from March to August 2019 in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to find out the influence of leaf clipping on the growth and yield of *aus* rice. The experiment comprised two factors; Factors A: three different seedling clipping *viz*. S_0 = no seedling clipping (control), S_1 = $1/3^{rd}$ seedling clipping and S_2 = $1/2^{nd}$ seedling clipping and Factor B: four different leaf clipping before panicle initiation *viz*. L_0 = no leaf clipping (control), L_1 = Lower 1 + 2 leaves clipping, L_2 = Lower 2 + 3 leaves clipping and L_3 = Flag leaf clipping. The experiment was laid out in Randomized Complete Block design (RCBD) with three replications. Different seedling clipping showed significant variations of all parameter except plant height. Different leaf clipping treatment also showed same effect on different plant characters. Interaction effect of seedling clipping and leaf clipping treatment also showed the significant variation on growth and yield parameters. The tallest plant (116.80 cm) was recorded from the combination of no seedling clipping with no leaf clipping. The highest effective tiller (27.69) and the longest panicle (35.81 cm) was obtained from the combination of $1/3^{rd}$ seedling clipping with no leaf clipping treatment. The highest non-effective tiller (15.36) was obtained from the combination of no seedling clipping with flag leaf clipping. The maximum number of filled grain panicle^{-1} (157.50) was recorded from the interaction effect of $1/3^{rd}$ seedling clipping with no leaf clipping. The highest 1000-grain weight (26.87 g) was found from the interaction effect of $1/3^{rd}$ seedling clipping and no leaf clipping. The maximum grain yield (6.08 t ha^{-1}) was recorded from $1/3^{rd}$ seedling clipping and no leaf clipping combination treatment. The maximum straw yield (6.24 t ha^{-1}) was obtained from the combination of no seedling clipping and flag leaf clipping. The highest biological yield (10.23 t ha^{-1}) was obtained from the combination of $1/3^{rd}$ seedling clipping with lower 1 + 2 leaves clipping. The highest harvest index (67.48 %) was observed from the interaction effect of $1/3^{rd}$ seedling clipping with no leaf clipping. $1/3^{rd}$ seedling clipping and No leaf clipping was given the best results on grain yield and harvest index. The lowest grain yield and highest straw yield was recorded the flag leaf clipping.

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LIST OF ABBREVIATIONS

AEZ	Agro-Ecological Zone
Anon.	Anonymous
AIS	Agriculture Information Service
BARC	Bangladesh Agricultural Research Council
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
BNNC	Bangladesh National Nutrition Council
BRRI	Bangladesh Rice Research Institute
CRRI	Central Rice Research Institute
CV %	Percent Coefficient of Variance
cv.	Cultivar (s)
DAT	Days After Transplanting
DRR	Directorate of Rice Research
eds.	Editors
et al.	et alii (and others)
etc.	et cetera (and other similar things)
FAO	Food and Agricultural Organization
IARI	Indian Agricultural Research Institute
ICAR	Indian Council of Agricultural Research
IRRI	International Rice Research Institute
L.	Linnaeus
LSD	Least Significant Difference
i.e.	id est (that is)
MoP	Muriate of Potash
NPTs	New Plant Types

SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources and Development Institute
TDM	Total Dry Matter
TSP	Triple Super Phosphate
UNDP	United Nations Development Programme
var.	Variety
viz.	Namely

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) belonging to the family Poaceae and subfamily Oryzoideae is the staple food for half of the world's population. With a compact genome, the cultivated rice species represents model for other cereals as well as other monocot plants (Shimamoto and Kyozuka, 2002). Rice cultivation is favored by the hot, humid climate and the large number of deltas across Asia's vast tropical and sub-tropical areas.

Rice is the primary food of about 65% of the world's population (Akter *et al.*, 2014). Rice that is grown in more than hundreds of countries that covers total area of about 160 million hectares and also producing more than 700 million tons every year. It is also known as a main staple food for over half of the world's population, especially in Southeast Asia along with rapidly growing populations (Grist, 1988). Asia accounts for 90% of the world's production of rice. Rice is the main staple food and the main source of energy for the population of Bangladesh that covers 80% of the total cropped area as about 12 million hectares with annual production 30.42 million tons thus contributes about 70 to 80 percent of total food grain production (BRRI, 2014). Now the position of Bangladesh is 4^{th} in both area and production, and sixth for the production of per hectare yield of rice which contributes 14.23 percent in GDP (BBS, 2018). It is reported that, more than 90% of all produced rice has been consumed in Asia (FAO, 2016). It is rice that covers on an average of 20% apparent calorie intake in the world and 30% for the Asian people (Hien *et al.*, 2006).

The cultivation of rice in Bangladesh varies according to seasonal changes in the water supply. More than half of the total production (55.50%) is obtained in *Boro* season occurring in December–May, second largest production in *Aman* season (37.90%) occurring in July-November and little contribution from *Aus* season (6.60%) occurring in April-June (Asia and pacific commission on agricultural statistics, 2016). Potential for increased rice production strongly depends on the ability to integrate a better crop management for the different varieties into the existing cultivation. Variety itself is a genetic factor, which contributes a lot in producing yield and yield components of a particular crop (Mahmud *et al*., 2013). In the year 2017, among *Aus* rice varieties high yielding modern varieties covered 73.08% and de-husked yield was 2.69 t ha^{-1} and local varieties covered 20.99% and de-husked yield was 1.65 t ha^{-1} (BBS, 2017).

The demand of rice is constantly increasing in Bangladesh with nearly three million people are being added each year to the total population of the country (BBS, 2015). To meet the total food demand of growing population, *Aus* rice production needs to be increased more even to compensate the future strategy of closing *Boro* cultivation for giving space to other non-rice crops cultivation.

Leaf is an unique media for photosynthesis which influenced by many plant factors such as leaf age, leaf position and mutual shading as well as environmental factors such as light, temperature, nutrition and water availability (Lieth and Pasian, 1990). The analysis of the regulation of assimilate allocation between shoot and root by means of partitioning control mechanism, which promotes the initiation of a compensatory adaptive response by the plant to changes in shoot and root dry matter partition (Gray, 1996). Thus leaf clipping in transplanted seedling may have option to translocate assimilate towards root zone for early establishing of seedling. It has been observed that leaf clipping either flag leaf or along 2nd and 3rd leaves have positive effect on grain production in modern variety. Misra and Misra (1991) (for pearl millet) and Mae (1997) (for rice) stated that the top three leaves translocate assimilate towards grain filling.

The top three leaves have most contribution for the yield of grain (Yoshida, 1981; Misra, 1987). Intensive study on rice yield after clipping of flag leaf and nearby leaf was done (Abou-khalifa *et al.,* 2008). By considering the importance of leaves for grain yield, it is necessary to analyse the morphological and the physiological characteristics of functional leaves to improve grain yield in rice (Yue *et al.,* 2006). Seedling leaf clipping at transplanting does not immediately improve plant water status, but it may alleviate drought stress in clipped plants.

It has also been reported that leaf clipping presumably removes transpiring biomass and conserves soil moisture (Georgias *et al.*, 1989). It was observed that severely clipped plants are less stressed than unclipped ones. Conservation of soil moisture' possibly allows transplants to survive for longer periods of time if no follow-up rains are received soon after transplanting. Clipping of the flag leaf from rice at any stage after the emergence of panicle was the main cause of significant reduction in grain yield (Singh and Ghosh, 1981). In another report, it was shown that the contribution of flag leaf is as much as 45% on rice grain yield and, when it was removed, and then it was the major component for the loss of rice yield (Abou-Khalifa *et al.*, 2008). In accordance with Mae (1997), 60–90% of total carbon in the panicles during harvest is derived from photosynthesis after heading, and 80% or more of nitrogen (N) in the panicles during harvest is absorbed before heading which is remobilized from vegetative organs. On the other hand, in case of wheat, above 34.5% grain yield reduction was reported after the clipping of flag leaf during the stage of heading (Mahmood and Chowdhury, 1997), while Birsin (2005) showed that removal of flag leaf which resulted in approximately 13, 34, 24% reduction in grain per spike, grain weight per spike and 1000-grain weight, respectively, and also increase 2.8% protein contents in grain. Similarly, it is believed that rice flag leaves are also a major source of remobilized minerals that is essential for the grains, and recent reports have tried to correlate the expression of gene levels on flag leaves with the concentration of mineral nutrients in rice grains (Narayanan *et al.*, 2007, Sperotto *et al.*, 2009). Flag leaf contributed to 45% of grain yield and is the single most component for yield loss (Magor, 1986). Cutting long duration rice leaves at the vegetative phase is also practiced in India (Copeland, 1972) and is now more frequently done in Thailand (Kupkanchanakul *et al*., 1991).

By keeping eyes on those points, it is important to examine the response of leaf clipping on growth and yield of *Aus* rice when this type of experiment is very scanty at home. Under these circumstances, the present research work was undertaken to achieve the following objectives:

1. To determine the effect of seedling clipping on *Aus* rice production,
2. To ascertain the position of leaf to be clipped down on growing rice plant and
3. To find out the combined effect of seedling clipping along with leaf clipping of growing plant on the growth and yield of *Aus* rice.

CHAPTER II

REVIEW OF LITERATURE

Rice is widely adaptable crop in different environmental condition. The growth and development of rice may be influenced by systems of cultivation. Leaf is an important part of rice plant and major source of photosynthetic activity. Leaf clipping practice on either at seedling stage or after seedling transplanting stage can influence different growth and yield attributes of rice. Yield potentiality also depends on physiological parameters like leaf area index, dry matter accumulation, translocation and regulation of assimilate association between shoot and root by means of partitioning physiology. The work so far done in Bangladesh on leaf clipping is not adequate and conclusive. An attempt was made in this section to collect and study relevant information available in the world to gather knowledge helpful in conducting the present research work and subsequently writing up the result and discussion. Some of the important and informative works and research findings so far been done on leaf clipping on the growth and yield of rice have been reviewed in this chapter under the following headings and sub-headings:

2.1 Impact of Leaf Clipping on growth parameters

2.1.1 Plant height

Hossain (2017) carried out an experiment to assess the effect of leaf cutting on plant growth and yield of selected BRRI released Aman varieties. The experiment had two leaf cutting managements i.e. T_1 = Leaf cutting (except flag and penultimate leaves) T_2 = Control (no leaf cutting) and imposed on five varieties e.g. V_1 = BRRI dhan32, V_2 = BRRI dhan33, V_3 = BRRI dhan39, V_4 = BRRI dhan62 and V_5 = BRRI dhan56. Irrespective of all the varieties under study, the maximum plant height was obtained in no leaf cutting (control treatment).

Medhi *et al.* (2015) set up a field trial to study the effect of foliage pruning on growth and yield of two low land rice varieties, TTB-303−1-42 (Dhansiri) and TTB-303−1-23 (Difalu) under rain-fed low land situation (50–100 cm water depth) during wet season. Experimental results showed that two times removal of foliage significantly reduced the plant height and prevented lodging.

Si Ayutthaya (2011) reported that rice leaf cutting length of 30 cm had been recommended at 30–60 day after planting and before flowering. It can be cut multiple times but the flag leaf should not be cut. Rice leaf cutting at 60 days after planting only one time had effect on uniform plant height and uniform flowering.

Usman *et al.* (2007) conducted an experiment to study the effect of detopping on grain yield of rice. The experiment consisted of six treatments *viz.* Control (T_1, No detopping), detopping at 22 DAT (T_2), detopping at 29 DAT (T_3), detopping at 36 DAT (T_4), detopping at 43 DAT (T_5) and detopping at 50 DAT (T_6). In respect of all the six treatments, the tallest plant (125 cm) was recorded from control (no detopping) treatment. Hence, it was concluded that detopping at an early vegetative stage of crop growth could reduce lodging in case of excessive vegetative growth.

Sardana *et al.* (2006) conducted a field experiment to study the effect of extent and stage of foliage clipping on the grain yield of basmati rice. Thirty days older seedlings of rice variety Basmati 386 were transplanted as the planting material. Total 10 treatments (combinations of different times, number and extent of foliage clipping) were arranged. The treatments were as follows: i) one-third of leaf clipping from top of the plant at 30 days after transplanting (DAT), ii) ½ of leaf clipping from top of the plant at 30 DAT, iii) one-third of leaf clipping from top of the plant at 45 DAT, iv) ½ of leaf clipping from top of the plant at 45 DAT, v) one-third of leaf clipping from top of the plant at 60 DAT, vi) ½ of leaf clipping from top of the plant at 60 DAT, vii) one-third of leaf clipping from top of the plant at 30 and 60 DAT, viii) ½ of leaf clipping from top of the plant at 30 and 60 DAT, ix) clipping of leaf just above growing point at the time of seedling transplanting and x) No leaf clipping. The extent (one-third or ½) and stage (30, 45 or 30 and 60 days after transplanting) of foliage clipping significantly influenced the plant height of Basmati 386 rice variety.

Islam *et al.* (2005) conducted a field experiment during the 2001 T. aman (wet season) and 2002 boro (dry season) to find out the effect of flag leaf clipping and gibberellic acid (GA_3) application on hybrid rice seed yield. IR58025A (female parent) and BR827R (male parent) were taken as experimental materials. Four treatments were applied: T_1 = control, T_2 = GA_3 application without flag leaf clipping, T_3 = flag leaf clipping without GA_3 application and T_4 = GA_3 application with flag leaf clipping. Half of the flag leaf of the A line was clipped using a sickle when primary tillers were at booting stage in both seasons. Results indicated that, in the T. aman season, plant height of the A line differed significantly among different treatments. The tallest plant height (90 cm) in T. aman season was observed in T_2 treatment where GA_3 was applied without flag leaf clipping. However, the differences during the Boro season were non-significant.

Molla *et al.* (2002) carried out a field trial to study green fodder harvest without affecting the seed yield of transplant aman rice. The experiment consists of two factors, (A) cultivar: (i) C_1 = Latishail (ii) C_2 = BR 10 (iii) C_3 = BR 11 and (iv) C_4 = BRRI dhan32 and (B) leaf clipping heights: (i) H_1 = clipping at 10 cm (ii) H_2 = clipping at 15 cm (iii) H_3= clipping at 20 cm and (iv) H_4 = control (no clipping). Plant height of the rice plants was significantly differed due to different cultivars and leaf clipping heights. The tallest plant was observed from control plot at all growth stages whereas; the shortest plant was recorded from leaf clipping at 10 cm height.

Ahmed *et al.* (2001) conducted an experiment to study the effect of nitrogen rate and time of leaf cutting on green fodder as well as seed yield of rice. The experiment included two factors, (A) Nitrogen level – viz. i) N_1 – 50 kg N ha^{-1},

ii) N_2 –75 kg N ha^{-1} and iii) N_3 – 100 kg N ha^{-1}, (B) Time of leaf cutting – viz. i) No cutting (control) – C_0, ii) Cutting at 21 DAT – C_1, iii) Cutting at 35 DAT – C_2 and iv) Cutting at 49 DAT – C_3. Plant height value was found to be the highest for no leaf cutting which was statistically similar to cutting at 21 DAT and the lowest for cutting at 49 DAT.

2.1.2 Number of effective tillers $hill^{-1}$

Fatima *et al.* (2019) carried out an experiment to study the effect of flag leaf clipping on growth yield, and yield attributes of hybrid rice varieties in Boro season. The experiment comprised of two factors. Factor A: Flag leaf clipping: T_1 = Flag leaf clipping at heading and T_2 = Control (without clipping). Factor B: Six hybrid rice varieties: V_1 = BRRI hybrid dhan1, V_2 = BRRI hybrid dhan2, V_3 = Heera 2, V_4 = Heera 4, V_5 = Nobin and V_6 = Moyna. Regardless of variety, all the studied parameters were exhibited superiority in control treatment. The highest number of effective tillers $hill^{-1}$ was recorded from Heera 4 under control condition.

Hossain (2017) carried out an experiment to assess the effect of leaf cutting on plant growth and yield of selected BRRI released Aman varieties. Irrespective of all the varieties under study, the highest numbers of tillers $hill^{-1}$ was obtained from no leaf cutting (control).

Boonreund and Marsom (2015) carried out experiments aimed at searching for the optimal length of cutting for Pathum Thani1 rice leaf for better yield. Length of rice leaf cutting was reported to have positive effect on broadcasting Thai jasmine rice yield but was not clarified in other variety. Treatments of the study were 7 cutting lengths (0, 5, 10, 15, 20, 25 and 30 cm from the leaf tip) which was performed by sickle 60 days after planting. The results showed that cutting of leaves had no significant effect on tiller number $plant^{-1}$. Tiller numbers was not significantly increased after cutting.

Foliage pruning up to 100 days after germination (DAG) had no adverse impact on tillers of the crop. The responses of both the varieties to leaf pruning were similar.

Daliri *et al.* (2009) carried out a field experiment in order to study the effect of cutting time and cutting height on yield and yield components of ratoon rice (*Oryza sativa* L.) Tarom langrodi variety. Results showed that the effect of cutting time on number of effective tiller hill^{-1} was found statistically significant. Cutting height had a significant effect on number of tiller in hill and number of effective tiller in hill. Interaction between cutting time and cutting height on number of tiller hill^{-1} and number of effective tillers hill^{-1} were significant.

Islam *et al.* (2005) conducted that during the 2001 T. aman (wet season) and 2002 Boro (dry season) to find out the effect of flag leaf clipping and gibberellic acid (GA_3) application on hybrid rice seed yield with a view to increasing per unit area production of hybrid seed. IR58025A (female parent) and BR827R (male parent) were taken as experimental materials. Four treatments were applied: T_1 = control, T_2 = GA_3 application without flag leaf clipping, T_3 = flag leaf clipping without GA_3 application and T_4 = GA_3 application with flag leaf clipping. Half of the flag leaf of the A line was clipped using a sickle when primary tillers were at booting stage in both seasons. Results indicated that, the number of tillers per hill remained statistically identical among all treatments in both seasons.

Molla *et al.* (2002) carried out an experiment to ascertain the feasibility of green fodder harvest without affecting the seed yield of transplant aman rice. The experiment consists of two factors, (A) cultivar: (i) C_1 = Latishail (ii) C_2 = BR 10 (iii) C_3 = BR 11 and (iv) C_4 = BRRI dhan32 and (B) leaf clipping heights: (i) H_1 = clipping at 10 cm (ii) H_2 = clipping at 15 cm (iii) H_3= clipping at 20 cm and (iv) H_4 = control (no clipping). Number of tillers hill^{-1} was significantly differed due to different cultivar and leaf clipping height. The highest number of tillers hill^{-1} was obtained from control plot at all growth stage whereas the lowest was recorded from clipping at 10 cm height.

Ahmed *et al.* (2001) carried out a field trial to study the effect of pre-flowering leaf cutting on forage and seed yield of transplant aman rice. The experiment consisted of four varieties namely Latishail, BR 10, BR 11 and BRRI dhan32 and four leaf cuttings *viz.*, no leaf cutting (T_1), leaf cutting at 21 DAT (T_2), leaf cutting at 28 DAT (T_3) and leaf cutting at 35 DAT (T_4). The effect of leaf cutting was found to be significant in respect of the crop characters. The highest value of productive tillers hill^{-1} (9.19) was found in control. The lowest value for all crop characters was observed when the leaf was cut at 35 DAT.

Ahmed *et al.* (2001) conducted an experiment to study the effect of nitrogen rate and time of leaf cutting on green fodder as well as seed yield of rice. The experiment included two factors, (A) Nitrogen level – viz. i) N_1 – 50 kg N ha^{-1}, ii) N_2 –75 kg N ha^{-1} and iii) N_3 – 100 kg N ha^{-1}, (B) Time of leaf cutting – viz. i) No cutting (control) – C_0, ii) Cutting at 21 DAT – C_1, iii) Cutting at 35 DAT – C_2 and iv) Cutting at 49 DAT – C_3. Number of total tillers hill^{-1} and number of productive tillers hill^{-1} were recorded to be the highest from no leaf cutting treatment which was statistically similar to cutting at 21 DAT and the lowest from leaf cutting at 49 DAT.

Hachiya (1989) carried out a field experiment to study on the effect of artificial leaf cutting on growth and yield of rice plants. The study produced the evidence that compensatory responses in rice growth, such as increases in the percentages of productive tillers were observed in response to artificial leaf cutting. However, such responses seemed to be minimal in cold years.

BRRI (1986) from the research work on effect of leaf clipping at two growth stages on grain yield of rice reported that some cultivars are more tolerant to leaf clipping than others are due to their genetic variability or genetic makeup. Another observation was that leaf clipping at PI (panicle initiation) stage had more detrimental effect than that at active tillering stage.

