EFFICACY OF SEEDLING AND LEAF CLIPPING ON THE PERFORMANCE OF Binadhan-13

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CERTIFICATE

*This is to certify that thesis entitled, "***EFFICACY OF SEEDLING AND LEAF CLIPPING ON THE PERFORMANCE OF Binadhan-13***" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment 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* ***Apu Saha,*** *Registration no.* ***14-05893*** *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.

Dated:
Place: Dhaka, Bangladesh

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Dedicated to

My Beloved Parents

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EFFICACY OF SEEDLING AND LEAF CLIPPING ON THE PERFORMANCE OF Binadhan-13

ABSTRACT

A field experiment was carried out at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the period from 1 July to 12 December, 2019 to investigate the efficacy of seedling and leaf clipping on the performance of an aromatic rice variety Binadhan-13. The experiment comprised of two factors; Factor A: Seedling top clipping (3) *viz.* S_0= Control (no clipping); S_1= 1/3rd top clipping; S_2=1/2nd top clipping and Factor B: Leaf clipping before panicle initiation (5) *viz.* L_0= Control (no clipping), L_1 =Lower 1st and 2nd leaves clipping, L_2 =Lower 2nd and 3rd leaves clipping, L_3=Lower 3rd and 4th leaves clipping, L_4 = Flag leaf clipping. The experiment was laid out in split plot design with three replications. Results revealed that seedling and leaf clipping either individually or combined showed significant variations in most of the characteristics of Binadhan-13. In case of seedling clipping, the effective tillers hill^{-1} (12.80), panicle length (25.38 cm), filled grains panicle^{-1} (87.75), total grains panicle^{-1} (106.72), 1000-grains weight (14.05 g), grain yield (3.29 t ha^{-1}), straw yield (7.55 t ha^{-1}), biological yield (10.84 t ha^{-1}) and harvest index (30.34 %) were observed in S_2 (1/2nd seedling top clipping) treatment. In case of leaf clipping, the maximum effective tillers hill^{-1} (12.98), panicle length (25.36 cm), filled grains panicle^{-1} (92.47), total grains panicle^{-1} (106.63), 1000-grains weight (14.43 g), grain yield (3.46 t ha^{-1}), straw yield (7.72 t ha^{-1}), biological yield (11.18 t ha^{-1}) and harvest index (30.89 %) were observed in L_0 (no leaf clipping) treatment. In case of combined effect, the maximum effective tillers hill^{-1} (14.30), panicle length (26.35 cm), filled grains panicle^{-1} (100.80), total grains panicle^{-1} (113.01), 1000-grains weight (14.69 g), grain yield (3.73 t ha^{-1}), biological yield (11.43 t ha^{-1}) and harvest index (32.59 %) were observed in S_2L_0 treatment combination. Based on the findings it was concluded that treatment combination of 1/2nd seedling top clipping (S_2) along with no leaf clipping (L_0) has positive influence on Binadhan-13 to have maximum yield attributes of grain yield.

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LIST OF ACRONYMS

%	Percentage
AEZ	Agro-Ecological Zone
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
BRRI	Bangladesh Rice Research Institute
cm	Centimeter
CV%	Percentage of coefficient of variance
cv.	Cultivar
DAE	Department of Agricultural Extension
DAT	Days after transplanting
^{0}C	Degree Celsius
et al.	And others
FAO	Food and Agriculture Organization
g	Gram(s)
ha^{-1}	Per hectare
hr	Hour(s)
HI	Harvest Index
kg	Kilogram
LSD	Least Significant Difference
Max	Maximum
mg	Milligram
Min	Minimum
MoP	Muriate of Potash
N	Nitrogen
No.	Number
NS	Not significant
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources and Development Institute
t	Ton
TSP	Triple Super Phosphate
viz.	Namely

CHAPTER I
INTRODUCTION

Rice (*Oryza sativa* L.) is the most vital cereal crop in tropical and subtropical countries which belongs to the family Poaceae (Singh *et al.,* 2012). It is the principal source of nutrition for more than half of the world's population and is grown in over a hundred countries throughout the world (Jahan *et al.,* 2017). In 2014-15, 159.64 million hectares of land produced a total of 474.86 million metric tons rice (USDA, 2015). Globally, rice provides 27% of nutritional energy and 20% nutritional protein (Kueneman, 2006) and it provides 20-80% nutritional energy and near about 12-17% of nutritional protein for Asians (FAOSTAT, 2017). Rice is the most broadly grown cereal crop in Bangladesh. For the people of our country, in their normal daily diet, rice delivers around 75% of the calories and 55% of the protein (Bhuiyan *et al.,* 2002). Bangladesh is ranked fourth not only in area but also in production of rice, as well as sixth in per hectare production (Sarkar *et al.,* 2016). Bangladesh produces 36.28 million tons of rice per year on 11.52 million hectares of land (BBS, 2018).

World food security has been threatened by rising food consumption, with estimates that by 2035, nearly 114 million tons of more rice will be needed, representing a 26 percent increase over the upcoming 25 years (Kumar and Ladha, 2011). Population expansion in Bangladesh requires a nonstop enhancement in rice production and for that reason, this has been given the highest priority (Bhuiyan, 2004). Rice is the main crop in Bangladesh and so its overall production needs to be amplified to achieve the food necessity of an over populated country.

Rice is commonly grown in Bangladesh throughout three seasons of Aus, Aman, and Boro, covering around 80% of the country's total cultivable land (AIS, 2011). More than half of the entire production (55.50%) is achieved in Boro season arising in December-May, the second greatest production (37.90%) in the Aman season arising in July-November, and only a small contribution (6.60%) from the Aus season arising in April-June (APCAS, 2016). Aman is the second most important rice growing season in Bangladesh. There are two types of transplanted Aman rice: coarse and fine rice, including some fine rice varieties being aromatic.

Agriculture of Bangladesh is dominated by the rice farming, and aromatic rice has a great choice among customers. The delightful aroma of this rice when cooked is the most unique feature of it. The most significant qualitative characteristics of rice grain is its aroma, and it is responsible for the product's high market value. 2-acetyl-1-pyrroline was recognized as the biochemical basis of aroma (Tanchotikul and Hsieh, 1991). Aromatic rice farming in Bangladesh is lucrative, demanding a higher price than coarse milled rice because of its fragrant nature (Raju and Reddy, 2000; Sikdar *et al.*, 2008). Basmati, Badshabhog, Kataribhog, Chinisagara, Dulabhog, Kalizira, Tulsimala, Banglamoti (BRRI dhan50), BRRI dhan34, BRRI dhan37 and BRRI dhan38 are the most common fragrant rice varieties in Bangladesh (Sarkar *et al.*, 2014). Maximum scented rice varieties have low yields, but their higher price and lower cultivation costs result in better profit margins than other kinds of varieties (Biswas *et al.*, 2016).

The majority of the farmers grow BRRI released varieties and local cultivars, with a few cultivating Bangladesh Institute of Nuclear Agriculture (BINA) released varieties. Aman rice cultivation covers a total of 28,225 hectares in a year, in which BRRI released varieties covering 22,700 hectares, local varieties covering 5,414 hectares, and BINA released varieties covering 111 hectares. BRRI, BINA, and local varieties produce rice in an average of 4.07, 4.04, and 2.58 t ha^{-1}, respectively (DAE, 2016).

Traditional rice cultivars in Bangladesh have a lower yield, and under the current condition, it is impossible to modify this yield with available resources. A lack of high yielding cultivars, weed infestation, deficiency of knowledge and a lack of effective agronomic management procedures, and other factors have contributed to reduced fragrant rice yields. In Bangladesh, the majority of scented rice varieties planted during the Aman season are traditional and photoperiod sensitive varieties (Chowdhury *et al.*, 2017).

According to IRRI (1993), to increase the yield of rice, we need to follow two processes: firstly, the cultivation of modern varieties, and secondly, advanced management approaches. Bangladesh needs to produce modern rice varieties in order to meet its rice requirement. As a result, we need to take effort to enhance yield per unit area through the use of modern rice cultivars, enhanced technology, and agronomic management approaches (such as clipping, irrigation, spacing, weed control, insect and pest managements etc.).

Such an improved variety is Binadhan-13 released by BINA which is a fine grain sweet smelled rice variety suitable for cultivation in Bangladesh during the transplanting

Aman season. It was developed by the use of gamma radiation and Datura extract from the local fine grain fragrant rice variety Kalizira (Islam *et al.*, 2018). At the same time, a modern technique such as leaf clipping can be applied to observe how it affects aromatic rice yield. Clipping can be done by two ways. One is done at the time of transplanting of seedling that is known as seedling top clipping. Another can be done at the time before panicle initiation which is known as leaf clipping.

The fundamental organ of photosynthesis that has been recognized as a critical factor, as well as having better photosynthetic capacity is named as plant leaf (Asana, 1968). In Rice, leaves are enormously vital organs for photosynthesis, which is a key factor in influencing crop growth rates. Photosynthesis is influenced by leaf area or leaf numbers and as a result, the efficiency of a plant depends on the growth of leaves (Karadogan and Akgun, 2009).

Seedling top clipping had a better establishment, recover from transplanting shock sooner than non-clipped leaves (Georgias *et al.*, 1989). When seedlings are transplanted into soil with limited or no standing water, decreased leaf area can make them less susceptible to desiccation. Clipping of rice seedling decreases the number of seedlings hill^{-1} which eventually helps in vigor seedling production hill^{-1}. Seedlings with energetic growth pattern can compete effectively under stress, influencing stand establishment and finally increasing grain yield by enhancing effective tillers hill^{-1}, filled grains panicle^{-1}, panicle length etc. But extreme clipping, on the other hand, might have undesirable effects on grain yield production. Seedling top clipping could be detrimental too because it reduces the availability of nutrients and carbohydrates for the plants to re-establish themselves after transplantation (Ashraf and Zia, 1980).

Rice leaf clipping is a farmer's perception for a variety of reasons, including weed control, ease of pest management, uniform plant height, promoting all plants to bloom at the same time and also suitable for harvesting purpose. Leaf clipping in transplanted seedling may have preference to shift assimilate towards root zone for quick establishment of seedling and enhance growth of the plant (Paez *et. al.*, 1995). Leaf clipping practiced in transplanted Aman rice can lessen the transplanting shock (Bardhan and Mandal, 1988). Leaf clipping during reproductive and ripening stages is directly connected to biomass production and grain yield of rice crop (Ray *et al.*, 1983).

The top three leaves have the most involvement in the purpose of grain yield (Yoshida, 1981; Misra, 1987). The top three leaves have a great influence as they help in assimilating maximum carbon for grain filling and also afford remobilized nitrogen for enhancing grain development (Misra and Misra, 1991; Mae, 1997). On the contrary, leaf clipping can be harmful because it reduces the availability of assimilate during grain filling (Echarte *et al.*, 2006).

Flag leaf, the topmost leaf which is located below the panicle, predominantly acts as the most significant source of photosynthetic energy during reproduction (Evans and Rawson, 1970). It is credited with playing a key role in the supply of photosynthates to the grains (Asana, 1968), for grain yield (Sheela *et al.*, 1990; Raj and Tripathi, 2000) and for increasing productivity (Padmaja, 1991). Flag leaf contributes up to 45 percent to rice grain yield, thus if it is removed, it becomes the primary cause of rice yield loss (Abou-Khalifa *et al.*, 2008). The foremost cause of considerable grain yield reduction was the clipping of the flag leaf from rice at any stage after the emergence of the panicle (Singh and Ghosh, 1981).

By considering the importance of leaves for the enhancement of grain yield, it is essential to investigate the morphological and the physiological features of functional leaves in order to develop rice grain yield (Yue *et al.*, 2006). So, this research was carried out to find out the efficacy of seedling and leaf clipping on the performance of modern aromatic rice variety, Binadhan-13. Under these circumstances, the current experiment was conducted to acquire the following objectives:

1) To study the effect of seedling top clipping on reducing transplanting shock.

2) To evaluate the optimum leaf clipping for higher yield.

3) To determine the combined effect of seedling and leaf clipping on the production and yield of aromatic rice.

CHAPTER II

REVIEW OF LITERATURE

Rice is the most widely cultivated cereal crop in Bangladesh. Aromatic rice contributes a small portion but a significant subgroup of rice production. Because of its flavor, deliciousness and premium price, fragrant rice has been introduced to the international market as a demandable product in current years. The yield of fine rice is lesser than coarse and medium rice cultivars. To overcome this situation, enhancement of aromatic rice production through intensive care, management and adoption of new technologies are essential. Seedling and leaf clipping practice on either at seedling stage or after seedling transplanting stage can impact on growth stages and yield attributes of rice. In this chapter, some of the most important and instructive works and research outcomes so far been done on the efficacy of seedling and leaf clipping on the growth and yield of rice have been discussed and presented under the following headings:

2.1 Seedling and leaf clipping on growth parameters

Plant height

Medhi *et al.* (2015) set up a field trial to see how foliage pruning affected the growth and yield of two land rice cultivars, TTB-303-1-42 (Dhansiri) and TTB-303-1-23 (Difalu), in a rain-fed low land condition (50-100 cm water profundity) during the wet season. According to the test data, multiple times expulsion of foliage considerably lowered plant height and prevented lodging.

Sherif *et al.* (2015) conducted an experiment that comprised of six levels of defoliation *viz.* 0, 20, 40, 60, 80 and 100% which were applied after one month of transplanting. The experiment revealed that the rice plants in the check (non-defoliated) plots grew in the first and second seasons 92.60 and 91.55 cm, respectively which were nearly taller than the defoliated plots. When leaves were defoliated at 20 or 40% in the first season, and at 20, 40, or 60% in the second season, resulted in somewhat shorter rice plants, ranging between 91.80-92.64 cm and 89.50-90.65 cm, respectively, but compared to the check, there was no significant dissimilarities. Again, when 60, 80, or 100% of the leaves were defoliated in the first season, the plant heights ranged from 90.00 to 90.50 cm, and when 80 or 100% of the leaves were defoliated in the second season, the plant heights ranged from 87.00 to 87.05 cm.

Ayutthaya (2011) concluded that rice leaf clipping length of 30 cm was recommended at 30-60 days after planting and prior to flowering. It is assumed to cut it on various occasions, but the flag leaf should not be clipped. Rice leaf clipping at 60 days after planting just one time had influence on plant height and identical flowering.

Karmaker and Karmakar (2019) observed that the C_0 (No leaf clipping) had the highest plant height (128.95 cm) whereas C_3 (leaf clipping time at 55 DAT) had the lowest plant height (116.83 cm). According to the findings, plant height was also considerably reduced in later leaf cut treatments compared to no and early clippings.

Total dry matter weight

Ros *et al.* (2003) reported that 30% defoliation of the leaves reduced root and shoot dry matter content by 30% at the time of panicle initiation, and reduced 20% of root dry matter content at the stage of maturity. On shoot, root, and straw dry matter, the united effects of leaf defoliation as well as root pruning were essentially additive. Rice yield response to nursery treatments was largely attributable to enhanced seedling vigor, which could be influenced by a variety of nutritional and non-nutritional seedling treatments that enhance seedling dry matter content. After seedling transplanting, leaf defoliation and a less amount of root pruning reduced seedling vigor. But when post-transplant development was not controlled by leaf defoliation, then seedling vigor was more advantageous.

Sherif *et al.* (2015) found that in the first season, by no leaf clipping or 20% clipping of rice leaves had the highest dry matter content, with levels of 1215.00 and 1103.60 gm^{-2}. In the second season, the comparable dry matter content were 1061.10 and 1164.94 gm^{-2}. In the first season, at 80 or 100% leaf clipping, the dry matter content reduced dramatically (938.15 and 765.00 gm^{-2}, respectively). Leaf clipping of 60, 80, or 100% revealed lesser dry matter content in the second season, with 866.11, 861.26, and 840.04 gm^{-2}, correspondingly.

2.2 Leaf clipping on yield contributing parameters

Effective tillers hill^{-1}

Medhi *et al.* (2015) revealed that the influence of leaf defoliation on the growth and yield of two low land rice varieties, TTB-303-1-42 (Dhansiri) and TTB-303-1-23 (Difalu), in a rainfed low land environment (50-100 cm water depth). Leaf defoliation up to 100 days after germination (DAG) had no negative impact on the crop's tillers, according to the findings.

Daliri *et al.* (2009) conducted a field experiment to see how time of cutting and the cutting height affected yield and yield constituents of the Tarom langrodi cultivar of ratoon rice (*Oryza sativa* L.). The influence of time of cutting on the quantity of effective tillers hill^{-1} was found to be statistically significant, according to the findings. Cutting height has a substantial impact on the quantity of tillers in the hill and the quantity of effective tillers hill^{-1}. There was a significant interaction between the time of cutting and the cutting height on the number of tillers hill^{-1} and the number of viable tillers hill^{-1}.

Fatima (2019) completed an experiment with different treatments that consisted of two factors. They are- Factor A: Flag leaf clipping: T_1 = Flag leaf clipping at heading and T_2 = Control (No leaf 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. According to the findings she found that irrespective of cultivars, the control treatment showed superiority in all attributes. Under control condition, Heera 4 had the highest number of effective tillers hill^{-1}.

Non-effective tillers hill^{-1}

Ahmed *et al.* (2001 a) investigated the impact of nitrogen rate and leaf clipping time on green fodder and rice seed yield. The test comprised of two factors, (A) Level of Nitrogen *viz.* N_1 = 50 kg N ha^{-1}, N_2 = 75 kg N ha^{-1} and N_3 = 100 kg N ha^{-1}, (B) Leaf clipping time *viz.* C_0 = No clipping (control), C_1 = Clipping at 21 DAT, C_2 = Clipping at 35 DAT and C_3 = Clipping at 49 DAT. The treatment of no leaf clipping got the maximum number of non-bearing turners hill^{-1}, which was actually like leaf clipping at 21 DAT, while the treatment of leaf clipping at 49 DAT got the lowest number.

Panicle length

Rahman *et al*. (2013) reported that when the flag leaf length is high, the panicle length is also high as a result of their experiment. With the variety BR11, they observed that when the average flag leaf length was 21.33, 25.90, 28.19, 37.33, 18.28, 37.84, 37.59, 25.90, 24.13, 35.50 cm, the average panicle length was 18.03, 18.54, 20.32, 34.98, 17.52, 33.87, 33.36, 19.85, 22.60, 31.65 cm, respectively and a significant correlation was established between them in correlation analysis. In the case of BR28, a similar significant finding was reported. Panicle length was found to be significantly and positively related with yield. They also discovered that the length of the flag leaf was positively related with the length of the panicle, also with grain yield.

Das *et al.* (2017) stated that leaf defoliation had no impact on panicle length of modern cultivars and in local cultivars of rice.

Boonreund and Marsom (2015) investigated the influence of leaf clipping length of Pathum Thani1 rice variety. The research used 7 clipping lengths (0, 5, 10, 15, 20, 25 and 30 cm from the leaf tip) that were applied using a sickle after 60 days of planting. According to the findings, clipping of leaves had no significant impact on the length of rice panicles**.**

Grains panicle^{-1}

Hossain (2017) directed a field trial where two factors were used; Factor A: five rice cultivars, 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 clipping, T_1 = Leaf clipping (aside from flag and penultimate leaves), T_2 = Control (no leaf clipping). Irrespective of all the cultivars studied, no leaf clipping (control) treatment yielded the maximum grains panicle^{-1} (105.63) than leaf clipping treatment (94.73 grains panicle^{-1}).

Karmaker and Karmakar (2019) stated that the maximum mean number of grains panicle^{-1} (118) was observed in C_0 (no leaf cutting) and the minimum number of grains panicle^{-1} (106) was observed in C_3 when the leaf cutting was done at 55 DAT in BRRI dhan41. They observed that the removal of forage at later stages of crop growth decreased photosynthetic leaf area, causing a negative effect on carbohydrate accumulation which in turn influenced the production of grains panicle^{-1}.

Filled grains panicle^{-1}

Ahmed *et al.* (2001 a) reported that the maximum number of sterile spikelets panicle^{-1} of rice was determined to be with the treatment of no leaf clipping; which was statistically identical to clipping at 21 DAT. The treatment of clipping at 49 DAT had the lowest value for the number of sterile spikelets panicle^{-1}.

Das *et al.* (2017) stated that the maximum number of filled grain panicle^{-1} in the rice variety Binadhan-8 was recorded with the treatment of no leaf clipping (104.00) which did not differ substantially from 2nd and 3rd leaf clipping. Flag leaf clipping (35.14 %), flag leaf with 2nd leaf clipping (62.62 %), and flag leaf with 2nd and 3rd leaf clipping (51.83 %) all result in significant decrease in filled grains panicle^{-1}.

Usman *et al*. (2007) observed the impacts of leaf defoliation on rice forage and grain yield. Control (T_1, no defoliation), defoliation at 22 DAT (T_2), defoliation at 29 DAT (T_3), defoliation at 36 DAT (T_4), defoliation at 43 DAT (T_5) and defoliation at 50 DAT (T_6) were the six treatments applied in the trial. The control (no defoliation) treatment had the largest number of spikelets panicle^{-1} (106.8) and filled grains panicle^{-1} (90) among all the six treatments.

Unfilled grains panicle^{-1}

Das *et al.* (2017) stated that the number of unfilled grains panicle^{-1} in Binadhan-8 enhanced with the increased leaf clipping intensity and the maximum number of unfilled grains panicle^{-1} was recorded with the treatment flag leaf with 3rd leaf clipping (79.40), which was identical with flag leaf with 2nd leaf clipping (65.91). The control treatment showed the minimum unfilled grains panicle^{-1} (33.99) which did not differ with 3rd leaf clipping only (39.57). The values of the flag leaf clipping and the second leaf clipping were equivalent and moderate.

Moballeghi *et al.* (2018) observed the impact of source-sink constraints on agronomic attributes and grain yield of several rice lines. The trial comprised of 2 factors: (A) Source-sink limitation in four levels (including defoliation of flag leaf, defoliation of one third the end of panicle, defoliation of other leaves except flag leaf and control or without defoliation) and (B) Lines of rice in four levels (line of No. 3, line of No. 6, line of No. 7 and line of No. 8). From the findings they observed that when all leaves except the flag leaf were defoliated, then panicle length and unfilled grains number panicle^{-1} were enhanced and panicle fertility percentage was reduced.

Total grains panicle^{-1}

Aktar-uz-zaman (2006) reported that the cutting of the flag leaf resulted in a 17.34% decrease in the number of spikelets panicle^{-1} in rain fed varieties of rice. Similarly, the removal of the penultimate leaf reduced the number of spikelets panicle^{-1} by 10.98%, removal of the third leaf reduced the number of spikelets panicle^{-1} by 7.20 %. However, flag leaf clipping, penultimate leaf clipping, and third leaf clipping one at a time, resulted in a loss of nearly 29.20 % in spikelets panicle^{-1}.

Usman *et al.* (2007) observed the impacts of leaf defoliation on rice forage and grain yield. Control (T_1, no defoliation), defoliation at 22 DAT (T_2), defoliation at 29 DAT (T_3), defoliation at 36 DAT (T_4), defoliation at 43 DAT (T_5) and defoliation at 50 DAT (T_6) were the six treatments applied in the trial. The control (no defoliation) treatment had the largest number of spikelets panicle^{-1} (106.8) and filled grains panicle^{-1} (90) among all the six treatments.

1000-grains weight

Sherif *et al.* (2015) found that clipping at 0, 20, 40, or 60% resulted in statistically identical values of 1000-grains weights, ranging between 21.87 and 23.18 g in the first season and between 27.47 and 29.21 g in the second season. In the first and second seasons, the least 1000-grains values were recorded at 80% (20.73 and 26.67 g) and 100% (20.28 and 24.71 g), respectively.

Hossain (2017) reported that irrespective of all the cultivars he studied, no leaf clipping (control) treatment yielded the maximum 1000-grains weight. Leaf clipping treatments reduced yield and yield contributing parameters when compared to the no leaf clipping (control) treatment. The weight of 1000-grains was considerably lower in plants with various leaf clipping treatments compared to plants with no leaf clipping (control) treatment.

Fatima (2019) led an experiment with different treatments that consisted of two factors. They are- Factor A: Flag leaf clipping: T_1 = Flag leaf clipping at heading and T_2 = Control (No leaf 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. According to the findings she found that irrespective of cultivars, the superiority of the analyzed attributes were found to be in the control treatment. Under control condition, Heera 4 had the highest weight of 1000 grains with no leaf clipping (control) treatment.

Das *et al.* (2017) observed that leaf defoliation had no significant influence on 1000 grains weight in modern varieties, but it had significant influence on 1000-grains weight in local varieties.

2.3 Leaf clipping on yield parameters

Grain yield

Hossain (2017) observed that regardless of the cultivars studied, the maximum grain yield was achieved with no leaf clipping (control). Leaf clipping reduced yield and yield contributing features when compared to the control. BRRI dhan33 yielded significantly more in control than other treatments (in control 6.75 t ha^{-1}, in leaf clipping treatment 4.75 t ha^{-1}). The highest grain yield (6.75 t ha^{-1}) was achieved with no leaf clipping. Leaf clipping (except flag leaf and the penultimate leaves) reduced grain yield loss by 10 to 28%. As a result of leaf clipping, there was a significant difference in grain filling time among different cultivars. With leaf clipping treatment, grain yield was reduced by 10% in BRRI dhan39 (in control 5.75 t ha^{-1}, in leaf clipping treatment 5.15 t ha^{-1}) which was the minimum reduction compared to the other varieties.

Karmaker and Karmakar (2019) conducted an experiment which comprised two factors. They are- factor A: Four nitrogen (N) rates (N_1 = 46, N_2 = 69, N_3 = 92 and N_4 = 115 kg N ha^{-1}) and factor B: four times of leaf clipping *viz.* C_0 = no leaf clipping, C_1 = leaf clipping at 25 DAT (Days after transplanting), C_2 = 40 DAT and C_3 = 55 DAT were assessed following split-plot design with three replications. They discovered that the treatment combination of 115 kg N ha^{-1} and no leaf clipping (N_4C_0) produced the highest mean grain yield (5.25 t ha^{-1}) when compared to other treatments.