2.1.3 Number of non-bearing tillers hill^{-1}

Ahmed *et al.* (2001) carried out a field trial to study the effect of nitrogen rate and time of leaf cutting on green fodder as well as seed yield of rice. The experiment included two factors, (A) Nitrogen level – viz. i) N_1 – 50 kg N ha^{-1}, ii) N_2 –75 kg N ha^{-1} and iii) N_3 – 100 kg N ha^{-1}, (B) Time of leaf cutting – viz. i) No cutting (control) – C_0, ii) Cutting at 21 DAT – C_1, iii) Cutting at 35 DAT – C_2 and iv) Cutting at 49 DAT – C_3. Maximum number of non-bearing tillers hill^{-1} was recorded from no leaf cutting treatment, which was statistically similar to leaf cutting at 21 DAT and the minimum was observed in leaf cutting at 49 DAT.

2.1.4 Total dry matter weight

Ros *et al.* (2003) conducted an experiment to explore the concept of seedling vigor of transplanted rice and to determine what plant attributes conferred vigor on the seedlings. Seedling vigor treatments were established by subjecting seedlings to short-term submergence (0, 1 and 2 days/work) in one experiment and to leaf clipping or root pruning and water stress in another to determine their effect on plant growth after transplanting. Pruning 30% of leaves depressed shoot and root dry mater by 30% at panicle initiation (PI) and root dry matter by 20% at maturity. The combined effects of leaf clipping and root pruning on shoot, root and straw dry matter were largely additive. It was concluded that the response of rice yield to nursery treatments is largely due to increased seedling vigor and can be affected by a range of nutritional as well as non-nutritional treatments of seedlings that increase seedling dry matter, nutrient content and nutrient concentration. Impairment of leaf growth and to a lesser extent root growth in the nursery depressed seedling vigor after transplanting. However, rather than increasing stress tolerance, seedling vigor was more beneficial when post-transplant growth was not limited by nutrient or water stresses.

2.1.5 Panicle length

Moballeghi *et al.* (2016) carried out a field experiment in order to study the effect of source-sink limitations on agronomic traits and grain yield of different lines of rice. Treatments of source-sink limitation in four levels (including cutting of flag leaf, cutting of one third the end of panicle, cutting of other leaves except flag leaf and control or without limitation) and lines of rice in four levels (line of No. 3, line of No. 6, line of No. 7 and line of No. 8) were the treatments. Among different source sink limitation treatments, increase in panicle length and decrease in panicle fertility percentage were recorded when all leaves except flag leaf was removed.

Boonreund and Marsom (2015) carried out experiments aimed to determine the optimal length of cutting for Pathum Thani1 rice leaf for better yield. Treatments of the study was 7 cutting lengths (0, 5, 10, 15, 20, 25 and 30 cm from the leaf tip) which was performed by sickle after 60 days after planting. The results showed that cutting of leaves had no significant effect on panicle length.

Rahman *et al.* (2013) carried out an investigation in order to explore the relationship between grain yield and flag leaf parameters. Yield composition; length and width of the flag leaf and panicle length were measured in some rice cultivars. Rice cultivars BR 3, BR 4, BR 11, BRRI dhan28, BRRI dhan29, BRRI dhan34 and BRRI dhan37 were used. Flag leaf (FL) was excised at the base during heading stage from some of the plants of the studied cultivars and let it grow to maturity. Length of flag leaf and panicle of two rice cultivars, BR 11 and BRRI dhan28 were measured and correlation between the characters was calculated. Plants with grater FL length had elongated panicle length, thus producing increased number of primary and secondary rachis resulted in increased number of grain in the panicle that ultimately improved the yield of the cultivar. Statistical analysis showed that the value of correlation coefficient r was 0.79 and 0.97 for BR 11 and BRRI dhan28, respectively. The flag leaves were excised after the emergence of panicle from some of the selected plants of all the examined cultivars and let it to grow. Phenotypic observation indicated various defects existed in the leaf cut plants throughout maturation where panicle length and branching were reduced. It was noticed that when FL length is high the panicle length is also high. In case of BR 11 when the average FL length was 21.33, 25.90, 28.19, 37.33, 18.28, 37.84, 37.59, 25.90, 24.13 and 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 and 31.65 cm, respectively and in case of correlation analysis, a significant correlation was found between them. Similar significant result was found in case of BRRI dhan28. Yield was significantly and positively associated with panicle length. They also found that flag leaf length was positively associated with panicle length, thereby indicating associated with grain yield.

Usman *et al.* (2007) conducted that the effect of detopping on forage and grain yield of rice. The experiment consisted of six treatments viz., Control (T_1, no detopping), detopping at 22 DAT (T_2), detopping at 29 DAT (T_3), detopping at 36 DAT (T_4), detopping at 43 DAT (T_5), and detopping at 50 DAT (T_6). In respect of all the six treatments, the tallest length of panicle (23.4 cm) was obtained from control (no detopping).

Ahmed *et al.* (2019) conducted that the effect of pre-flowering leaf cutting on forage and seed yield of transplant aman rice. The experiment consisted of four varieties namely Latishail, BR 10, BR 11 and BRRI dhan32 and four leaf cuttings *viz.*, no leaf cutting (T_1), leaf cutting at 21 DAT (T_2), leaf cutting at 28 DAT (T_3) and leaf cutting at 35 DAT (T_4). The highest value of panicle length (23.52 cm) was found in control. The yield and yield contributing characters decreased by leaf cutting as compared to control. The lowest value for all crop characters were observed when the leaf was cut at 35 DAT. It was reported that increasing day of leaf cutting gradually decrease the panicle length.

Kupkanchanakul *et al.* (1990) conducted an experiment to study the effect of leaf cutting for herbage in deep water rice and observed that panicle length decreased due to leaf cutting. It was concluded that increasing day of leaf cutting gradually decreased the panicle length.

2.2 Impact of Leaf Clipping on yield parameters

2.2.1 Number of filled grains panicle^{-1}

Fatima *et al.* (2019) conducted an experiment to study the effect of flag leaf clipping on growth yield, and yield attributes of hybrid rice varieties in Boro season. The experiment comprised of two factors. Factor A: Flag leaf clipping: T_1 = Flag leaf clipping at heading and T_2 = Control (without clipping). Factor B: Six hybrid rice varieties: V_1 = BRRI hybrid dhan1, V_2 = BRRI hybrid dhan2, V_3 = Heera 2, V_4 = Heera 4, V_5 = Nobin and V_6 = Moyna. Chlorophyll content (SPAD value) in penultimate leaf after 15 days after heading, grain filling duration, yield contributing characters and yield were investigated after cutting of flag leaf. Regardless of variety, all the studied parameters were exhibited superiority in control treatment. Chlorophyll and nitrogen content (SPAD value) in penultimate leaf (1.35% to 17.27%) and grain filling duration were increased (4.5 to 6.25 days) by virtue of clipping of flag leaf. The highest number of filled grains panicle^{-1} was recorded from Heera 4 under control condition.

Ali *et al.* (2017) conducted pot experiments to evaluate the impact of five different types of leaf clipping on the yield attributes of modern (Binadhan-8) and local (Terebaile) rice variety. Following leaf clipping treatments were applied for both the experiments: L_0 - Control (without leaf cutting), L_1 - Flag leaf cut, L_2- 2nd leaf cut, L_3 - 3rd leaf cut, L_4 - Both flag leaf and 2nd leaf cut and L_5 - Flag leaf with 2nd and 3rd leaves cut together. Leaf clipping was done prior to panicle emergence stage following the assigned treatment. In Binadhan-8 variety, flag leaf alone or flag leaf with 2nd leaf and 2nd and 3rd leaves cutting showed profound reduction in grain number panicle^{-1} (35.14, 62.62, and 51.83%, respectively) while, cutting of 2nd leaf and 3rd leaf alone exert no significant impact compared to control. In Terebaile variety, only flag leaf cut showed non-significant impact on grain number panicle^{-1}. Profound impact was observed by cutting flag leaf with 2nd leaf (55.47 %) and flag leaf with 2nd and 3rd leaf (58.96%) on grain number panicle^{-1}.

Hossain (2017) conducted an experiment to assess the effect of leaf cutting on plant growth and yield of selected BRRI released Aman varieties. The experiment consisted of two factors: Factor A: five varieties, V_1 = BRRI dhan32, V_2 = BRRI dhan33, V_3 = BRRI dhan39, V_4 = BRRI dhan62 and V_5 = BRRI dhan56 and Factor B: two leaf cutting, T_1 = Leaf cutting (except flag and penultimate leaves) T_2 = Control (no leaf cutting). Irrespective of all the varieties under study, the highest number of grains panicle^{-1} was obtained in no leaf cutting (control) treatment.

Boonreund and Marsom (2015) conducted an experiment aimed at searching for the optimal length of cutting for Pathum Thani1 rice leaf for better yield. Treatments of the study was seven cutting lengths *viz.*, (0, 5, 10, 15, 20, 25 and 30 cm from the leaf tip) which was performed by sickle after 60 days after planting. Number of grains panicle^{-1} increased significantly after cutting of rice leaf.

Rahman *et al.* (2013) conducted an investigation in order to explore the relationship between grain yield and flag leaf parameters. Yield composition, length and width of the flag leaf and panicle length were measured in some rice cultivars. Rice cultivars BR 3, BR 4, BR 11, BRRI dhan28, BRRI dhan29, BRRI dhan34, and BRRI dhan37 were used. Flag leaf (FL) was excised at the base during heading stage from some of the plants of the studied cultivars and let it grow to maturity and data were collected to study the effect of FL cutting on grain yield. Plants with grater FL length had elongated panicle length, thus producing increased number of primary and secondary rachis resulted in increased number of grain in the panicle that ultimately improved the yield of the cultivar.

Aktar-uz-zaman (2006) conducted an experiment to study on source-sink manipulation and their effect on grain yield in rice of rainfed varieties. There were nine treatments in source-sink manipulation: T_0 = Control, T_1 = Defoliation of flag leaf, T_2 = Defoliation of penultimate leaf, T_3 = Defoliation of tertiary leaf

(Third leaf), T_4 = Defoliation of flag leaf & penultimate leaf, T_5 = Defoliation of flag leaf, penultimate leaf & tertiary leaf, T_6 = Defoliation of all leaves, T_7 = Defoliation of all leaves without flag leaf, T_8 = Removal of 50% Spikelets. It was observed that the defoliation of flag leaf caused significant reduction on spikelets per panicle by 17.34 %. Similarly, the removal of penultimate leaf caused reduction of 10.98 % for spikelets per panicle. Likewise, the defoliation of third leaf caused reduction of 7.20 % for spikelets per panicle. Similarly, the defoliation of flag leaf, penultimate leaf and third at a time caused reduction of 29.20 % for spikelets per panicle.

Ahmed *et al.* (2019) conducted that the effect of pre-flowering leaf cutting on forage and seed yield of transplant aman rice. The possibility of extent usage of rice for human and livestock simultaneously was studied. The experiment consisted of four varieties namely Latishail, BR 10, BR 11 and BRRI dhan32 and four leaf cuttings *viz.*, no leaf cutting (T_1), leaf cutting at 21 DAT (T_2), leaf cutting at 28 DAT (T_3) and leaf cutting at 35 DAT (T_4). The highest value of grains panicle^{-1} (92.69) was found in control. The yield and yield contributing characters decreased by leaf cutting as compared to control. The lowest value for all crop characters was observed when the leaf was cut at 35 DAT.

Ahmed *et al.* (2019) carried out a field trial to study the effect of nitrogen rate and time of leaf cutting on green fodder as well as seed yield of rice. The experiment included two factors, (A) Nitrogen level – viz. i) N_1 – 50 kg N ha^{-1}, ii) N_2 –75 kg N ha^{-1} and iii) N_3 – 100 kg N ha^{-1}, (B) Time of leaf cutting – viz. i) No cutting (control) – C_0, ii) Cutting at 21 DAT – C_1, iii) Cutting at 35 DAT – C_2 and iv) Cutting at 49 DAT – C_3. Number of total spikelets panicle^{-1} and number of grains panicle^{-1} were found to be the highest from no leaf cutting treatment; which was statistically similar to cutting at 21 DAT. The lowest value for number of total spikelets panicle^{-1} and number of grains panicle^{-1} were recorded from cutting at 49 DAT.

Ghosh and Sharma (1998) from their study on the effect of foliage pruning on performance of rice under semi-deep water situation (50–100 cm) 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.

Wang *et al.* (1996) from their experiment on partitioning of ^{15}C photo assimilates during grain filling, yield components and their relation of late-transplanting rice, observed that partial removal of leaves had little influence on the number of grains per panicle.

Alejar *et al.* (1995) carried out an experiment to study the effect of source-sink imbalance on rice leaf senescence and yield. The planting materials for the experiment used were a slow senescing rice cultivar, Hankang and a rapid senescing cultivar, IR 66; which were grown in waterlogged soil and at heading half the lamina of the flag, penultimate and 3rd leaves were cut transversely, half of the spikelets panicle^{-1} were removed or leaves and panicles were left intact. The slow senescing Hankang gave heavier panicles compared with that of rapid senescing IR 66.

Sharma and De (1994) conducted an experiment to study the effect of foliage cutting on growth and yield of different rice cultivars under semi-deep water conditions (0–80 cm). In 1990 and 1991, four rice cultivars – Utkalprabha, Panidhan, CN573-321-7−1 and Jaladhi−1 were sown in dry soil and grown thereafter under semi-deep water conditions (0–80 cm). The crops were subjected to foliage cutting at the collar of the uppermost leaf. Decrease in grain yield of rice with two times cutting of foliage was due to a reduction in the number of grains panicle^{-1}.

Hachiya (1989) carried out a field experiment to study on the effect of artificial leaf cutting on growth and yield of rice plants. The study produced the evidence: that compensatory response in rice growth, such as increases in the percentages of ripening grains was observed. However, such responses seemed to be minimal in cold years.

Sairam and Dube (1984) from their experiment on effects of plant densities and defoliation treatments on yield and yield attributing characters of rice (*Oryza sativa*) reported that removal of flag leaf decreased the number of grains per panicle.

Nagato and Chaudhry (1970) carried out several studies to understand the influence of panicle clipping, flag leaf cutting on ripening of *japonica* and *indica* rice. In the experiments of flag leaf cutting, six varieties that is, Dular, Karalath, Te-Tep, Bluebonnet (*indica*), Kinmaze and Towada (*japonica*) were used as experimental planting materials. In flag leaf cutting trial, entire flag leaf and half of the flag leaf were cut at two growth stages in the following way: (C) Control (no cut), (1) 1 cut - entire flag leaf was cut before heading, (2) ½ cut - half of the flag leaf was cut before heading, (3) 1 cut - entire flag leaf was cut at heading stage and (4) ½ cut - half of the flag leaf was cut at heading stage. In leaf cutting trial, secondary branches were influenced to a greater degree compared to primary branches. Entire leaf cutting treatment exerted greater negative influence on the ripening as compared to ½ leaf cutting treatment. In case of cutting one week before heading treatment, some of the inferior florets especially on secondary branches appeared as "White-husk", florets which stopped growth in the early stage and appeared as white, papery structures. In this way, the number of spikelets per panicle particularly on secondary branches was decreased and the supply of carbohydrates for the remaining spikelets was increased and hence resulted in better ripening. Again, an increasing trend of sterile, abortive and opaque kernels were recorded in cutting before heading treatment. This increasing trend was expected to be more in the cutting after heading treatment but in reality, it was less. This was because in cutting before heading treatment, number of spikelets per panicle were decreased (which in return will result in the decrease of sterile, abortive and opaque kernels). This was true in case of Dular and Karalath in which number of spikelets per panicle especially on secondary branches decreased considerably. In case of Towada and Kinmaze, sterile, abortive and opaque kernels increased because number of spikelets per panicle on secondary branches did not decreased as much. Te-Tep and Bluebonnet behaved intermediately in reduction of number of spikelets per panicle and occurrence of sterility etc. Cutting at heading treatment showed an increase in sterile, abortive and opaque kernels. Occurrence of milky-white kernels ranges from small to large degree depending upon the variety and generally, an increasing trend was found in all the tested varieties. However, when the sterile, abortive and opaque kernels occurred abnormally as in case of secondary branches of Dular, Towada, Karalath and Te-Tep, the competition for nutrients among the spikelets was ameliorated in the remaining kernels and as a result, milky-white kernels were decreased. White-belly kernels generally increased in treated plots but in case the number of spikelets per panicle decreased and sterile, abortive and opaque kernels occur numerously in cutting before heading treatment (Dular and Bluebonnet), the competition in later stage of ripening was decreased and consequently the white-belly kernels were also decreased.

Sato (1970) designed an experiment to investigate the effects of cutting leaf-blade and thinning panicle branch at heading time of fruiting and the amount of starch in the culms in the tissue of rice plant. By cutting off all the leaf blades at heading time, the fruiting percentage lowered. By thinning the panicle branches, the reversed effect was observed. In the culms of plants deprived of leaf blades, starch diminished especially in grains contents.

Owen (1968) investigated the relation between leaf area duration and grain yield of two tropical rice varieties. Different Leaf area index (LAI) regimes during growth were imposed on two tropical rice, Sirona and HD34, by partial defoliation at different growth stages. In addition, part of the plant was completely defoliated after panicle emergence. It was concluded that the partial removal of some leaves only before panicle emergence reduced the number of spikelets formed per panicle but the numbers of spikelets formed per panicle was not affected from defoliation after the panicle emergence.

2.2.2 Number of unfilled grains panicle^{-1}

Ali *et al.* (2017) carried out a pot experiments to evaluate the impact of five different types of leaf clipping on the yield attributes of modern (Binadhan-8) and local (Terebaile) rice variety. Following leaf clipping treatments were applied for both the experiments: L_0 - Control (without leaf cutting), L_1 - Flag leaf cut, L_2- 2nd leaf cut, L_3 - 3rd leaf cut, L_4 - Both flag leaf and 2nd leaf cut and L_5 - Flag leaf with 2nd and 3rd leaves cut together. Leaf clipping was done prior to panicle emergence stage following the assigned treatment. Number of unfilled grain increased with higher intensity of leaf cutting.

Moballeghi *et al.* (2016) conducted a field experiment in order to study the effect of source-sink limitations on agronomic traits and grain yield of different lines of rice. Treatments of source-sink limitation in four levels (including cutting of flag leaf, cutting of one third the end of panicle, cutting of other leaves except flag leaf and control or without limitation) and lines of rice in four levels (line of No. 3, line of No. 6, line of No. 7 and line of No. 8) were the treatments. Among different source sink limitation treatments, increase in unfilled grain number per panicle and decrease in panicle fertility percentage were recorded when all leaves except flag leaf removed.

Medhi *et al.* (2015) set up a field trial to study the effect of foliage pruning on growth and yield of two low land rice varieties, TTB-303−1-42 (Dhansiri) and TTB-303−1-23 (Difalu) under rain-fed low land situation (50–100 cm water depth) during wet season. Grain sterility was 5.89–8.27% higher at delayed pruning and two times pruning. The responses of both the varieties to leaf pruning were similar.

Rahman *et al.* (2013) conducted an investigation in order to explore the relationship between grain yield and flag leaf parameters. Yield composition, length and width of the flag leaf and panicle length were measured in some rice cultivars. Rice cultivars BR 3, BR 4, BR 11, BRRI dhan28, BRRI dhan29, BRRI dhan34, and BRRI dhan37 were used. Flag leaf (FL) was excised at the base during heading stage from some of the plants of the studied cultivars and let it grow to maturity and data were collected to study the effect of FL cutting on grain yield. The flag leaves were excised after the emergence of panicle from some of the selected plants of all the examined cultivars and let it to grow. Phenotypic observation indicated various defects existed in the leaf cut plants throughout maturation including late maturation, decaying, shrunken and reduced grain size, as well as increased sterility. Removal of flag leaf led to a decline in the seed-setting rate, which eventually reduced the grain yield.

Usman *et al.* (2007) carried out a field trial to study the effect of detopping on forage and grain yield of rice. The experiment consisted of six treatments viz., Control (T_1, no detopping), detopping at 22 DAT (T_2), detopping at 29 DAT (T_3), detopping at 36 DAT (T_4), detopping at 43 DAT (T_5), and detopping at 50 DAT (T_6). In respect of all the six treatments, number of sterile spikelets panicle^{-1} (18) were obtained from control (no detopping) treatment.