Fatima (2019) observed the chlorophyll content (SPAD value) in penultimate leaf 15 days after heading, grain filling duration, yield contributing characters and yield after cutting of flag leaf. Regardless of all cultivars, all of the analyzed characters showed that the control treatment was superior. The treatment of cutting of flag leaf enhanced the value of chlorophyll and nitrogen content (SPAD value) in penultimate leaf (1.35% to 17.27%) and grain filling duration (4.5 to 6.25 days). Under control condition, Heera-4 cultivar produced the highest grain yield. In Boro rice cultivars, the cutting of the flag leaf reduced grain yield from 15.69% to 29.43%.

Abou-Khalifa *et al.* (2008) stated that the flag leaf contributed to 45% of grain yield and exclusion of flag leaf is the single most component for yield loss.

Ros *et al.* (2003) found that the removing 30% of leaves reduced grain yield by 20%.

Boonreund and Marsom (2015) observed that the length of rice leaf cutting had a good impact on Thai jasmine rice yield, but this was not confirmed in other varieties. The study used seven different cutting lengths (0, 5, 10, 15, 20, 25, and 30 cm from the leaf tip), all of which were done by sickle 60 days after planting. Cutting leaves had no significant effect on yield, according to the findings. After cutting, grain yield increased considerably. The best length of rice leaf cutting was 15-30 cm, which produced the most grain yield.

Khatun *et al.* (2011) conducted an experiment to see how leaf cutting affected rice growth and yield, and found that the flag leaf cutting treatment provided the lowest grain yield.

Prakash *et al.* (2011) found a positive relationship between grain yield and flag leaf area in rice varieties.

Straw yield

Ahmed *et al.* (2001 b) stated that among the varieties and the different leaf clipping treatments, the Latishail variety with 35 DAT leaf clipping produced the highest forage yield. The highest straw yield (5.60 t ha^{-1}) was found in control. Leaf clipping reduced yield and yield contributing parameters when compared to control. When the leaf was cut at 35 DAT, the lowest value for all crop characters was noticed. Leaf clipping at an early stage of crop growth (28 DAT for studied modern varieties and 35 DAT for Latishail) could generate grain or seed yields that were nearly similar to control condition, with the additional forage yield.

Hossain (2017) directed a field trial where two factors were used; Factor A: five rice cultivars, 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 clipping, T_1 = Leaf clipping (aside from flag and penultimate leaves), T2 = Control (no leaf clipping). Regardless of all the cultivars studied, no leaf clipping (control) treatment produced the maximum straw yield than leaf clipping treatment.

Biological yield

Usman *et al.* (2007) observed the impacts of leaf defoliation on rice forage and grain yield. Control (T_1, no defoliation), defoliation at 22 DAT (T_2), defoliation at 29 DAT (T_3), defoliation at 36 DAT (T_4), defoliation at 43 DAT (T_5) and defoliation at 50 DAT (T_6) were the six treatments applied in the trial. The control (no defoliation) treatment had the highest biological yield (9.6 t ha^{-1}) among all the six treatments.

Fatima (2019) led an experiment with different treatments that consisted of two factors. They are- Factor A: Flag leaf clipping: T_1 = Flag leaf clipping at heading and T_2 = Control (No leaf 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. According to the findings she found that Heera 4 had the highest biological yield with no leaf clipping (control) treatment.

Harvest index

Karmaker and Karmakar (2019) reported from their experiment that the treatment combination of 115 kg N ha^{-1} and no leaf clipping (N_4C_0) produced the highest mean harvest index (46%) compared to other treatment combinations.

Usman *et al.* (2007) observed the impacts of leaf defoliation on rice forage and grain yield. Control (T_1, no defoliation), defoliation at 22 DAT (T_2), defoliation at 29 DAT (T_3), defoliation at 36 DAT (T_4), defoliation at 43 DAT (T_5) and defoliation at 50 DAT (T_6) were the six treatments applied in the trial. The control (no defoliation) treatment had the highest harvest index (42.70%) among all the six treatments.

On basis of the above reviews, it is cleared that seedling and leaf clipping has significant effect on the growth and yield of Binadhan-13. Therefore, it may have enough scope studying the clipping management in favor of growth and yield improvement of the aromatic rice Binadhan-13.

CHAPTER III
MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the period from 1 July to 12 December, 2019. The site of the experiment, climatic condition, soil condition, planting materials, fertilizer application, experimental design and layout, treatments, crop growing techniques, intercultural operations, procedures of data collection and statistical analysis all are covered in this chapter.

3.1 Experimental site

The experimental site is geographically located at an altitude of 8.6 meter above sea level and at 23°77′ N latitude and 90°33′ E longitude (Anon., 2004). The experimental field is part of the Agro-ecological zone, AEZ-28 named as “The Modhupur Tract” (Anon., 1988 a). The research site has been displayed in the Map of AEZ of Bangladesh in Appendix-I for a complete overview.

3.2 Climate

The experimental area was subjected to a subtropical climate with three different seasons: firstly, winter season which occurs during November to February, secondly pre-monsoon period or hot season which occurs during March to April and finally monsoon period which occurs during May to October. The Weather Station of Bangladesh, Sher-e-Bangla Nagar, Dhaka, recorded detailed meteorological data in respect of maximum and minimum temperature, total rainfall and relative humidity, which are reported in Appendix II.

3.3 Soil

Soil of the research site was of general soil type. The texture of the soil was of silty clay loam which is the part of Tejgaon series (Anon., 1988 a). The location lies in the Madhupur tract's Agro-Ecological Zone (AEZ No. 28) and has a pH of 5.8–6.5 (Anon., 1988 b). For understanding soil characteristics, a soil sample was collected from the experimental field ranging in depth from 0 to 15 cm of the soil. The soil sample was evaluated at the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka, and is displayed on Appendix III.

3.4 Planting materials

In this study, Binadhan-13 (*Oryza sativa* L.) was used as the planting material. This rice variety was collected from Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, Bangladesh.

3.5 Description of the planting materials

Binadhan-13 has been released by Bangladesh Institute of Nuclear Agriculture (BINA). It is an aromatic rice cultivar with fine grains that is best suited for cultivation in Bangladesh in transplanting Aman season. With the use of gamma radiation and Datura extract, it was produced from the local fine grain fragrant rice variety Kalizira (Islam *et al.*, 2018).

Binadhan-13 has the following major features:

• The leaves stay green throughout maturity.

• The variety is relatively resistant to lodging.

• Grains which are not filled are nearly absent.

• The yield of grain is 3.2-3.6 t ha^{-1}.

• The weight of 1000 grains is 13.2 g.

• The crop duration is 138-142 days.

3.6 Experimental schedule and details

Experimental duration: July to December, 2019 in transplanting Aman season.

Seedbed preparation date: 1st July, 2019

Seed sowing date: 1st July, 2019

Land preparation & fertilization date: 25 July, 2019

Layout preparation date: 26 July, 2019

Seedling clipping & transplanting date: 29 July, 2019

Leaf clipping date: 15 to 18 October, 2019

Harvesting Date: 3 December 2019

3.7 Seed sprouting

Seeds that were healthy and disease-free were selected following standard technique. Vitavax-200 was used to treat seeds at a dosage of 2.5 g kg^{-1} seeds. Seeds were submerged in water for 24 hr in a bucket. After that, they were taken out of the water and placed in gunny sacks. After 48 hr, the seeds began to sprout and were ready to sow in 72 hr.

3.8 Preparation of nursery bed and seed sowing

Puddling was used to set up the nursery bed, which was followed by ploughing and laddering. On 1 July 2019, the sprouted seeds were spread in the seed bed at a rate of 30 g m^{-2} area. The bed was delicately irrigated as and when it was needed.

3.9 Preparation of the main field

The experimental plot was opened on 25 July 2019 with a power tiller. Several ploughings followed by laddering were done to obtain a desirable, weed free and cultivable land.

3.10 Fertilizer application

For transplanting Aman rice cultivation, the following fertilizer doses were used recommended by BINA.

Fertilizers	Quantity (kg ha^{-1})
Urea	160
TSP	90
MoP	120
Gypsum	90
Zinc sulphate	5

All of the fertilizers except urea were applied as a basal dose during the final land preparation on 25 July, 2019. Urea was applied in three equal installments. The first dose of urea was given at 15 days after transplantation. The second dose of urea was added as top dressing at 30 DAT and the third dose was applied at 55 DAT as recommended by BINA.

3.11 Experimental design and layout

On 26 July 2019, the experiment was laid out in split-plot design with 3 replications. Each replication was divided into 15 sub plots where treatment combinations were assigned in each plot. There were 45-unit plots in total where the size of each unit plot was 2.4 m × 2.4 m. The blocks were separated by 1.0 m and the unit plots by 0.50 m, respectively. The configuration of the experimental field layout has been displayed on Appendix IV.

3.12 Treatments

The experiment was consisted of two factors as stated below:

Factor A: Seedling top clipping (3) *viz.*

S_0= Control (no clipping)

S_1 =1/3rd top clipping

S_2= 1/2nd top clipping

Factor B: Leaf clipping before panicle initiation (5) *viz.*

L_0= Control (no clipping)

L_1= Lower 1st and 2nd leaves clipping

L_2= Lower 2nd and 3rd leaves clipping

L_3= Lower 3rd and 4th leaves clipping

L_4= Flag leaf clipping

Seedling top clipping assigned in main plot and leaf clipping in sub plot.

3.13 Treatment combinations

The experiment was consisted of 15 treatment combinations as mentioned below:

S_0L_0 = No seedling top clipping × Control (no leaf clipping)

S_0L_1 = No seedling top clipping × Lower 1st and 2nd leaves clipping

S_0L_2 = No seedling top clipping × Lower 2nd and 3rd leaves clipping

S_0L_3 = No seedling top clipping × Lower 3rd and 4th leaves clipping

S_0L_4 = No seedling top clipping × Flag leaf clipping

S_1L_0 = 1/3rd top clipping × Control (no leaf clipping)

S_1L_1 = 1/3rd top clipping × Lower 1st and 2nd leaves clipping

S_1L_2 = 1/3rd top clipping × Lower 2nd and 3rd leaves clipping

S_1L_3 = 1/3rd top clipping × Lower 3rd and 4th leaves clipping

S_1L_4 = 1/3rd top clipping × Flag leaf clipping

S_2L_0 = 1/2nd top clipping × Control (no leaf clipping)

S_2L_1 = 1/2nd top clipping × Lower 1st and 2nd leaves clipping

S_2L_2 = 1/2nd top clipping × Lower 2nd and 3rd leaves clipping

S_2L_3 = 1/2nd top clipping × Lower 3rd and 4th leaves clipping

S_2L_4 = 1/2nd top clipping × Flag leaf clipping

3.14 Transplanting and seedling clipping

When the age of seedling was 29 days, then they were uprooted and clipping was done according to treatments to certain plots before transplanting. Then seedling were transplanted in the main field on 29 July 2019 maintaining row to row distance 25 cm and hill to hill distance 15 cm. Two seedlings were planted in each hill. Tag was given to each plot consisting certain treatments.

3.15 Intercultural operations

3.15.1 Gap filling

After one week of transplantation, died off seedlings in some hills were replaced by vigorous and healthy seedlings according to treatments.

3.15.2 Irrigation and drainage

There was sufficient rainfall in this season. To ensure sufficient water, irrigation was given through irrigation channel when required. In the flowering stages, irrigation was given properly. Drainage was also done when water was excess in the plot for excessive rainfall. Before harvesting, the field was dried out.

3.15.3 Weeding

Various weeds were grown on the plots. Hand weeding was done at 15 DAT, 30 DAT and 45 DAT.

3.15.4 Plant protection measures

To control the infestation of yellow stem borer, Diazinon 60 EC @ 850 ml ha^{-1} was applied 2 times at 20 DAT and 40 DAT during early growth stages. Actara 25 WG @ 60 g ha^{-1} was applied at 80 DAT to control the infestation of brown plant hopper. Rodenticide was used to control rats. During the grain filling period, crops were protected from birds by using net and covering the experimental area.

3.15.5 Leaf clipping

Leaf clipping was done according to the treatment requirement to the certain plots before panicle initiation on 15 to 18 October 2019.

3.16 Harvesting, threshing and drying

On 3 December 2019, the rice plant was harvested when the grains were fully mature. The maturity of grains was determined by observing bright black color of seeds which were firm but not brittle. Five pre-selected hills per plot were harvested first, from which various data were obtained previously. Then 1 m^2 area from middle portion of each plot was separately harvested. They were bundled and tagged before being brought to the threshing floor. Manual threshing was conducted. The grains were cleaned and sun dried to 12-14% moisture content. Straw was also properly dried in the sun.

3.17 Collection of data

The following parameters were observed to record data:

3.17.1 Crop growth characters

- Plant height (cm)
- Leaves hill^{-1} (no.)
- Leaf area hill^{-1} (cm^2)
- Tillers hill^{-1} (no.)
- Above ground dry matter weight (g)

3.17.2 Yield contributing characters

- Effective tillers hill^{-1} (no.)
- Non-effective tillers hill^{-1} (no.)
- Filled grains panicle^{-1} (no.)
- Unfilled grains panicle^{-1} (no.)
- Total grains panicle^{-1} (no.)
- 1000-grains weight (g)

3.17.3 Yield characters

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

3.18 Procedure of data collection

i) Plant height (cm)

The height of five randomly selected plants was determined by measuring the distance from the soil surface to the tip of the plant at 20, 40, 60, 80, 100 DAT and harvest respectively. Mean plant height of rice plant were calculated and expressed in cm.

ii) Leaves hill^{-1} (no.)

The number of leaves of five randomly selected hills from the inner rows per plot were measured at different stages of crop growth (20, 40, 60, 80, 100 DAT, respectively) by counting the number of leaves of the plant and the mean value of the number of leaves was calculated.

iii) Leaf area hill^{-1} (cm^2)

Leaf area was manually calculated by the procedure of counting the total number of leaves plant^{-1} and measuring the length and average width of leaf and multiplying by a correction factor of 0.75 (Yoshida, 1981). It was done at 20, 40, 60, 80 and 100 DAT, respectively.

$$\text{Leaf area hill}^{-1} = \frac{\text{Surface area of leaf sample (cm}^2\text{)} \times \text{No. of leaves hill}^{-1} \times \text{Correction factor}}{\text{No. of leaves sampled}}$$

iv) Tillers hill^{-1} (no.)

From pre-selected hills, the number of tillers hill^{-1} was counted at 20, 40, 60, 80, 100 DAT and harvest, respectively. Then the mean value was measured for each hill as the tiller number hill^{-1}. For counting, only tillers with three or more leaves were included.

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

Plants were collected from three hills of outer portion of each plot to measure total above ground dry matter weight hill^{-1}. It was recorded at 20, 40, 60, 80 and 100 DAT, respectively by drying plant sample. The sample plants were dried in oven for about 72 hours at 70°C. The value was then averaged.

vi) Panicle length (cm)

The length of each panicle was measured from basal node of the rachis to the apex of each panicle. Panicle length was measured using a meter scale from five selected panicles and then the mean value was measured.

vii) Effective tillers hill^{-1} (no.)

The number of panicle bearing tillers hill^{-1} was used to calculate the total number of effective tillers hill^{-1}. Data on effective tillers hill^{-1} were recorded from five randomly selected hill at harvesting time and then the mean value was measured.

viii) Non-effective tillers hill^{-1} (no.)

The tillers with no panicle on the head were counted as part of the measurement of the total number of non-effective tillers hill^{-1}. Data on non-effective tillers hill^{-1} were counted from five pre-selected (used in effective tiller count) hill at harvesting time and then the average value was measured.

ix) Filled grains panicle^{-1} (no.)

The total number of filled grains was randomly collected from the selected five plants in each plot, and then the mean value of filled grains panicle^{-1} was calculated.

x) Unfilled grains panicle^{-1} (no.)

The total number of unfilled grains was also collected randomly from the selected five plants of a plot based on, no or partially developed grain in spikelet and then the mean value of unfilled grains panicle^{-1} was measured.

xi) Total grains panicle^{-1} (no.)

The number of fertile grains panicle^{-1} alone with the number of sterile grains panicle^{-1} gave the total number of grains panicle^{-1}.

xii) 1000-grains weight (g)

A thousand cleaned dried seeds were counted at random from each sample and at the stage when the grains contained 12-14% moisture content, then they were weighed using a digital electric balance, and the mean value of weight was expressed in grams.

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

At 14% moisture, grain yield was adjusted. The grains from each unit plot were sun dried and carefully weighed. The dry weight of grains of central 1m^2 area was evaluated and then the final grain yield of each plot was recorded and then converted to t ha^{-1} in both locations.

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

After separating the grains, straw yield was counted from the central 1 m^2 area of each plot. After threshing the sub-samples were sun dried to a constant weight and finally converted to t ha^{-1}.

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

The biological yield was calculated as the sum of grain yield and above ground straw yield.

Biological yield = Grain yield + straw yield

xvi) Harvest index (%)

Harvest index was evaluated on dry weight basis with the help of following formula.

Harvest index (HI %) = $\frac{\text{Grain yield}}{\text{Biological yield}} \times 100$

Here, Biological yield = Grain yield + straw yield

3.19 Statistical analysis

All of the useful data collected from the first was assembled and evaluated statistically using the analysis of variance (ANOVA) method with the help of a data analysis software named Statistix 10, and the mean differences were adjusted using the Least Significant Difference (LSD) test at a probability level of 5% (Gomez and Gomez, 1984).

CHAPTER IV
RESULTS AND DISCUSSION

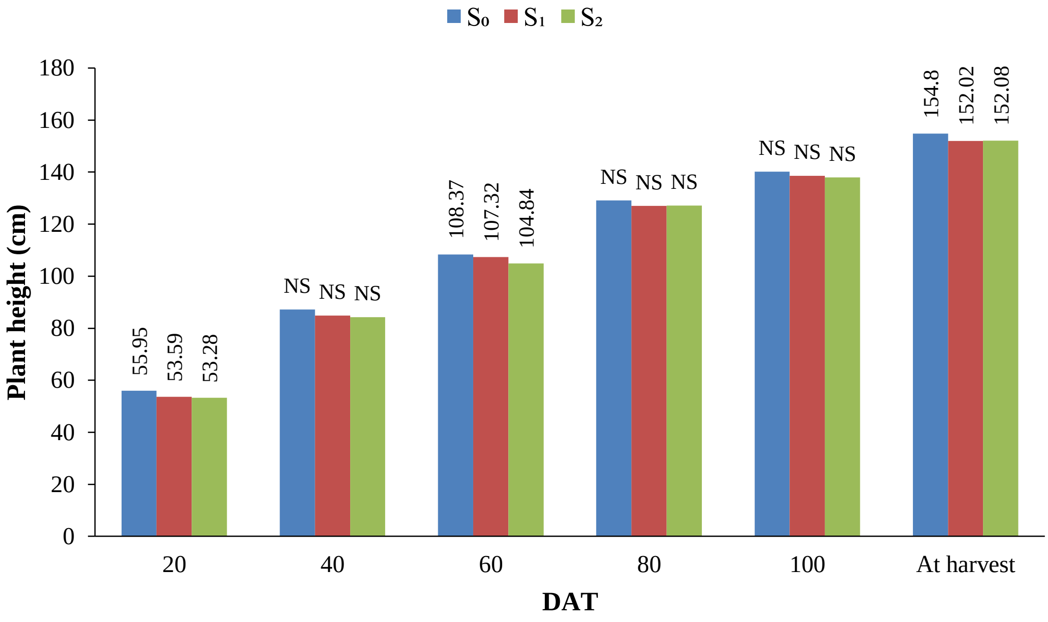
This chapter comprises presentation and discussion on the results obtained from the experiment. Data on various growth parameters, yield contributing characters and yield parameters of Binadhan-13 were recorded. The findings have been presented and deliberated by using related tables, graphs and possible clarifications are given under the following headings.

4.1 Growth parameters

4.1.1 Plant height (cm)

4.1.1.1 Seedling clipping

Plant height is a vital growth parameter. In terms of plant height, various treatments had variation at different growth stages (Fig. 1). From the experiment, result revealed that, plant height showed significant variation only at 20, 60 DAT and at harvest due to seedling clipping. The maximum plant height (55.95, 87.16, 108.37, 129.16, 140.21 and 154.80 cm at 20, 40, 60, 80, 100 DAT and harvest, respectively) was observed in S_0 treatment which was statistically identical with S_1 (107.32 cm) treatment at 60 DAT. Whereas the minimum plant height (53.28, 84.29 and 104.84 at 20, 40 and 60 DAT, respectively) was observed in S_2 treatment which was statistically identical with S_1 (53.59 cm) treatment at 20 DAT. At 80 DAT, the minimum plant height (127.07 cm) was observed in S_1 treatment. At 100 DAT, the minimum plant height (137.93) was observed in S_2 treatment. At harvest, the minimum plant height (152.02 cm) was observed in S_1 treatment which was statistically identical with S_2 (152.08 cm) treatment at harvest. It's possible that this is due to inherent characteristics of the variety that aren't greatly affected by cultural treatment, despite numerical changes that affect plant height. Confalonieri *et al.* (2011) identified plant height as a crucial component in predicting rice yield potential and developed a model to predict the growth in plant height.

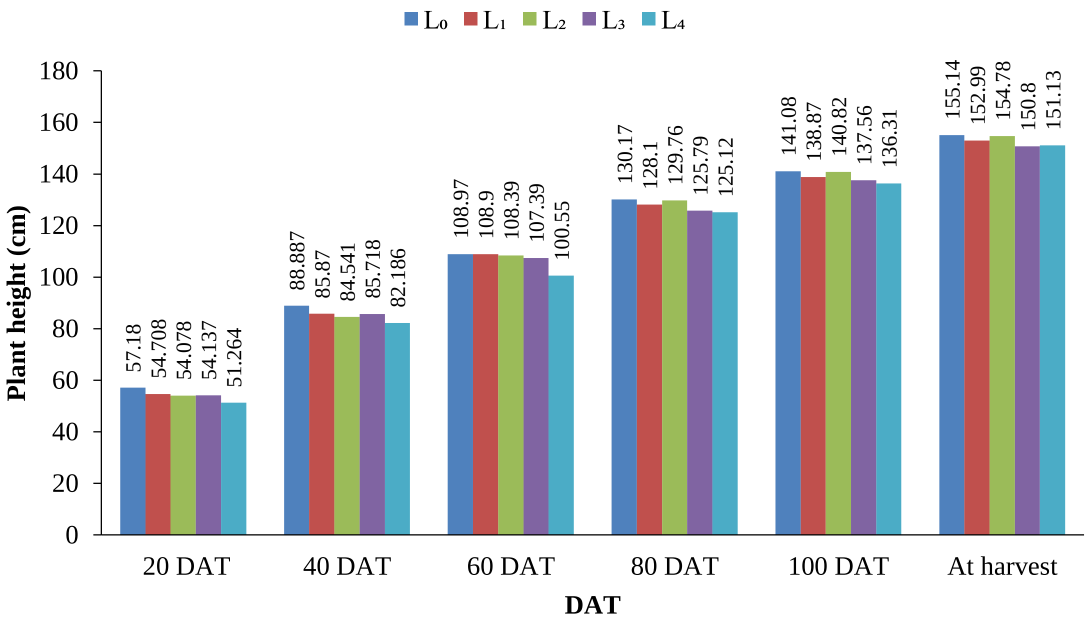


S_0= Control (no clipping), S_1=1/3rd top clipping and S_2= 1/2nd top clipping

Figure 1. Effect of seedling clipping on plant height of Binadhan-13 at different DAT ($LSD_{(0.05)}$= 0.61, NS, 2.47, NS, NS and 2.22 at 20, 40, 60, 80, 100 DAT and harvest, respectively).

4.1.1.2 Leaf clipping

Leaf clipping showed significant effect on plant height of Binadhan-13 (Fig. 2). From the experiment result revealed that the maximum plant height (57.180, 88.887, 108.97, 130.17, 141.08 and 155.14 cm at 20, 40, 60, 80, 100 DAT and harvest, respectively) was observed in L_0 treatment which was statistically identical with L_1 (108.90 cm) , L_2 (108.39 cm) and L_3 (107.39 cm) treatment at 60 DAT; with L_2 (129.76 cm) treatment at 80 DAT; with L_2 (140.82 cm) at 100 DAT and with L_1 (152.99 cm) and L_2 (154.78 cm) treatment at harvest respectively. Whereas the minimum plant height (51.264, 82.186, 100.55, 125.12 and 136.31 cm at 20, 40, 60, 80 and 100 DAT, respectively) was observed in L_4 treatment which was statistically identical with L_3 (125.79 cm) treatment at 80 DAT and with L_3 (137.56 cm) treatment at 100 DAT. At harvest, minimum plant height was observed in L_3 (150.80 cm) treatment which was statistically identical with L_4 (151.13 cm) treatment. Photosynthesis takes place in mesophyll cells, which are found in specialized organs like leaves. The rigid cell wall that encases photosynthetic cells regulates cell expansion and distribution within photosynthetic tissues. Leaf area influences the link between photosynthesis and plant growth. Clipping leaves lowers photosynthetic area, which affects photosynthesis and, as a consequence, has an influence on plant dry matter accumulation. As a result, plant height is reduced in clipped plants in comparison to non-clipped plants. The results of this study are consistent with those of Sherif *et al.* (2015); Karmaker and Karmakar (2019) and Medhi *et al.* (2015). According to Sherif *et al.* (2015), the plant heights varied from 90.00 to 90.50 cm when 60, 80 or 100% of the leaves were clipped in the first season (2013-14), and from 87.00 to 87.05 cm when 80 or 100% of the leaves were defoliated in the second season (2014-15). Karmaker and Karmakar (2019) stated that the maximum plant height (128.95 cm) was recorded at C_0 (No leaf clipping) and the minimum plant height (116.83 cm) was found in C_3 (leaf clipping time at 55 DAT). Medhi *et al.* (2015) also discovered that multiple times defoliation of leaves significantly reduced the plant height and prevented lodging.