Ahmed *et al.* (2001) conducted an experiment to study the effect of pre-flowering leaf cutting on forage and seed yield of transplant aman rice. The experiment consisted of four varieties namely Latishail, BR 10, BR 11 and BRRI dhan32 and four leaf cuttings *viz.*, no leaf cutting (T_1), leaf cutting at 21 DAT (T_2), leaf cutting at 28 DAT (T_3) and leaf cutting at 35 DAT (T_4). The highest value of sterile spikelets (18.68) was found in control. The yield and yield contributing characters decreased by leaf cutting as compared to control. The lowest value for all crop characters were observed when the leaf was cut at 35 DAT.

Ahmed *et al.* (2001) conducted an experiment to study the effect of nitrogen rate and time of leaf cutting on green fodder as well as seed yield of rice. The experiment included two factors, (A) Nitrogen level – viz. i) N_1 – 50 kg N ha^{-1}, ii) N_2 –75 kg N ha^{-1} and iii) N_3 – 100 kg N ha^{-1}, (B) Time of leaf cutting – viz. i)

No cutting (control) – C_0, ii) Cutting at 21 DAT – C_1, iii) Cutting at 35 DAT – C_2 and iv) Cutting at 49 DAT – C_3. Number of sterile spikelets panicle^{-1} was found to be the highest for no leaf cutting treatment; which was statistically similar to cutting at 21 DAT. The lowest value for number of sterile spikelets panicle^{-1} was recorded from cutting at 49 DAT.

Muduli *et al.* (1995) set up a field experiment to study the effect of flag leaf on spikelet sterility and grain yield in rice. The flag leaf of semi-dwarf high yielding rice cv. IR 36, Lalat and Bhuban and the local tall cv. Khandasagar was removed at panicle emergence, 7 or 14 days later in field trials. Spikelet sterilities in the three semi-dwarf cultivars were 14.7–18.2%, 12.1–15.8% and 11.7–14.9% with flag leaf removal at 0, 7 and 14 days after panicle emergence, respectively and 10.1–12.8% where the flag leaf was not removed. The corresponding values for the local cultivar were 75.3%, 70.7%, 62.6% and 59.7%, respectively.

Imam (1967) conducted an experiment with three varieties of rice to investigate the effects of removing of panicle bearing culms and removing photosynthesizing leaves after flowering on the fertility of different varieties. The highest percentage of sterility of spikelets was found in IR 8 following by Latishail and IR 5 when some of the panicle bearing culms were removed. Again, the highest percentage of sterility of spikelets was in IR 8 followed by IR 5 and Latishail when some of the photosynthesizing leaves were removed.

Kashibuchi (1967) worked on the effect of removing ears or leaves of some culms within a hill at the heading stage on filling of grains in rice. He observed that removing of some leaves of some culms increased the number of unfilled spikelets. From this, it was concluded that removing of some leaf blades of some culms decreased the concentration of carbohydrate among the culms.

2.2.4 1000-grains weight

Fatima *et al.* (2019) carried out a field trial to study the effect of flag leaf clipping on growth yield, and yield attributes of hybrid rice varieties in Boro season. The experiment comprised of two factors. Factor A: Flag leaf clipping: T_1 = Flag leaf clipping at heading and T_2 = Control (without clipping). Factor B: Six hybrid rice varieties: V_1 = BRRI hybrid dhan1, V_2 = BRRI hybrid dhan2, V_3 = Heera2, V_4 = Heera4, V_5 = Nobin and V_6 = Moyna. Chlorophyll content (SPAD value) in penultimate leaf after 15 days after heading, grain filling duration, yield contributing characters and yield were investigated after cutting of flag leaf. Regardless of variety, all the studied parameters were exhibited superiority in control treatment. The highest weight of 1000-grains was recorded from Heera4 under control condition.

After harvesting, 1000-grains weight from leaf cut plant was measured and significant reduction of weight was observed compared with 1000-grains weight of the control plant. Among cultivars, the 100-grain weight of leaf cut plants was reduced about two fold in the BR3 and BRRI dhan34 from those of uncut plants. The weight of 1000-grains was measured from the control and treated (flag leaf excised) plants. Weight of 1000-grains of BR 3 was 27.5 g and 14 g for control and treated, respectively. Similarly, 1000-grains weight of BR 4 had 26 g and 17 g, BR 11 had 25.7 g and 18 g, BRRI dhan34 had 31 g and 16.5 g, BRRI dhan37 had 23.1 g and 15 g for control and treated, respectively.

The effect of detopping was significant on all the yield and yield components of rice except 1000-grain weight. In respect of all the six treatments, the maximum 1000-grain weight (22 g) was obtained from control (no detopping) treatment. The yield and yield contributing characters decreased by detopping when compared with control.

Significant variation was observed for all the characters among the varieties and treatments but interaction (genotypes × treatments interactions) was not significant. Effect of source-sink manipulations on grain yield and different sink characters were analyzed. It was observed that the defoliation of flag leaf caused significant reduction on 1000-grain weight by 10.69%. Similarly, the removal of penultimate leaf caused reduction of 6.45% for 1000-grain weight. Likewise, the defoliation of third leaf caused reduction of 3.59% for 1000-grain weight. Similarly, the defoliation of flag leaf, penultimate leaf and third leaf at a time caused reduction of 15.67% for 1000-grain weight. On the other hand, there was 6.33% increase in 1000-grain weight by sink manipulation (removal of 50% spikelets).The effect of leaf cutting was significant in respect of the crop characters except 1000-grain weight. The highest value of 1000-grain weight (22.72 g) was recorded from control treatment. The yield and yield contributing characters decreased by leaf cutting as compared to control. The lowest value for all crop characters were observed when the leaf was cut at 35 DAT.The maximum 1000-grain weight was recorded from no leaf cutting treatment, which was statistically similar to cutting at 21 DAT; but 1000-grain weight was also similar to cutting at 35 DAT. The minimum weight of 1000-grains was observed from leaf cutting at 49 DAT.

Sharma and De (1994) conducted an experiment to study the effect of foliage cutting on growth and yield of different rice cultivars under semi-deep water conditions (0–80 cm). In 1990 and 1991, four rice cultivars – Utkalprabha, Panidhan, CN573-321-7−1 and Jaladhi−1 were sown in dry soil and grown thereafter under semi-deep water conditions (0–80 cm). These crops were subjected to foliage cutting at the collar of the uppermost leaf. 1000-grain weight remained unaffected and was not responsible for decrease in grain yield with two cuts of foliage.

Hachiya (1989) carried out a field experiment to study on the effect of artificial leaf cutting on growth and yield of rice plants. The study revealed that compensatory response in rice growth, such as increases in the 1,000-grains weight, was observed.

Imam (1967) conducted an experiment with three varieties of rice to investigate the effects of removal of panicle bearing culms and removing photosynthesizing leaves after flowering on the fertility of different varieties. IR8 and IR5 were identical for 1,000-grain weight value in both parts of the experiment and significantly superior to Latishail in every report, which produced the lowest value of 1000-grain weight.

2.3 Impact of Leaf Clipping on yield

2.3.1 Grain yield

Chlorophyll and nitrogen content (SPAD value) in penultimate (1.35% to 17.27%) and grain filling duration were increased (4.5 to 6.25 days) by virtue of clipping of flag leaf. The highest grain yield was recorded from Heera 4 under control condition. The clipping of the flag leaf reduced grain yield from 15.69% to 29.43% in the test Boro rice varieties.

Hossain (2017) conducted an experiment to assess the effect of leaf cutting on plant growth and yield of selected BRRI released Aman varieties. The experiment consisted of two factors: Factor A: five varieties, V_1 = BRRI dhan32, V_2 = BRRI dhan33, V_3 = BRRI dhan39, V_4 = BRRI dhan62 and V_5 = BRRI dhan56 and Factor B: two leaf cutting, T_1 = Leaf cutting (except flag and penultimate leaves) T_2 = Control (no leaf cutting). Irrespective of all the varieties under study, the highest grain yield was obtained in no leaf cutting (control). The yield and yield contributing characters was decreased by leaf cutting as compared to the control. Among the varieties, BRRI dhan33 gave the significantly higher yield in control (control 6.75 t ha^{-1}, treated 4.75 t ha^{-1}). The highest grain yield was obtained in no leaf cutting (6.75 t ha^{-1}). The leaf cutting (except flag leaf and penultimate leaves) reduced about 10 to 28% loss of grain yield. Remarkable variation in grain filling duration was also noticed in the different varieties due to leaf cutting. Reduction of grain yield was minimum (10%) in BRRI dhan39 (control 5.75 t ha^{-1}, treated 5.15 t ha^{-1}) with leaf cutting than that of the rest varieties.

Medhi *et al.* (2015) set up a field trial to study the effect of foliage pruning on growth and yield of two low land rice varieties, TTB-303−1-42 (Dhansiri) and TTB-303−1-23 (Difalu) under rain-fed low land situation (50–100 cm water depth) during wet season. Foliage pruning up to 100 DAG produced grain yield comparable with that of no pruning but pruning there after (120 DAG) and two times pruning (80 + 100 DAG, 100 + 120 DAG and 80 + 120 DAG) reduced grain yield. The responses of both the varieties to leaf pruning were similar.

Rahman *et al.* (2013) carried out an investigation in order to explore the relationship between grain yield and flag leaf parameters. Yield composition; length and width of the flag leaf and panicle length were measured in some rice cultivars. Rice cultivars BR 3, BR 4, BR 11, BRRI dhan28, BRRI dhan29, BRRI dhan34 and BRRI dhan37 were used. Flag leaf (FL) was excised at the base during heading stage from some of the plants of the studied cultivars and let it grow to maturity and data were collected to study the effect of FL cutting on grain yield. Length of flag leaf and panicle of two rice cultivars, BR 11 and BRRI dhan28 were measured and correlation between the characters was calculated. Statistical analysis showed that the value of correlation coefficient r was 0.79 and 0.97 for BR 11 and BRRI dhan28, respectively. Removal of flag leaf led to a decline in the seed-setting rate, which eventually reduced the grain yield. Results indicated that yield was always reduced significantly when flag leaf was removed from the plant at anthesis. This is might be due to the inappropriate food supply to sink that mostly flag leaf does and thus the effect was observed as various defects in the floral identity.

Asli *et al.* (2011) conducted a field experiment to evaluate the sink and source relationship in different rice (*Oryza sativa* L.) cultivars. Treatments consisted of combination of three cultivars included beejar, khazar and binam and four sink and source manipulations treatments comprising: (i) control, (ii) flag leaf blade removed, (iii) thinning consisted of cutting rows 2, 4 and 6 to ground level and (iv) thinning and cutting flag leaf blade. Removal of the flag leaf blade at anthesis resulted in a decrease of 12 % in grain yield. This more considerable decrease in grain yield showed that flag leaf has an important role in grain filling. The comparison between control and defoliated plants indicated that cultivars differed in the ability to remobilize reserves from the stems to the grains. In khazar, beejar and binam cultivars, removal of flag leaf resulted in a decrease of 10%, 18% and 6.5% grain yield, respectively. There were significant effects between thinning treatments and cutting of flag leaf blade. Whenever these two treatments occurred synchronized, grain yield increased about 9%. The study of components of yield revealed that thinning and removal of flag leaf blade treatments had no significant effects on number of panicle per unit area, which is because of the time of treatments application. Cutting flag leaf resulted in decrease of grain weight by 7% and represents the importance of flag leaf supplied material for grain growth. In three cultivars of khazar, beejar and binam with removed flag leaf, grain weight decreased by 4%, 12% and 4%, respectively. In general, grains weight is more under photo-assimilate stress than number of grain.

Khatun *et al.* (2011) from their research work on influences of leaf cutting on growth and yield of rice observed that the lowest grain yield of rice was produced from flag leaf cutting treatment.

Daliri *et al.* (2009) carried out a field experiment in order to study the effect of cutting time and cutting height on yield and yield components of ratoon rice (*Oryza sativa* L.) Tarom langrodi variety. Results showed that the effect of cutting time on grain yield was found statistically significant. Cutting height had a significant effect on grain yield. According to results, cutting time at physiological maturity and cutting at 40 cm height from soil surface for the best grain yield of ratoon rice were recommended.

Abou-khalifa *et al.* (2008) conducted field experiments during two summer seasons i.e. 2003 and 2004 to study the effect of leaf cutting on physiological traits and yield of two rice cultivars *viz.* hybrid rice cultivar H5 (IR 70368 A /G 178) and traditional inbred Egyptian local rice cultivar Sakha 103. The leaf cutting was followed from flag leaf as follows: i) L - Control = without leaf cutting, ii) L_1 - flag leaf cut, iii) L_2 - second leaf cut, iv) L_3 - third leaf cut, v) L_4 - both flag leaf and second leaf cut and vi) L_5 - flag leaf, second leaf and third leaf removed all together. Grain yield was severely affected by L_5, followed by L_4, L_1, L_3 and L_2 in sequence. However, as a single component affecting grain yield is the removal of flag leaf. The flag leaf contributed maximum to the yield of rice grains. In L_5, L_4, L_1, L_2 and L_3 treatments, the loss of grain yield was 59.87, 94.92, 44.89, 29.58 and 19.98 % (relative % of control) respectively. Flag leaf contributed to 45% of grain yield and it was the single most component responsible for yield loss. The contribution of leaf removal in hybrid rice was minimum, suggesting the probability of maximum translocation of photosynthesis from stem to the grain during grain feeling stage of hybrid rice after leaf removal.

Konboon *et al.* (2007) carried out field trials to study the effect of rice leaf cutting in dry-seed broadcasting rice. The farmers in Ponsai district, Rol Et province has initiated leaf cutting method for improving productivity of dry-seed broadcasting rice. In 2004–2005 cropping season, an average rice grain yield of approximately 6.25 ton ha^{-1} was obtained due to those practice applied by the farmers.

Usman *et al.* (2007) conducted an experiment to study the effect of detopping on forage and grain yield of rice. The experiment consisted of six treatments viz., Control (T_1, no detopping), detopping at 22 DAT (T_2), detopping at 29 DAT (T_3), detopping at 36 DAT (T_4), detopping at 43 DAT (T_5), and detopping at 50 DAT (T_6). The effect of detopping was significant on all the yield and yield components of rice. In respect of all the six treatments, the highest grain yield (4.1 t ha^{-1}) was obtained from control (no detopping). The yield and yield contributing characters decreased by detopping when compared with control. The results revealed that the highest green fodder yield (3.5 t ha^{-1}) was obtained from foliage cutting at 50 DAT with the lowest grain yield (3.0 t ha^{-1}). The highest grain yield (4.1 t ha^{-1}) was recorded in control, which was not significantly different from T_2, T_3 and T_4. Detopping at 36 DAT (T_4) gave an identical grain yield (3.5 t ha^{-1}) of control plot with higher additional forage yield (2.4 t ha^{-1}). Hence, it was concluded that detopping at an early vegetative stage of crop growth could produce almost similar grain or seed yield of control plot with the additional forage yield and reduce lodging in case of excessive vegetative growth.

Aktar-uz-zaman (2006) conducted an experiment to study on source-sink manipulation and their effect on grain yield in rice of rainfed varieties. There were nine treatments in source-sink manipulation: T_0 = Control, T_1 = Defoliation of flag leaf, T_2 = Defoliation of penultimate leaf, T_3 = Defoliation of tertiary leaf (Third leaf), T_4 = Defoliation of flag leaf & penultimate leaf, T_5 = Defoliation of flag leaf, penultimate leaf & tertiary leaf, T_6 = Defoliation of all leaves, T_7 = Defoliation of all leaves without flag leaf, T_8 = Removal of 50% Spikelets. Significant variation was observed for all the characters among the varieties and treatments but interaction (genotypes × treatments interactions) was not significant. Effect of source-sink manipulations on grain yield and different sink characters were analyzed. It was observed that the defoliation of flag leaf caused significant reduction on grain yield per plant by 34.82%. Similarly, the removal of penultimate leaf caused reduction of 22.67% for grain yield per plant. Likewise, the defoliation of third leaf caused reduction of 15.67% for grain yield per plant. Similarly, the defoliation of flag leaf, penultimate leaf and third at a time caused reduction of 54.67% for grain yield per plant. On the other hand, there was 56.31% reduction in grain yield per plant by sink manipulation (removal of 50% spikelets). Both these facts indicated that the present materials suffered from source limitation, therefore it was concluded that the flag leaf contributed 34.82% in the total grain production per plant. The penultimate leaf contributes 22.67% in the grain yield per plant; third leaf contributes 15.67% in the grain yield production of rainfed rice.

Sardana *et al.* (2006) conducted a field experiment to study the effect of extent and stage of foliage clipping on the grain yield of basmati rice (Basmati 386). The treatments were as follows: i) ⅓ of leaf clipping from top of the plant at 30 days after transplanting (DAT), ii) ½ of leaf clipping from top of the plant at 30 DAT, iii) ⅓ of leaf clipping from top of the plant at 45 DAT, iv) ½ of leaf clipping from top of the plant at 45 DAT, v) ⅓ of leaf clipping from top of the plant at 60 DAT, vi) ½ of leaf clipping from top of the plant at 60 DAT, vii) ⅓ of leaf clipping from top of the plant at 30 and 60 DAT, viii) ½ of leaf clipping from top of the plant at 30 and 60 DAT, ix) clipping of leaf just above growing point at the time of seedling transplanting and x) No leaf clipping. The extent (⅓ or ½) and stage (30, 45 or 30 and 60 DAT) of foliage clipping significantly influenced the grain yield through their marked influence on yield attributes. The maximum grain yield (2.90 t ha^{-1}) was registered in case of clipping of ⅓ foliage from the top at 30 DAT followed by clipping at the time of transplanting just above the growing point (2.50 t ha^{-1}). Grain yield linearly decreased with each successive delay in clipping from 30 to 60 DAT and the difference between 30 (2.60 t ha^{-1}) and 60 DAT (1.90 t ha^{-1}) was significant (mean of ⅓ and ½ foliage clipping). Similarly, foliage clipping only once (irrespective of the stage and extent of clipping) produced higher grain yield (1.90–2.90 t ha^{-1}) than clipping twice at 30 and 60 DAT (1.50–1.70 t ha^{-1}). Such reduction was significant as compared to clipping once at 30 (2.60 t ha^{-1}) or 45 DAT (2.30 t ha^{-1}). Similarly, foliage clipping of ⅓ portion from the top produced higher grain yield (2.20 t ha^{-1}) than clipping ½ foliage from top (2.0 t ha^{-1}). Clipping once at 60 DAT or twice at 30 and 60 DAT resulted in lower grain yield as compared to control where no foliage clipping was done. Lower yield in case of clipping made at time of transplanting of seedlings as compared to that of 30 DAT might be due to lesser ability of plants to withstand clipping shock because the seedlings at this stage were also under transplanting shock. On the other hand, foliage clipping at 45 and 60 DAT might have adversely influenced the subsequent growth and possibly took more time to recover from such shock leading to reduced grain yield. Clipping of only ⅓ of foliage from the top was found to be better than clipping to ½. It was concluded that partial foliage clipping up to ⅓ portion from top at 30 DAT has beneficial effect on traditional tall basmati rice.

Islam *et al.* (2005) conducted a field experiment during the 2001 T. aman (wet season) and 2002 Boro (dry season) to find out the effect of flag leaf clipping and gibberellic acid (GA_3) application on hybrid rice seed yield with a view to increase per unit area production of hybrid seed. IR58025A (female parent) and BR827R (male parent) were taken as experimental materials. Four treatments were applied: T_1 = control, T_2 = GA_3 application without flag leaf clipping, T_3 = flag leaf clipping without GA_3 application and T_4 = GA_3 application with flag leaf clipping. Half of the flag leaf of the A line was clipped using a sickle when primary tillers were at booting stage in both seasons. The outcrossing rate in the Boro season (30%) was the highest in T_4 where GA_3 and flag leaf clipping were done simultaneously. The average outcrossing rate (20%) was also the highest in T_4 in the T. aman season, but the differences were non-significant. The highest hybrid rice seed yield (1,676 kg ha^{-1}) was observed in T_4 treatment (GA_3 application with flag leaf clipping), which was significantly higher (1,229 kg ha^{-1}) than that of the control plots in the Boro season. Differences in the T_2, T_3 and T_4 were non-significant. No significant differences were observed in terms of seed yield among different treatments during T. aman season. It was concluded that hybrid rice seed yield was increased by the application of GA_3 and flag leaf clipping.

Ros *et al.* (2003) conducted an experiment to explore the concept of seedling vigor of transplanted rice and to determine what plant attributes conferred vigor on the seedlings. Seedling vigor treatments were established by subjecting seedlings to short-term submergence (0, 1 and 2 days/work) in one experiment and to leaf clipping or root pruning and water stress in another to determine their effect on plant growth after transplanting. Pruning 30% of leaves depressed grain yield by 20% at maturity. It was concluded that the response of rice yield to nursery treatments is largely due to increased seedling vigor and can be effected by a range of nutritional as well as non-nutritional treatments of seedlings that increase seedling dry matter, nutrient content and nutrient concentration.

Molla *et al.* (2002) conducted an experiment to ascertain the feasibility of green fodder harvest without affecting the seed yield of transplant aman rice. The experiment consists of two factors, (A) cultivar (i) C_1 = Latishail (ii) C_2 = BR 10 (iii) C_3 = BR 11 and (iv) C_4 = BRRI dhan32 and (B) leaf clipping heights (i) H_1

= clipping at 10 cm (ii) H_2 = clipping at 15 cm (iii) H_3= clipping at 20 cm and (iv) H_4 = control (no clipping). Seed yield was significantly differed due to different cultivar and leaf clipping height. The highest value of all parameters except seed yield were obtained from control plot at all growth stage where the lowest were recorded from clipping at 10 cm height. The plants, which were clipped at 20 cm height, produced an average green fodder yield in addition to higher seed yield, which was statistically similar to control. Therefore, it is possible to get green fodder by leaf clipping without seriously affecting the rice seed yield.

Ahmed *et al.* (2001 a) carried out a field trial to study the effect of pre-flowering leaf cutting on forage and seed yield of transplant aman rice. The possibility of extent usage of rice for human and livestock simultaneously was studied. The experiment consisted of four varieties namely Latishail, BR 10, BR 11 and BRRI dhan32 and four leaf cuttings *viz.*, no leaf cutting (T_1), leaf cutting at 21 DAT (T_2), leaf cutting at 28 DAT (T_3) and leaf cutting at 35 DAT (T_4). The highest grain yield was obtained in no leaf cutting which was statistically identical to leaf cutting at 21 and 28 DAT. The highest value of grain yield (4.71 t ha^{-1}) was found in control treatment. The yield and yield contributing characters decreased by leaf cutting as compared to control. The lowest value for all crop characters were observed when the leaf was cut at 35 DAT. Leaf cutting at early stage (leaf cutting at 28 DAT for studied modern varieties and 35 DAT for Latishail) of crop growth could produce almost similar grain or seed yield of control crops with the additional forage yield.

Ahmed *et al.* (2001 b) conducted an experiment to study the effect of nitrogen rate and time of leaf cutting on green fodder as well as seed yield of rice. The experiment included two factors, (A) Nitrogen level – viz. i) N_1 – 50 kg N ha^{-1}, ii) N_2 –75 kg N ha^{-1} and iii) N_3 – 100 kg N ha^{-1}, (B) Time of leaf cutting – viz. i) No cutting (control) – C_0, ii) Cutting at 21 DAT – C_1, iii) Cutting at 35 DAT – C_2 and iv) Cutting at 49 DAT – C_3. Grain yield was found to be the maximum for no leaf cutting which was statistically similar to cutting at 21 DAT and the minimum for cutting at 49 DAT. It was concluded that there is a tremendous possibility to get green forage and grain or seed from the same rice plant with leaf cutting practice.

Angrish (2000) from his experiment on lodging control in the tall statured Taraori basmati (*Oryza sativa* L.) by foliage pruning reported that cutting of excessive foliage of tall statured varieties of rice did not cause any adverse effect on grain yield.

Muduli *et al.* (1995) set up a field experiment to study the effect of flag leaf on spikelet sterility and grain yield in rice. The flag leaf of semi-dwarf high yielding rice cv. IR 36, Lalat and Bhuban and the local tall cv. Khandasagar was removed at panicle emergence, 7 or 14 days later in field trials. Removal of the flag leaf at any time after panicle emergence caused a significant decrease in grain yield compared with that of the control treatment. The highest decrease in grain yield was recorded when the flag leaf was removed at panicle emergence.

Sharma and De (1994) conducted an experiment to study the effect of foliage cutting on growth and yield of different rice cultivars under semi-deep water conditions (0–80 cm). In 1990 and 1991, four rice cultivars – Utkalprabha, Panidhan, CN573-321-7−1 and Jaladhi−1 were sown in dry soil and grown thereafter under semi-deep water conditions (0–80 cm). These crops were subjected to foliage cutting at the collar of the uppermost leaf. The grain yield of CN573-321-7−1 was the highest and the effect of foliage cutting was the least pronounced; whereas Jaladhi−1 gave the lowest grain yield which further decreased significantly when foliage was removed. Cutting in September had no effect on the yield of CN573-321-7−1, Panidhan and Utkalprabha, but the later cut in October had a detrimental effect, particularly when cutting was done a second time. Nevertheless, a single late cutting in October was not found to be harmful to the yield of the tall cultivar CN573-321-7−1 and the long-duration semi-tall Panidhan. The results suggest that foliage could be harvested for feeding cattle from the long-duration, tall and photosensitive rice cultivars without any adverse effect on grain yield under semi-deep lowland conditions.

Das and Mukherjee (1992) from their research work on the effect of seedling uprooting time and leaf removal on grain and straw yields of rainy season rice reported that late leaf cutting reduced the grain yield.

Singh and Singh (1992) studied the effect of defoliation on grain yield of rice at different stages of panicle development. They observed about 30% to 40% reduction in grain yield after defoliation of all leaves at booting stage and anthesis stage, respectively.

Rao (1991) conducted greenhouse trials to study the effects of defoliation, defoliation + shading or removal of parts of the panicle on yield and grain quality in rice cv. Tulasi and Rasi. In defoliation experiments, removal of the flag leaf had the most effect on grain yield while removal of the 4^{th} leaf had little effect on yield. Percentage high density (HD) grain was decreased the most by removing the flag leaf or removing all except the top 4 leaves. Experiments, which combined defoliation with shading of different plant organs, showed that the leaves were the most important organs governing grain filling.

Kupkanchanakul *et al.* (1990) conducted an experiment to observe the effect of leaf cutting for rice herbage on grain yield of deep-water rice. Leaf cutting for forage at 40, 70, 100 and 40 + 100 days after emergence gave grain yields of 2.13, 2.20, 2.24 and 1.94 ton ha^{-1} respectively, compared with 2.02 ton ha^{-1} without cutting.

Hachiya (1989) carried out a field experiment to study on the effect of artificial leaf cutting on growth and yield of rice plants. The study produced three sets of evidence: (1) Yield loss was considered to be caused mainly due to the decrease in the number of ears among the yield components, (2) Compensatory responses in rice growth, such as increases in the percentages of productive tillers, ripening grains and in the 1,000-grain weight, were observed. However, such responses seemed to be minimal in cold years, (3) Loss of the entireties of the upper two leaves of each culm through insect injury was estimated to cause inevitable yield loss even in warm climate conditions. The loss of half the area of those leaves seemed to cause yield loss even in ordinary climate conditions.

Satoto (1989) set up an experiment to study the effect of row ratio and leaf clipping on MR 365A out-crossing and seed yield. He observed that leaf clipping on rice MR 365A had no significant effect in respect of seed yield.

Sairam and Dube (1984) from their experiment on effects of plant densities and defoliation treatments on yield and yield attributing characters of rice (*Oryza sativa*) reported that removal of flag leaf decreased the rice grain yield.

Sato (1970) designed an experiment to investigate into the effects of cutting leaf-blade and thinning panicle branch at heading time of fruiting and the amount of starch in the culms in the tissue of rice plant. By cutting off all the leaf blades at heading time, the grain harvested became very poor in quality. By thinning the panicle branches, the reversed effect was observed. In the culms of plants deprived of leaf blades, starch diminished especially in grains contents.

Owen (1968) investigated the relation between leaf area duration and grain yield of two tropical rice varieties. Different Leaf area index (LAI) regimes during growth were imposed on two tropical rice, Sirona and HD34, by partial defoliation at different growth stages. In addition, part of the plant was completely defoliated after panicle emergence. Grain yield showed the least association with leaf area duration (treatment) after panicle emergence, but were the most influenced by leaf area duration before panicle emergence. From this observation, it was concluded that the partial removal of some leaves only before panicle emergence reduced the grain yield but the treatment did not have same effect after the panicle emergence.

Imam (1967) conducted an experiment with three varieties of rice to investigate the effects of removing of panicle bearing culms and removing photosynthesizing leaves after flowering on the fertility of different varieties. In all the varieties, the yield increased with the increase in photosynthesizing leaves. The highest and lowest grain yields per panicle were obtained in IR5 and Latishail respectively in both parts of the experiment while IR8 being intermediate in both the case.

2.3.2 Straw yield

Fatima *et al.* (2019) carried out an experiment to study the effect of flag leaf clipping on growth yield, and yield attributes of hybrid rice varieties in Boro season. The experiment comprised of two factors. Factor A: Flag leaf clipping: T_1 = Flag leaf clipping at heading and T_2 = Control (without clipping). Factor B: Six hybrid rice varieties: V_1 = BRRI hybrid dhan1, V_2 = BRRI hybrid dhan2, V_3 = Heera2, V_4 = Heera4, V_5 = Nobin and V_6 = Moyna. Regardless of the test varieties, all the studied parameters exhibited superiority in control treatment. Chlorophyll and nitrogen content (SPAD value) in penultimate leaf was increased (1.35% to 17.27%) by virtue of clipping of flag leaf. The highest straw yield was recorded from Heera4 under control condition.

Hossain (2017) carried out an experiment to assess the effect of leaf cutting on plant growth and yield of selected BRRI released Aman varieties. The experiment consisted of two factors: Factor A: five varieties, V_1 = BRRI dhan32, V_2 = BRRI dhan33, V_3 = BRRI dhan39, V_4 = BRRI dhan62 and V_5 = BRRI dhan56 and Factor B: two leaf cutting, T_1 = Leaf cutting (except flag and penultimate leaves) T_2 = Control (no leaf cutting). Irrespective of all the varieties under study, the highest straw yield was obtained in no leaf cutting (control).

Usman *et al.* (2007) conducted an experiment to study the effect of detopping on forage and grain yield of rice. The experiment consisted of six treatments viz., Control (T_1, no detopping), detopping at 22 DAT (T_2), detopping at 29 DAT (T_3), detopping at 36 DAT (T_4), detopping at 43 DAT (T_5), and detopping at 50 DAT (T_6). In respect of all the six treatments, the highest straw yield (5.6 t ha^{-1}) was obtained from control (no detopping). The yield and yield contributing characters decreased by detopping when compared with control. The results revealed that the highest green fodder yield (3.5 t ha^{-1}) was obtained from foliage cutting at 50 DAT. Detopping at 36 DAT (T_4) gave higher additional forage yield (2.4 t ha^{-1}). Hence, it was concluded that detopping at an early vegetative stage of crop growth could produce almost similar grain or seed yield of control plot with the additional forage yield and reduce lodging in case of excessive vegetative growth.

Ros *et al.* (2003) conducted an experiment to explore the concept of seedling vigor of transplanted rice and to determine what plant attributes conferred vigor on the seedlings. Seedling vigor treatments were established by subjecting seedlings to short-term submergence (0, 1 and 2 days/work) in one experiment and to leaf clipping or root pruning and water stress in another to determine their effect on plant growth after transplanting. Pruning 30% of leaves depressed straw yield by 20% at maturity. The combined effects of leaf dipping and root pruning on shoot, root and straw dry matter were largely additive.

Ahmed *et al.* (2001 a) carried out a field trial to study the effect of pre-flowering leaf cutting on forage and seed yield of transplant aman rice. The possibility of extent usage of rice for human and livestock simultaneously was studied. The experiment consisted of four varieties namely Latishail, BR 10, BR 11 and BRRI dhan32 and four leaf cuttings *viz.*, no leaf cutting (T_1), leaf cutting at 21 DAT (T_2), leaf cutting at 28 DAT (T_3) and leaf cutting at 35 DAT (T_4). The results revealed that among the varieties and the different leaf cutting treatments, Latishail variety with leaf cutting at 35 DAT gave the significantly higher forage yield. The highest value of straw yield (5.60 t ha^{-1}) was found in control. The yield and yield contributing characters decreased by leaf cutting as compared to control. The lowest value for all crop characters were observed when the leaf was cut at 35 DAT. Leaf cutting at early stage (leaf cutting at 28 DAT for studied modern varieties and 35 DAT for Latishail) of crop growth could produce almost similar grain or seed yield of control crops with the additional forage yield.

Ahmed *et al.* (2001 b) conducted an experiment to study the effect of nitrogen rate and time of leaf cutting on green fodder as well as seed yield of rice. The experiment included two factors, (A) Nitrogen level – viz. i) N_1 – 50 kg N ha^{-1}, ii) N_2 –75 kg N ha^{-1} and iii) N_3 – 100 kg N ha^{-1}, (B) Time of leaf cutting – viz. i) No cutting (control) – C_0, ii) Cutting at 21 DAT – C_1, iii) Cutting at 35 DAT – C_2 and iv) Cutting at 49 DAT – C_3. Cumulative straw yield and straw yield were found to be the highest for no leaf cutting which was statistically similar to cutting at 21 DAT and the lowest for cutting at 49 DAT. Amount of green forage and forage dry matter were the highest for cutting at 49 DAT. It was concluded that there is a tremendous possibility to get green forage and grain or seed from the same rice plant with leaf cutting practice.

Kupkanchanakul *et al.* (1990) conducted an experiment to observe the effect of leaf cutting for rice herbage on grain yield of deep-water rice. Leaf cutting for forage at 40, 70, 100 or 40 + 100 days after emergence gave herbage yields of 0.7, 0.7, 1.0 and 1.40 ton ha^{-1}, respectively.

BRRI (1989) from their research work on getting foliage from deep water aman rice without affecting total yield reported that local aman rice variety gave the maximum forage yield at post-flood condition leaf cutting practice.

2.3.3 Biological yield

Fatima *et al.* (2019) carried out an experiment to study the effect of flag leaf clipping on growth yield, and yield attributes of hybrid rice varieties in Boro season. The experiment comprised of two factors. Factor A: Flag leaf clipping: T_1 = Flag leaf clipping at heading and T_2 = Control (without clipping). Factor B: Six hybrid rice varieties: V_1 = BRRI hybrid dhan1, V_2 = BRRI hybrid dhan2, V_3 = Heera2, V_4 = Heera4, V_5 = Nobin and V_6 = Moyna. The highest biological yield were recorded from Heera4 under control condition.

Usman *et al.* (2007) conducted an experiment to study the effect of detopping on forage and grain yield of rice. The experiment consisted of six treatments viz., Control (T_1, no detopping), detopping at 22 DAT (T_2), detopping at 29 DAT (T_3), detopping at 36 DAT (T_4), detopping at 43 DAT (T_5), and detopping at 50 DAT (T_6). In respect of all the six treatments, the highest biological yield (9.6 t ha^{-1}) was obtained from control (no detopping).

Ahmed *et al.* (2001 a) carried out a field trial to study the effect of pre-flowering leaf cutting on forage and seed yield of transplant aman rice. The experiment consisted of four leaf cuttings *viz.*, no leaf cutting (T_1), leaf cutting at 21 DAT (T_2), leaf cutting at 28 DAT (T_3) and leaf cutting at 35 DAT (T_4). The highest value of biological yield (10.31 t ha^{-1}) was found in control.

2.3.4 Harvest Index

Hossain (2017) carried out an experiment to assess the effect of leaf cutting on plant growth and yield of selected BRRI released Aman varieties. The experiment consisted of two factors: Factor A: five varieties, V_1 = BRRI dhan32, V_2 = BRRI dhan33, V_3 = BRRI dhan39, V_4 = BRRI dhan62 and V_5 = BRRI dhan56 and Factor B: two leaf cutting, T_1 = Leaf cutting (except flag and penultimate leaves) T_2 = Control (no leaf cutting). Irrespective of all the varieties under study, the highest harvest index was obtained in no leaf cutting (control).

Daliri *et al.* (2009) carried out a field experiment in order to study the effect of cutting time and cutting height on yield and yield components of ratoon rice (*Oryza sativa* L.) Tarom langrodi variety. Results showed that the effect of cutting time on harvest index was found statistically significant. Cutting height had a significant effect on harvest index.

Usman *et al.* (2007) conducted an experiment to study the effect of detopping on forage and grain yield of rice. The experiment consisted of six treatments viz., Control (T_1, no detopping), detopping at 22 DAT (T_2), detopping at 29 DAT (T_3), detopping at 36 DAT (T_4), detopping at 43 DAT (T_5), and detopping at 50 DAT

(T_6). In respect of all the six treatments, the highest harvest index (42.70%) were obtained from control (no detopping).

Ahmed *et al.* (2001) carried out a field trial to study the effect of pre-flowering leaf cutting on forage and seed yield of transplant aman rice. The experiment consisted of four varieties namely Latishail, BR 10, BR 11 and BRRI dhan32 and four leaf cuttings *viz.*, no leaf cutting (T_1), leaf cutting at 21 DAT (T_2), leaf cutting at 28 DAT (T_3) and leaf cutting at 35 DAT (T_4). The highest value of harvest index (45.59%) was found in control.

2.4 Impact of seedling clipping

Mapfumo *et al.* (2007) conducted an experiment to study the effect of cultivar, seedling age and leaf clipping on establishment, growth and yield of pearl millet (*Pennisetum glaucum*) and sorghum (*Sorghum bicolor*) transplants. This study explored the viability of intensifying pearl millet and sorghum production through use of nurseries and transplanting to address the problem of poor stand establishment. The experiments were carried out over two seasons, the 1999/2000 and 2000/2001 seasons in the southeastern Lowveld of Zimbabwe where the mean rainfall is less than 500 mm per annum. Treatments included two pearl millet cultivars (PMV2 and PMV3) and two sorghum cultivars (Mutode and Macia). These crops were transplanted with and without leaf clipping at three seedling ages (30, 40 and 50 days for pearl millet; 29, 39 and 49 days for sorghum). Transplants were raised in nursery seedbeds. In the 1999/2000 season, there were significant effects of cultivar ($P<0.05$) and leaf clipping ($P<0.01$) on pearl millet grain yield. In case of pearl millet, clipped seedlings yielded 932 kg ha^{-1} compared to 797 kg ha^{-1} for non-clipped seedlings for cultivar PMV2 while cultivar PMV3 yielded 902 kg ha^{-1} compared to 820 kg ha^{-1} for non-clipped seedlings. In case of sorghum, Mutode yielded significantly ($P<0.05$) higher than Macia in both seasons, however, leaf clipping tended to increase yields for both cultivars. An increase in seedling age from 29 days also tended to reduce yields. It was concluded that leaf clipping of 30-day old seedlings at transplanting might enhance sorghum and pearl millet yields in the semi-arid tropics.

Haferkamp and Karl (1999) from their study on the clipping effects on growth dynamics of Japanese brome reported that the effect of clipping leaves was found to subsequently reduce plant height growth and above ground biomass in field studies.

Accordin to Chivasa *et al.* (1998) in Zimbabwe, observations in farmers' fields showed that farmers clipped all the fully extended leaves of seedlings into approximately half at transplanting. It appears however that the merits of this practice are not well understood by the farmers even though good establishment, better yields and rapid maturity were reported.

Onodera *et al.* (1998) carried out an experiment to study the effects of leaf clipping on rice seedling. They reported that due to leaf cutting treatment in seedlings, especially rooting power did not increase. Rooting power increased in case of adult seedlings and the effect is relatively significant. Since the experiment was done at low temperatures, it was considered to be effective in promoting survival of seedlings in unfavourable weather conditions. In the seedlings with sheared leaves, tillers occurred from the sheared nodes. Since the leaves were suppressed, it had a compensatory effect compared to non-sheared seedlings. Higher-order of stress occurred. In mature seedlings, increased number of leaves was observed. The total number of leaves on the main stem increased, but there was a difference in the heading period.