L_0= Control (no clipping), L_1= Lower 1st and 2nd leaves, L_2= Lower 2nd and 3rd leaves, L_3= Lower 3rd and 4th leaves clipping and L_4= Flag leaf clipping

Figure 2. Effect of leaf clipping on plant height of Binadhan-13 at different DAT ($LSD_{(0.05)}$= 2.87, 1.66, 2.04, 1.83, 1.87 and 2.16 at 20, 40, 60, 80, 100 DAT and harvest, respectively).

4.1.1.3 Combined effect of seedling and leaf clipping

Binadhan-13 showed significant variation due to combined effect of seedling and leaf clipping (Table 1). From the experiment result revealed that the maximum plant height (59.59, 91.34 and 112.78 cm at 20, 40 and 60 DAT, respectively) was observed in S_0L_0 treatment combination which was statistically identical with S_1L_0 (57.17 cm) treatment combination at 20 DAT; with S_1L_0 (89.34 cm) treatment combination at 40 DAT; with S_1L_1 (111.48 cm), S_0L_2 (110.83 cm), S_1L_3 (109.74 cm) and S_1L_0 (108.88 cm) at 60 DAT, respectively. At 80 DAT, maximum plant height (133.90 cm) was observed in S_0L_2 treatment combination which was statistically identical with S_0L_0 (132.46 cm) and S_1L_0 (130.32 cm) treatment combinations. At 100 DAT, maximum plant height (144.91 cm) was observed in S_0L_2 treatment combination which was statistically identical with S_0L_0 (143.19 cm) and S_1L_0 (142.14 cm) treatment combinations. At harvest, maximum plant height (159.05 cm) was observed in S_0L_2 treatment combination which was statistically identical with S_0L_0 (157.42 cm) and S_1L_0 (155.33 cm) treatment combinations. While the minimum plant height (49.89 cm) was observed in S_2L_4 treatment combination which was statistically identical with S_1L_4 (50.03 cm) treatment combination at 20 DAT. At 40 DAT the minimum plant height (80.15 cm) was observed in S_1L_4 treatment combination which was statistically identical with S_2L_4 (80.27 cm) treatment combination. At 60 DAT the minimum plant height (98.59 cm) was observed in S_1L_4 treatment combination which was statistically identical with S_2L_4 (99.68 cm). At 80 DAT the minimum plant height (122.65 cm) was observed in S_0L_4 treatment combination which was statistically identical with S_1L_3 (123.60 cm) treatment combination. At 100 DAT the minimum plant height (133.43 cm) was observed in S_0L_4 treatment combination which was statistically identical with S_1L_3 (134.86 cm) treatment combination. Finally at harvest the minimum plant height (148.65 cm) was observed in S_1L_3 treatment combination which was statistically identical with S_2L_3 (149.91 cm) treatment combination. When seedlings were transplanted $hill^{-1}$, competition among seedlings for sun radiation was most likely the major cause of plant elongation. Clipping leaves lowers photosynthetic area, which affects photosynthesis and, as a consequence, has an influence on plant dry matter accumulation. As a result, plant height is reduced in comparison to non-clipped plants.

Table 1. Combined effect of seedling and leaf clipping on plant height of Binadhan-13 at different DAT

Treatment Combinations	Plant height (cm)					
	20 DAT	40 DAT	60 DAT	80 DAT	100 DAT	Harvest
S_0L_0	59.59 a	91.34 a	112.78 a	132.46 ab	143.19 ab	157.42 ab
S_0L_1	55.32 b-d	88.18 bc	108.29 b-e	127.96 c-e	138.73 c-e	152.91 c-e
S_0L_2	54.89 b-d	85.57 b-e	110.83 a-c	133.90 a	144.91 a	159.05 a
S_0L_3	56.07 bc	84.56 d-f	106.55 d-f	128.81 c-e	140.78 b-d	153.84 b-e
S_0L_4	53.88 cd	86.13 b-e	103.38 fg	122.65 g	133.43 f	150.79 d-f
S_1L_0	57.17 ab	89.34 ab	108.88 a-e	130.32 a-c	142.14 a-c	155.33 a-c
S_1L_1	54.28 cd	84.83 c-e	111.48 ab	128.91 b-d	139.90 b-d	153.80 b-e
S_1L_2	53.36 d	83.23 e-g	107.89 c-e	126.09 d-g	137.95 de	150.94 d-f
S_1L_3	53.14 d	86.85 b-d	109.74 a-d	123.60 fg	134.86 ef	148.65 f
S_1L_4	50.03 e	80.15 g	98.59 h	126.41 d-g	138.36 de	151.37 d-f
S_2L_0	54.77 b-d	85.98 b-e	105.26 ef	127.73 c-e	137.92 de	152.69 c-e
S_2L_1	54.53 cd	84.59 c-e	106.94 c-f	127.42 c-f	137.96 de	152.26 c-f
S_2L_2	53.98 cd	84.82 c-e	106.44 d-f	129.27 b-d	139.60 b-d	154.33 b-d
S_2L_3	53.20 d	85.75 b-e	105.88 d-f	124.95 e-g	137.04 d-f	149.91 ef
S_2L_4	49.89 e	80.27 fg	99.68 gh	126.30 d-g	137.14 d-f	151.24 d-f
$LSD_{(0.05)}$	2.87	3.13	3.53	3.17	3.24	3.74
CV(%)	3.13	2.17	1.96	1.47	1.38	1.45

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.

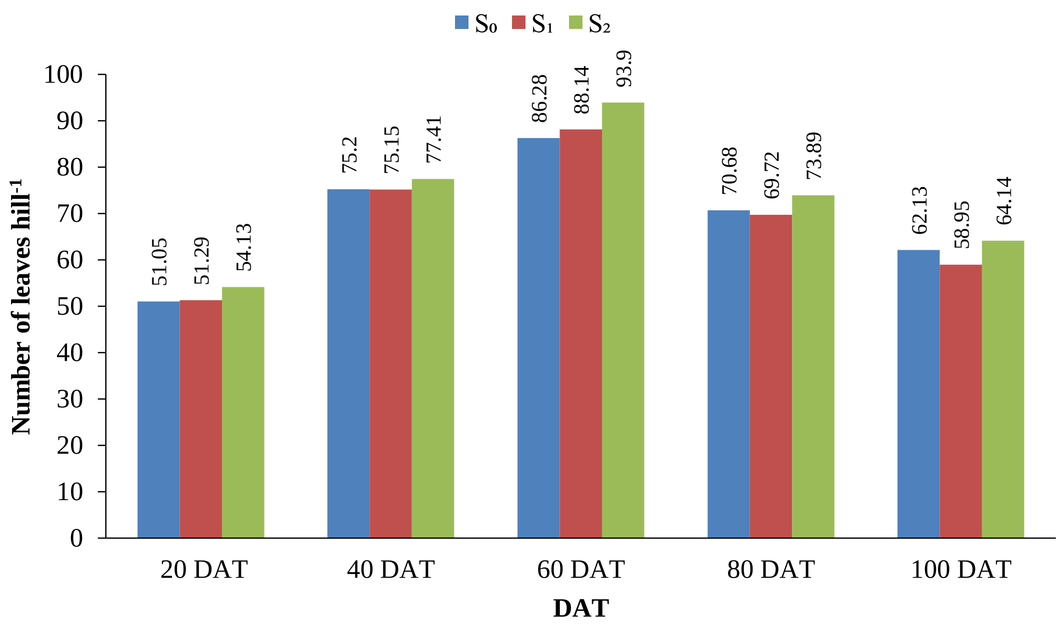
NS= Non-significant
S_0= Control (no clipping)
S_1=1/3rd top clipping
S_2= 1/2nd top clipping

L_0= Control (no clipping)
L_1= Lower 1st and 2nd leaves clipping
L_2= Lower 2nd and 3rd leaves clipping
L_3= Lower 3rd and 4th leaves clipping
L_4= Flag leaf clipping

4.1.2 Leaves hill^{-1} (no.)

4.1.2.1 Seedling clipping

A leaf is the source of photosynthesis which ensures the vitality of plant and also an essential part of above ground dry matter. Seedling clipping had significant effect on number of leaves hill^{-1} at various days after transplanting (Fig. 3). From the experiment result revealed that the maximum number of leaves hill^{-1} (54.13, 77.41, 93.90, 73.89 and 64.14 at 20, 40, 60, 80 and 100 DAT, respectively) was observed in S_2 treatment. On the contrary, the minimum number of leaves hill^{-1} (51.05) at 20 DAT was observed in S_0 treatment. At 40 DAT, the minimum number of leaves hill^{-1} (75.15) was observed in S_1 treatment. At 60 DAT, the minimum number of leaves hill^{-1} (86.28) was observed in S_0 treatment. At 80 and 100 DAT the minimum number of leaves hill^{-1} (69.72 and 55.26, respectively) was observed in S_1 treatment. The number of leaves on a plant is related with the tiller number of the plant. When tiller number is increased, the leaf number is also increased. This study also showed significant variation in number of leaves hill^{-1} due to seedling clipping. So, leaf number is a valuable growth parameter.

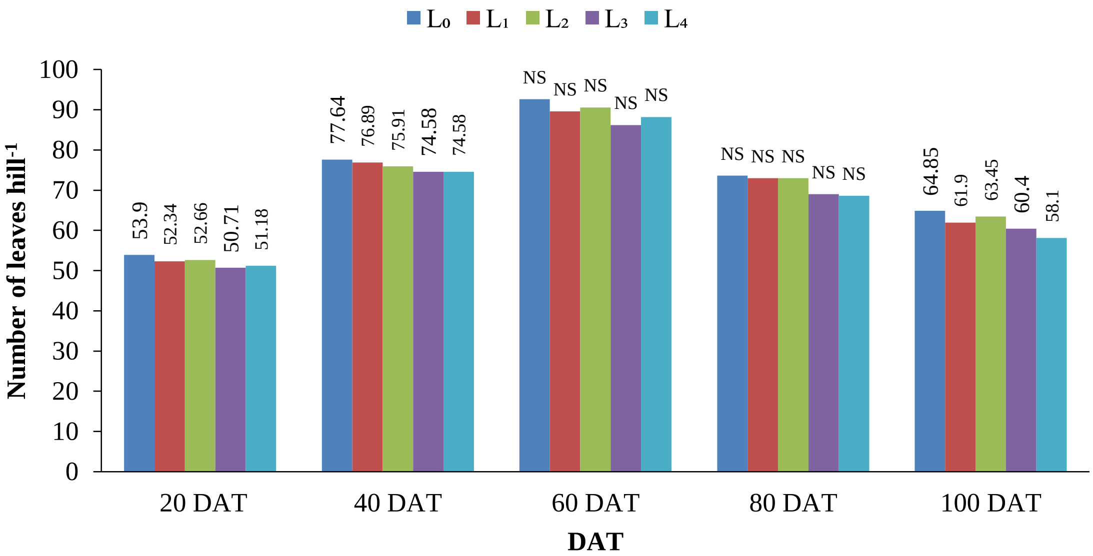


S_0= Control (no clipping), S_1=1/3rd top clipping and S_2= 1/2nd top clipping

Figure. 3. Effect of seedling clipping on number of leaves hill^{-1} of Binadhan-13 at different DAT ($LSD_{(0.05)}$= 0.84, 0.90, 6.79, 2.29 and 3.86 at 20, 40, 60, 80 and 100 DAT, respectively).

4.1.2.2 Leaf clipping

Leaf clipping showed significant effect on number of leaves hill^{-1} at 20 DAT, 40 DAT and 100 DAT (Fig. 4). From the experiment result revealed that the maximum number of leaves hill^{-1} (53.90, 77.64, 92.60, 73.60 and 64.85 at 20, 40, 60, 80 and 100 DAT, respectively) was observed in L_0 treatment which was statistically identical with L_2 (52.66) and L_1 (52.34) treatment at 20 DAT; with L_1 (76.89) and L_2 (75.91) treatment at 40 DAT and finally with L_2 (63.45) and L_1 (61.90) treatment at 100 DAT, respectively. While the minimum number of leaves hill^{-1} (50.71) was observed in L_3 treatment at 20 DAT which was statistically identical with L_4 (51.18) treatment. At 40 DAT, the minimum number of leaves hill^{-1} (74.58) was observed in L_4 treatment which was statistically identical with L_3 (74.58) treatment. Finally at 100 DAT, the minimum number of leaves hill^{-1} (58.10) was observed in L_4 treatment which was statistically identical with L_3 (60.40) treatment. Leaf clipping declines the relationship between source and sink, affecting the plant's growth and yield characteristics. This study also showed the similar criteria. As a consequence, number of leaves hill^{-1} was decreased due to various leaf clipping treatments compared to control treatment.



L_0= Control (no clipping), L_1= Lower 1st and 2nd leaves, L_2= Lower 2nd and 3rd leaves, L_3= Lower 3rd and 4th leaves clipping and L_4= Flag leaf clipping

Figure 4. Effect of leaf clipping on number of leaves hill^{-1} of Binadhan-13 at different DAT ($LSD_{(0.05)}$= 1.85, 1.89, NS, NS and 3.85 at 20, 40, 60, 80 and 100 DAT, respectively).

4.1.2.3 Combined effect of seedling and leaf clipping

Binadhan-13 showed significant variation on number of leaves hill^{-1} due to combined effect of seedling and leaf clipping (Table 2). From the experiment result revealed that the maximum number of leaves hill^{-1} (59.50, 82.27, 101.40, 80.10 and 68.40 at 20, 40, 60, 80 and 100 DAT, respectively) was observed in S_2L_0 treatment combination which was statistically identical with S_2L_2 (94.20), S_2L_4 (93.30), S_2L_1 (92.10), S_0L_2 (90.30) and S_1L_0 (90.00) treatment combinations at 60 DAT; with S_2L_1 (76.50), S_2L_2 (75.45), S_0L_1 (73.20), S_1L_3 (72.90), S_0L_0 (72.30) and S_0L_2 (72.30) at 80 DAT and finally with S_2L_2 (67.50), S_0L_0 (65.25), S_2L_1 (64.20) and S_0L_2 (63.60) treatment combinations at 100 DAT, respectively. While the minimum number of leaves hill^{-1} (49.93) was observed in S_0L_4 treatment combination which was statistically identical with S_2L_3 (50.87), S_1L_4 (51.10), S_1L_3 (51.10), S_1L_0 (51.10), S_0L_0 (51.10) treatment combination at 20 DAT. At 40 DAT the minimum number of leaves hill^{-1} (73.60) was observed in S_0L_4 treatment combination which was statistically identical with S_0L_3 (73.87), S_2L_3 (74.40) and S_1L_4 (74.93) treatment combinations. At 60 DAT the minimum number of leaves hill^{-1} (82.80) was observed in S_0L_3 treatment combination which was statistically identical with S_0L_4 (83.40), S_0L_0 (86.40), S_1L_2 (87.30), S_1L_3 (87.30), S_1L_4 (87.90), S_0L_1 (88.50) and S_2L_3 (88.50) treatment combinations. At 80 DAT the minimum number of leaves hill^{-1} (66.00) was observed in S_2L_3 treatment combination which was statistically identical with S_1L_4 (66.90), S_0L_4 (67.50), S_0L_3 (68.10) and S_1L_0 (68.40) treatment combinations. Finally at 100 DAT the minimum number of leaves hill^{-1} (54.90) was observed in S_1L_4 treatment combination which was statistically identical with S_1L_3 (59.40), S_2L_4 (59.40), S_1L_2 (59.25), S_0L_4 (60.00) and S_1L_1 (60.30) treatment combinations. The increase in number of leaves hill^{-1} was found due to increase of tiller number which was related with seedling clipping whereas leaf clipping reduced the number of leaves hill^{-1} compared to non-clipped one, because of declination of the relationship between source and sink occurred by leaf clipping, affected plant's growth and yield characteristics.

Table 2. Combined effect of seedling and leaf clipping on number of leaves hill^{-1} of Binadhan-13 at different DAT

Treatment Combinations	No. of leaves hill^{-1}				
	20 DAT	40 DAT	60 DAT	80 DAT	100 DAT
S_0L_0	51.10 cd	74.93 b-d	86.40 b	72.30 a-d	65.25 a-c
S_0L_1	52.03 b-d	78.13 b	88.50 b	73.20 a-d	61.20 b-d
S_0L_2	52.03 b-d	75.47 b-d	90.30 ab	72.30 a-d	63.60 a-c
S_0L_3	50.17 d	73.87 d	82.80 b	68.10 cd	60.60 b-d
S_0L_4	49.93 d	73.60 d	83.40 b	67.50 cd	60.00 cd
S_1L_0	51.10 cd	75.73 b-d	90.00 ab	68.40 cd	60.90 b-d
S_1L_1	51.57 b-d	74.40 cd	88.20 b	69.30 b-d	60.30 cd
S_1L_2	51.57 b-d	75.20 b-d	87.30 b	71.10 b-d	59.25 cd
S_1L_3	51.10 cd	75.47 b-d	87.30 b	72.90 a-d	59.40 cd
S_1L_4	51.10 cd	74.93 cd	87.90 b	66.90 d	54.90 d
S_2L_0	59.50 a	82.27 a	101.40 a	80.10 a	68.40 a
S_2L_1	53.43 bc	78.13 b	92.10 ab	76.50 ab	64.20 a-c
S_2L_2	54.37 b	77.07 bc	94.20 ab	75.45 a-c	67.50 ab
S_2L_3	50.87 cd	74.40 cd	88.50 b	66.00 d	61.20 b-d
S_2L_4	52.50 b-d	75.20 b-d	93.30 ab	71.40 b-d	59.40 cd
$LSD_{(0.05)}$	3.19	3.27	11.39	8.68	6.66
CV(%)	3.64	2.56	7.56	7.21	6.40

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.

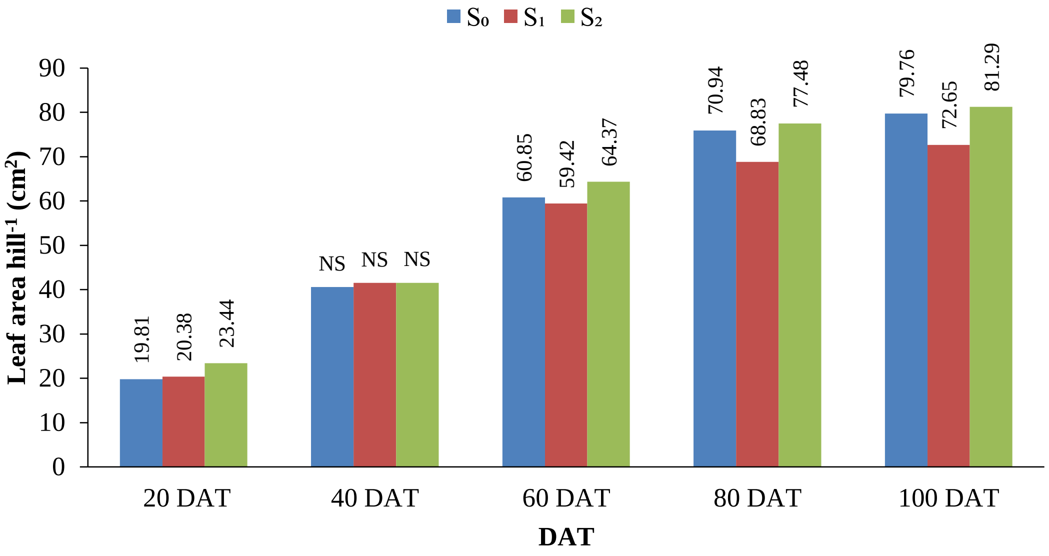
NS= Non-significant
S_0= Control (no clipping)
S_1=1/3rd top clipping
S_2= 1/2nd top clipping

L_0= Control (no clipping)
L_1= Lower 1st and 2nd leaves clipping
L_2= Lower 2nd and 3rd leaves clipping
L_3= Lower 3rd and 4th leaves clipping
L_4= Flag leaf clipping

4.1.3 Leaf area hill^{-1} (cm^2)

4.1.3.1 Seedling clipping

Significant variation was observed in leaf area due to seedling clipping (Fig. 5). From the experiment result revealed that the maximum leaf area (23.44, 41.548, 64.37, 77.48 and 81.29 at 20, 40, 60, 80 and 100 DAT, respectively) was observed in S_2 treatment which was statistically similar with S_0 (75.94 cm^2) treatment at 80 DAT and with S_1 (79.26 cm^2) treatment at 100 DAT, respectively. While the minimum leaf area (19.81 and 40.599 cm^2 at 20 and 40 DAT, respectively) was observed in S_0 treatment which was statistically identical with S_1 (20.38 cm^2) at 20 DAT. At 60, 80 and 100 DAT the minimum leaf area (59.42 cm^2, 68.83 cm^2 and 72.65 cm^2 , respectively) was observed in S_1 treatment which was statistically identical with S_0 (60.85 cm^2) treatment at 60 DAT. Leaves are one of the most vital organs. Photosynthesis occurs in leaves and is the process through which plants make food using light, carbon dioxide (CO2), and water. Chloroplasts in leaves catch light and use it to make food. As the leaf area enhances, more light energy is captured. Stomata on the underside of leaves, take in carbon dioxide. Because photosynthesis relies on the sun's energy to synthesize sugar from carbon dioxide and water, higher carbon dioxide concentrations make plants more productive. Sugar is used by plants and ecosystems as an energy source as well as a basic building element for growth. Carbon dioxide intake by plants is influenced by leaf area, which in turn influences plant development. Seedling clipping alters the physiology of leaf area to some extent compared to non-clipping seedlings, which is due to the fact that seedling clipping reduces competition among seedlings and aids in proper nutrient uptake surrounding its source, which aids in vigor growth (increasing leaf area, effective tiller number, above ground dry matter weight, and so on) of the seedling, which has an impact on yield or yield contributing characters of the rice plant. Ros *et al*. (2003) also showed the similar result that leaf area was increased with the treatment of seedling clipping compared to control treatment which is supported by the findings.

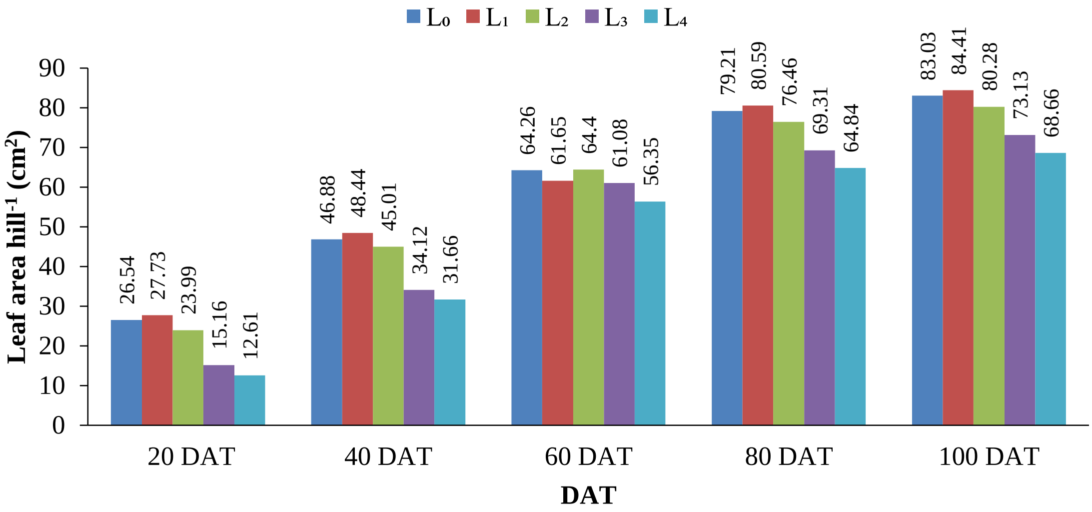


S_0= Control (no clipping), S_1=1/3rd top clipping and S_2= 1/2nd top clipping

Figure 5. Effect of seedling clipping on leaf area hill-1 of Binadhan-13 at different DAT (LSD(0.05)= 2.18, NS, 2.03, 2.20 and 2.20 at 20, 40, 60, 80 and 100 DAT, respectively).

4.1.3.2 Leaf clipping

In case of leaf area no clipping or clipping some extent showed better result comparable to others treatment (Fig. 6). From the experiment result revealed that the maximum leaf area (27.73 and 48.44 cm^2 at 20 and 40 DAT, respectively) was observed in L_1 treatment which was statistically identical with L_0 (26.54 cm^2) treatment at 20 DAT and with L_0 (46.88 cm^2) at 40 DAT. At 60 DAT the maximum leaf area (64.40 cm^2) was observed in L_2 treatment which was statistically identical with L_0 (64.26 cm^2) and L_1 (61.65 cm^2) treatment. At 80 and 100 DAT the maximum leaf area (80.59 cm^2 and 84.31 cm^2, respectively) was observed in L_1 treatment which was statistically identical with L_0 (79.21 cm^2) treatment at 80 DAT and with L_0 (83.03 cm^2) treatment at 100 DAT. While minimum leaf area (12.61, 31.66, 56.35, 64.84 and 68.66 cm^2 at 20, 40, 60, 80 and 100 DAT, respectively) was observed in L_4 treatment. The study showed that leaf clipping had also a great impact on leaf area since leaf area was proportional to the number of leaves. Similarly, Ros *et al.* (2003) reported that reducing leaves affected the plant's photosynthetic activities, which had an impact on rice growth, development and grain yield.



L_0= Control (no clipping), L_1= Lower 1st and 2nd leaves, L_2= Lower 2nd and 3rd leaves, L_3= Lower 3rd and 4th leaves clipping and L_4= Flag leaf clipping

Figure 6. Effect of leaf clipping on leaf area hill^{-1} of Binadhan-13 at different DAT ($LSD_{(0.05)}$= 1.58, 2.93, 2.99, 1.95 and 1.95 at 20, 40, 60, 80 and 100 DAT, respectively).