Páez *et al.* (1995) conducted an experiment to determine the short-term interacting effects of clipping height and frequency with water stress on growth and biomass allocation of Guinea grass (*Panicum maximum* Jacq.). After seedling establishment, plants were clipped at four frequencies and three heights, followed by exposure to water stress. Some plants were reirrigated to determine recovery. Plants were harvested after the water stress and reirrigation periods. In response to water stress, plants clipped at greater heights experienced a greater reduction of leaf and culm biomass than plants clipped at lower heights. Root biomass of stressed plants increased linearly with increasing clipping height. Leaf area declined linearly in stressed plants and increased in unstressed plants as clipping height increased and frequency decreased. Leaf area ratio (LAR) and specific leaf weight (SLW) of unstressed plants varied little; for stressed plants, however, LAR decreased and SLW increased as clipping height increased and frequency decreased. In well-watered plants, the root-to-shoot ratio (R/S) was lowest with higher clipping; in the stressed plants, R/S increased with increasing clipping heights. During rewatering, a height × stress interaction for leaf and culm biomass and leaf area was due to a smaller recovery for higher-clipped than for lower-clipped plants. Water stress decreased leaf and culm biomass and leaf area, reducing LAR and increasing SLW. These effects were greater in plants cut to greater heights and less frequently. Water stress also enhanced root biomass, suggesting photosynthates migration toward the roots.

Páez and González (1995) conducted a study to determine the short-term interacting effects of clipping management and water stress on photosynthesis and water relations of guineagrass (*Panicum maximum* Jacq.). The experiments were conducted outdoors in pots in Maracaibo, Venezuela. After seedling emergence and establishment, plants were clipped at four frequencies and three heights for 3 mo, followed by exposure to water stress. After a stress cycle of 15 d, a group of plants was reirrigated for 21 d, to observe recovery. Photosynthesis and transpiration rates, stomatal conductance, leaf water potential, and water use efficiency (WUE) were measured. During the stress period, the most closely clipped plants had greater photosynthesis, but not increased stomatal conductance. Photosynthesis was also greater in more frequently clipped plants, and both photosynthesis and conductance were reduced by water stress. Upon rewatering, photosynthesis increased sharply. Leaf transpiration rates were not affected by clipping height or frequency during water stress. A linear decrease in WUE occurred as cutting height increased, but clipping frequency did not alter

WUE. Water stress reduced leaf water potential, and this effect occurred sooner in plants clipped less frequently and to greater heights. After reirrigation, the highest photosynthesis in closely clipped plants was associated with increased stomatal conductance; leaf transpiration rate, WUE, and water potential were not altered by clipping height or frequency. Partial defoliation may relieve water stress to some degree. The increase in photosynthesis caused by close clipping is not fully related to higher stomatal conductance as previously reported, so other factors must also be involved.

Dupriez and De Leener (1988) from their experiments reported that root distribution might be modified when seedlings are transplanted or pricked out. They observed that shoots and roots could be trimmed at the same time and in this way, the roots are able to recover before the leaves begin to transpire abundantly and exhaustion of the re-born rootlets is avoided.

CHAPTER III

MATERIALS AND METHODS

This chapter presents a brief description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design, crop growing procedure, fertilizer application, uprooting of seedlings, intercultural operations, data collection and statistical analysis.

3.1 Location of the experimental field

The field experiment was conducted at Sher-e- Bangla Agricultural University, Dhaka during the period from March to August 2019. The location of the experimental site has been shown in Appendix I.

3.2 Soil of the experimental field

Soil of the experimental site was silty clay loam in texture belonging to Tejgaon series (Anon., 1988 a). The area represents the Agro-Ecological Zone of Madhupur tract (AEZ No. 28) with pH 5.8–6.5, ECE-25–28 (Anon., 1988 b). The analytical data of the soil sample collected from the experimental area were analyzed in the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and have been presented in Appendix II.

3.3 Climate of the experimental field

The experimental area was under the subtropical climate and was characterized by high temperature, high humidity and heavy precipitation with occasional gusty winds during the period from March to August, but scanty rainfall associated with moderately low temperature prevailed during the period from March to August (Idris *et al.*, 1979). The detailed meteorological data in respect of air temperature, relative humidity, rainfall and sunshine hour recorded by the meteorology centre, Dhaka for the period of experimentation have been presented in Appendix III.

3.4 Plant materials and features

The improved variety of rice cv. BRRI dhan82 was used as planting material for the present study. The variety is recommended for *aus* season. It is modern transplanted *aus* rice released by BRRI in 2018 (BRRI, 2019). The feature of the variety is presented below:

Name of Variety	:	BRRI dhan82
Height	:	110–120 cm
Maturity	:	135–145 days
Number of grains panicle^{-1}	:	170–200
1000 grain weight	:	23–26 g
Yield	:	5.50–6.00 t ha^{-1}

3.5 Experimental details

Sowing Date: 13 March, 2019

Transplanting Date: 17 April, 2019

Harvesting Date: 25 August, 2019

Fertilizer Applied: Urea, TSP, MoP, Gypsum and Zinc sulphate

Spacing: 25 cm × 20 cm

3.6 Experimental treatments

The experiment consisted of two factors as mentioned below:

Factor A: Seedling clipping (3)

S_0 – No seedling clipping (Control)

S_1 – 1/3rd clipping and

S_2 – 1/2nd clipping.

Factor B: Leaf clipping before panicle initiation (4)

L_0 – No leaf clipping (Control),

L_1 – Lower 1 + 2 leaves clipping,

L_2 – Lower 2 + 3 leaves clipping and

L3 – Flag leaf clipping.

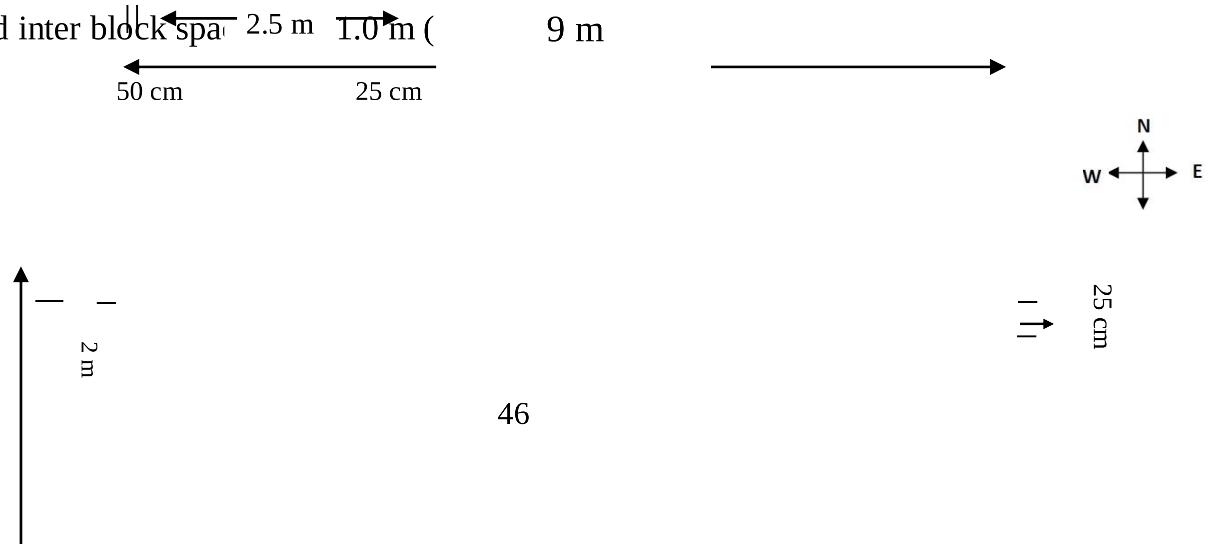
3.6.1 Treatment combinations

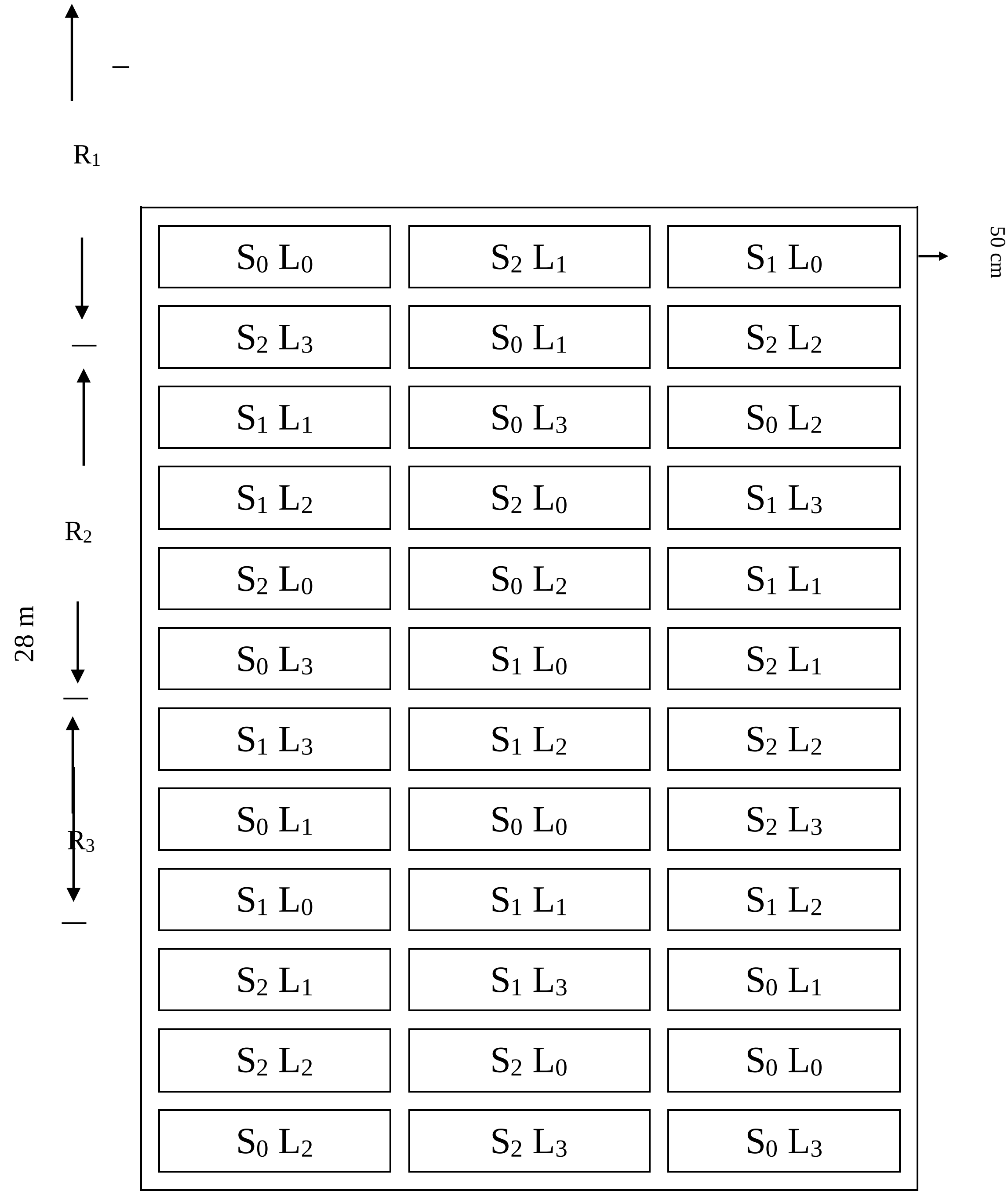
This two-factor experiment was included in 12 treatment combinations.

$S_0 L_0$	:	No seedling clipping × No clipping
$S_0 L_1$	:	No seedling clipping × Lower 1 + 2 leaves clipping
$S_0 L_2$	:	No seedling clipping × Lower 2 + 3 leaves clipping
$S_0 L_3$	:	No clipping × Flag leaf clipping
$S_1 L_0$	:	1/3rd clipping × No clipping
$S_1 L_1$	:	1/3rd clipping × Lower 1 + 2 leaves clipping
$S_1 L_2$	:	1/3rd clipping × Lower 2 + 3 leaves clipping
$S_1 L_3$	:	1/3rd clipping × Flag leaf clipping
$S_3 L_0$	:	1/2nd clipping × No clipping
$S_3 L_1$	:	1/2nd clipping × Lower 1 + 2 leaves clipping
$S_3 L_2$	:	1/2nd clipping × Lower 2 + 3 leaves clipping
$S_3 L_3$	:	1/2nd clipping × Flag leaf clipping

3.6.2 Experimental design and layout

The experiment was laid out in Randomized Complete Block design (RCBD) with three replications. The size of the individual plot was 4.0 m × 2.5 m and total numbers of plots were 36. There were 12 treatment combinations. Lay out of the experiment was done on 10 April, 2019 with inter plot spacing of 0.25 m and inter block spa 1.0 m (





Unit Plot Size = 4.0 m × 2.5 m

Plot Spacing = 0.25 m

Between replication = 0.50 m

Legend:

S_0 = No clipping

S_1 = 1/3rd clipping

S_2 = 1/2nd clipping

L_0 = No clipping

L_1 = Lower 1 + 2 leaves clipping

L_2 = Lower 2 + 3 leaves clipping

L_3 = Flag leaf clipping

Figure 1: Field layout of the experiment in Randomized Complete Block design

3.7 Cultivation procedure

3.7.1 Growing of Crop

3.7.1.1 Plant materials collection

Healthy and vigorous seeds of *aus* rice cv. BRRI dhan82 was collected from Bangladesh Rice Research Institute (BRRI), Joydebpur, Gazipur. The seeds were collected just 20 days ahead of the sowing of seeds in seedbed.

3.7.1.2 Seed sprouting

Healthy seeds were selected by specific gravity method. Seeds were then immersed in water in bucket for 24 hours. Then seeds were taken out of water and kept thickly in gunny bags. The seeds started sprouting after 48 hours and were sown after 72 hours.

3.7.1.3 Seed bed preparation and seedling raising

A piece of high land was selected in the Agronomy Field Laboratory, Sher-e-Bangla Agricultural University, Dhaka for raising seedlings. The land was puddled well with country plough followed by levelling with a ladder. Seed were sown in the seedbed @ 70 g m^{-2} on 13 March 2019. Proper care was taken to raise the healthy seedlings in the nursery bed. Weeds were removed and irrigation was given in the nursery bed as and when necessary.

3.7.1.4 Final land preparation

The land was first opened with a tractor drawn disc plough on 12 April 2019. The land was then puddled thoroughly by repeated ploughing and cross ploughing with a country plough and subsequently levelled by laddering. The field layout was made on 15 April 2019 according to experimental specification immediately after final land preparation. Weeds and stubbles were cleared off from individual plots and finally plots were levelled properly by wooden plank so that no water pocket could remain in the field.

3.7.1.5 Fertilizer application

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

Cow-dung	:	5 t ha^{-1}
Urea	:	220 kg ha^{-1}
TSP	:	165 kg ha^{-1}
MoP	:	180 kg ha^{-1}
Gypsum	:	70 kg ha^{-1}
Zinc	:	10 kg ha^{-1}

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

3.7.1.6 Uprooting of seedlings

The seedbed was made wet by application of water in the morning and evening on the previous day before uprooting. The seedlings were uprooted without causing any mechanical injury to the roots and were kept in the soft mud in shade. The age of seedling on the day of uprooting was 35 days.

3.7.1.7 Transplanting

35 days older rice seedlings were transplanted on 17 April, 2019 in 36 experimental plots which were puddled further with spade on the day of transplanting. Transplanting was done by using two seedlings $hill^{-1}$ with 25 cm × 20 cm spacing between the rows and hills, respectively.

3.7.2 Intercultural operation

3.7.2.1 Gap filling

Seedlings in some hills were died off and those were replaced by healthy seedling within 10 days of transplantation.

3.7.2.2 Weeding

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

3.7.2.3 Irrigation and drainage

Flood irrigation was given to maintain a level of standing water up to 2–4 cm till maximum tillering stage and after that, a water level of 7–10 cm was maintained up to grain filling stage and then drained out after milk stage to enhance maturity.

3.7.2.4 Herbicide application

Spraying were done by a hand crop sprayer (model - AM S021, capacity - 20 Litre, Brand name- AGROS, Made in- Zhejiang, China, Working Pressure: 0.2–0.3 Mpa) at 5 days after transplanting.

3.7.2.5 Plant protection measures

The crop was attacked by yellow rice stem borer (*Scirpopagain certulas*) at the panicle initiation stage which was successfully controlled with Sumithion @ 1.5 L ha^{-1}. Yet to keep the crop growth in normal, Basudin was applied at tillering stage @ 17 kg ha^{-1} while Diazinon 60 EC @ 850 ml ha^{-1} were applied to control rice bug.

3.7.2.6 General observations of the experimental field

Regular observations were made to see the growth stages of the crop. In general, the field looked nice with normal green plants, which were vigorous and luxuriant in the treatment plots than that of control plots.

3.8 Harvesting, threshing and cleaning

The rice plant was harvested depending upon the maturity of grains and harvesting was done manually from each plot. Maturity of crop was determined when 80–90% of the grains become golden yellow in colour. Ten (10) pre-selected hills per plot from which different data were collected and 3.00 m^2 areas from middle portion of each plot was separately harvested and bundled, properly tagged and then brought to the threshing floor. Enough care was taken for harvesting, threshing and cleaning of rice seed. Fresh weight of grain and straw were recorded plot wise. Finally, the grain weight was adjusted to a moisture content of 13%. The straw was sun dried and the yields of grain and straw plot^{-1} were recorded and converted to t ha^{-1}.

3.9 Recording of plant data

The growth and yield parameters were taken at harvest from pre-demarcated area.

3.9.1 Crop growth parameters

a) Plant height (cm)
b) Effective tillers hill^{-1} (no.)
c) Non-effective tillers hill^{-1} (no.)
d) Above ground dry mater weight hill^{-1} (g)

3.9.2 Yield contributing parameters

a) Panicle length (cm)
b) Filled grains panicle^{-1} (no.)
c) Unfilled grains panicle^{-1} (no.)
d) Weight of 1000-grains (g)

3.9.3 Yield parameters

e) Grain yield (t ha^{-1})
f) Straw yield (t ha^{-1})
g) Biological yield (t ha^{-1})
h) Harvest index (%)

3.10 Procedure of recording data

3.10.1 Plant height (cm)

The height of plant was measured at the time harvest for all the entries on 10 randomly selected plants from the middle rows. The height was measured from the base of the plant to the tip of the longest leaf or tip of the longest ear head, whichever was longer and the average was recorded in centimetres.

3.10.2 Effective tillers hill^{-1}

The total number of effective tillers hill^{-1} was counted as the number of panicle bearing tillers per hill. Data on effective tiller per hill were recorded from 10 randomly selected hill at harvesting time and average value was recorded.

3.10.3 Non-effective tillers hill^{-1}

The total number of non-effective tillers hill^{-1} was counted as the tillers, which have no panicle on the head. Data on non-effective tiller per hill were counted from 10 pre-selected (used in effective tiller count) hill at harvesting time and average value was recorded.

3.10.4 Above ground dry matter weight hill^{-1} (g)

Total above ground dry matter weight hill^{-1} was recorded at the time of harvest by drying plant sample. Data were recorded from plant samples hill^{-1} plot^{-1} selected at random from the outer rows of each plot leaving the border line and expressed in gram.

3.10.5 Panicle length (cm)

Panicle length was measured with a meter scale from 10 selected panicles and average value was recorded.

3.10.6 Filled grains panicle^{-1}

The total number of filled grains was collected randomly from selected 10 plants of a plot and then average number of filled grains per panicle was recorded.

3.10.7 Unfilled grains penicle^{-1}

The total number of unfilled grains was collected randomly from selected 10 plants of a plot based on no or partially developed grain in spikelet and then average number of unfilled grains per panicle was recorded.

3.10.8 1000-seeds weight (g)

One thousand clean and dried seeds were randomly taken from the four sample hills of each plot and the weight was taken in an electrical balance.

3.10.9 Grain yield (t ha^{-1})

Final grain yield was adjusted at 14% moisture. The grain yield t ha^{-1} was measured by the following formula:

$$\text{Grain yield (t ha}^{-1}\text{)} = \frac{\text{Grain yield per unti plot (kg)} \times 10000}{\text{Area of unit plot in square meter} \times 1000}$$

3.10.10 Straw yield (t ha^{-1})

The straw yield t ha^{-1} was measured by the following formula:

$$\text{Straw yield (t ha}^{-1}\text{)} = \frac{\text{Straw yield per unti plot (kg)} \times 10000}{\text{Area of unit plot in square meter} \times 1000}$$

3.10.11 Biological yield (t ha^{-1})

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

$$\text{Biological yield (t ha}^{-1}\text{)} = \text{Grain yield (t ha}^{-1}\text{)} + \text{Straw yield (t ha}^{-1}\text{)}$$

3.10.12 Harvest Index (%)

Harvest Index denotes the ratio of economic yield to biological yield and was calculated with the following formula:

$$\text{Harvest Index (\%)} = \frac{\text{Economic Yield (Grain weight)}}{\text{Biological Yield (Total weight)}} \times 100$$

3.11 Statistical Analysis

The recorded data were compiled and subjected to statistical analysis. Analysis of variance was done following MSTAT-C (Russell, 1986). The mean differences were adjudged by Least Significant Difference (LSD) at 5% levels of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

This chapter comprises presentation of results followed by discussion of the experiment with a view to study the growth and yield of aus rice varieties as influenced by seedling and leaf clipping. Data on different growth and yield characters have been presented in Tables 1–7 and Figures 2–7. The analyses of variance on different parameters are presented in Appendices IV to VI. The presented results and discussion was made with pertinent interpretations under the following headings.