4.1.3.3 Combined effect of seedling and leaf clipping

Binadhan-13 showed significant variation on leaf area due to combined effect of seedling and leaf clipping (Table 3). From the experiment result revealed that the maximum leaf area (30.24 cm^2) was observed in S_2L_1 treatment combination which was statistically identical with S_2L_0 (29.60 cm^2) treatment combination at 20 DAT. At 40 DAT the maximum leaf area (51.42 cm^2) was observed in S_0L_0 treatment combination which was statistically identical with S_1L_1 (50.20 cm^2), S_1L_2 (49.85 cm^2), S_2L_0 (48.56 cm^2) and S_2L_1 (48.32 cm^2) treatment combinations. At 60, 80 and 100 DAT the maximum leaf area (70.68, 86.79 and 90.61 cm^2, respectively) was observed in S_2L_0 treatment combination which was statistically identical with S_2L_1 (69.37 cm^2) and S_1L_2 (67.20 cm^2) treatment combinations at 60 DAT; with S_2L_1 (84.66 cm^2) and S_0L_1 (83.57 cm^2) treatment combination at 80 DAT and with S_2L_1 (88.48 cm^2) and S_0L_1 (87.39 cm^2) treatment combinations at 100 DAT. While the minimum leaf area (11.29 cm^2) was observed in S_1L_4 treatment combination which was statistically identical with S_1L_3 (12.16 cm^2) and S_0L_4 (12.21 cm^2) treatment combination at 20 DAT. At 40 DAT the minimum leaf area (28.56 cm^2) was observed in S_0L_4 treatment combination which was statistically identical with S_1L_4 (32.74 cm^2) and S_0L_3 (33.61 cm^2) treatment combination. At 60, 80 and 100 DAT the minimum leaf area (53.41, 61.49 and 65.32 cm^2) was observed in S_1L_4 treatment combination which was statistically identical with S_0L_1 (56.20 cm^2) and S_2L_4 (57.28 cm^2) treatment combination at 60 DAT. Seedling clipping decreased the competition among the seedlings and helped in uptake nutrients suitably surroundings its source, which helped in vigor growth. On the other hand, leaf area was diminished by leaf clipping and so it reduced photosynthesis which ultimately reduced growth and yield of rice.

Table 3. Combined effect of seedling and leaf clipping on leaf area of Binadhan-13 at different DAT

Treatment Combinations	Leaf area (cm^2)				
	20 DAT	40 DAT	60 DAT	80 DAT	100 DAT
S_0L_0	25.51 cd	51.42 a	62.50 c-f	82.57 b	86.39 b
S_0L_1	26.41 b-d	46.78 ab	56.20 hi	83.57 ab	87.39 ab
S_0L_2	19.34 e	42.63 bc	64.59 b-d	78.12 c	81.94 c
S_0L_3	15.55 fg	33.61 de	62.60 c-e	69.86 ef	73.68 ef
S_0L_4	12.21 h	28.56 e	58.37 e-i	65.58 g	69.40 g
S_1L_0	24.51 d	40.65 c	59.61 d-h	68.26 fg	72.08 fg
S_1L_1	26.54 b-d	50.20 a	59.38 e-h	73.54 de	77.36 de
S_1L_2	27.39 a-c	49.85 a	67.20 abc	75.59 cd	79.42 cd
S_1L_3	12.16 h	34.13 d	57.51 f-i	65.25 g	69.07 g
S_1L_4	11.29 h	32.74 de	53.41 i	61.49 h	65.32 h
S_2L_0	29.60 ab	48.56 a	70.68 a	86.79 a	90.61 a
S_2L_1	30.24 a	48.32 a	69.37 ab	84.66 ab	88.48 ab
S_2L_2	25.25 cd	42.57 bc	61.41 d-g	75.67 cd	79.49 cd
S_2L_3	17.75 ef	34.61 d	63.12 c-e	72.82 de	76.64 de
S_2L_4	14.33 gh	33.68 d	57.28 g-i	67.44 fg	71.26 fg
$LSD_{(0.05)}$	2.73	5.07	5.17	3.38	3.38
CV(%)	7.64	7.30	4.99	2.71	2.57

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.

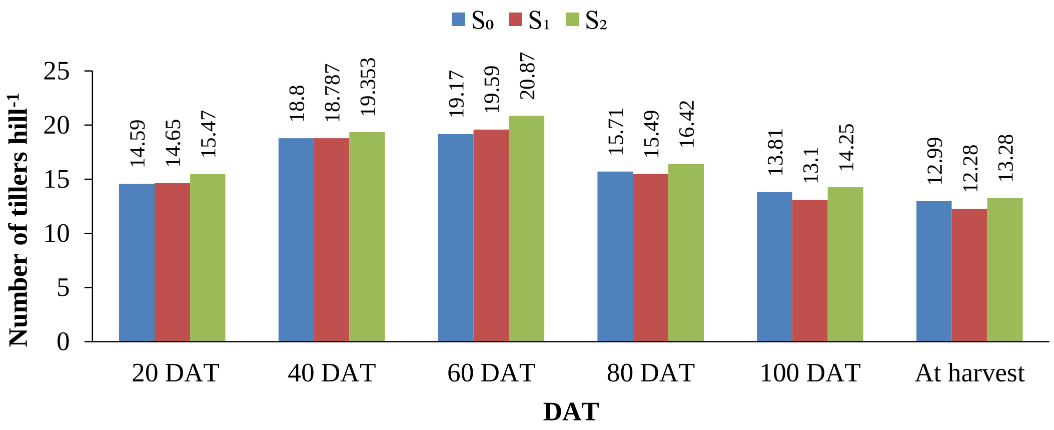
NS= Non-significant
S_0= Control (no clipping)
S_1=1/3rd top clipping
S_2= 1/2nd top clipping

L_0= Control (no clipping)
L_1= Lower 1st and 2nd leaves clipping
L_2= Lower 2nd and 3rd leaves clipping
L_3= Lower 3rd and 4th leaves clipping
L_4= Flag leaf clipping

4.1.4 Tillers hill^{-1} (no.)

4.1.4.1 Seedling clipping

Binadhan-13 showed significant variation on number of tillers hill^{-1} due to the effect of seedling clipping at various days after transplanting (Fig. 7). From the experiment result revealed that the maximum number of tillers hill^{-1} (15.47, 19.353, 20.87, 16.42, 14.25 and 13.28 at 20, 40, 60, 80, 100 DAT and harvest, respectively) was observed in S_2 treatment which was statistically identical with S_1 (19.59) treatment at 60 DAT. While the minimum number of tillers hill^{-1} (14.59) at 20 DAT was observed in S_0 treatment which was statistically identical with S_1 (14.65) treatment. At 40 DAT the minimum number of tillers hill^{-1} (18.787) was observed in S_1 treatment which was statistically identical with S_0 (18.80) treatment. At 60 DAT the minimum number of tillers hill^{-1} (19.17) was observed in S_0 treatment. At 80, 100 DAT and harvest, the minimum number of tillers hill^{-1} (15.49, 13.10 and 12.28, respectively) was observed in S_1 treatment which was statistically identical with S_0 (15.71) treatment at 80 DAT. Higher seedling hill^{-1} can result in intense competition among the plants, which can result in persistent shading, a reduction in the number of tillers hill^{-1} and lodging, and therefore an increase in the production of straw rather than grain. Clipping seedlings can aid with vigor seedling development by removing competition among the plants, allowing the plant to better utilize its resources and affect the number of tillers hill^{-1}. As a result, seedling clipping caused increased number of tillers hill^{-1} compared to control treatment (Daliri *et al*., 2009).

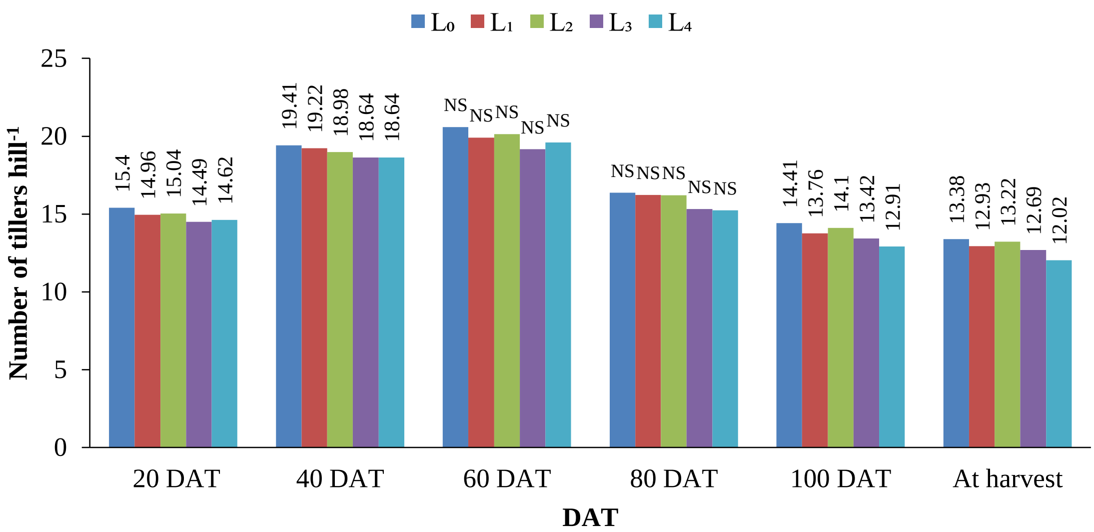


S_0= Control (no clipping), S_1=1/3rd top clipping and S_2= 1/2nd top clipping

Figure 7. Effect of seedling clipping on tillers hill^{-1} of Binadhan-13 at different DAT ($LSD_{(0.05)}$= 0.24, 0.23, 1.51, 0.51, 0.86 and 0.42 at 20, 40, 60, 80, 100 DAT and harvest, respectively).

4.1.4.2 Leaf clipping

Significant effect was observed on number of tillers hill^{-1} of Binadhan-13 due to leaf clipping at 20, 40, 100 DAT and harvest (Fig. 8). From the experiment result revealed that the maximum number of tillers hill^{-1} (15.40, 19.41, 20.58, 16.36, 14.41 and 13.38 at 20, 40, 60, 80, 100 DAT and harvest, respectively) was observed in L_0 treatment which was statistically identical with L_2 (15.04) and L_1 (14.96) treatment at 20 DAT; with L_1 (19.22) and L_2 (18.98) treatment at 40 DAT; with L_2 (14.10) and L_1 (13.76) treatment at 100 DAT and with L_2 (13.22) and L_1 (12.93) treatment at harvest. While the minimum number of tillers hill^{-1} (14.49 and 18.64 at 20 and 40 DAT, respectively) was observed in L_3 treatment which was statistically identical with L_4 (14.62) treatment at 20 DAT. At 100 DAT and harvest, the minimum number of tillers hill^{-1} (12.91 and 12.02 respectively) was observed in L_4 treatment which was statistically identical with L_3 (13.42) treatment at 100 DAT and with L_3 (12.69) and L_1 (12.93) treatment at harvest. The present study showed that the highest number of tillers hill^{-1} was found in control treatment compared to leaf clipping treatments. It might be due to sufficient availability of the number of leaves, which has an impact on leaf area and leaf area index that aids in initiation of more tillers hill^{-1} (Fatima, 2019).



L_0= Control (no clipping), L_1= Lower 1st and 2nd leaves, L_2= Lower 2nd and 3rd leaves, L_3= Lower 3rd and 4th leaves clipping and L_4= Flag leaf clipping

Figure 8. Effect of leaf clipping on tillers hill^{-1} of Binadhan-13 at different DAT ($LSD_{(0.05)}$= 0.53, 0.47, NS, NS, 0.85 and 1.02 at 20, 40, 60, 80, 100 DAT and harvest, respectively).

4.1.4.3 Combined effect of seedling and leaf clipping

Binadhan-13 showed significant variation on number of tillers hill^{-1} due to combined effect of seedling and leaf clipping (Table 4). From the experiment result revealed that the maximum number of tillers hill^{-1} (17.00, 20.57, 22.53, 17.80, 15.20 and 14.60 at 20, 40, 60, 80, 100 DAT and harvest, respectively) was observed in S_2L_0 treatment which was statistically identical with S_2L_2 (20.93), S_2L_4 (20.73), S_2L_1 (20.47), S_0L_2 (20.07) and S_1L_0 (20.00) treatment at 60 DAT; with S_2L_1 (17.00), S_2L_2 (16.77), S_0L_1 (16.27), S_1L_3 (16.20), S_0L_0 (16.07) and S_0L_2 (16.07) treatment at 80 DAT, with S_2L_2 (15.00), S_0L_0 (14.50), S_2L_1 (14.27) and S_0L_2 (14.13) at 100 DAT and with S_2L_1 (13.67), S_2L_2 (13.67), S_0L_0 (13.53) and S_0L_3 (13.40) at harvest. While the minimum number of tillers hill^{-1} (14.27 and 18.40 at 20 and 40 DAT, respectively) was observed in S_0L_4 treatment combination which was statistically identical with S_0L_3 (14.33), S_2L_3 (14.53), S_0L_0 (14.60), S_1L_0 (14.60), S_1L_3 (14.60) and S_1L_4 (14.60) treatment combination at 20 DAT and with S_0L_3 (18.47), S_1L_1 (18.60), S_2L_3 (18.60) and S_1L_4 (18.73) treatment combination at 40 DAT. At 60 DAT the minimum number of tillers hill^{-1} (18.40) was observed in S_0L_3 treatment combination which was statistically identical with S_0L_4 (18.53), S_0L_0 (19.20), S_1L_2 (19.40), S_1L_3 (19.40), S_0L_1 (19.67) and S_2L_3 (19.67) treatment combinations. At 80, 100 DAT and harvest the minimum number of tillers hill^{-1} (14.87, 12.20 and 11.73, respectively) was observed in S_1L_4 treatment combination which was statistically identical with S_0L_4 (15.00), S_0L_3 (15.13) and S_1L_0 (15.20) treatment at 80 DAT; with S_1L_2 (13.17), S_1L_3 (13.20), S_2L_4 (13.20), S_0L_4 (13.33), and S_1L_1 (13.40) treatment combination at 100 DAT and with S_1L_0 (12.00) at harvest. Number of tillers hill^{-1} is a vital morphological character which is related to yield of rice. Higher seedling hill^{-1} can cause higher competition among the plants. That results in continuing shading, increases production of straw instead of grain. Clipping of seedling along with no leaf clipping aid in some cases in vigor seedling production by elimination of the competition among the plants and allowing the plant to better utilize its resources. As a consequence, it impacts the number of tillers per hill^{-1}.

Table 4. Combined effect of seedling and leaf clipping on tillers hill^{-1} of Binadhan-13 at different DAT

Treatment Combinations	No. of tillers hill^{-1}					
	20 DAT	40 DAT	60 DAT	80 DAT	100 DAT	Harvest
S_0L_0	14.60 cd	18.73 b-d	19.20 b	16.07 a-d	14.50 a-c	13.53 a-c
S_0L_1	14.87 b-d	19.53 b	19.67 b	16.27 a-d	13.60 b-d	12.40 b-d
S_0L_2	14.87 b-d	18.87 b-d	20.07 ab	16.07 a-d	14.13 a-c	13.33 a-d
S_0L_3	14.33 d	18.47 d	18.40 b	15.13 cd	13.47 b-d	13.40 a-c
S_0L_4	14.27 d	18.40 d	18.53 b	15.00 cd	13.33 cd	12.27 b-d
S_1L_0	14.60 cd	18.93 b-d	20.00 ab	15.20 cd	13.53 b-d	12.00 cd
S_1L_1	14.73 b-d	18.60 cd	19.60 b	15.40 b-d	13.40 cd	12.73 b-d
S_1L_2	14.73 b-d	18.80 b-d	19.40 b	15.80 b-d	13.17 cd	12.67 b-d
S_1L_3	14.60 cd	18.87 b-d	19.40 b	16.20 a-d	13.20 cd	12.27 b-d
S_1L_4	14.60 cd	18.73 cd	19.53 b	14.87 d	12.20 d	11.73 d
S_2L_0	17.00 a	20.57 a	22.53 a	17.80 a	15.20 a	14.60 a
S_2L_1	15.27 bc	19.53 b	20.47 ab	17.00 ab	14.27 a-c	13.67 ab
S_2L_2	15.53 b	19.27 bc	20.93 ab	16.77 a-c	15.00 ab	13.67 ab
S_2L_3	14.53 cd	18.60 cd	19.67 b	14.67 d	13.60 b-d	12.40 b-d
S_2L_4	15.00 b-d	18.80 b-d	20.73 ab	15.87 b-d	13.20 cd	12.07 b-d
$LSD_{(0.05)}$	0.91	0.82	2.53	1.93	1.48	1.77
CV(%)	3.64	2.56	7.56	7.21	6.40	8.17

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.

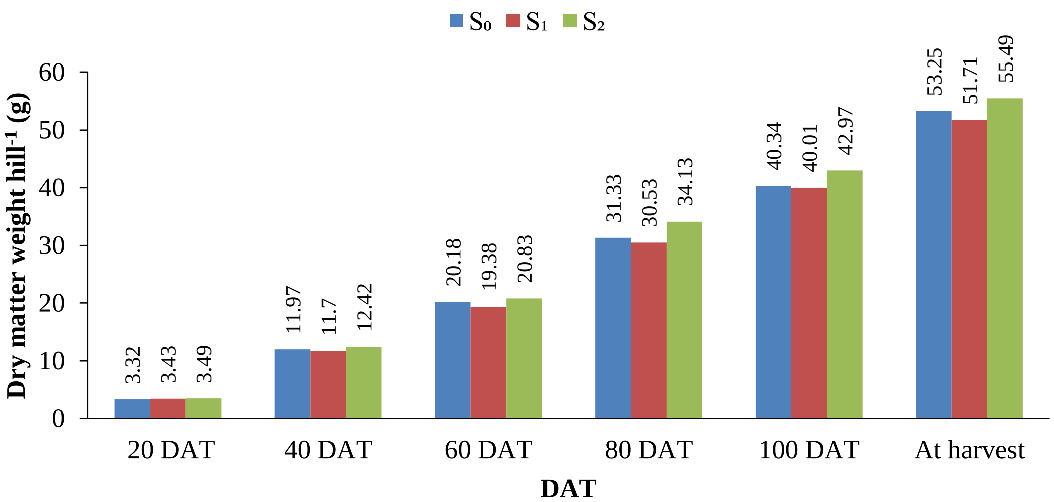
NS= Non-significant
S_0= Control (no clipping)
S_1=1/3rd top clipping
S_2= 1/2nd top clipping

L_0= Control (no clipping)
L_1= Lower 1st and 2nd leaves clipping
L_2= Lower 2nd and 3rd leaves clipping
L_3= Lower 3rd and 4th leaves clipping
L_4= Flag leaf clipping

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

4.1.5.1 Seedling clipping

Seedling clipping showed significant effect on above ground dry matter weight hill^{-1} of Binadhan-13 at various days after transplanting (Fig. 9). From the experiment result revealed that the maximum above ground dry matter weight hill^{-1} (3.49, 12.42, 20.83, 34.13, 42.97 and 55.49 g at 20, 40, 60, 80, 100 DAT and harvest, respectively) was observed in S_2 treatment which was statistically identical with S_1 (3.43 g) treatment at 20 DAT; with S_0 (11.97 g) treatment at 40 DAT; with S_0 (20.18 g) treatment at 60 DAT. While the minimum above ground dry matter weight hill^{-1} (3.32 g at 20 DAT) was observed in S_0 treatment. At 40, 60, 80, 100 DAT and harvest, the minimum above ground dry matter hill^{-1} (11.70, 19.38, 30.53, 40.01 and 51.71 g, respectively) was observed in S_1 treatment which was statistically identical with S_0 (31.33 g) treatment at 80 DAT; with S_0 (40.34 g) treatment at 100 DAT. Excess seedlings hill^{-1} cause intra-plant competition in rice plants, resulting in lower dry matter at a later stage owing to tiller death and early senescence. Clipping to some extent aids proper plant growth and increases dry matter accumulation by utilizing the plant's surrounding resources, when compared to a plant that is not clipped (Ros *et al*., 2003). The present findings showed the similar result as dry matter weight hill^{-1} was increased with seedling clipping as compared to non-clipped plants.

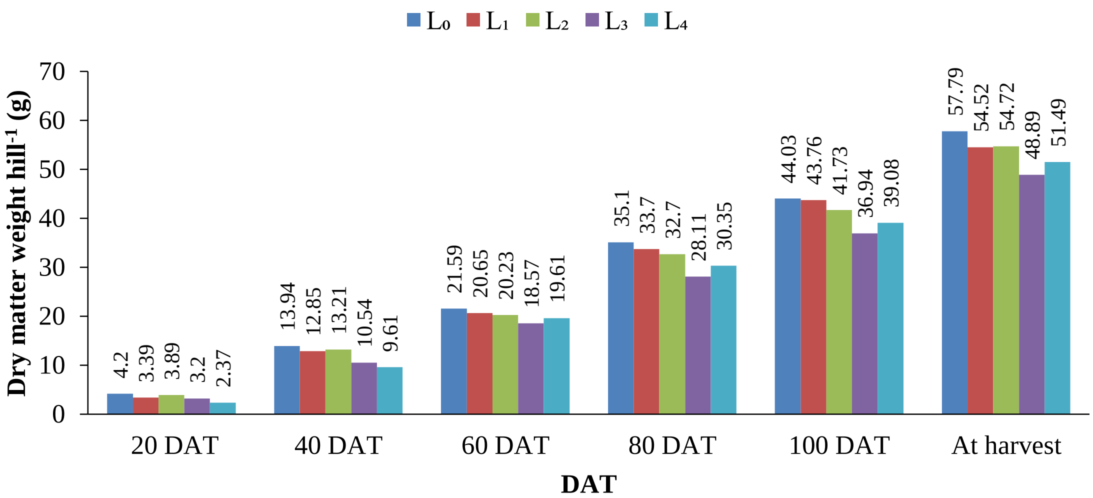


S_0= Control (no clipping), S_1=1/3rd top clipping and S_2= 1/2nd top clipping

Figure 9. Effect of seedling clipping on above ground dry matter weight hill^{-1} of Binadhan-13 at different DAT ($LSD_{(0.05)}$= 0.13, 0.54, 0.78, 1.94, 2.05 and 1.47 at 20, 40, 60, 80, 100 DAT and harvest, respectively).

4.1.5.2 Leaf clipping

Leaf clipping of Binadhan-13 showed significant variation on above ground dry matter weight hill^{-1} at various days after transplanting (Fig. 10). From the experiment result revealed that the maximum above ground dry matter weight hill^{-1} (4.20, 13.94, 21.59, 35.10, 44.03 and 57.79 g at 20, 40, 60, 80, 100 DAT and harvest, respectively) was observed in L_0 treatment which was statistically identical with L_1 (33.70 and 43.76 g) treatment at 80 and at 100 DAT, respectively. While the minimum above ground dry matter weight hill^{-1} (2.37 and 9.61 g at 20 and 40 DAT, respectively) was observed in L_4 treatment. At 60, 80, 100 DAT and harvest the minimum above ground dry matter weight hill^{-1} (18.57, 28.11, 36.94 and 48.89 g, respectively) was observed in L_3 treatment. The leaf area where photosynthesis occurs is influenced by the number of leaves. When photosynthesis exceeds respiration, the plant's dry matter accumulation increases, allowing it to grow and develop. However, leaf clipping lowers leaf area, then less photosynthesis occurs, which influences on plant growth and development compared to that of non-clipped plants. Similarly, Sherif *et al*. (2015) stated that in the first season (2013-14) they saw a significant loss in dry matter content at 80 and 100 % defoliation (938.15 and 765.00 gm^{-2}, respectively). Defoliations of 60, 80, or 100 % resulted in low levels of dry matter content in the second season (2014-15), with 866.11, 861.26, and 840.04 gm^{-2}, respectively.



L_0= Control (no clipping), L_1= Lower 1st and 2nd leaves, L_2= Lower 2nd and 3rd leaves, L_3= Lower 3rd and 4th leaves clipping and L_4= Flag leaf clipping

Figure 10. Effect of leaf clipping on above ground dry matter weight hill^{-1} of Binadhan-13 at different DAT ($LSD_{(0.05)}$= 0.16, 0.55, 0.77, 1.69, 2.06 and 1.83 at 20, 40, 60, 80, 100 DAT and harvest, respectively).

4.1.5.3 Combined effect of seedling and leaf clipping

Combined effect of seedling and leaf clipping showed significant variation in respect of above ground dry matter weight hill^{-1} of Binadhan-13 at various days after transplanting (Table 5). From the experiment result revealed that the maximum above ground dry matter weight hill^{-1} (4.29, 14.65, 23.04, 38.92, 47.85 and 60.83 g at 20, 40, 60, 80, 100 DAT and harvest, respectively) was observed in S_2L_0 treatment combination which was statistically identical with S_1L_0 (4.25 g) and S_0L_0 (4.07 g) treatment combination at 20 DAT; with S_0L_0 (13.72 g) treatment combination at 40 DAT; with S_2L_1 (38.72 g) treatment combination at 80 DAT; with S_2L_1 (47.45 g) treatment combination at 100 DAT and with S_2L_1 (58.34 g) treatment combination at harvest. While the minimum above ground dry matter weight hill^{-1} (2.31 g) was observed in S_0L_4 treatment combination which was statistically identical with S_1L_4 (2.36 g) and S_2L_4 (2.42 g) treatment combination at 20 DAT. At 40 and 60 DAT the minimum above ground dry matter weight hill^{-1} (9.12 and 18.26 g, respectively) was observed in S_1L_4 treatment combination which was statistically identical with S_0L_4 (9.84 g) and S_2L_4 (9.88 g) treatment combination at 40 DAT and with S_1L_3 (18.26 g), S_0L_3 (19.26 g) and S_0L_2 (19.46 g) treatment combination at 60 DAT. At 80, 100 DAT and harvest, the minimum above ground dry matter weight hill^{-1} (27.80, 36.63 and 48.26 g, respectively) was observed in S_1L_3 treatment combination which was statistically identical with S_0L_3 (28.03 g) treatment combination at 80 DAT; with S_0L_3 (36.85 g) and S_2L_3 (37.33 g) at 100 DAT; with S_1L_4 (48.71 g), S_2L_3 (48.90 g) and S_0L_3 (49.49 g) at harvest. Seedling clipping along with no leaf clipping treatment combinations impact growth because non clipping plant has greater leaf area which captures more sunlight and produces more photosynthetic product than clipping one, and that were being used well by optimum seedling comparable to increased number of seedlings, which has an impact on above ground dry matter weight hill^{-1} (g).

Table 5. Combined effect of seedling and leaf clipping on above ground dry matter weight hill^{-1} of Binadhan-13 at different DAT

Treatment Combinations	Above ground dry matter weight hill^{-1} (g)					
	20 DAT	40 DAT	60 DAT	80 DAT	100 DAT	Harvest
S_0L_0	4.07 ab	13.72 ab	21.21 b	33.66 b	42.59 b	57.07 bc
S_0L_1	3.29 e	12.59 c	20.97 b	31.28 b-e	40.80 b-e	52.44 e-g
S_0L_2	3.98 bc	13.47 bc	19.46 cd	33.67 b	42.69 b	56.35 b-d
S_0L_3	2.97 f	10.23 de	19.26 cd	28.03 fg	36.85 f	49.49 gh
S_0L_4	2.31 g	9.84 ef	20.02 bc	30.02 c-g	38.74 c-f	50.91 f-h
S_1L_0	4.25 a	13.46 bc	20.54 bc	32.73 bc	41.65 bc	55.47 b-e
S_1L_1	3.72 cd	12.71 c	19.86 bc	31.11 b-f	43.03 b	52.79 ef
S_1L_2	3.81 b-d	12.98 bc	19.98 bc	32.07 b-d	41.09 b-d	53.30 d-f
S_1L_3	2.99 f	10.23 de	18.26 d	27.80 g	36.63 f	48.26 h
S_1L_4	2.36 g	9.12 f	18.26 d	28.92 d-g	37.65 d-f	48.71 h
S_2L_0	4.29 a	14.65 a	23.04 a	38.92 a	47.85 a	60.83 a
S_2L_1	3.18 ef	13.25 bc	21.11 b	38.72 a	47.45 a	58.34 ab
S_2L_2	3.89 b-d	13.18 bc	21.25 b	32.36 bc	41.39 b-d	54.51 c-e
S_2L_3	3.66 d	11.15 d	18.19 d	28.51 e-g	37.33 ef	48.90 h
S_2L_4	2.42 g	9.88 ef	20.54 bc	32.11 b-d	40.84 b-e	54.85 c-e
$LSD_{(0.05)}$	0.27	0.95	1.33	2.93	3.57	3.16
CV(%)	4.70	4.68	3.91	5.43	5.15	3.51

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.

NS= Non-significant
S_0= Control (no clipping)
S_1=1/3rd top clipping
S_2= 1/2nd top clipping

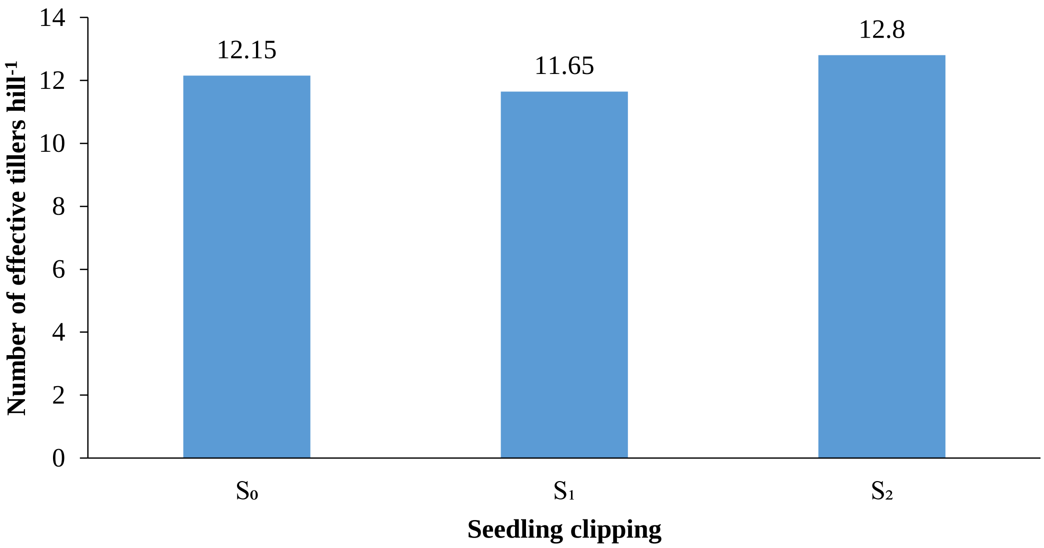
L_0= Control (no clipping)
L_1= Lower 1st and 2nd leaves clipping
L_2= Lower 2nd and 3rd leaves clipping
L_3= Lower 3rd and 4th leaves clipping
L_4= Flag leaf clipping

4.2. Yield contributing characters

4.2.1 Effective tillers hill^{-1} (no.)

4.2.1.1 Seedling clipping

Binadhan-13 showed significant effect on number of effective tillers hill^{-1} due to seedling clipping (Fig. 11). Result revealed that the maximum number of effective tillers hill^{-1} was observed in S_2 (12.80) treatment. While the minimum number of effective tillers hill^{-1} was observed in S_1 (11.65) treatment. Seedling clipping increases the effective tiller by establishing optimum tillers hill^{-1} and utilizing its resources properly. By developing optimum tillers hill^{-1} and appropriately utilizing resources, seedling clipping increases the effective tiller number. Seedling clipping helps to establish ideal optimum seedlings hill^{-1} in the field by eliminating competition for vital resources including nutrients, water, light, and air, resulting in superior seedling hill^{-1} development. Non-clipped seedlings hill^{-1}, on the other hand, generate more low-productive tillers. It's probable that a lack of suitable nutrients, light, and mutual shading by a large number of total tillers caused weak tillers to decay, resulting in a decrease in effective tillers. This study is supported by the findings observed by Daliri *et al*. (2009).

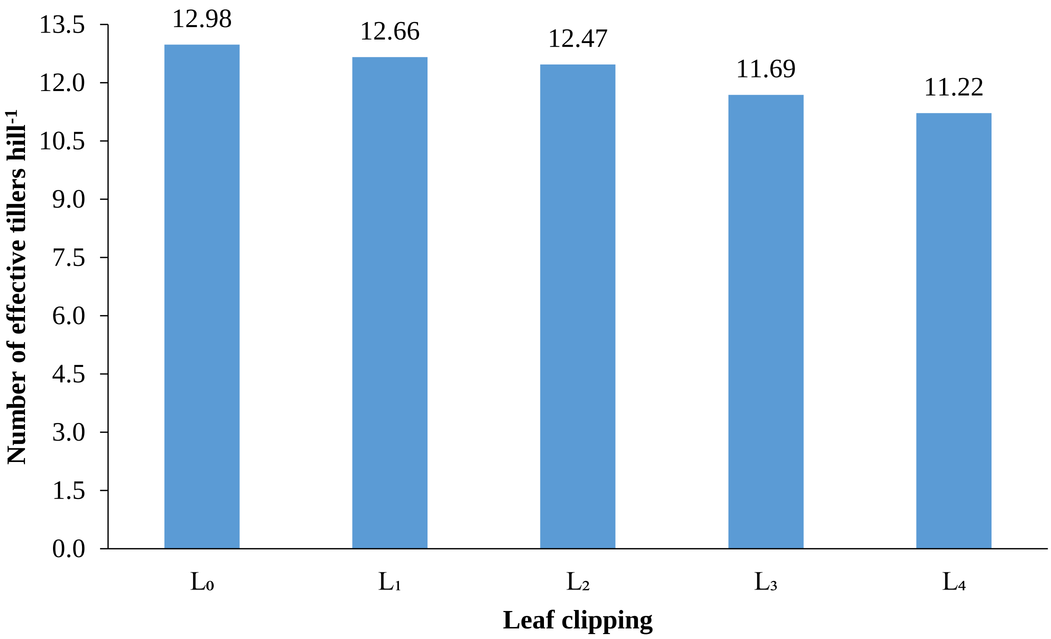


S_0= Control (no clipping), S_1=1/3rd top clipping and S_2= 1/2nd top clipping

Figure 11. Effect of seedling clipping on effective tillers hill^{-1} of Binadhan-13 ($LSD_{(0.05)}$= 0.43).

4.2.1.2 Leaf clipping

Leaf clipping of Binadhan-13 significantly effect on number of effective tillers hill^{-1} (Fig. 12). From the experiment result showed that the maximum number of effective tillers hill^{-1} was observed in L_0 (12.98) treatment which was statistically identical with L_1 (12.66) and L_2 (12.47) treatment. While minimum number of effective tillers hill^{-1} was observed in L_4 (11.22) treatment. The present study showed that the highest number of effective tillers hill^{-1} was found in control treatment compared to leaf clipping treatment. It could be due to a decrease in the number of leaves, which has an effect on leaf area and leaf area index, as leaf area index is proportional to the number of leaves, and a decrease in it affects photosynthetic activities. Panicles obtain food resources from leaves; hence it has an impact on panicle initiation. Previous study found highest number of effective tillers hill^{-1} in control (no leaf cutting) condition (Fatima, 2019). On the contrary, it was found that clipping of leaves had no significant influence on the number of effective tillers hill^{-1} (Boonreund and Marsom, 2015).



L_0= Control (no clipping), L_1= Lower 1st and 2nd leaves, L_2= Lower 2nd and 3rd leaves, L_3= Lower 3rd and 4th leaves clipping and L_4= Flag leaf clipping

Figure 12. Effect of leaf clipping on effective tillers hill^{-1} of Binadhan-13 ($LSD_{(0.05)}$= 1.01).

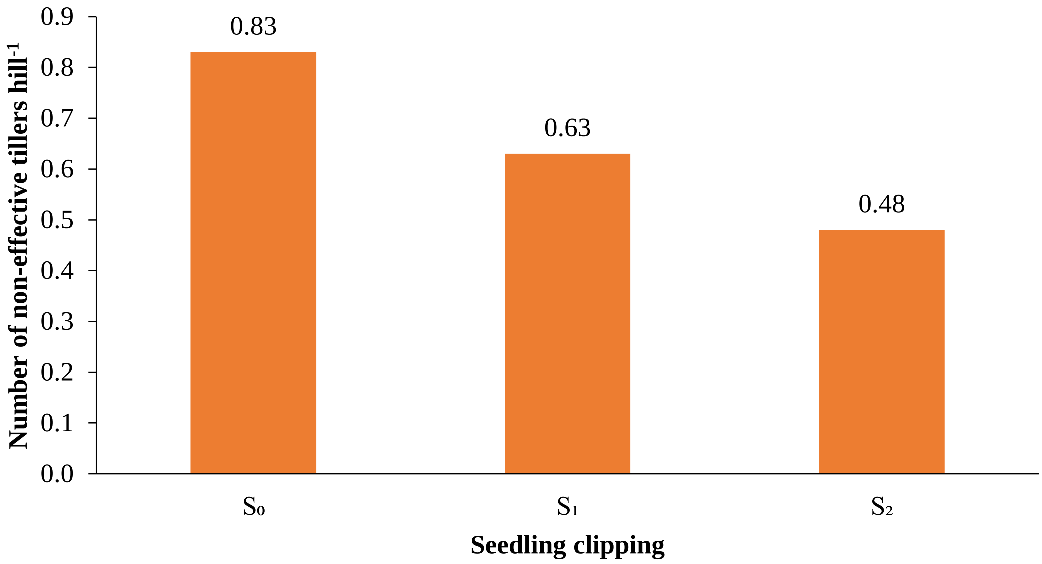
4.2.1.3 Combined effect of seedling and leaf clipping

Combined effect of seedling and leaf clipping showed significant variation on number of effective tillers hill^{-1} of Binadhan-13 (Table 6). Result revealed that the maximum number of effective tillers hill^{-1} (14.30) was observed in S_2L_0 treatment combination which was statistically identical with S_2L_1 (13.57), S_2L_2 (12.93), and S_0L_0 (12.90) treatment combinations. On the contrary, minimum number of effective tillers hill^{-1} (10.80) was observed in S_1L_4 treatment combination which was statistically identical with S_1L_3 (11.27) and S_0L_4 (11.13) treatment combination. Seedling clipping aids to establish optimum seedling hill^{-1} in the field, which reduces seedling competition, whereas various leaf clipping reduces the number of leaves, which has an impact on leaf area and leaf area index, as leaf area index is related to the number of leaves, and reduction of it reduces photosynthetic activities of the plant, which has an impact on rice growth, development, and grain yield.

4.2.2 Non-effective tillers hill^{-1} (no.)

4.2.2.1 Seedling clipping

Binadhan-13 showed significant effect on number of non-effective tillers hill^{-1} due to seedling clipping (Fig. 13). Result revealed that the maximum number of non-effective tillers hill^{-1} was observed in S_0 (0.83) treatment. While the minimum number of non-effective tillers hill^{-1} was observed in S_2 (0.48) treatment which was statistically identical with S_1 (0.63) treatment. The present findings showed that seedling clipping had a great impact on the number of non-effective tillers hill^{-1}, as a result a smaller number of non-effective tillers hill^{-1} was found from clipped seedlings compared to non-clipped seedlings. Seedling clipping assists in the formation of the optimum seedlings hill^{-1} in the field, reduces nutritional competition among plants, and so reduces the number of non-effective tillers. Daliri *et al*. (2009) observed that seedling clipping allowed the crop to absorb more plant nutrients, moisture, and light radiation for growth, perhaps resulting in a lower number of non-effective tillers hill^{-1} for less plant competition among leaves.

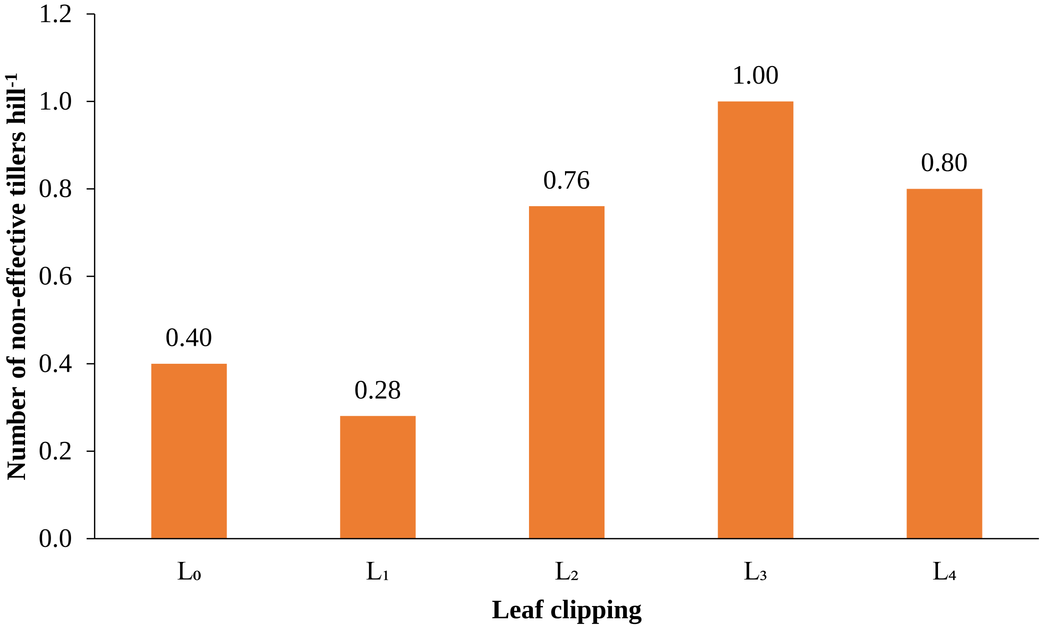


S_0= Control (no clipping), S_1=1/3rd top clipping and S_2= 1/2nd top clipping

Figure 13. Effect of seedling clipping on non-effective tillers hill^{-1} of Binadhan-13 ($LSD_{(0.05)}$=0.03).

4.2.2.2 Leaf clipping

Leaf clipping of Binadhan-13 significantly effect on the number of non-effective tillers hill^{-1} (Fig. 14). From the experiment result showed that the maximum number of non-effective tillers hill^{-1} was observed in L_3 (1.00) treatment which was statistically identical with L_4 (0.80) treatment. While the minimum number of non-effective tillers hill^{-1} was observed in L_1 (0.28) treatment which was statistically identical with L_0 (0.40) treatment. The present study showed that the least number of non-effective tillers hill^{-1} was found in control treatment compared to leaf clipping treatments. It might be due to sufficient availability of the number of leaves, which has an impact on leaf area and leaf area index that aids in initiation of more effective tillers hill^{-1}. Fatima (2019) stated that the least number of non-effective tillers hill^{-1} was observed in control (no leaf cutting) condition. On the contrary, different outcome was noticed by Ahmed *et al.* (2001 a) who discovered that control treatment had the greatest number of non-bearing turners hill^{-1}, which was ultimately like 21 DAT leaf clipping and moreover 49 DAT leaf clipping found the lowest number of non-bearing turners hill^{-1}.



L_0= Control (no clipping), L_1= Lower 1st and 2nd leaves, L_2= Lower 2nd and 3rd leaves, L_3= Lower 3rd and 4th leaves clipping and L_4= Flag leaf clipping

Figure 14. Effect of leaf clipping on non-effective tillers hill^{-1} of Binadhan-13 ($LSD_{(0.05)}$= 0.23).

4.2.2.3 Combined effect of seedling and leaf clipping

Combined effect of seedling and leaf clipping showed significant variation on number of non-effective tillers hill^{-1} of Binadhan-13 (Table 6). Result revealed that the maximum number of non-effective tillers hill^{-1} (1.13) was observed in S_0L_4 treatment combination which was statistically identical with S_0L_3 (1.07), S_1L_3 (1.00), S_1L_4 (0.93), S_2L_3 (0.93) and S_0L_2 (0.80) treatment combinations. On the other hand, the minimum number of non-effective tillers hill^{-1} (0.10) was observed in S_2L_1 treatment combination which was statistically identical with S_1L_1 (0.20), S_1L_0 (0.27), S_2L_0 (0.30) and S_2L_4 (0.33) treatment combinations. Lack of seedling clipping increases competition for various resources, but excessive leaf clipping reduces leaf area, resulting in less solar uptake and photosynthetic output, resulting in poor plant growth and development.

Table 6. Combined effect of seedling and leaf clipping on effective and non-effective tillers hill^{-1} of Binadhan-13

Treatment Combinations	Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)
S_0L_0	12.90 a-c	0.63 c-e
S_0L_1	11.87 c-e	0.53 d-f
S_0L_2	12.53 b-d	0.80 a-d
S_0L_3	12.33 b-e	1.07 ab
S_0L_4	11.13 de	1.13 a
S_1L_0	11.73 c-e	0.27 e-g
S_1L_1	12.53 b-e	0.20 fg
S_1L_2	11.93 c-e	0.73 b-d
S_1L_3	11.27 de	1.00 a-c
S_1L_4	10.80 e	0.93 a-c
S_2L_0	14.30 a	0.30 e-g
S_2L_1	13.57 ab	0.10 g
S_2L_2	12.93 a-c	0.73 b-d
S_2L_3	11.47 c-e	0.93 a-c
S_2L_4	11.73 c-e	0.33 e-g
$LSD_{(0.05)}$	1.74	0.39
CV(%)	8.47	36.38

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.

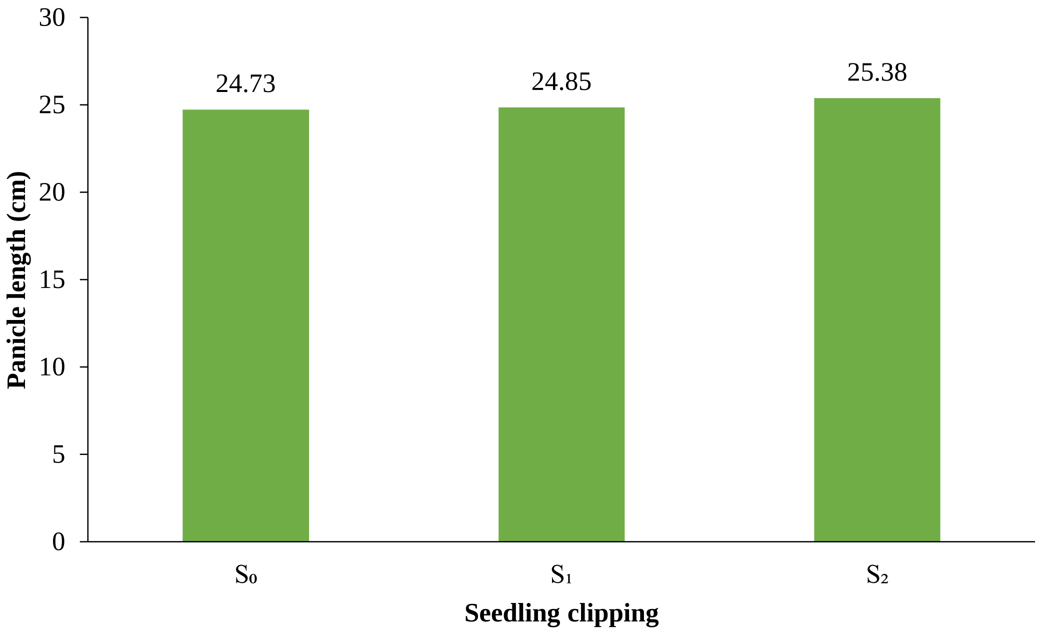
NS= Non-significant
S_0= Control (no clipping)
S_1=1/3rd top clipping
S_2= 1/2nd top clipping

L_0= Control (no clipping)
L_1= Lower 1st and 2nd leaves clipping
L_2= Lower 2nd and 3rd leaves clipping
L_3= Lower 3rd and 4th leaves clipping
L_4= Flag leaf clipping

4.2.3 Panicle length (cm)

4.2.3.1 Seedling clipping

Seedling clipping of Binadhan-13 significantly impact on panicle length (Fig. 15). From the experiment result revealed that the maximum panicle length (25.38 cm) was observed in S_2 treatment. While the minimum panicle length (24.73 cm) was observed in S_0 treatment which was statistically identical with S_1 (24.85 cm). The present study showed that the highest panicle length was found in leaf clipping treatment compared to control treatment. Since seedling clipping reduces competition for nutrients among plants, maintaining a certain number of seedlings hill^{-1} ensures that plants grow in both aerial and underground parts through efficient use of solar radiation, water, and nutrients without competing with established seedlings hill^{-1}, and aids in the development of yield contributing characters such as panicle length (Rahman *et al.*, 2013).

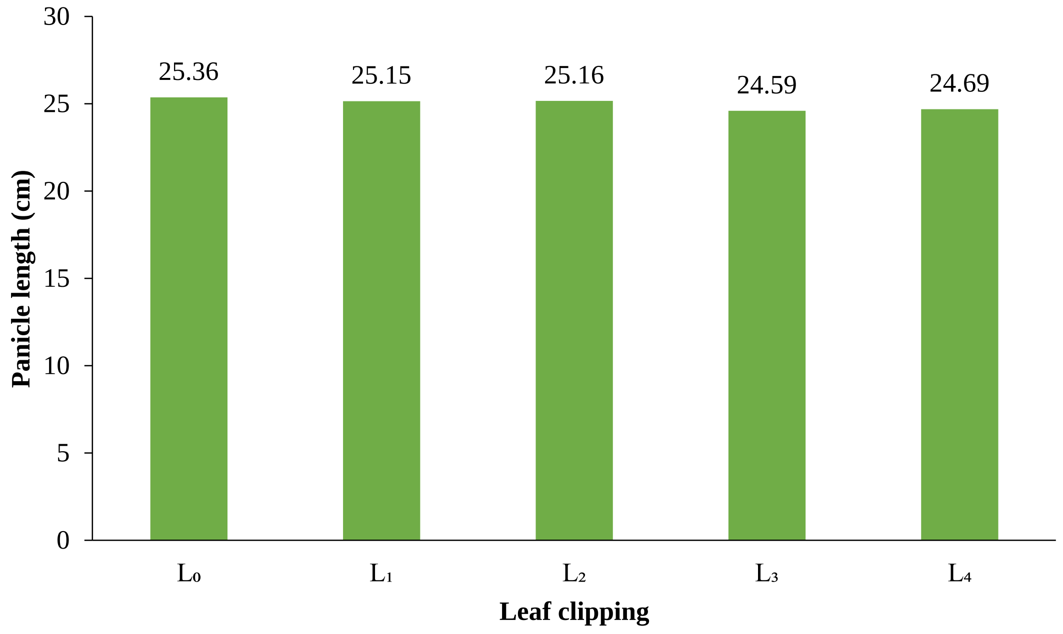


S_0= Control (no clipping), S_1=1/3rd top clipping and S_2= 1/2nd top clipping

Figure 15. Effect of seedling clipping on panicle length of Binadhan-13 ($LSD_{(0.05)}$= 0.19).

4.2.3.2 Leaf clipping

Leaf clipping of Binadhan-13 showed significant effect on panicle length (Fig. 16). From the experiment result showed that the maximum panicle length was observed in L_0 (25.36 cm) treatment which was statistically identical with L_1 (25.15 cm) and L_2 (25.16 cm) treatment. While the minimum panicle length was observed in L_3 (24.59 cm) treatment. The present study showed that the highest panicle length was found in control treatment compared to leaf clipping treatments. The flag leaf, which is the highest leaf below the panicle and supplies the most essential source of photosynthetic energy during reproduction and grain filling, has a significant influence on rice panicle growth and grain output. Rahman *et al.* (2013) stated that flag leaf increases the panicle length in some extent which supported the present finding. Dissimilar consequence was stated by Das *et al.* (2017) and Boonreund and Marsom (2015) who found that clipping of leaves had no significant impact on panicle length of rice.



L_0= Control (no clipping), L_1= Lower 1st and 2nd leaves, L_2= Lower 2nd and 3rd leaves, L_3= Lower 3rd and 4th leaves clipping and L_4= Flag leaf clipping

Figure 16. Effect of seedling clipping on panicle length of Binadhan-13 ($LSD_{(0.05)}$= 0.62).