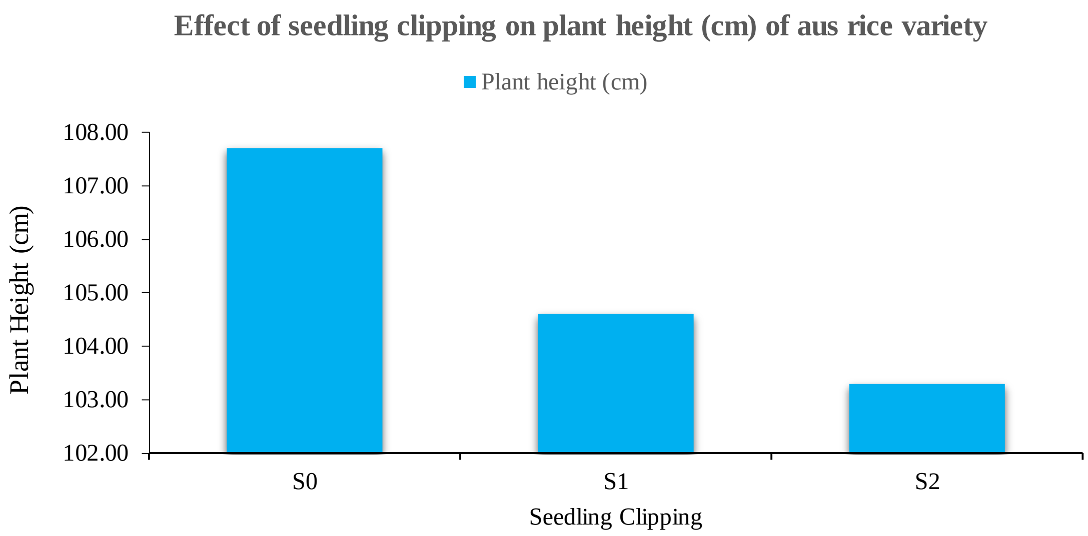
4.1 Plant height (cm)

4.1.1 Effect of seedling clipping

The plant height of aus rice varied non-significantly due to the seedling clipping (Fig. 2 and Appendix IV). Numerically taller (107.70 cm) plant was obtained from no clipping (S_0) treatment and shorter (103.30 cm) one was obtained from half height seedling clipping (S_2). Boonreund and Marsom (2015) reported that cutting of seedling had no significant effect on plant height.

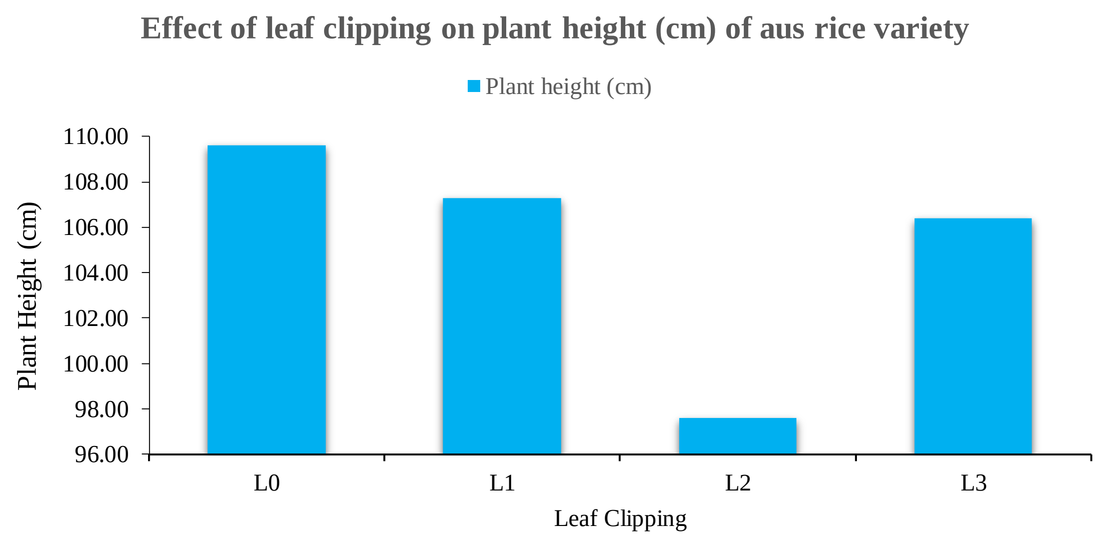
4.1.2 Effect of leaf clipping

The plant height varied significant due to the leaf clipping in the *aus* rice field (Figure 3 and Appendix IV). The tallest (109.60 cm) plant was recorded from the no clipping (L_0) treatment, which was identical (107.30 cm) with lower 1+2 leaf clipping (L_1) and (106.40 cm) with flag leaf clipping (L_3) treatment. On the other hand, the dwarf (97.58 cm) plant was found from lower 2+3 leaf clipping (L_2) treatment. Similar result was found in Medhi *et al.* (2015) and Ahmed *et al.* (2001 b). Hossain (2017) and Molla *et al.* (2002) reported that the maximum plant height was obtained in no leaf cutting (control treatment). Sardana *et al.* (2006) also found the extent (one-third or ½) and stage (30, 45 or 30 and 60 days after transplanting) of foliage clipping significantly influenced the plant height of Basmati 386 rice variety.



S_0 = No clipping, S_1 = 1/3rd clipping and S_2 = 1/2nd clipping

Figure 2: Effect of seedling clipping on plant height (cm) of aus rice at harvest (LSD value = 5.22)



L_0 = No clipping, L_1 = Lower 1+2 leaves clipping, L_2 = Lower 2+3 leaves clipping and L_3 = Flag leaf clipping

Figure 3: Effect of leaf clipping on plant height (cm) of aus rice at harvest (LSD value = 6.03)

4.1.3 Interaction effect of seedling clipping and leaf clipping

Plant height was significantly affected by the combined of seedling clipping and leaf clipping shown in Table 1 and Appendix IV. At harvesting time, the tallest plant (116.80 cm) was recorded from the combination of no seedling clipping with no leaf clipping (S_0L_0) which was statistically similar to (111.40 cm) no seedling clipping with lower 1 + 2 leaves clipping (S_0L_1). On the other hand, the shortest (95.73 cm) was obtained from the treatment combination of $1/2^{nd}$ seedling clipping with lower 2 + 3 leaves clipping (S_2L_2) which was statistically similar to (98.43 cm) $1/3^{rd}$ seedling clipping with lower 2 + 3 leaves clipping (S_1 L_2) and (98.57 cm) no seedling clipping with lower 2 + 3 leaves clipping (S_0 L_2) treatment combination.

4.2 Above ground dry matter hill^{-1} (g)

4.2.1 Effect of seedling clipping

Significant variation was found in above ground dry matter hill^{-1} (g) due to the seedling clipping in the *aus* rice field (Table 2 and Appendix V). The maximum dry matter (45.72 g) hill^{-1} was recorded from $1/3^{rd}$ seedling clipping (S_1) treatment. On the other hand, the minimum dry matter (36.38 g) hill^{-1} was obtained from $1/2^{nd}$ seedling clipping (S_2) treatment. Ros *et al.* (2003) conducted an experiment to explore the concept of seedling vigor of transplanted rice and to determine what plant attributes conferred vigor on the seedlings. He was shown that the combined effects of leaf dipping and root pruning on shoot, root and straw dry matter were largely additive. It was concluded that the response of rice yield to nursery treatments is largely due to increased seedling vigor and can be effected by a range of nutritional as well as non-nutritional treatments of seedlings that increase seedling dry matter, nutrient content and nutrient concentration. Impairment of leaf growth and to a lesser extent root growth in the nursery depressed seedling vigor after transplanting. However, rather than increasing stress tolerance, seedling vigor was more beneficial when post-transplant growth was not limited by nutrient or water stresses.

Table 1: Combined effect of seedling clipping and leaf clipping on plant height (cm) of aus rice at harvest

Treatment combination	Plant height (cm)
$S_0 L_0$	116.80 a
$S_0 L_1$	111.40 ab
$S_0 L_2$	98.57 fg
$S_0 L_3$	104.00 c-f
$S_1 L_0$	109.40 bc
$S_1 L_1$	102.10 ef
S_1L_2	98.43 fg
$S_1 L_3$	108.60 bc
$S_2 L_0$	102.50 d-f
$S_2 L_1$	108.40 b-d
$S_2 L_2$	95.73 g
$S_2 L_3$	106.50 b-e
LSD (0.05)	**6.03**
CV (%)	**9.38**

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

S_0 = No clipping, S_1 = 1/3rd clipping and S_2 = 1/2nd clipping

L_0 = No clipping, L_1 = Lower 1+2 leaves clipping, L_2 = Lower 2+3 leaves clipping and L_3 = Flag leaf clipping

4.2.2 Effect of leaf clipping

The leaf clipping had significant effect on dry matter hill^{-1} in aus rice field (Table 2 and Appendix V). No leaf clipping (L_0) produced maximum dry matter (43.84 g) hill^{-1}. On the other hand, the lower 2+3 (L_2) produced minimum dry matter (37.87 g) hill^{-1}.

Table 2: Combined effect of seedling clipping and leaf clipping on dry matter hill^{-1} (g), panicle length (cm) and 1000-grains weight (g) of aus rice at harvest

Treatment	Dry matter (g)
Effect of seedling clipping	
S_0	40.19 b
S_1	45.72 a
S_2	36.38 c
LSD $_{(0.05)}$	**0.78**
Effect of leaf clipping	
L_0	43.84 a
L_1	40.95 b
L_2	37.87 c
L_3	40.38 b
LSD $_{(0.05)}$	**0.89**
Combined effect of seedling clipping and leaf clipping	
S_0L_0	44.01 d
S_0L_1	41.04 e
S_0L_2	37.20 h
S_0L_3	38.50 g
S_1L_0	47.87 a
S_1L_1	45.50 b
S_1L_2	44.50 cd
S_1L_3	45.01 bc
S_2L_0	39.66 f
S_2L_1	36.30 i
S_2L_2	31.92 j
S_2L_3	37.63 gh
LSD $_{(0.05)}$	**0.89**
CV (%)	**5.30**

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

S_0 = No clipping, S_1 = 1/3rd clipping and S_2 = 1/2nd clipping

L_0 = No clipping, L_1 = Lower 1+2 leaves clipping, L_2 = Lower 2+3 leaves clipping and L_3 = Flag leaf clipping

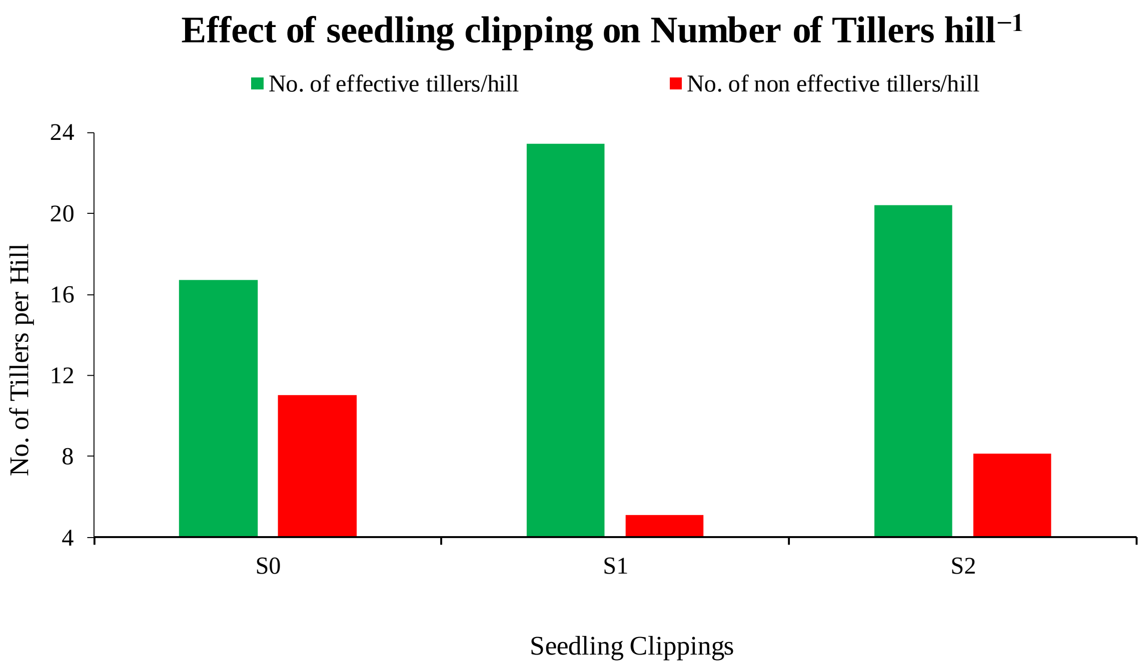
4.2.3 Interaction effect of seedling clipping and leaf clipping

Significant variation was found in dry matter hill^{-1} (g) due to the seedling clipping with leaf clipping in the *aus* rice field (Table 2 and Appendix V). The maximum dry matter (47.87 g) hill^{-1} was recorded from the combined effect of 1/3rd seedling clipping with no leaf clipping (S_1L_0) treatment. On the other hand, the minimum dry matter (31.92 g) hill^{-1} was obtained from the combination of 1/2nd seedling clipping with lower 2+3 leaves clipping (S_2L_2) treatment.

4.3 Number of effective tillers hill^{-1}

4.3.1 Effect of seedling clipping

Productive tillers unit area^{-1} determined the final yield of rice. The number of effective tillers hill^{-1} was significantly influenced by seedling clipping in *aus* rice (Figure 4 and Appendix IV). 1/3rd height seedling clipping (S_1) gave the highest effective tiller (23.42) and no seedling clipping (S_0) treatment in the field gave the lowest effective tiller (16.73).

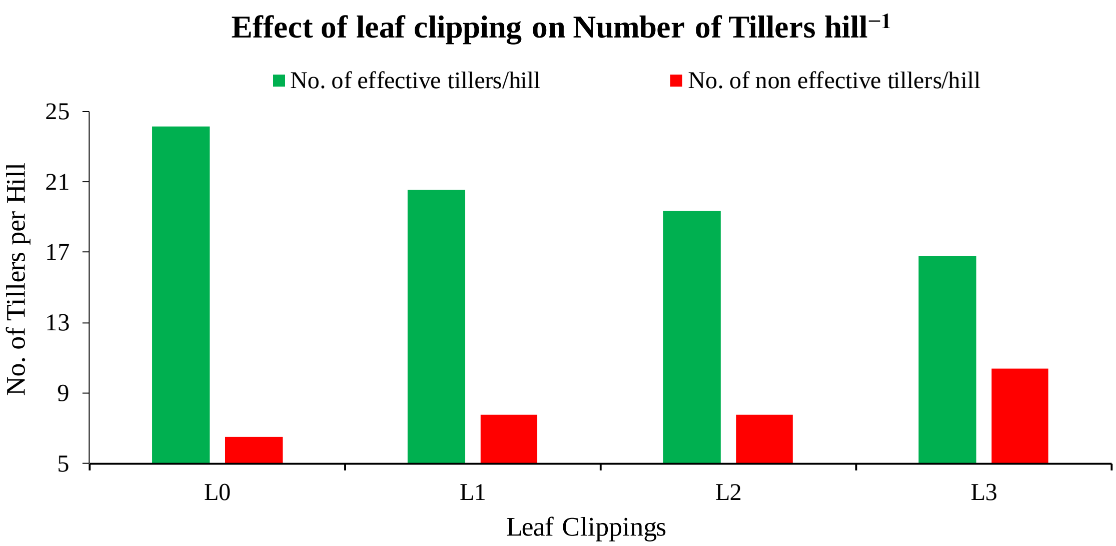


S_0 = No clipping, S_1 = 1/3rd clipping and S_2 = 1/2nd clipping

Figure 4: Effect of seedling clipping on no. of effective tillers hill^{-1} and no. of non-effective tillers hill^{-1} of aus rice at harvest (LSD value = 0.45 and 0.26)

4.3.2 Effect of leaf clipping

The leaf clipping had significant effect on numbers of effective tillers hill^{-1} (Figure 5 and Appendix IV). No leaf clipping (L_0) produced higher number (24.13) and flag leaf clipping (L_3) produced lower number (16.75) of productive tiller. Similar results were observed by Fatima *et al.* (2019), Daliri *et al.* (2009), Ahmed *et al.* (2001 a) and Ahmed *et al.* (2001 b). The same result was reported by Hossain (2017). He found the highest numbers of tillers hill^{-1} was obtained from no leaf cutting (control). Tiller numbers was not significantly increased after cutting. Molla *et al.* (2002) found that number of tillers hill^{-1} was significantly differed due to different cultivar and leaf clipping height. The highest number of tillers hill^{-1} was obtained from control plot at all growth stage whereas the lowest was recorded from clipping at 10 cm height. On the other hand, the dissimilar result was reported by Boonreund and Marsom (2015). He found that cutting of leaves had no significant effect on tiller number plant^{-1}. Hachiya (1989) also found the dissimilar result. He found that increases in the percentages of productive tillers was observed in response to artificial leaf cutting.



L_0 = No clipping, L_1 = Lower 1+2 leaves clipping, L_2 = Lower 2+3 leaves clipping and L_3 = Flag leaf clipping

Figure 5: Effect of leaf clipping on no. of effective tillers hill^{-1} and no. of non-effective tillers hill^{-1} of aus rice at harvest (LSD value = 0.52 and 0.30)

4.3.3 Interaction effect of seedling clipping and leaf clipping

Effective tiller hill^{-1} was significantly affected by the combined of seedling clipping with leaf clipping (Table 3 and Appendix IV). The highest effective tiller (27.69) was obtained from the combination of 1/3rd seedling clipping with no leaf clipping ($S_1 L_0$) treatment. The second highest effective tiller (25.00) was obtained from the combination of 1/2nd seedling clipping with no leaf clipping ($S_2 L_0$) treatment which was statistically similar (24.69) to 1/3rd seedling clipping with lower 1 + 2 leaves clipping ($S_1 L_1$) treatment. On the other hand, the lowest effective tiller (13.62) was found from the combination of no seedlling clipping with flag leaf clipping ($S_0 L_3$) treatment.

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

4.4.1 Effect of seedling clipping

The number of non-effective tillers hill^{-1} varied significantly due to the seedling clipping in *aus* rice (Figure 4 and Appendix IV). The maximum number of non-effective tillers hill^{-1} (11.01) was obtained from no seedling clipping (S_0) treatment. The minimum number of non-effective tillers hill^{-1} (5.13) was obtained from 1/3rd seedling clipping (S_1) treatment. Seedling clipping facilitated the crop for absorption of greater amount plant nutrient, moisture and solar radiation for growth, perhaps lower plant competition among leaves resulted in lower number of non-effective tillers hill^{-1}.

4.4.2 Effect of leaf clipping

It was evident from that leaf clipping had significant effect on numbers of non-effective tiller hill^{-1} (Figure 5 and Appendix IV). Flag leaf clipping (L_3) produced higher number (10.38) and no leaf clipping (L_0) produced lower number (6.53) of productive tiller. The dissimilar result was recorded in Ahmed *et al.* (2001 b).He was found that the maximum number of non-bearing tillers hill^{-1} was recorded from no leaf cutting treatment.