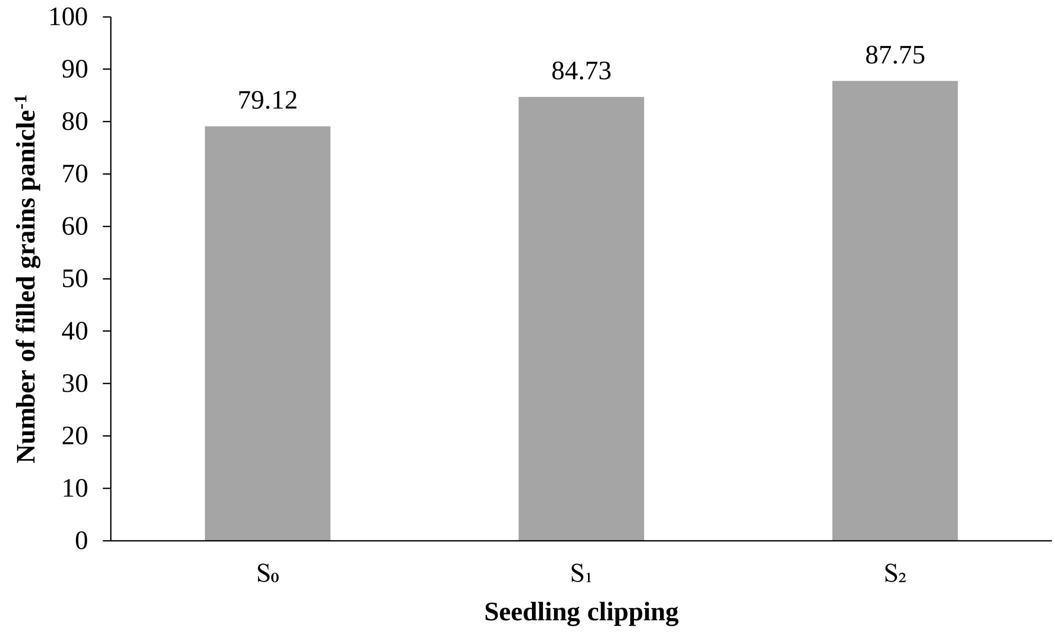
4.2.3.3 Combined effect of seedling and leaf clipping

Combined effect of seedling and leaf clipping showed significant variation on panicle length (cm) of Binadhan-13 (Table 7). Result revealed that the maximum panicle length (26.35 cm) was observed in S_2L_0 treatment combination which was statistically identical with S_2L_2 (25.57 cm) and S_2L_1 (25.50 cm) treatment combination. On the other hand, the minimum panicle length (24.43 cm) was observed in S_0L_4 treatment combination which was statistically identical with S_0L_3 (24.45 cm) and S_1L_3 (24.46 cm) treatment combinations. Seedling vigor (seedling size, health, and growth rate) is influenced by a number of variables, including genetics and environmental impacts, and may be manipulated through management. Seedling clipping and no leaf clipping improve seedling growth and development, resulting in an increased panicle length as compared to other treatments.

4.2.4 Filled grains panicle^{-1} (no.)

4.2.4.1 Seedling clipping

Filled grains panicle^{-1} is an important yield contributing characters which influences the yield of the plant. Seedling clipping showed significant variation in respect of filled grains panicle^{-1} of Binadhan-13 (Fig. 17). From the experiment result revealed that the maximum number of filled grains panicle^{-1} (87.75) was observed in S_2 treatment which was statistically identical with S_1 (84.73) treatment. On the other hand, the minimum number of filled grains panicle^{-1} (79.12) was observed in S_0 treatment. The present findings showed that seedling clipping had a great impact on the number of filled grains panicle^{-1}, as a result the highest number of filled grains panicle^{-1} was found from clipped seedlings compared to non-clipped seedlings. Seedling clipping promotes in the development of optimum seedlings hill^{-1} in the field and reduces nutrient competition among plants. Seedling clipping allowed the crop to absorb more plant nutrients, moisture, and light radiation for growth, perhaps leading to a larger number of filled grains panicle^{-1} due to less plant competition among leaves (Usman *et al*., 2007).

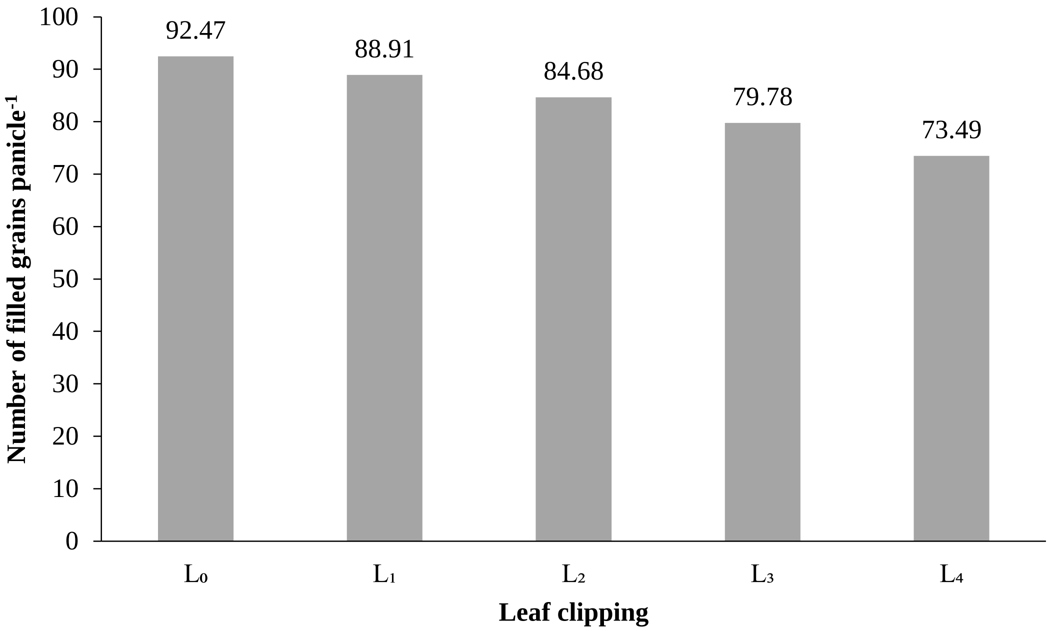


S_0= Control (no clipping), S_1=1/3rd top clipping and S_2= 1/2nd top clipping

Figure 17. Effect of seedling clipping on filled grains panicle^{-1} of Binadhan-13 ($LSD_{(0.05)}$=6.13).

4.2.4.2 Leaf clipping

Leaf clipping of Binadhan-13 showed significant effect on number of filled grains panicle^{-1} (Fig. 18). From the experiment result showed that the maximum number of filled grains panicle^{-1} was observed in L_0 (92.47) treatment which was statistically identical with L_1 (88.91) treatment. While minimum number of filled grains panicle^{-1} was observed in L_4 (73.49) treatment. The present study showed that the highest number of filled grains panicle^{-1} was found in control treatment compared to leaf clipping treatments. Similar findings were found by Das *et al.* (2017) and Usman *et al.* (2007). Das *et al.* (2017) stated that the decrease in filled grains occurred by flag leaf cut (35.14%), flag leaf with 2nd leaf cut (62.62%) and flag leaf with 2nd and 3rd leaf cut (51.83 %). Usman *et al.* (2007) found that the maximum number of filled grains panicle^{-1} (90) were obtained from control (no defoliation) treatment. Ahmed *et al.* (2001 a) also observed that no leaf clipping treatment had the highest number of sterile spikelets panicle^{-1}; which was statistically identical to clipping at 21 DAT. The minimum value for number of sterile spikelets panicle^{-1} was recorded from clipping at 49 DAT.



L_0= Control (no clipping), L_1= Lower 1st and 2nd leaves, L_2= Lower 2nd and 3rd leaves, L_3= Lower 3rd and 4th leaves clipping and L_4= Flag leaf clipping

Figure 18. Effect of leaf clipping on filled grains panicle^{-1} of Binadhan-13 ($LSD_{(0.05)}$= 5.14).

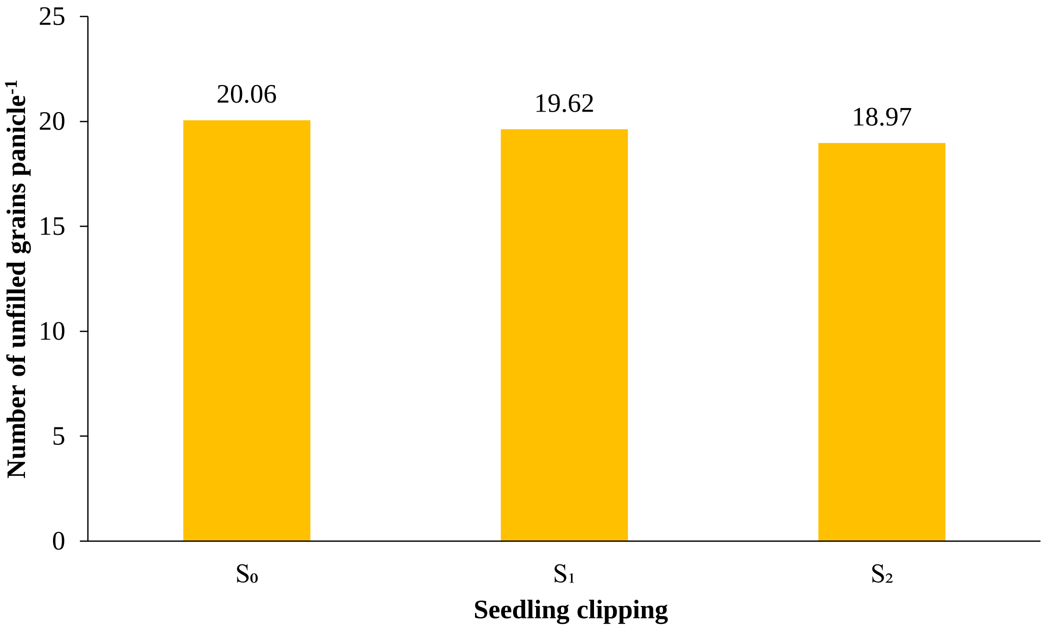
4.2.4.3 Combined effect of seedling and leaf clipping

Combined effect of seedling and leaf clipping showed significant variation on number of filled grains panicle^{-1} of Binadhan-13 (Table 7). Result revealed that the maximum number of filled grains panicle^{-1} (100.80) was observed in S_2L_0 treatment combination which was statistically identical with S_2L_1 (96.20) and S_1L_0 (93.38) treatment combination. On the other hand, the minimum number of filled grains panicle^{-1} (69.47) was observed in S_0L_4 treatment combination which was statistically identical with S_1L_4 (75.24) and S_2L_4 (75.75) treatment combination. Seedling clipping aids in the establishment of optimum seedling hill^{-1} in the field, which reduces seedling competition, whereas various leaf clipping reduces the number of leaves, which has an impact on leaf area and leaf area index, as leaf area index is related to the number of leaves, and reduction of it reduces the plant's photosynthesis, which has an impact on rice growth, development, and grain yield.

4.2.5 Unfilled grains panicle^{-1} (no.)

4.2.5.1 Seedling clipping

Seedling clipping showed significant variation in respect of unfilled grains panicle^{-1} of Binadhan-13 (Fig. 19). From the experiment result revealed that the maximum number of unfilled grains panicle^{-1} (20.06) was observed in S_0 treatment which was statistically similar with S_1 (19.62) treatment while minimum number of unfilled grains panicle^{-1} (18.97) was observed in S_2 treatment. The present findings showed that seedling clipping had a great impact on the number of unfilled grains panicle^{-1}, as a result the highest number of unfilled grains panicle^{-1} was found from non-clipped seedlings compared to clipped seedlings. Seedling clipping aids in the establishment of optimum seedlings hill^{-1} in the field, decreases the competition for nutrients among plants. Das *et al*. (2017) observed that because of less plant competition among leaves, seedling clipping allowed the crop to absorb more plant nutrients, moisture, and sun radiation for development, possibly, which led to a lower number of unfilled grains panicle^{-1}.

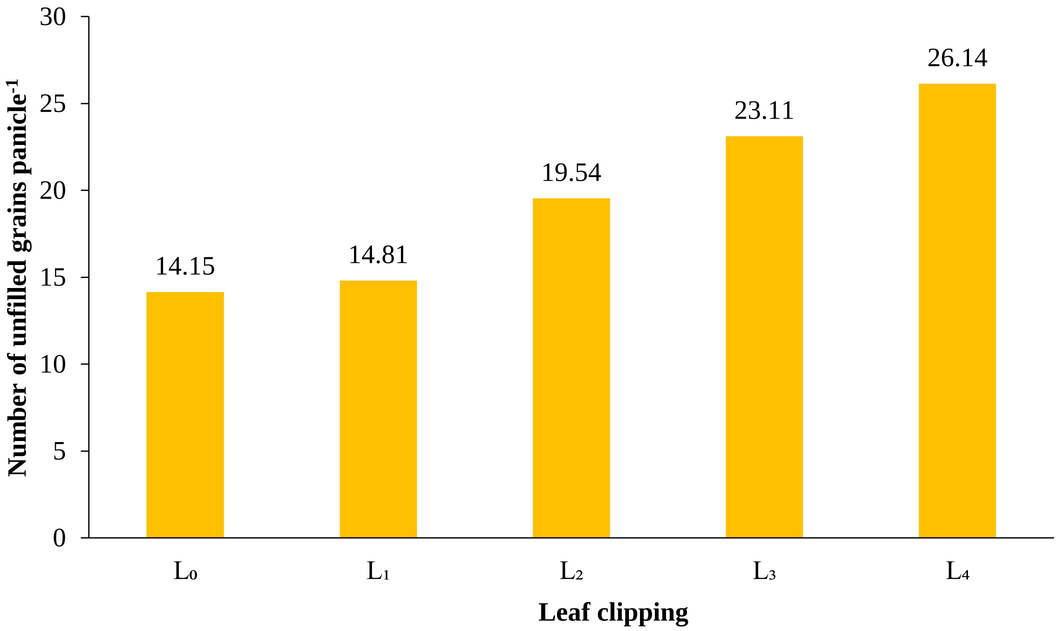


S_0= Control (no clipping), S_1=1/3rd top clipping and S_2= 1/2nd top clipping

Figure 19. Effect of seedling clipping on unfilled grains panicle^{-1} of Binadhan-13 ($LSD_{(0.05)}$= 0.82).

4.2.5.2 Leaf clipping

Leaf clipping of Binadhan-13 showed significant effect on number of unfilled grains panicle^{-1} (Fig. 20). From the experiment result showed that the maximum number of unfilled grains panicle^{-1} was observed in L_4 (26.14) treatment. While the minimum number of unfilled grains panicle^{-1} was observed in L_0 (14.15) treatment which was statistically identical with L_1 (14.81) treatment. Das *et al.* (2017) stated that unfilled grain number increased with higher intensity of leaf cutting and was the highest (79.40) in flag leaf with 3rd leaf cut, which was similar with flag leaf with 2nd leaf cut (65.91). The lowest unfilled grain was observed in the control (33.99) treatment. The present study showed that the highest number of unfilled grains panicle^{-1} was found in leaf clipping treatments compared to control treatment. Das *et al.* (2017) found that the number of unfilled grains enhanced with the degree of leaf clipping, peaking at the number of unfilled grains 79.40 in flag leaves with third leaf cut, which was similar to flag leaves with second leaf cut (65.91). The control (33.99) treatment had the smallest number of unfilled grains.



L_0= Control (no clipping), L_1= Lower 1st and 2nd leaves, L_2= Lower 2nd and 3rd leaves, L_3= Lower 3rd and 4th leaves clipping and L_4= Flag leaf clipping

Figure 20. Effect of leaf clipping on unfilled grains panicle^{-1} of Binadhan-13 ($LSD_{(0.05)}$= 1.53).

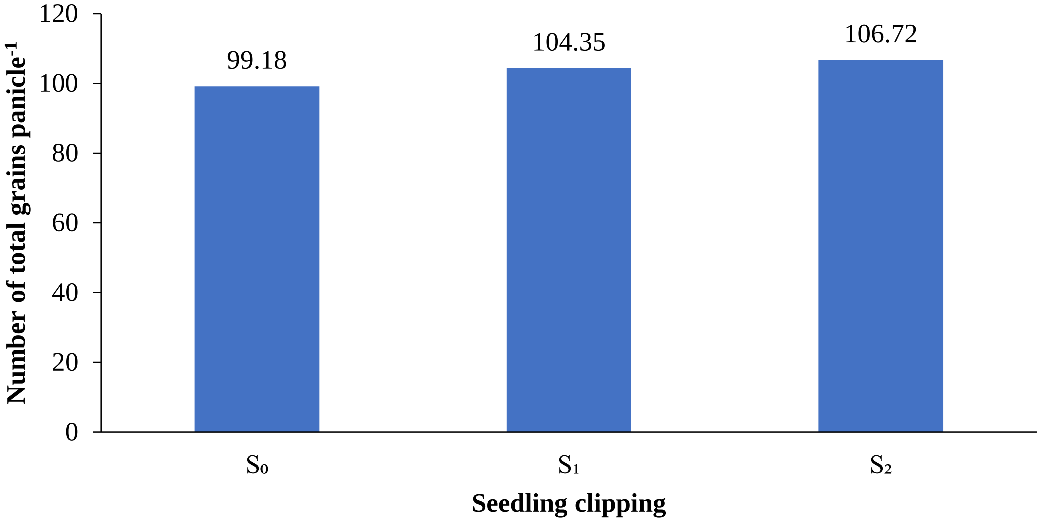
4.2.5.3 Combined effect of seedling and leaf clipping

Combined effect of seedling and leaf clipping showed significant variation on number of unfilled grains panicle^{-1} of Binadhan-13 (Table 7). Result revealed that the maximum number of unfilled grains panicle^{-1} (28.07) was observed in S_0L_4 treatment combination. On the other hand, the minimum number of unfilled grains panicle^{-1} (12.21) was observed in S_2L_0 treatment combination which was statistically identical with S_2L_1 (13.57) and S_1L_1 (14.32) treatment combination. Seedling clipping aids in the establishment of optimum seedling hill^{-1} in the field, which reduces seedling competition and thus decreases the number of unfilled grains. But various leaf clipping increases the number of unfilled grains, which has an impact on leaf area and leaf area index, as leaf area index is related to the number of leaves, and reduction of it reduces photosynthesis activities of the plant, which has an impact on rice growth, development, and grain yield.

4.2.6 Total grains panicle^{-1} (no.)

4.2.6.1 Seedling clipping

Seedling clipping showed significant variation in respect of total grains panicle^{-1} of Binadhan-13 (Fig. 21). From the experiment result revealed that the maximum number of total grains panicle^{-1} (106.72) was observed in S_2 treatment which was statistically identical with S_1 (104.35) treatment while minimum number of total grains panicle^{-1} (99.18) was observed in S_0 treatment. The present findings showed that seedling clipping had a great impact on the number of total grains panicle^{-1}, as a result the highest number of total grains panicle^{-1} was found from clipped seedlings compared to non-clipped seedlings. Seedling clipping assists in the development of optimum seedlings hill^{-1} in the field and reduces nutrient competition among plants. Seedling clipping reduces competition among plant leaves, allowing the crop to absorb more plant nutrients, moisture, and solar radiation for growth, perhaps leading to a larger number of total grains panicle^{-1}.

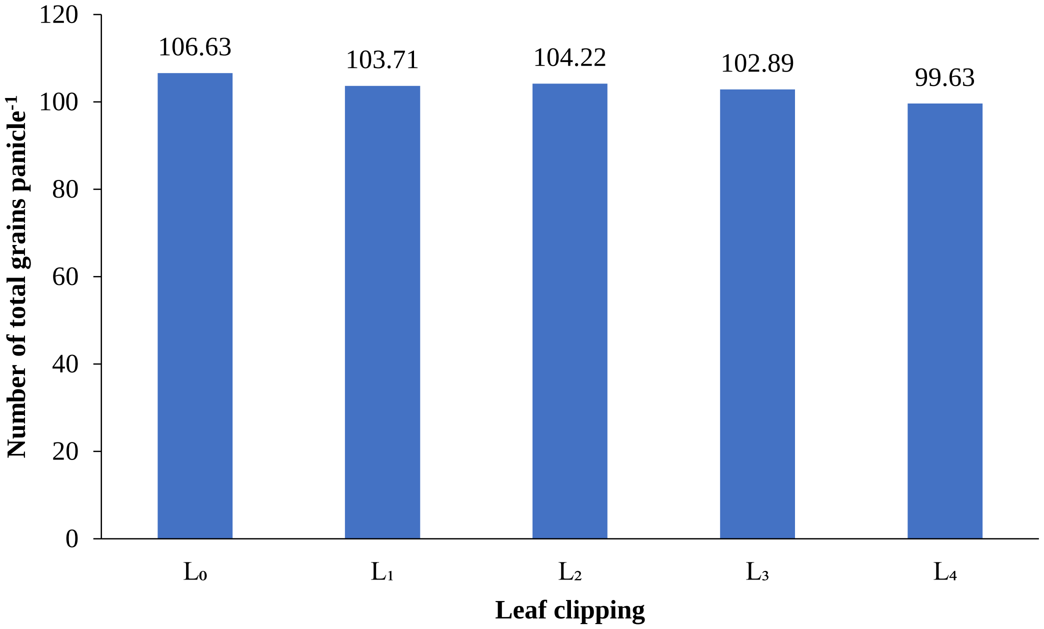


S_0= Control (no clipping), S_1=1/3rd top clipping and S_2= 1/2nd top clipping

Figure 21. Effect of seedling clipping on total grains panicle^{-1} of Binadhan-13 ($LSD_{(0.05)}$= 5.64).

4.2.6.2 Leaf clipping

Leaf clipping of Binadhan-13 showed significant effect on number of total grains panicle^{-1} (Fig. 22). From the experiment result showed that the maximum number of total grains panicle^{-1} was observed in L_0 (106.63) treatment which was statistically identical with L_2 (104.22), L_1 (103.71) and L_3 (102.89) treatment. While the minimum number of total grains panicle^{-1} was observed in L_4 (99.63) treatment. The present study showed that the highest number of total grains panicle^{-1} was found in control treatment compared to leaf clipping treatments. It could be for the reason of a sufficient number of leaves, which influences leaf area and leaf area index, resulting in an increase in total grains panicle^{-1}. Similar findings were found by Usman *et al.* (2007) and Aktar-uz-zaman (2006). According to Usman *et al.* (2007), the control (no defoliation) treatment produced the most spikelets panicle^{-1} (106.8). Aktar-uz-zaman (2006) also found that defoliation of the flag leaf generated a 17.34% reduction in spikelets panicle^{-1}. Similarly, the removal of the penultimate leaf reduced number of spikelets panicle^{-1} by 10.98%, defoliation of the third leaf reduced the number of spikelets panicle^{-1} by 7.20% and defoliation of the flag leaf, penultimate leaf, and third leaf at a same time reduced the number of spikelets panicle^{-1} by 29.20%.



L_0= Control (no clipping), L_1= Lower 1st and 2nd leaves, L_2= Lower 2nd and 3rd leaves, L_3= Lower 3rd and 4th leaves clipping and L_4= Flag leaf clipping

Figure 22. Effect of leaf clipping on total grains panicle^{-1} of Binadhan-13 ($LSD_{(0.05)}$= 5.55).

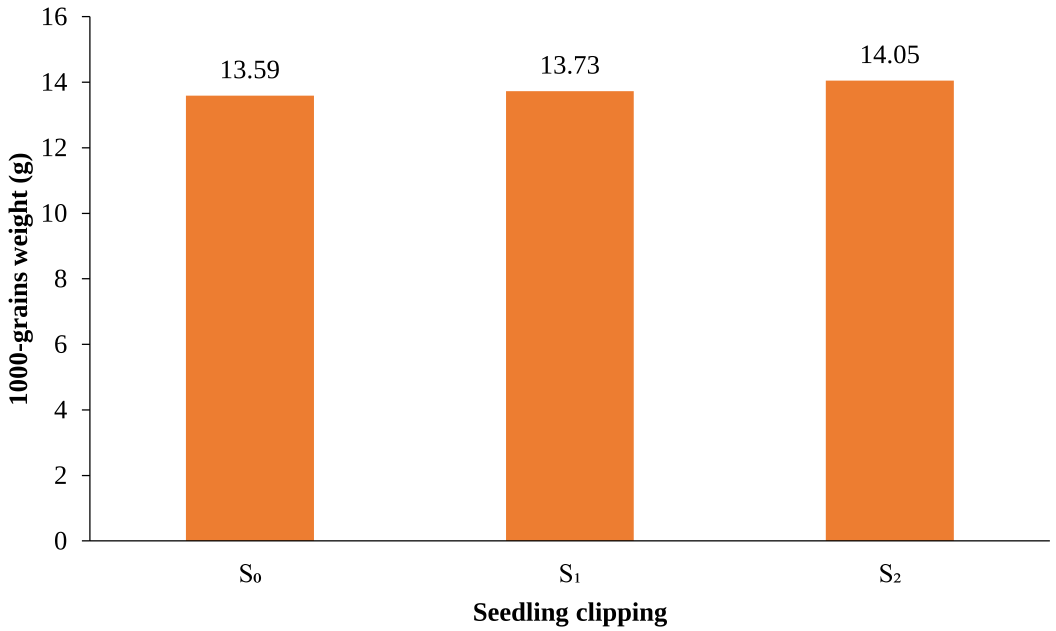
4.2.6.3 Combined effect of seedling and leaf clipping

Combined effect of seedling and leaf clipping showed significant variation on number of total grains panicle^{-1} of Binadhan-13 (Table 7). Results revealed that the maximum number of total grains panicle^{-1} (113.01) was observed in S_2L_0 treatment combination which was statistically identical with S_2L_1 (109.77), S_1L_0 (108.14), S_1L_2 (107.69), S_2L_2 (105.19) and S_2L_3 (104.67) treatment combinations. On the other hand, the minimum number of total grains panicle^{-1} (97.53) was observed in S_0L_4 treatment combination which was statistically identical with S_0L_0 (98.73), S_0L_1 (98.80), S_0L_2 (99.77), S_1L_4 (100.39), S_2L_4 (100.95), S_0L_3 (101.05) and S_1L_1 (102.57) treatment combination. Seedling clipping helps to build optimum seedlings hill^{-1} in the field, reducing seedling competition. More non-effective tillers are produced as a result of the vast number of seedlings hill^{-1}, resulting in mutual shadowing, lodging, and the production of more straw rather than grain. Optimum seedling clipping and no leaf clipping boost production by utilizing the proper resources of its surroundings.