Table 3: Combined effect of seedling clipping and leaf clipping on no. of effective tillers hill^{-1} and no. of non-effective tillers hill^{-1} of aus rice at harvest

Treatment combination	No. of effective tillers hill^{-1}	No. of non-effective tillers hill^{-1}
$S_0 L_0$	19.69 d	8.16 d
$S_0 L_1$	17.28 e	10.51 b
$S_0 L_2$	16.34 f	10.00 c
$S_0 L_3$	13.62 g	15.36 a
$S_1 L_0$	27.69 a	4.93 h
$S_1 L_1$	24.69 b	5.06 gh
$S_1 L_2$	21.69 c	5.26 g
$S_1 L_3$	19.62 d	5.29 g
$S_2 L_0$	25.00 b	6.50 f
$S_2 L_1$	19.70 d	7.70 e
$S_2 L_2$	20.00 d	7.90 de
$S_2 L_3$	17.00 e	10.50 b
LSD $_{(0.05)}$	**0.52**	**0.30**
CV (%)	**6.51**	**5.18**

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

S_0 = No clipping, S_1 = 1/3rd clipping and S_2 = 1/2nd clipping

L_0 = No clipping, L_1 = Lower 1+2 leaves clipping, L_2 = Lower 2+3 leaves clipping and L_3 = Flag leaf clipping

4.4.3 Interaction effect of seedling clipping and leaf clipping

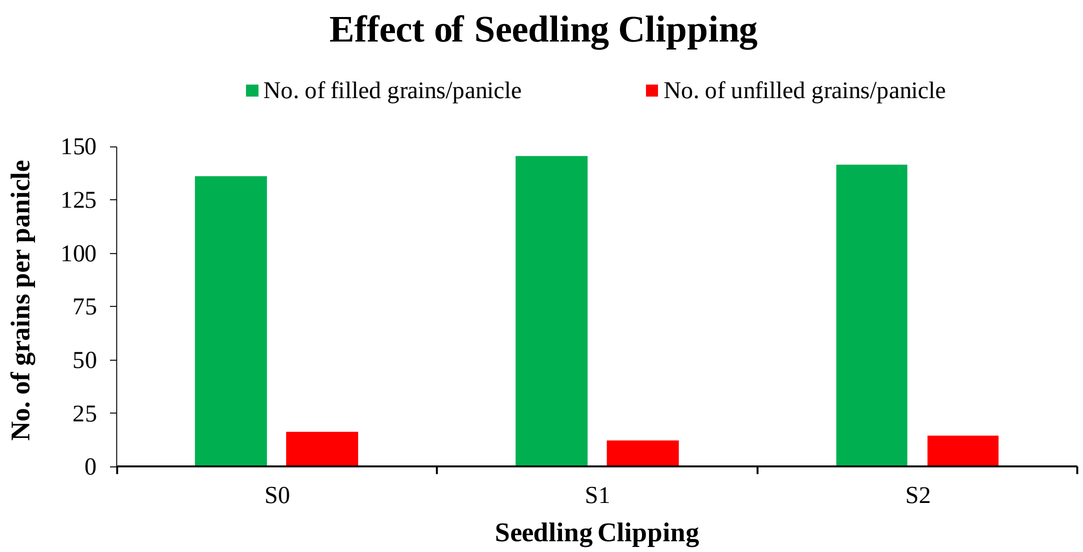
Non-effective tiller hill^{-1} was significantly affected by the combined of seedling clipping and leaf clipping treatment (Table 3 and Appendix IV). The highest non-effective tiller (15.36) was obtained from the combination of no seedling clipping with flag leaf clipping (S_0L_3) treatment. The lowest (4.93) was found from the combination of 1/3rd seedling clipping with no leaf clipping (S_1L_0)

treatment which was statistically similar with S_1L_1 (5.06), S_1L_2 (5.29) and S_1L_3 (5.26) treatment.

4.5 Number of filled grains panicle^{-1}

4.5.1 Effect of seedling clipping

Significant variation was found in filled grains panicle^{-1} due to the seedling clipping in the *aus* rice field (Figure 6 and Appendix IV). The maximum number of filled grains panicle^{-1} (145.60) was recorded from 1/3rd seedling clipping (S_1) treatment and the minimum (136.10) was obtained from no seedling clipping (S_0) treatment.

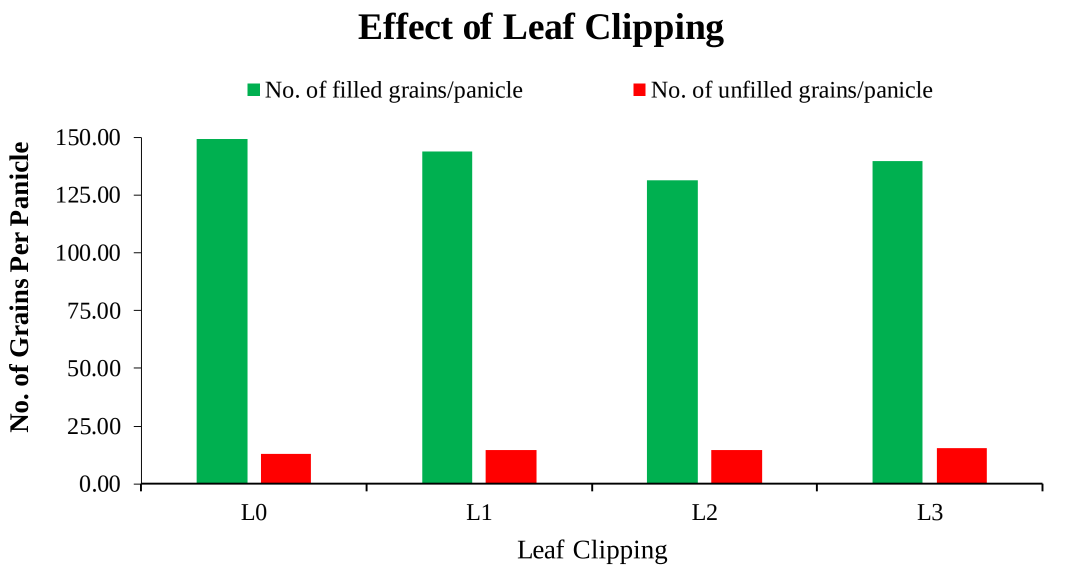


S_0 = No clipping, S_1 = 1/3rd clipping and S_2 = 1/2nd clipping

Figure 6: Effect of seedling clipping on no. of filled grains panicle^{-1} and no. of unfilled grains panicle^{-1} of aus rice at harvest (LSD value = 1.58 and 0.25)

4.5.2 Effect of leaf clipping

Significant variation was found in filled grains panicle^{-1} due to the *aus* rice leaf clipping (Fig. 7 and Appendix IV). The maximum number of filled grains panicle^{-1} (149.40) was recorded from no leaf clipping (L_0) treatment and the minimum (131.20) was obtained from lower 2 + 3 leaves clipping (L_2) treatment. These results were in agreement with Fatima *et al.* (2019) who reported that the highest number of filled grains panicle^{-1} was recorded from Heera 4 under control condition. Hossain (2017) also found that the highest number of grains panicle^{-1} was obtained in no leaf cutting (control) treatment. Dissimilar result was found from Boonreund and Marsom (2015) who recorded increased grains panicle^{-1} with cutting of rice leaf. Daliri *et al.* (2009) opined that the effect of leaf cutting time on percent filled grains panicle^{-1} was found statistically significant. Usman *et al.* (2007) recorded that the number of grains panicle^{-1} was obtained from control (no detopping) treatment. These results were in agreement with Ahmed *et al.* (2001 a) who reported that the yield and yield contributing characters decreased by leaf cutting as compared to control.



L_0 = No clipping, L_1 = Lower 1+2 leaves clipping, L_2 = Lower 2+3 leaves clipping and L_3 = Flag leaf clipping

Figure 7: Effect of leaf clipping on no. of filled grains panicle^{-1} and no. of unfilled grains panicle^{-1} of aus rice at harvest (LSD value = 1.82 and 0.28)

4.5.3 Interaction effect of seedling clipping and leaf clipping

Significant variation was found in filled grains panicle^{-1} due to the seedling clipping with leaf clipping in the *aus* rice field (Table 4 and Appendix IV). The maximum number of filled grain panicle^{-1} (157.50) was recorded from the combined effect of 1/3rd seedling clipping with no leaf clipping (S_1L_0) treatment. The minimum number of filled grain panicle^{-1} (127.20) was obtained from the combination of 1/2nd seedling clipping with lower 2 + 3 leaves clipping ($S_2 L_2$) treatment.

Table 4: Combined effect of seedling clipping and leaf clipping on no. of filled grains panicle^{-1} and no. of unfilled grains panicle^{-1} of aus rice at harvest

Treatment combination	No. of filled grain panicle^{-1}	No. of unfilled grain panicle^{-1}
$S_0 L_0$	144.00 d	15.10 d
$S_0 L_1$	139.00 e	15.82 c
$S_0 L_2$	130.30 g	17.11 b
$S_0 L_3$	131.30 g	18.15 a
$S_1 L_0$	157.50 a	11.04 i
$S_1 L_1$	153.50 b	12.50 g
$S_1 L_2$	136.00 f	12.15 h
$S_1 L_3$	135.50 f	13.43 f
$S_2 L_0$	146.50 c	13.15 f
$S_2 L_1$	139.50 e	16.00 c
$S_2 L_2$	127.20 h	14.50 e
$S_2 L_3$	152.60 b	15.35 d
LSD $_{(0.05)}$	**1.82**	**0.28**
CV (%)	**7.76**	**8.14**

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

S_0 = No clipping, S_1 = 1/3rd clipping and S_2 = 1/2nd clipping

L_0 = No clipping, L_1 = Lower 1+2 leaves clipping, L_2 = Lower 2+3 leaves clipping and L_3 = Flag leaf clipping

4.6 Number of unfilled grains panicle^{-1}

4.6.1 Effect of seedling clipping

Unfilled grains panicle^{-1} varied significantly due to the seedling clipping (Figure 6 and Appendix IV). The maximum number of unfilled grains panicle^{-1} (16.55) was recorded from no seedling clipping (S_0) treatment. On the other hand, the minimum number of unfilled grain panicle^{-1} (12.28) was obtained from 1/3rd seedling clipping (S_1) treatment.

4.6.2 Effect of leaf clipping

Significant variation was obtained in unfilled grain due to the effect of leaf clipping (Figure 7 and Appendix IV). Flag leaf clipping (L_3) produced highest unfilled grain (15.64) and the lowest unfilled grain (13.10) from no leaf clipping (L_0). Rahman *et al.* (2013) was shown that removal of flag leaf led to a decline in the seed-setting rate, which eventually reduced the grain yield. Ahmed *et al.* (2001 b) was also found that the number of sterile spikelets panicle^{-1} was found to be the highest for no leaf cutting treatment.

4.6.3 Interaction effect of seedling clipping and leaf clipping

Significant variation was obtained in unfilled grains due to the combined effect of seedling clipping and leaf clipping in *aus* rice shown in Table 4 and Appendix IV. Combined effect of no seedling clipping with lower 2 + 3 leaves clipping (S_0L_3) gave highest unfilled grain (18.15). On the other hand, the lowest unfilled grain (11.04) was found from the combined effect of 1/3rd seedling clipping with no leaf clipping (S_1L_0) treatment.

4.7 Panicle length (cm)

4.7.1 Effect of seedling clipping

The panicle length varied significantly due to seedling clipping treatments shown in Table 4 and Appendix V. It was observed that the longest panicle (33.48 cm) was observed from the treatment of 1/3rd seedling clipping (S_1). The shortest (25.92 cm) panicle length was observed from no seedling clipping treatment (S_0). This confirms the report of Boonreund and Marsom (2015) who observed that panicle length was differed due to different seedling clipping treatments.

4.7.2 Effect of leaf clipping

The panicle length varied significantly due to leaf clipping shown in Table 4 and Appendix V. It was observed that no leaf clipping (L_0) produced significantly longer (32.71 cm) panicle. The second longer panicle length (29.12 cm and 29.11 cm) was measured from lower 2 + 3 leaves clipping (L_2) and flag leaf clipping (L_3). On the other hand, the shortest panicle length (27.72 cm) was measured from lower 1 + 2 leaves clipping (L_1). This confirms the report of Boonreund and Marsom (2015) who showed that cutting of leaves had no significant effect on panicle length. Similar result was found that Usman *et al.* (2007). He was shown in the tallest length of panicle (23.4 cm) was obtained from control (no detopping).

4.7.3 Interaction effect of seedling clipping and leaf clipping

Panicle length was significantly affected by the combined of seedling clipping and leaf clipping (Table 5 and Appendix V). The longest (35.81 cm) panicle was observed from the combination of 1/3rd seedling clipping and no leaf clipping (S_1L_0) treatment. Second highest panicle length (33.63 cm) was obtained from the combination of 1/3rd seedling clipping with lower 2+3 leaves clipping (S_1L_2) which as the statistically similar result was found that (33.24 cm) 1/3rd seedling clipping with flag leaf clipping (S_1L_3) treatment. On the other hand, the shorter panicle length (22.53 cm) was found from the combination of no seedling clipping and lower 1 + 2 leaves clipping (S_0L_1) treatment.

Table 5: Combined effect of seedling clipping and leaf clipping on panicle length (cm) and 1000-grains weight (g) of aus rice at harvest

Treatment	Panicle length (cm)	1000-grains weight (g)
Effect of seedling clipping		
S_0	25.92 c	18.30 c
S_1	33.48 a	24.40 a
S_2	29.60 b	21.58 b
LSD $_{(0.05)}$	**0.34**	**0.15**
Effect of leaf clipping		
L_0	32.71 a	23.21 a
L_1	27.72 c	22.21 b
L_2	29.12 b	21.22 c
L_3	29.11 b	19.06 d
LSD $_{(0.05)}$	**0.40**	**0.17**
Combined effect of seedling clipping and leaf clipping		
S_0L_0	30.69 d	19.60 i
S_0L_1	22.53 i	19.24 j
S_0L_2	25.24 h	18.20 k
S_0L_3	25.20 h	16.15 l
S_1L_0	35.81 a	26.87 a
S_1L_1	31.25 c	25.89 b
S_1L_2	33.63 b	24.80 c
S_1L_3	33.24 b	20.04 h
S_2L_0	31.62 c	23.16 d
S_2L_1	29.39 e	21.50 e
S_2L_2	28.48 g	20.67 g
S_2L_3	28.90 f	20.98 f
LSD $_{(0.05)}$	**0.40**	**0.17**
CV (%)	**6.79**	**6.46**

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

S_0 = No clipping, S_1 = 1/3rd clipping and S_2 = 1/2nd clipping

L_0 = No clipping, L_1 = Lower 1+2 leaves clipping, L_2 = Lower 2+3 leaves clipping and L_3 = Flag leaf clipping

4.8 1000-grains weight (g)

4.8.1 Effect of seedling clipping

Effect of seedling clipping showed significant variation in 1000 grains weight (Table 4 and Appendix V). 1/3rd seedling clipping (S_1) gave the highest 1000 grains weight (24.40 g). The lowest 1000 grains weight (18.30 g) was found from no seedling clipping (S_0) treatment. This finding was in agreement with Fatima *et al.* (2019) who showed that seedling clipping regime had significant effect on 1000-grains weight.

4.8.2 Effect of leaf clipping

Weight of 1000 grains showed significant variation among the different leaf clipping (Table 4 and Appendix V). No leaf clipping produced highest 1000 grains weight (23.21 g). The second highest 1000 grains weight (22.21 g) was found in lower 1+2 leaves clipping (L_1) treatment. The lowest 1000 grains weight (21.22 g) was obtained from lower 2+3 leaves clipping (L_2) treatment. Similar findings were reported by Hossain (2017). He was recorded that the 1000-grains weight was significantly reduced in plants those had the leaves cut compared with the plant in control treatment. Dissimilar findings were reported by Ali *et al.* (2017). He was shown that the leaf clipping had non-significant effect on 1000-grains weight of modern variety BINA dhan8. Rahman *et al.* (2013) was shown that the weight of 1000-grains of BR 3 was 27.5 g and 14 g for control and treated, respectively. Similarly, 1000-grains weight of BR 4 had 26 g and 17 g, BR 11 had 25.7 g and 18 g, BRRI dhan34 had 31 g and 16.5 g, BRRI dhan37 had 23.1 g and 15 g for control and treated, respectively. Ahmed *et al.* (2001 a) recorded that the highest value of 1000-grain weight (22.72 g) was recorded from control treatment.

4.8.3 Interaction effect of seedling clipping and leaf clipping

Combined effect of seedling clipping and leaf clipping showed significant variation in 1000-grains weight (g) shown in Table 5 and Appendix V. The highest grain weight (26.87 g) was found from the combined effect of 1/3rd seedling clipping and no leaf clipping (S_1L_0) treatment. The second highest grain weight (25.89 g) was obtained from the combined effect of 1/3rd seedling clipping with lower 1+2 leaves clipping (S_1L_1) treatment. On the other hand, the lowest grain weight (16.15 g) was found with the combined effect of no seedling clipping with flag leaf clipping (S_0L_3) treatment.

4.9 Grain yield (t ha^{-1})

4.9.1 Effect of seedling clipping

Rice grain yield varied significantly due to the different seedling clipping in the *aus* rice field (Table 6 and Appendix VI). The maximum grain yield (5.47 t ha^{-1}) was recorded from 1/3rd height seedling clipping (S_2) treatment. On the other hand, the minimum grain yield (4.29 t ha^{-1}) was obtained from no seedling clipping treatment. These might be due to the fact that the seedling clipping kept the rice field well aerated which facilitated the crop for absorption of greater amount of plant nutrients, moisture and greater reception of solar radiation for better growth. Ros *et al.* (2003) found that the response of rice yield to nursery treatments is largely due to increased seedling vigor and can be effected by a range of nutritional as well as non-nutritional treatments of seedlings that increase seedling dry matter, nutrient content and nutrient concentration. Das and Mukherjee (1992) from their research work on the effect of seedling removal on grain and straw yields of rainy season rice reported that late seedling cutting reduced the grain yield.

4.9.2 Effect of leaf clipping

Rice grain yield varied significantly for different leaf clipping shown in Table 6 and Appendix VI. The maximum grain yield (5.44 t ha^{-1}) was recorded by no leaf clipping (L_0) treatment. The second highest grain yield (4.93 t ha^{-1}) was recorded from lower 1 + 2 leaves clipping (L_1) treatment. On the other hand, the lowest grain yield (4.24 t ha^{-1}) was recorded from flag leaf clipping (L_3)

treatment. Fatima (2019) recorded significant variation was found for grain yield due to leaf removal. The highest grain yield (5.70 t ha^{-1}) was observed from no clipping, whereas the lowest (4.73 t ha^{-1}) was recorded from flag leaf clipping. 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; Misra, 1987; Misra and Misra, 1991). Tambussi *et al.* (2007) also found the similar result and stated that Grains filling is sustained by current photosynthesis of the upper parts of the plant, i.e. the flag leaf and penultimate leaves and the ear. Fatima *et al.* (2019) opined that yield contributing characters and yield were investigated after cutting of flag leaf. Hossain (2017) recorded highest grain yield (6.75 t ha^{-1}) in BRRI dhan33 with no leaf cutting. Angrish (2000) from his experiment on lodging control in the tall statured Taraori basmati (*Oryza sativa* L.) by foliage pruning reported that cutting of excessive foliage of tall statured varieties of rice did not cause any adverse effect on grain yield. Muduli *et al.* (1995) found decreased grain yield when the flag leaf was removed at panicle emergence. Das and Mukherjee (1992) reported that late leaf cutting reduce the grain yield and this was true for present experiment.

4.9.3 Interaction effect of seedling clipping and leaf clipping

Rice grain yield varied significantly due to different seedling clipping and leaf clipping combinations (Table 6 and Appendix VI). The maximum grain yield (6.08 t ha^{-1}) was recorded from 1/3rd height seedling clipping and no leaf clipping ($S_1 L_0$) combination treatment. On the other hand, the minimum grain yield (3.95 t ha^{-1}) was recorded from the no seedling clipping and flag leaf clipping ($S_0 L_3$) treatment combination.

4.10 Straw yield (t ha^{-1})

4.10.1 Effect of seedling clipping

Rice straw yield varied significantly due to the different seedling clipping in the *aus* rice field (Table 6 and Appendix VI). The maximum straw yield (5.64 t ha^{-1})

was recorded from no seedling clipping (S_0) treatment. The minimum straw yield (4.18 t ha^{-1}) was obtained from 1/3rd height seedling clipping (S_1) treatment. This result was in agreement with the findings of Ros *et al.* (2003) who noted that the combined effect of leaf clipping and seedling pruning on the production of shoot, root and straw dry matter was greater.

4.10.2 Effect of leaf clipping

Significant variation in straw yield due to leaf clipping was evident (Table 6 and Appendix VI). Flag leaf clipping (L_3) recorded the maximum straw yield (5.56 t ha^{-1}). On the other hand, no leaf clipping (L_0) recorded the minimum straw yield (4.11 t ha^{-1}). Fatima *et al.* (2019), Hossain (2017) and Usman *et al.* (2007) observed that the highest straw yield was obtained in no leaf cutting (control). Fatima (2019) recorded that the statistically significant variation was recorded for dry straw yield due to flag leaf clipping in Boro rice. The highest dry straw yield (7.29 t ha^{-1}) was recorded from no leaf clipping (control), whereas the lowest (5.84 t ha−1) was recorded from flag leaf clipping.