4.2.7 1000-grains weight (g)

4.2.7.1 Seedling clipping

Effect of seedling clipping showed significant variation on 1000-grains weight of Binadhan-13 (Fig. 23). From the experiment result revealed that the maximum 1000-grains weight of Binadhan-13 (14.05 g) was observed in S_2 treatment. While the minimum 1000-grains weight of Binadhan-13 (13.59 g) was observed in S_0 treatment which was statistically identical with S_1 (13.73 g) treatment. The present findings showed that seedling clipping had a great impact on 1000-grains weight, as a result the highest 1000-grains weight was found from clipped seedlings compared to non-clipped seedlings. Seedling clipping facilitates the development of optimum seedlings hill^{-1} in the field and reduces plant competition for resources. Seedling clipping reduced plant competition among leaves, allowing the crop to absorb more plant nutrients, moisture, and sunlight for growth, perhaps leading to a greater 1000-grains weight.

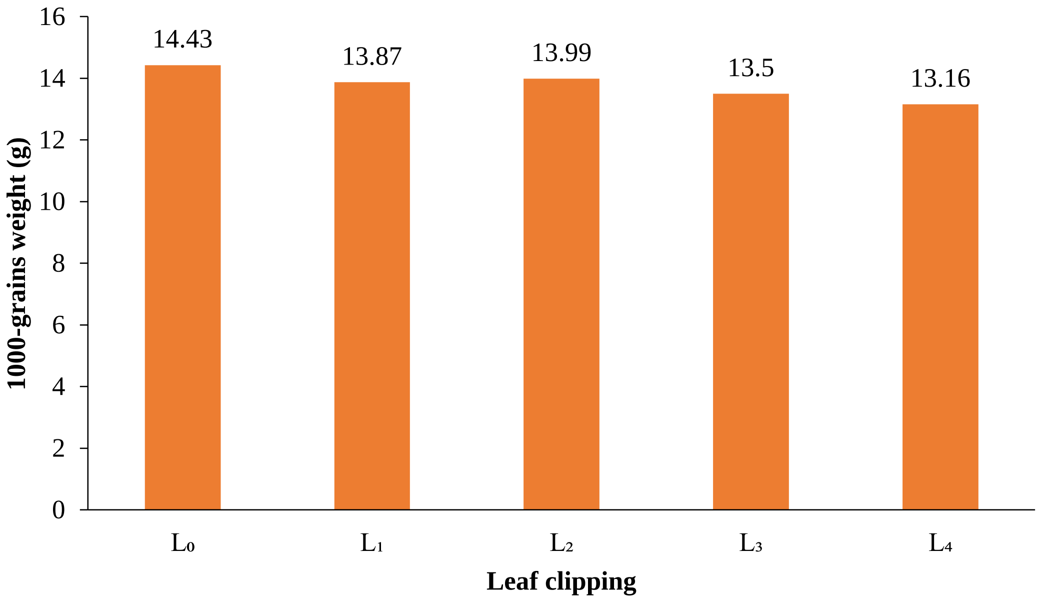


S_0= Control (no clipping), S_1=1/3rd top clipping and S_2= 1/2nd top clipping

Figure 23. Effect of seedling clipping on 1000-grains weight of Binadhan-13 ($LSD_{(0.05)}$= 0.27).

4.2.7.2 Effect of leaf clipping

Leaf clipping showed significant effect on 1000-grains weight of Binadhan-13 (Fig. 24). From the experiment result showed that the maximum 1000-grains weight of Binadhan-13 was observed in L_0 (14.43 g) treatment which was statistically identical with L_2 (13.99 g) treatment. While the minimum 1000-grains weight of Binadhan-13 was observed in L_4 (13.16 g) treatment which was statistically identical with L_3 (13.50 g) treatment. The present study showed that the highest number of 1000-grains weight was found in control treatment compared to leaf clipping treatments. It might be due to sufficient availability of the number of leaves, which has an impact on leaf area and leaf area index that aids in grain development. Fatima (2019) found that Heera-4 shown to have a maximum weight of 1000 grains under control (no flag leaf clipping) conditions. Das *et al.* (2017) observed that leaf defoliation has a substantial influence on the weight of 1000 grains of local variety. Hossain (2017) stated that the weight of 1000 grains was considerably lower in plants with the leaves clipped compared to the control condition.



L_0= Control (no clipping), L_1= Lower 1st and 2nd leaves, L_2= Lower 2nd and 3rd leaves, L_3= Lower 3rd and 4th leaves clipping and L_4= Flag leaf clipping

Figure 24. Effect of leaf clipping on 1000-grains weight of Binadhan-13 ($LSD_{(0.05)}$= 0.49).

4.2.7.3 Combined effect of seedling and leaf clipping

Combined effect of seedling and leaf clipping showed significant variation on 1000-grains weight of Binadhan-13 (Table 7). Result revealed that the maximum 1000-grains weight of Binadhan-13 (14.69 g) was observed in S_2L_0 treatment combination which was statistically identical with S_0L_0 (14.56 g), S_2L_1 (14.38 g), S_2L_2 (14.34 g), S_1L_2 (14.21 g) and S_1L_0 (14.04 g). On the other hand, the minimum 1000 grains weight of Binadhan-13 (13.04 g) was observed in S_0L_4 treatment combination which was statistically identical with S_0L_3 (13.16 g), S_2L_4 (13.17 g), S_1L_4 (13.28 g), S_0L_2 (13.43 g), S_1L_1 (13.47 g), S_1L_3 (13.65 g), S_2L_3 (13.69 g) and S_0L_1 (13.77 g) treatment combination. Higher number of seedlings hill^{-1} intensifies competition for many resources. Seedling clipping promotes in the development of ideal number of seedlings hill^{-1} in the field and reduces nutrient competition among plants. Seedling clipping reduces plant competition among leaves, allowing the crop to absorb more plant nutrients, moisture, and sunlight for growth, perhaps leading to an increase in 1000-grains weight. On the other hand, various leaf clipping reduces the number of leaves, which has an effect on leaf area and leaf area index, and a reduction in it reduces the plant's photosynthesis activities, affecting rice growth, development, and grain yield. Plant growth and development suffer as a result of severe leaf clipping, which lowers leaf area, limits sunlight intake, and diminishes photosynthetic production. As a result, the 1000-grains weight of the S_2L_0 treatment combination was higher than the other treatment combinations. In comparison to other treatments, seedling clipping and no leaf clipping boost seedling growth and development, resulting in a higher 1000-grains weight.

Table 7. Combined effect of seedling and leaf clipping on panicle length, filled grains panicle^{-1}, unfilled grains panicle^{-1}, total grains panicle^{-1} and weight of 1000-grains of Binadhan-13

Treatment Combinations	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	Total grains panicle^{-1} (no.)	Weight of 1000-grains (g)
S_0L_0	24.67 bc	83.24 de	15.49 g-i	98.73 cd	14.56 ab
S_0L_1	25.34 bc	82.27 de	16.53 gh	98.80 cd	13.77 b-f
S_0L_2	24.79 bc	82.01 de	17.76 fg	99.77 b-d	13.43 d-f
S_0L_3	24.45 c	78.61 de	22.44 cd	101.05 b-d	13.16 f
S_0L_4	24.43 c	69.47 f	28.07 a	97.53 d	13.04 f
S_1L_0	25.06 bc	93.38 a-c	14.76 hi	108.14 a-c	14.04 a-e
S_1L_1	24.61 bc	88.25 b-d	14.32 h-j	102.57 b-d	13.47 d-f
S_1L_2	25.11 bc	86.70 b-d	20.99 de	107.69 a-d	14.21 a-d
S_1L_3	24.46 c	80.06 de	22.88 b-d	102.95 a-d	13.65 c-f
S_1L_4	25.02 bc	75.24 ef	25.15 b	100.39 b-d	13.28 ef
S_2L_0	26.35 a	100.80 a	12.21 j	113.01 a	14.69 a
S_2L_1	25.50 ab	96.20 ab	13.57 ij	109.77 ab	14.38 a-c
S_2L_2	25.57 ab	85.33 cd	19.86 ef	105.19 a-d	14.34 a-c
S_2L_3	24.86 bc	80.67 de	24.00 bc	104.67 a-d	13.69 c-f
S_2L_4	24.62 bc	75.75 ef	25.20 b	100.95 b-d	13.17 f
$LSD_{(0.05)}$	1.07	8.90	2.65	9.60	0.84
CV(%)	2.54	6.30	8.04	5.51	3.62

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.

NS= Non-significant
S_0= Control (no clipping)
S_1=1/3rd top clipping
S_2= 1/2nd top clipping

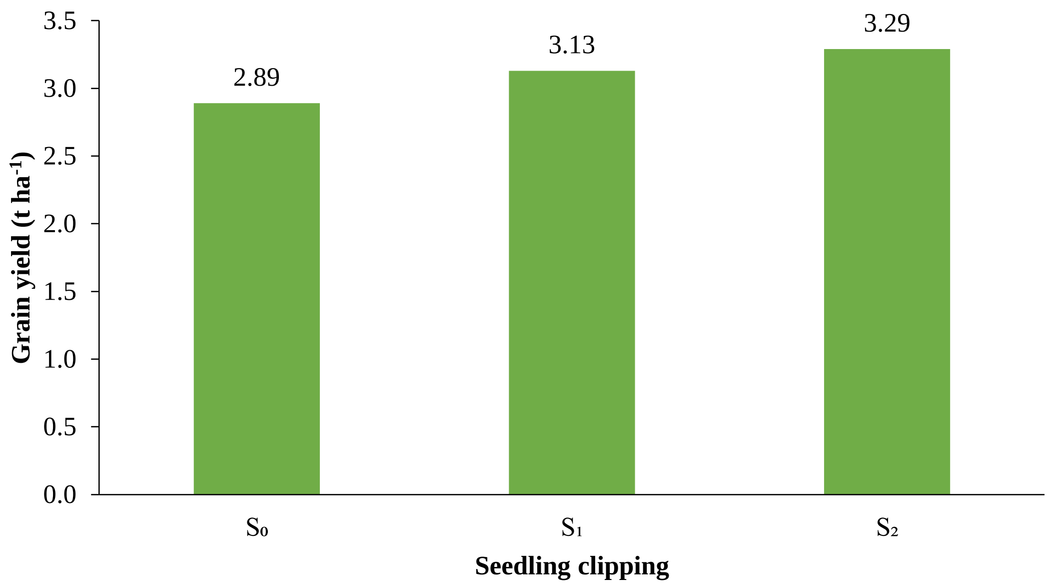
L_0= Control (no clipping)
L_1= Lower 1st and 2nd leaves clipping
L_2= Lower 2nd and 3rd leaves clipping
L_3= Lower 3rd and 4th leaves clipping
L_4= Flag leaf clipping

4.3 Yield characters

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

4.3.1.1 Seedling clipping

Grain yield (t ha^{-1}) of Binadhan-13 showed significant variation due to effect of different seedling clipping (Fig. 25). From the experiment result revealed that the maximum grain yield (3.29 t ha^{-1}) was observed in S_2 treatment. Whereas the minimum grain yield (2.89 t ha^{-1}) was observed in S_0 treatment. Seedling clipping kept the field well aerated, reduced competition among plants and thus increases growth and yield. The present findings showed that seedling clipping had a great impact on grain yield, as a result the highest grain yield was found from clipped seedlings compared to non-clipped seedlings. These results might be attributable to the fact that seedling clipping maintained the rice field properly aerated, allowing the crop to absorb more plant nutrients, moisture, and receive more sun radiation for higher development (Boonreund and Marsom, 2015).

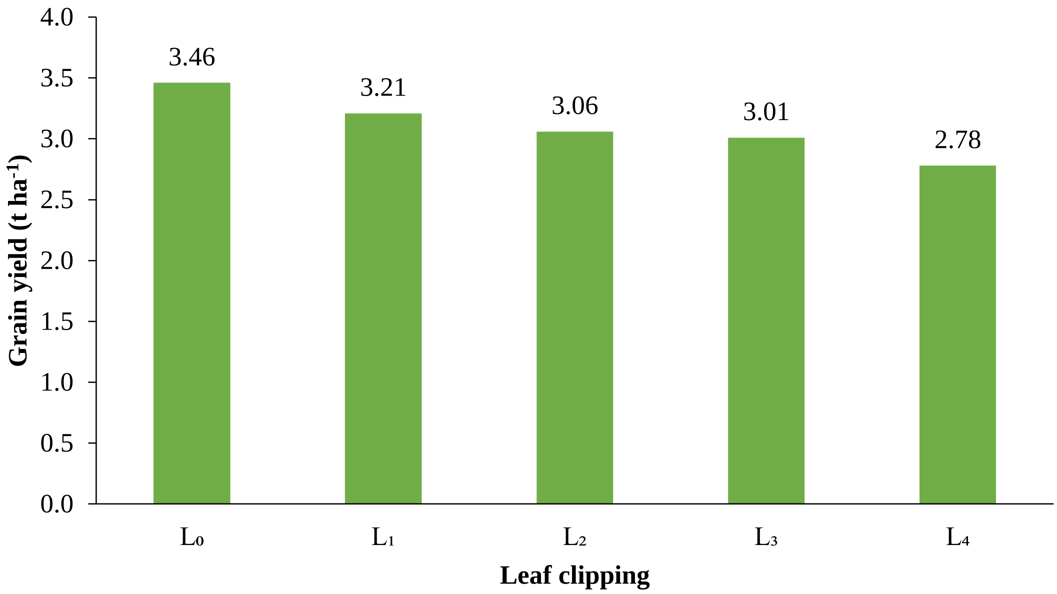


S_0= Control (no clipping), S_1=1/3rd top clipping and S_2= 1/2nd top clipping

Figure 25. Effect of seedling clipping on grain yield of Binadhan-13 ($LSD_{(0.05)}$= 0.11).

4.3.1.2 Leaf clipping

Leaf clipping of showed significant effect on grain yield (t ha^{-1}) of Binadhan-13 (Fig. 26). From the experiment result showed that the maximum grain yield of Binadhan-13 was observed in L_0 (3.46 t ha^{-1}) treatment. While the minimum grain yield of Binadhan-13 was observed in L_4 (2.78 t ha^{-1}) treatment. The present study showed that the highest grain yield was found in control treatment compared to leaf clipping treatments. It might be due to sufficient availability of the number of leaves, which has an impact on leaf area and leaf area index that aids in grain yield. Similar findings were found by Fatima (2019), Karmaker and Karmakar (2019), Abou-Khalifa *et al*. (2008) and Ros *et al.* (2003). According to Karmaker and Karmakar (2019), the treatment combination of 115 kg N ha^{-1} and no leaf clipping (N_4C_0) produced the highest mean grain yield (5.25 t ha^{-1}) when compared to other treatments. Hossain (2017) found that leaf defoliation reduced grain yield by the least amount (10%) in BRRI dhan39 (control 5.75 t ha^{-1}, treated 5.15 t ha^{-1}) compared to the other varieties. According to Abou-Khalifa *et al.* (2008), flag leaf contributes 45% of grain yield, and flag leaf removal is the single most important factor in yield loss, which was also true in our experiment. Ros *et al.* (2003) discovered that removing 30% of leaves reduced grain output by 20%.



L_0= Control (no clipping), L_1= Lower 1st and 2nd leaves, L_2= Lower 2nd and 3rd leaves, L_3= Lower 3rd and 4th leaves clipping and L_4= Flag leaf clipping

Figure 26. Effect of leaf clipping on grain yield of Binadhan-13 ($LSD_{(0.05)}$= 0.11).

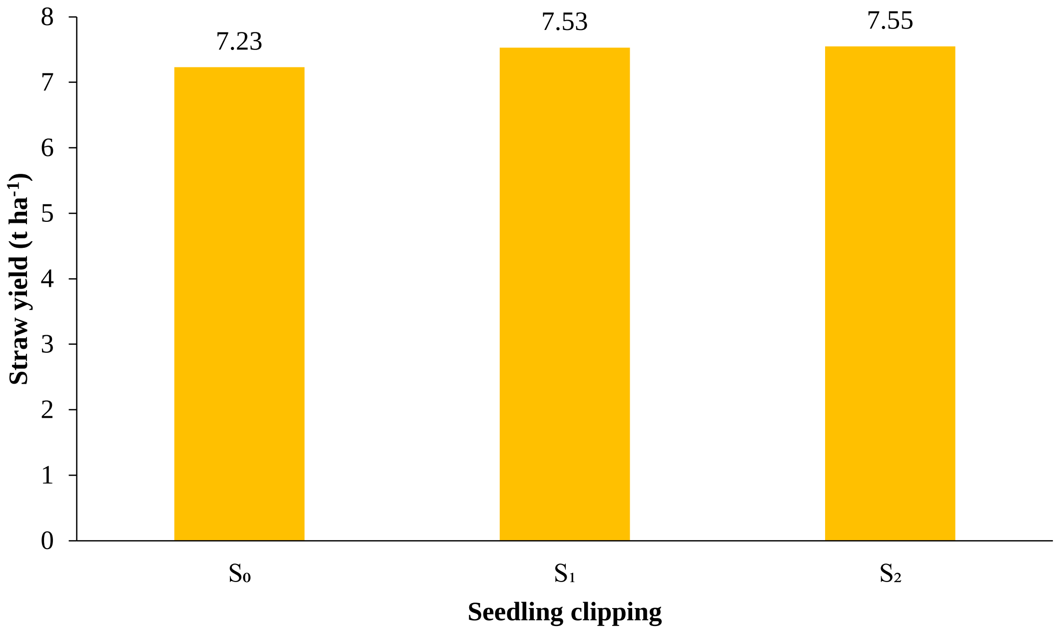
4.3.1.3 Combined effect of seedling and leaf clipping

Combined effect of seedling and leaf clipping showed significant variation on grain yield (t ha^{-1}) of Binadhan-13 (Table 8). Result revealed that the maximum grain yield of Binadhan-13 (3.73 t ha^{-1}) was observed in S_2L_0 treatment combination which was statistically identical with S_1L_0 (3.61 t ha^{-1}) and S_2L_1 (3.57 t ha^{-1}) treatment combination. On the other hand, the minimum grain yield of Binadhan-13 (2.66 t ha^{-1}) was observed in S_0L_4 treatment combinations which was statistically equivalent with S_0L_1 (2.82 t ha^{-1}), S_1L_4 (2.83 t ha^{-1}), S_2L_4 (2.86 t ha^{-1}), S_0L_3 (2.89 t ha^{-1}) and S_1L_3 (2.93 t ha^{-1}) treatment combinations. In the extreme seedling $hill^{-1}$, competition among plants for different growth factors led in delayed plant growth, decreased production of effective tillers $hill^{-1}$, increased non-effective tillers $hill^{-1}$, fewer grains $panicle^{-1}$, and the highest number of sterile spikelet $panicle^{-1}$. Due to competition among seedlings for space, light, air, water, and nutrients, yield characters were negatively impacted, resulting in reduced yield. Primary job of a leaf is to provide food for the plant through photosynthesis. Chlorophyll, the green pigment that gives plants their distinctive appearance, absorbs light energy. Clipping leaves reduces leaf area, which has an influence on light absorption and photosynthesis, resulting in a reduced grain development rate.

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

4.3.2.1 Seedling clipping

Straw yield (t ha^{-1}) of Binadhan-13 showed significant variation due to effect of different seedling clipping (Fig. 27). From the experiment result revealed that the maximum straw yield (7.55 t ha^{-1}) was observed in S_2 treatment which was statistically identical with S_1 (7.53 t ha^{-1}) treatment. Whereas minimum straw yield (7.23 t ha^{-1}) was observed in S_0 treatment. The present findings showed that seedling clipping had a great impact on straw yield, as a result the highest straw yield was found from clipped seedlings compared to non-clipped seedlings. Seedling clipping at a specific level helps in the production of vigor seedlings $hill^{-1}$, creates more biomass by transferring enough food supplies from the body to the expanding panicles, favoring the development of more straw and grain as compared to week seedlings. Week seedlings are produced because of intense competition among seedlings for nutrients.

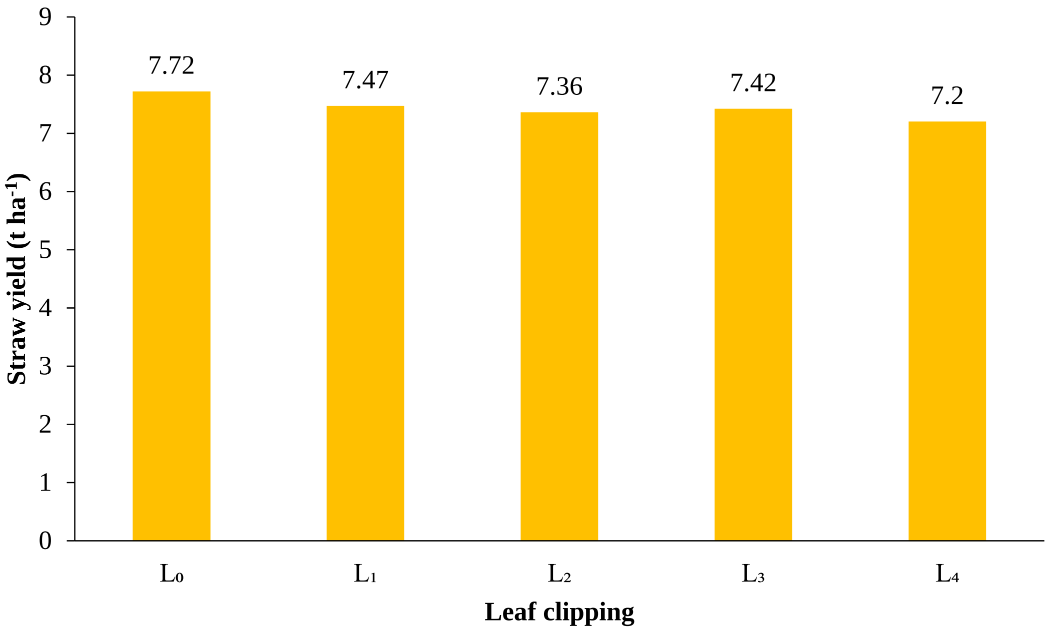


S_0= Control (no clipping), S_1=1/3rd top clipping and S_2= 1/2nd top clipping

Figure 27. Effect of seedling clipping on straw yield of Binadhan-13 ($LSD_{(0.05)}$= 0.23).

4.3.2.2 Leaf clipping

Leaf clipping of showed significant effect on straw yield (t ha^{-1}) of Binadhan-13 (Fig. 28). From the experiment result showed that the maximum straw yield of Binadhan-13 was observed in L_0 (7.72 t ha^{-1}) treatment which was statistically identical with L_1 (7.47 t ha^{-1}), L_3 (7.42 t ha^{-1}) and L_2 (7.36 t ha^{-1}). While the minimum straw yield of Binadhan-13 was observed in L_4 (7.20 t ha^{-1}) treatment. The present study showed that the highest straw yield was found in control treatment compared to leaf clipping treatments. It might be due to sufficient availability of the number of leaves, which has an impact on leaf area and leaf area index that aids in the development of more straw and grain. Hossain (2017) observed that the maximum straw production was obtained with no leaf clipping treatment (control), regardless of the cultivars studied.



L_0= Control (no clipping), L_1= Lower 1st and 2nd leaves, L_2= Lower 2nd and 3rd leaves, L_3= Lower 3rd and 4th leaves clipping and L_4= Flag leaf clipping

Figure 28. Effect of leaf clipping on straw yield of Binadhan-13 ($LSD_{(0.05)}$= 0.38).

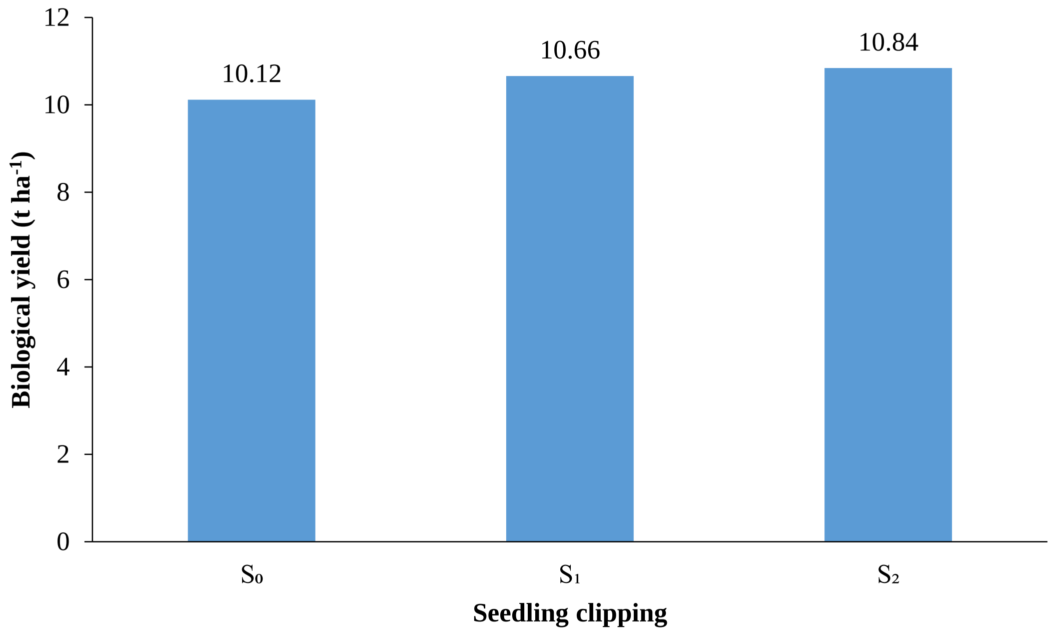
4.3.2.3 Combined effect of seedling and leaf clipping

Combined effect of seedling and leaf clipping showed significant variation on straw yield (t ha^{-1}) of Binadhan-13 (Table 8). Result revealed that the maximum straw yield of Binadhan-13 (7.77 t ha^{-1}) was observed in S_0L_0 treatment combination which was statistically identical with S_2L_0 (7.71 t ha^{-1}), S_2L_1 (7.69 t ha^{-1}), S_2L_3 (7.68 t ha^{-1}) and S_1L_1 (7.67 t ha^{-1}) treatment combinations. On the other hand, the minimum straw yield of Binadhan-13 (6.99 t ha^{-1}) was observed in S_0L_4 treatment combination which was statistically identical with S_0L_1 (7.05 t ha^{-1}) treatment combination. Extreme seedling $hill^{-1}$ enhance competition for various resources, seedling clipping aids in the establishment of optimum seedling $hill^{-1}$ in the field, which reduces seedling competition. Whereas extreme leaf clipping reduces leaf area result in less sunlight capture and less photosynthetic production and thus impact in poor growth and development of the plant. Therefore, seedling clipping and no leaf clipping improve seedling growth and development, resulting in an increased straw yield as compared to other treatments.