4.10.3 Interaction effect of seedling clipping and leaf clipping

The straw yield varied significantly due to different seedling clipping and leaf clipping treatment combinations (Table 6 and Appendix VI). The maximum straw yield (6.24 t ha^{-1}) was obtained from the combination of no seedling clipping and flag leaf clipping (S_0L_3) treatment. The second maximum (5.55 t ha^{-1}) was recorded with the combination of no seedling clipping with lower 2 + 3 leaves clipping (S_0L_2) which was statistically similar (5.51 t ha^{-1}) with no seedling clipping with lower 1 + 2 leaves clipping (S_0 L_1) treatment. The minimum straw yield (2.93 t ha^{-1}) was found from the combination of 1/3rd seedling clipping and no leaf clipping (S_1 L_0) treatment.

Table 6: Combined effect of seedling clipping and leaf clipping on grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%) of aus rice at harvest

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
Effect of seedling clipping				
S_0	4.29 c	5.64 a	9.93 a	43.22 c
S_1	5.47 a	4.18 c	9.65 b	56.87 a
S_2	4.69 b	4.79 b	9.48 b	49.40 b
LSD $_{(0.05)}$	**0.08**	**0.17**	**0.18**	**1.03**
Effect of leaf clipping				
L_0	5.44 a	4.11 c	9.55 b	57.29 a
L_1	4.93 b	4.85 b	9.78 a	50.39 b
L_2	4.64 c	4.97 b	9.61 ab	48.29 c
L_3	4.24 d	5.56 a	9.81 a	43.36 d
LSD$_{(0.05)}$	**0.09**	**0.19**	**0.21**	**1.19**
Combined effect of seedling clipping and leaf clipping				
S_0L_0	4.62 ef	5.25 c	9.87 b	46.84 e
S_0L_1	4.33 g	5.51 b	9.84 b	44.06 fg
S_0L_2	4.25 gh	5.55 b	9.80 bc	43.22 g
S_0L_3	3.95 i	6.24 a	10.20 a	38.77 h
S_1L_0	6.08 a	2.93 f	9.01 g	67.48 a
S_1L_1	5.76 b	4.47 d	10.23 a	56.34 c
S_1L_2	5.44 d	4.20 e	9.63 cd	56.45 bc
S_1L_3	4.60 f	5.14 c	9.74 bc	47.20 e
S_2L_0	5.63 c	4.15 e	9.79 bc	57.56 b
S_2L_1	4.70 e	4.56 d	9.26 f	50.76 d
S_2L_2	4.25 gh	5.15 c	9.40 ef	45.19 f
S_2L_3	4.18 h	5.30 c	9.48 de	44.10 fg
LSD$_{(0.05)}$	**0.09**	**0.19**	**0.21**	**1.19**
CV (%)	**6.20**	**8.33**	**5.25**	**5.41**

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

S_0 = No clipping, S_1 = 1/3rd clipping and S_2 = 1/2nd clipping

L_0 = No clipping, L_1 = Lower 1+2 leaves clipping, L_2 = Lower 2+3 leaves clipping and L_3 = Flag leaf clipping

4.11 Biological yield (t ha^{-1})

4.11.1 Effect of seedling clipping

The biological yield varied significantly due to different seedling clipping treatments shown in Table 6 and Appendix VI. No seedling clipping (S_0) gave the highest biological yield (9.93 t ha^{-1}). On the other hand, 1/2nd height seedling clipping (S_2) treatment gave the lowest biological yield (9.48 t ha^{-1}) which was statistically similar (9.65 t ha^{-1}) with 1/3rd seedling clipping (S_1) treatment. Dissimilar results were recorded by Fatima *et al.* (2019), Usman *et al.* (2007) and Ahmed *et al.* (2001 a).

4.11.2 Effect of leaf clipping

The biological yield varied significantly due to the leaf clipping shown in Table 6 and Appendix VI. It was observed that the flag leaf clipping (L_3) produced significantly highest biological yield (9.81 t ha^{-1}) which was statistically similar (9.78 t ha^{-1}) with lower 1 + 2 leaves clipping (L_1) and (9.61) lower 2 + 3 leaves clipping (L_2) treatment. On the other hand, the lowest biological yield (9.55 t ha^{-1}) was recorded from the no leaf clipping (L_0) treatment. Dissimilar results were recorded by Fatima *et al.* (2019), Usman *et al.* (2007) and Ahmed *et al.* (2001 a).

4.11.3 Interaction effect of seedling clipping and leaf clipping

Biological yield was significantly affected by the combined of different seedling clipping and leaf clipping treatment in *aus* rice field (Table 6 and Appendix VI). The highest biological yield (10.23 t ha^{-1}) was obtained from the combination of 1/3rd height seedling clipping with lower 1 + 2 leaves clipping (S_1L_1) which was statistically similar (10.20 t ha^{-1}) with no seedling clipping and flag leaf clipping (S_0L_3) treatment. On the other hand, the lowest biological yield (9.01 t ha^{-1}) was found from the combination 1/3rd seedling clipping with no leaf clipping (S_1L_0) treatment.

4.12 Harvest Index (%)

4.12.1 Effect of seedling clipping

Harvest index (%) of rice varied significantly due to the different seedling clipping in the *aus* rice field (Table 6 and Appendix VI). The height harvest index (56.87 %) was recorded from 1/3rd height seedling clipping (S_1) treatment. On the other hand, the lowest harvest index (43.22 %) was obtained from no seedling clipping (S_0) treatment. This result was in agreement with the findings of Ros *et al.* (2003) who argued that the combined effects of seedling pruning was given the highest value of harvest index of rice.

4.12.2 Effect of leaf clipping

Leaf clipping showed significant variation in harvest index (Table 6 and Appendix VI). No leaf clipping (L_0) showed the highest harvest index (57.29 %) whereas, lowest harvest index (43.36 %) in flag leaf clipping (L_3) treatment. These findings are being supported from the work of Hossain (2017), Daliri *et al.* (2009), Usman *et al.* (2007) and Ahmed *et al.* (2001 a), who obtained that the highest harvest index was obtained in no leaf cutting (control).

4.12.3 Interaction effect of seedling clipping and leaf clipping

Combined effect of seedling clipping and leaf clipping showed significant variation in harvest index of *aus* rice field (Table 6 and Appendix VI). The highest harvest index (67.48 %) was observed from the combined effect of 1/3rd seedling clipping with no leaf clipping (S_1L_0) treatment. The second highest (57.56 %) was observed from the combined effect of 1/2nd seedling clipping with no leaf clipping (S_2L_0) treatment which was statistically similar with (56.45 %) 1/3rd height seedling clipping and lower 2 + 3 leaves clipping (S_1L_2) and (56.34 %) 1/3rd height seedling clipping and lower 1+2 leaves clipping (S_1L_1) treatment. On the other hand, the lowest harvest index (38.77 %) was obtained from the combined of no seedling clipping with flag leaf clipping (S_0L_3) treatment.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted during the period from March to August 2019 at the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to study the influence of seedling and leaf clipping on the growth and yield of *aus* rice. The experiment comprised two factors; Factors A: three different seedling clipping *viz.* S_0 = no seedling clipping (control), S_1 = 1/3rd height seedling clipping and S_2 = 1/2nd height seedling clipping and Factor B: four different leaf clipping before panicle initiation *viz.* L_0 = no leaf clipping (control), L_1 = Lower 1 + 2 leaves clipping, L_2 = Lower 2 + 3 leaves clipping and L_3 = Flag leaf clipping.

The experiment was laid out in Randomized Complete Block design (RCBD) with three replications. The size of the individual plot was 4.0 m × 2.5 m and total numbers of plots were 36. The data were collected on plant height (cm), number of effective tillers hill^{-1}, number of non-effective tillers plant^{-1}, number of filled grains panicle^{-1}, number of unfilled grains panicle^{-1}, above ground dry matter hill^{-1}, panicle length, 1000-grains weight, grain yield, straw yield, biological yield and harvest index.

Collected data were compiled and the mean separations were tested following least significant difference (LSD) test at 5% level of significance.

Seedling and leaf clipping either individually or combined showed significant variations in some parameters.

In respect of seedling clipping, the tallest plant (107.70 cm) was obtained from the no seedling clipping and the dwarf (103.30 cm) was from 1/2nd height clipping treatment. While for leaf clipping, the tallest (109.60 cm) plant was recorded from the no leaf clipping and the dwarf (97.58 cm) plant was at lower 2 + 3 leaf clipping treatment. Combination treatment showed that the tallest plant (116.80 cm) was observed from no seedling clipping with no leaf clipping (control) and the shortest (95.73 cm) from 1/2nd height seedling clipping with lower 2 + 3 leaves clipping.

1/3rd seedling clipping gave the highest effective tiller (23.42) and no seedling clipping treatment gave the lowest effective tiller (16.73). No leaf clipping produced higher number (24.13) and flag leaf clipping produced lower number (16.75) of productive tiller. The highest effective tiller (27.69) was obtained from the combination of 1/3rd height seedling clipping with no leaf clipping treatment and the lowest effective tiller (13.62) was found from the combination of no seedlling clipping with flag leaf clipping treatment.

The maximum number of non-effective tillers hill^{-1} (11.01) was obtained from no seedling clipping and the minimum (5.13) was obtained from 1/3rd height seedling clipping treatment. Flag leaf clipping produced higher number (10.38) and no leaf clipping produced lower number (6.53) of productive tiller. The highest non-effective tiller (15.36) was obtained from the combination of no seedling clipping with flag leaf clipping and the lowest (4.93) was 1/3rd height seedling clipping with no leaf clipping.

The maximum number of filled grains panicle^{-1} (145.60) was recorded from 1/3rd height seedling clipping and the minimum (136.10) was obtained from no seedling clipping treatment. The maximum number of filled grains panicle^{-1} (149.40) was recorded from no leaf clipping and the minimum (131.20) was obtained from lower 2+3 leaves clipping (L_2) treatment. The maximum number of filled grain panicle^{-1} (157.50) was recorded from the combined effect of 1/3rd height seedling clipping with no leaf clipping and the minimum (127.20) was obtained from 1/2nd height seedling clipping with lower 2+3 leaves clipping.

The maximum number of unfilled grains panicle^{-1} (16.55) was recorded from no seedling clipping and the minimum number of unfilled grain panicle^{-1} (12.28) was obtained from 1/3rd height seedling clipping treatment. Flag leaf clipping produced highest unfilled grain (15.64) and the lowest (13.10) from no leaf clipping treatment. Combined effect of no seedling clipping with lower 2+3 leaves clipping gave highest unfilled grain (18.15) and the lowest unfilled grain (11.04) was found from the combined effect of 1/3rd seedling clipping with no leaf clipping.

The maximum above ground dry matter (45.72 g) hill^{-1} was recorded from 1/3rd height seedling clipping and the minimum (36.38 g) was obtained from 1/2nd height seedling clipping treatment. No leaf clipping produced maximum above ground dry matter (43.84 g) hill^{-1} and the lower 2 + 3 leaves clipping produced minimum (37.87 g). The maximum above ground dry matter (47.87 g) hill^{-1} was recorded from the combined effect of 1/3rd height seedling clipping with no leaf clipping and the minimum (31.92 g) was obtained from the combination of 1/2nd height seedling clipping with lower 2 + 3 leaves clipping.

The longest panicle (33.48 cm) was observed from the treatment of 1/3rd height seedling clipping and the shortest (25.92 cm) was observed from no seedling clipping treatment. No leaf clipping produced longer (32.71 cm) panicle and the shortest (27.72 cm) one was measured from lower 1 + 2 leaves clipping treatment. The longest (35.81 cm) panicle was observed from the combination of 1/3rd height seedling clipping and no leaf clipping treatment and the shortest panicle length (22.53 cm) was found from the combination of no seedling clipping and lower 1 + 2 leaves clipping treatment.

1/3rd height seedling clipping gave the highest 1000-grains weight (24.40 g) and the lowest (18.30 g) was found from no seedling clipping treatment. No leaf clipping produced highest 1000 grains weight (23.21 g) and the lowest (21.22 g) was obtained from lower 2+3 leaves clipping treatment. The highest 1000-grain weight (26.87 g) was found from the combined effect of 1/3rd seedling clipping and no leaf clipping and the lowest grain weight (16.15 g) was found with the combined effect of no seedling clipping with flag leaf clipping treatment.

Based on the results of the present experiment, the following conclusion can be drawn:

1. The maximum grain yield (6.08 t ha^{-1}) was recorded from treatment combination of 1/3rd height seedling clipping and no leaf clipping treatment and the minimum (3.95 t ha^{-1}) was recorded from the no seedling clipping and flag leaf clipping treatment combination.

2. The maximum straw yield (6.24 t ha^{-1}) was obtained from the combination of no seedling clipping and flag leaf clipping and the minimum (2.93 t ha^{-1}) was found from the combination of 1/3rd height seedling clipping and no leaf clipping treatment.

3. The highest biological yield (10.23 t ha^{-1}) was obtained from the combination of 1/3rd height seedling clipping with lower 1 + 2 leaves clipping and the lowest (9.01 t ha^{-1}) was found from the combination 1/3rd height seedling clipping with no leaf clipping treatment.

4. The highest harvest index (67.48 %) was observed from the combined effect of 1/3rd height seedling clipping with no leaf clipping and the lowest (38.77 %) was obtained from no seedling clipping with flag leaf clipping treatment.

However, to reach a specific conclusion and recommendation, more research work with different seedling clipping and leaf clipping on rice may be done over different Agro-ecological zones of the country.

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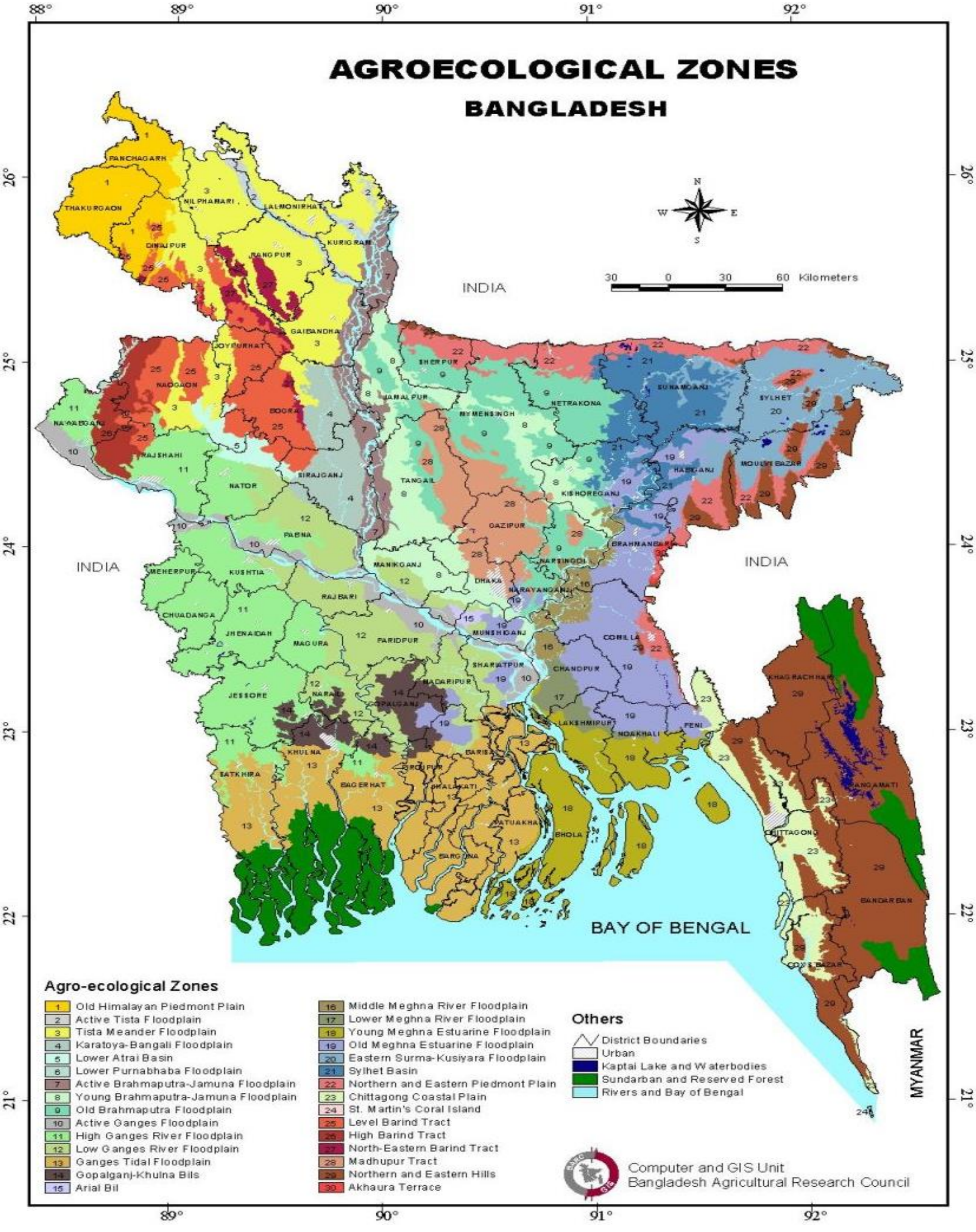
APPENDICES

Appendix I: Map showing the experimental sites under study



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

Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy Farm, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping Pattern	Potato-Aus rice-Aman rice

A. Physical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% Clay	30

Chemical properties of the initial soil

Characteristics	Value
Textural class	Silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.077
Available P (ppm)	20.00
Exchangeable K (mel 100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix III: Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from March, 2019 to August, 2019

Year	Month	Air Temperature (°C)			Relative Humidity (%)	Total Rainfall (mm)	Sunshine (Hour)
		Max	Min	Mean			
2019	March	34	24	30	44	57.6	301.5
	April	37	28	33	54	225.1	294
	May	39	29	35	61	259.3	294.5
	June	36	29	33	67	273.6	226.5
	July	34	28	31	74	380.6	194
	August	34	27	31	73	254.8	203.5

Source: Bangladesh Metrological Department (Climate and weather division) Agargaon, Dhaka.

Appendix IV: Analysis of variance (ANOVA) of data on plant height (cm), no. of effective tiller hill^{-1}, no. of non-effective tiller hill^{-1}, no. of filled grains panicle^{-1} and no. of unfilled grains panicle^{-1}

Source of variation	df	Plant height (cm)	No. of effective tillers hill^{-1}	No. of non-effective tillers hill^{-1}	No. of filled grains Panicle^{-1}	No. of unfilled grains panicle^{-1}
Replication	2	183.570	2.340	0.970	6.088	0.542
Seedling clipping (A)	2	60.590^{NS}	134.650*	103.460*	272.727*	54.999*
Leaf clipping (B)	3	248.030*	84.550*	23.800*	531.024*	10.073*
A × B	6	60.950*	2.460**	6.505**	175.501*	1.451**
Error	22	12.680	0.093	0.031	1.158	0.028

*Significant at 5% level of probability

** Significant at 1% level of probability

Appendix V: Analysis of variance (ANOVA) of data on dry matter hill^{-1} (g), panicle length (cm) and 1000-seeds weight (g)

Source of variation	Df	Dry matter hill^{-1} (g)	Panicle length (cm)	1000-seeds weight (g)
Replication	2	4.190	2.950	0.736
Seedling clipping (A)	2	264.825*	171.764*	111.897*
Leaf clipping (B)	3	54.053**	40.943**	28.359*
A × B	6	5.933**	5.342**	5.011**
Error	22	0.279	0.055	0.010

*Significant at 5% level of probability

** Significant at 1% level of probability

Appendix VI: Analysis of variance (ANOVA) of data on grain yield (t ha^{-1}), straw yield (t ha^{-1}), biological yield (t ha^{-1}) and harvest index (%)

Source of variation	df	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest Index (%)
Replication	2	0.335	0.221	1.098	0.657
Seedling clipping (A)	2	4.323**	6.394*	0.600**	560.192*
Leaf clipping (B)	3	2.298**	3.199**	0.138**	300.898*
A × B	6	0.247**	0.383**	0.432**	26.779*
Error	22	0.003	0.013	0.015	0.492

*Significant at 5% level of probability

** Significant at 1% level of probability