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

4.3.3.1 Seedling clipping

Binadhan-13 showed significant variation on biological yield due to effect of different seedling clipping (Fig. 29). From the experiment result revealed that the maximum biological yield (10.84 t ha^{-1}) was observed in S_2 treatment which was statistically identical with S_1 (10.66 t ha^{-1}) treatment. Whereas the minimum biological yield (10.12 t ha^{-1}) was observed in S_0 treatment. The present findings showed that seedling clipping had a great impact on biological yield, as a result the highest biological yield was found from clipped seedlings compared to non-clipped seedlings. Seedling clipping aids in the establishment of optimum seedlings $hill^{-1}$ in the field, decreases the competition for nutrients among plants. Because of less plant competition among leaves, seedling clipping allowed the crop to absorb more plant nutrients, moisture, and sun radiation for development, possibly, which led to a higher biological yield.

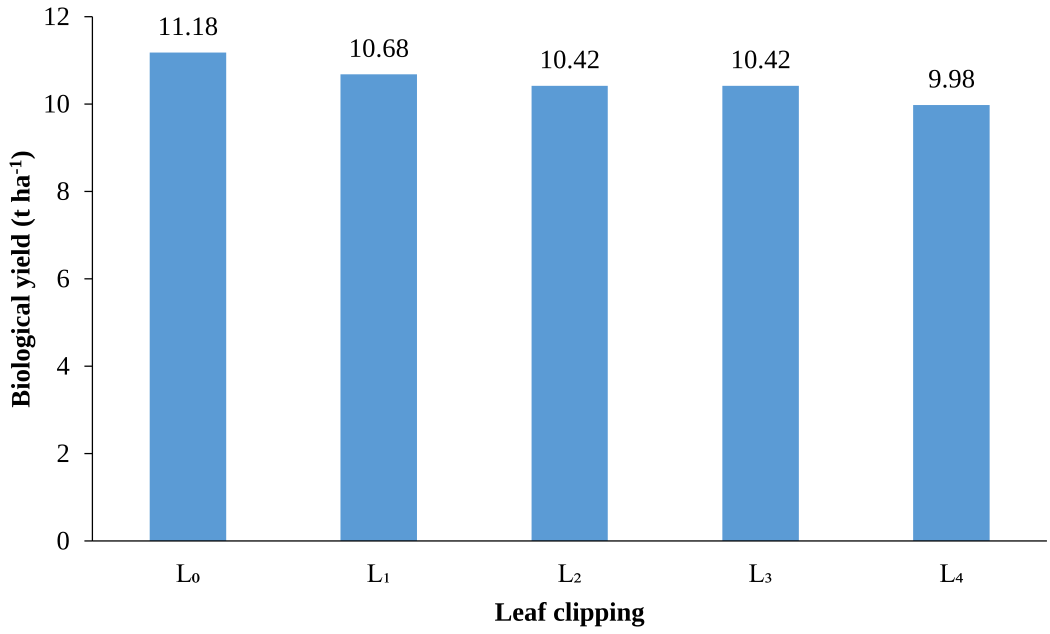


S_0= Control (no clipping), S_1=1/3rd top clipping and S_2= 1/2nd top clipping

Figure 29. Effect of seedling clipping on biological yield of Binadhan-13 ($LSD_{(0.05)}$= 0.18)

4.3.3.2 Leaf clipping

Different leaf clipping of Binadhan-13 showed significant effect on biological yield (Fig. 30). From the experiment result showed that the maximum biological yield of Binadhan-13 was observed in L_0 (11.18 t ha^{-1}) treatment. While the minimum biological yield of Binadhan-13 was observed in L_4 (9.98 t ha^{-1}) treatment. The present study showed that the highest biological yield was found in control treatment compared to leaf clipping treatments. It might be due to sufficient availability of the number of leaves, which has an impact on leaf area and leaf area index that aids in plant growth. Usman *et al.* (2007) observed that the highest biological yield was obtained from control treatment as compared to other leaf clipping treatments.



L_0= Control (no clipping), L_1= Lower 1st and 2nd leaves, L_2= Lower 2nd and 3rd leaves, L_3= Lower 3rd and 4th leaves clipping and L_4= Flag leaf clipping

Figure 30. Effect of leaf clipping on biological yield of Binadhan-13 ($LSD_{(0.05)}$= 0.40).

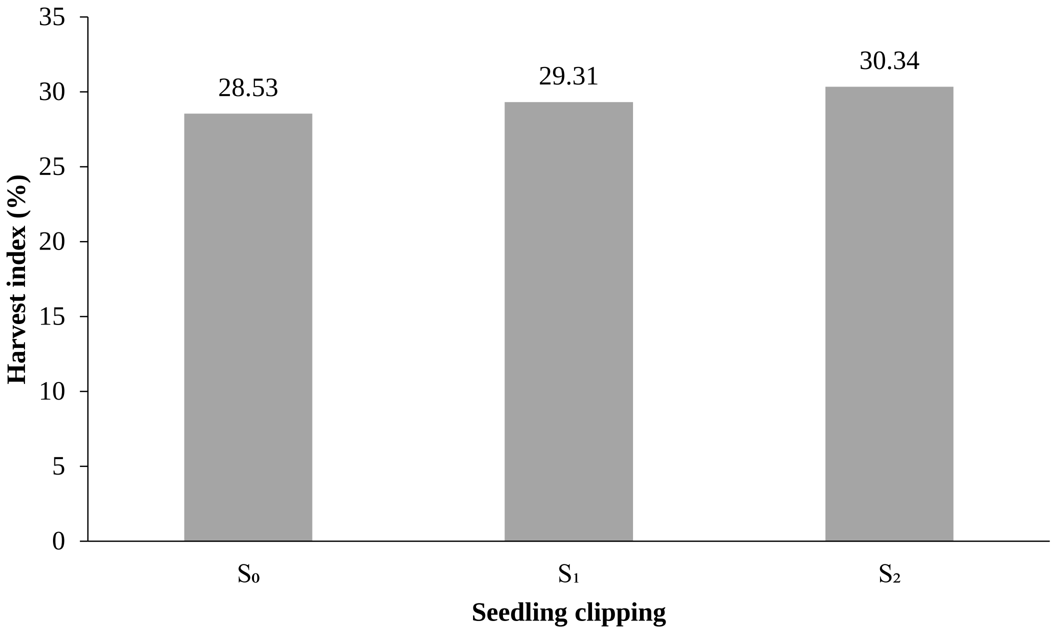
4.3.3.3 Combined effect of seedling and leaf clipping

Combined effect of seedling and leaf clipping showed significant variation on biological yield (t ha^{-1}) of Binadhan-13 (Table 8). Result revealed that the maximum biological yield of Binadhan-13 (11.43 t ha^{-1}) was observed in S_2L_0 treatment combination which was statistically identical with S_1L_0 (11.31 t ha^{-1}), S_2L_1 (11.27 t ha^{-1}), S_1L_1 (10.92 t ha^{-1}), S_1L_0 (10.88 t ha^{-1}) and S_0L_0 (10.80 t ha^{-1}) treatment combinations. On the other hand, the minimum biological yield of Binadhan-13 (9.65 t ha^{-1}) was observed in S_0L_4 treatment combination which was statistically identical with S_0L_1 (9.87 t ha^{-1}), S_0L_3 (10.05 t ha^{-1}), S_1L_4 (10.06 t ha^{-1}), S_0L_2 (10.22 t ha^{-1}) and S_2L_4 (10.23 t ha^{-1} treatment combinations. Optimum seedling along with no leaf clipping influences growth may be reason that no leaf clipping plant have higher leaf area which capture more sunlight and produce more photosynthetic product comparable to clipping one and that were being utilized properly by optimum seedling comparable to increased number of seedling as a result it impacts on biological yield.

4.3.4 Harvest index (%)

4.3.4.1 Seedling clipping

Harvest index (%) of Binadhan-13 showed significant variation due to effect of different seedling clipping (Fig. 31). From the experiment result revealed that the maximum harvest index (30.34 %) was observed in S_2 treatment which was statistically identical with S_1 (29.31 %) treatment. Whereas the minimum harvest index (28.53 %) was observed in S_0 treatment. The present findings showed that seedling clipping had a great impact on harvest index, as a result the highest harvest index was found from clipped seedlings compared to non-clipped seedlings. Seedling clipping facilitates the development of optimum seedlings $hill^{-1}$ in the field and reduces plant competition for resources. Seedling clipping reduced plant competition among leaves, allowing the crop to absorb more plant nutrients, moisture, and sunlight for growth, perhaps leading to a greater harvest index.

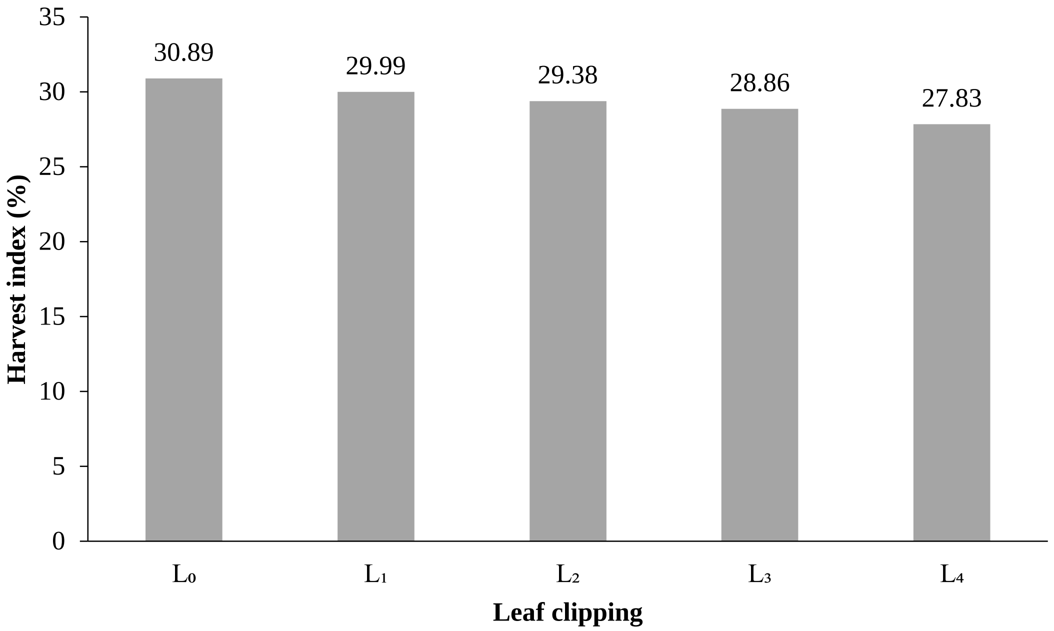


S_0= Control (no clipping), S_1=1/3rd top clipping and S_2= 1/2nd top clipping

Figure 31. Effect of seedling clipping on harvest index of Binadhan-13 ($LSD_{(0.05)}$= 1.15).

4.3.4.2 Leaf clipping

Different leaf clipping of Binadhan-13 showed significant effect on harvest index (%) (Fig. 32). From the experiment result showed that the maximum harvest index of Binadhan-13 was observed in L_0 (30.89 %) treatment which was statistically identical with L_1 (29.99 %) and L_2 (29.38 %) treatment. While the minimum harvest index of Binadhan-13 was observed in L_4 (27.83 %) treatment which was statistically identical with L_3 (28.86 %) treatment. The present study showed that the highest harvest index was found in control treatment compared to leaf clipping treatments. It might be due to sufficient availability of the number of leaves, which has an impact on leaf area and leaf area index that aids in crop growth and grain yield. Similar findings were found by Karmaker and Karmakar (2019) and Usman *et al.* (2007). According to Karmaker and Karmakar (2019), the treatment combinations of 115 kg N ha^{-1} and no leaf clipping (N_4C_0) produced the greatest mean harvest index (46%) when compared to other treatment combinations. Usman *et al.* (2007) stated that the control treatment had the greatest harvest index (42.70%).



L_0= Control (no clipping), L_1= Lower 1st and 2nd leaves, L_2= Lower 2nd and 3rd leaves, L_3= Lower 3rd and 4th leaves clipping and L_4= Flag leaf clipping

Figure 32. Effect of leaf clipping on harvest index of Binadhan-13 ($LSD_{(0.05)}$= 1.69).

4.3.4.3 Combined effect of seedling and leaf clipping

Different seedling along with different leaf clipping showed significant variation on harvest index (%) of Binadhan-13 (Table 8). Result revealed that the maximum harvest index of Binadhan-13 (32.59 %) was observed in S_2L_0 treatment combination which was statistically identical with S_1L_0 (31.97 %) and S_2L_1 (31.70 %) treatment combination. On the other hand, the minimum harvest index of Binadhan-13 (27.51 %) was observed in S_0L_4 treatment combination which was statistically identical with S_1L_0 (31.97 %), S_2L_4 (27.91 %), S_1L_4 (28.07 %), S_0L_0 (28.12 %), S_1L_3 (28.22 %), S_1L_2 (28.55 %), S_0L_1 (28.56 %), S_0L_3 (28.79 %), S_0L_2 (29.67 %) and S_1L_1 (29.73 %) treatment combinations. Seedling vigor (seedling size, health, and growth rate) is influenced by a number of variables, including genetics and environmental impacts, and may be manipulated through management. Various leaf clipping reduces the number of leaves, which has an impact on leaf area and leaf area index, and reduction of it reduces photosynthesis activities of the plant, which has an impact on rice growth, development, and grain yield. Seedling clipping and no leaf clipping improve seedling growth and development, resulting in an increased harvest index as compared to other treatments.

Table 8. Combined effect of seedling and leaf clipping on grain yield, straw yield, biological yield and harvest index of Binadhan-13

Treatment Combinations	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
S_0L_0	3.04 b-d	7.77 a	10.80 a-e	28.12 c
S_0L_1	2.82 de	7.05 bc	9.87 gh	28.56 c
S_0L_2	3.04 b-d	7.18 a-c	10.22 e-h	29.67 bc
S_0L_3	2.89 de	7.15 a-c	10.05 f-h	28.79 c
S_0L_4	2.66 e	6.99 c	9.65 h	27.51 c
S_1L_0	3.61 a	7.69 a	11.31 ab	31.97 ab
S_1L_1	3.24 b	7.67 ab	10.92 a-c	29.73 bc
S_1L_2	3.05 b-d	7.62 a-c	10.67 b-f	28.55 c
S_1L_3	2.93 c-e	7.42 a-c	10.35 c-g	28.22 c
S_1L_4	2.83 de	7.24 a-c	10.06 f-h	28.07 c
S_2L_0	3.73 a	7.71 a	11.43 a	32.59 a
S_2L_1	3.57 a	7.69 a	11.27 ab	31.70 ab
S_2L_2	3.09 b-d	7.29 a-c	10.38 c-g	29.92 a-c
S_2L_3	3.19 bc	7.68 ab	10.88 a-d	29.57 bc
S_2L_4	2.86 de	7.37 a-c	10.23 d-h	27.91 c
$LSD_{(0.05)}$	0.29	0.66	0.69	2.94
CV(%)	5.68	5.29	3.91	5.94

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.

NS= Non-significant
S_0= Control (no clipping)
S_1=1/3rd top clipping
S_2= 1/2nd top clipping

L_0= Control (no clipping)
L_1= Lower 1st and 2nd leaves clipping
L_2= Lower 2nd and 3rd leaves clipping
L_3= Lower 3rd and 4th leaves clipping
L_4= Flag leaf clipping

CHAPTER V

SUMMARY AND CONCLUSION

The field experiment was carried out at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the time period from 1st July to 12 December-2019, to investigate the efficacy of seedling and leaf clipping on growths, yield and yield contributing characters of Binadhan-13. The experiment comprised of two factors, Factor A: Seedling clipping (3) *viz.* S_0= Control (no clipping), S_1 =1/3rd top clipping and S_2= 1/2nd top clipping and Factor B: Leaf clipping before panicle initiation (5) *viz.* L_0= Control (no clipping), L_1= Lower 1st and 2nd leaves clipping, L_2= Lower 2nd and 3rd leaves clipping, L_3= Lower 3rd and 4th leaves clipping and L_4= Flag leaf clipping. The experiment was laid out in split plot design with three replications. The total numbers of unit plots were 45. The size of unit plot was 55.76 m^2 (2.4 m × 2.4 m). Seedling top clipping was assigned in main plot and leaf clipping was assigned in sub plot. Data on different growth parameters, yield contributing characters and yield parameters were recorded to find out the efficacy of seedling and leaf clipping for the production of highest grain yield of Binadhan-13.

Seedling and leaf clipping either individually or combined showed significant variations in most of the characters of Binadhan-13.

In respect of seedling clipping, the maximum plant height (55.95, 87.16, 108.37, 129.16, 140.21 and 154.80 cm at 20, 40, 60, 80, 100 DAT and harvest, respectively) were observed in S_0 treatment. The maximum number of leaves $hill^{-1}$ (54.13, 77.41, 93.90, 73.89 and 64.14 at 20, 40, 60, 80 and 100 DAT, respectively), leaf area (23.44, 41.548, 64.37, 77.48 and 81.29 at 20, 40, 60, 80 and 100 DAT, respectively), number of tillers $hill^{-1}$ (15.47, 19.353, 20.87, 16.42, 14.25 and 13.28 at 20, 40, 60, 80, 100 DAT and harvest, respectively), above ground dry matter weight $hill^{-1}$ (3.49, 12.42, 20.83, 34.13, 42.97 and 55.49 g at 20, 40, 60, 80, 100 DAT and harvest, respectively), effective tillers $hill^{-1}$ (12.80) were observed in S_2 treatment. The maximum number of non-effective tillers $hill^{-1}$ (0.83) was observed in S_0 (0.83) treatment. The maximum panicle length (25.38 cm), maximum number of filled grains $panicle^{-1}$ (87.75) were observed in S_2 treatment. The maximum number of unfilled grains $panicle^{-1}$ (20.06) was observed in S_0 treatment. The maximum number of total grains $panicle^{-1}$ (106.72), 1000 grains weight of Binadhan-13 (14.05 g), grain yield (3.29 t ha^{-1}), straw yield (7.55 t ha^{-1}), biological yield (10.84 t ha^{-1}) and the maximum harvest index (30.34 %) were observed in S_2 treatment.

On the other hand, the minimum plant height (53.28, 84.29 and 104.84 at 20, 40 and 60 DAT, respectively) was observed in S_2 treatment. At 80 DAT the minimum plant height (127.07 cm) was observed in S_1 treatment. At 100 DAT, the minimum plant height (137.93) was observed in S_2 treatment. At harvest, the minimum plant height (152.02 cm) was observed in S_1 treatment. The minimum number of leaves $hill^{-1}$ (51.05) at 20 DAT was observed in S_0 treatment. At 40 DAT, the minimum number of leaves $hill^{-1}$ (75.15) was observed in S_1 treatment. At 60 DAT, minimum number of leaves $hill^{-1}$ (86.28) was observed in S_0 treatment. At 80 and 100 DAT the minimum number of leaves $hill^{-1}$ (69.72 and 55.26, respectively) was observed in S_1 treatment. The minimum leaf area (19.81 and 40.599 cm^2 at 20 and 40 DAT, respectively) was observed in S_0 treatment. At 60, 80 and 100 DAT the minimum leaf area (59.42 cm^2, 68.83 cm^2 and 72.65 cm^2, respectively) was observed in S_1 treatment. The minimum number of tillers $hill^{-1}$ (14.59) at 20 DAT was observed in S_0 treatment. At 40 DAT the minimum number of tillers $hill^{-1}$ (18.787) was observed in S_1 treatment. At 60 DAT the minimum number of tillers $hill^{-1}$ (19.17) was observed in S_0 treatment. At 80, 100 DAT and harvest, the minimum number of tillers $hill^{-1}$ (15.49, 13.10 and 12.28, respectively) was observed in S_1 treatment. The minimum above ground dry matter weight $hill^{-1}$ (3.32 g at 20 DAT) was observed in S_0 treatment. At 40, 60, 80, 100 DAT and harvest, the minimum above ground dry matter $hill^{-1}$ (11.70, 19.38, 30.53, 40.01 and 51.71 g, respectively) was observed in S_1 treatment. The minimum number of effective tillers $hill^{-1}$ was observed in S_1 (11.65) treatment. The minimum number of non-effective tillers $hill^{-1}$ was observed in S_2 (0.48) treatment. The minimum panicle length (24.73 cm), number of filled grains $panicle^{-1}$ (79.12) were observed in S_0 treatment. The minimum number of unfilled grains $panicle^{-1}$ (18.97) was observed in S_2 treatment. The minimum number of total grains $panicle^{-1}$ (99.18), 1000 grains weight of Binadhan-13 (13.59 g), grain yield (2.89 t ha^{-1}), straw yield (7.23 t ha^{-1}), biological yield (10.12 t ha^{-1}) and harvest index (28.53 %) were observed in S_0 treatment.

In respect of leaf clipping, the maximum plant height (57.180, 88.887, 108.97, 130.17, 141.08 and 155.14 cm at 20, 40, 60, 80, 100 DAT and harvest, respectively), number of leaves hill^{-1} (53.90, 77.64, 92.60, 73.60 and 64.85 at 20, 40, 60, 80 and 100 DAT, respectively) were observed in L_0 treatment. The maximum leaf area (27.73 and 48.44 cm^2 at 20 and 40 DAT, respectively) was observed in L_1 treatment. At 60 DAT the maximum leaf area (64.40 cm^2) was observed in L_2 treatment. At 80 and 100 DAT the maximum leaf area (80.59 cm^2 and 84.31 cm^2, respectively) was observed in L_1 treatment. The maximum number of tillers hill^{-1} (15.40, 19.41, 20.58, 16.36, 14.41 and 13.38 at 20, 40, 60, 80, 100 DAT and harvest, respectively), above ground dry matter weight hill^{-1} (4.20, 13.94, 21.59, 35.10, 44.03 and 57.79 g at 20, 40, 60, 80, 100 DAT and harvest, respectively), number of effective tillers hill^{-1} (12.98) were observed in L_0 treatment. The maximum number of non-effective tillers hill^{-1} (1.00) was observed in L_3 treatment. The maximum panicle length (25.36 cm), number of the filled grains panicle^{-1} (92.47) were observed in L_0 treatment. The maximum number of unfilled grains panicle^{-1} (26.14) was observed in L_4 treatment. The maximum number of total grains panicle^{-1} (106.63), 1000 grains weight of Binadhan-13 (14.43 g), grain yield (3.46 t ha^{-1}), straw yield (7.72 t ha^{-1}), biological yield (11.18 t ha^{-1}) and maximum harvest index (30.89 %) of Binadhan-13 were observed in L_0 treatment.

On the other hand, the minimum plant height (51.264, 82.186, 100.55, 125.12 and 136.31 cm at 20, 40, 60, 80 and 100 DAT, respectively) was observed in L_4 treatment. The minimum number of leaves hill^{-1} (50.71) was observed in L_3 treatment at 20 DAT. At 40 and 100 DAT, the minimum number of leaves hill^{-1} (74.58 and 58.10, respectively) was observed in L_4 treatment. The minimum leaf area (12.61, 31.66, 56.35, 64.84 and 68.66 cm^2 at 20, 40, 60, 80 and 100 DAT, respectively) was observed in L_4 treatment. The minimum number of tillers hill^{-1} (14.49 and 18.64 at 20 and 40 DAT, respectively) was observed in L_3 treatment. At 100 DAT and harvest, the minimum number of tillers hill^{-1} (12.91 and 12.02, respectively) was observed in L_4 treatment. The minimum above ground dry matter weight hill^{-1} (2.37 and 9.61 g at 20 and 40 DAT, respectively) was observed in L_4 treatment. At 60, 80, 100 DAT and harvest the minimum above ground dry matter weight hill^{-1} (18.57, 28.11, 36.94 and 48.89 g, respectively) was observed in L_3 treatment. The minimum number of effective tillers hill^{-1} (11.22) was observed in L_4 treatment. The minimum number of non-effective tillers hill^{-1} (0.28) was observed in L_1 treatment. The minimum panicle (24.59

cm) length was observed in L_3 treatment. The minimum number of the filled grains panicle^{-1} (73.49) was observed in L_4 treatment. The minimum number of unfilled grains panicle^{-1} (14.15) was observed in L_0 treatment. The minimum number of total grains panicle^{-1} (99.63), 1000 grains weight (13.16 g), grain yield (2.78 t ha^{-1}), straw yield (7.20 t ha^{-1}), biological yield (9.98 t ha^{-1}) and harvest index (27.83 %) of Binadhan-13 was observed in L_4 treatment.

In respect of combined effect, the maximum plant height (59.59, 91.34 and 112.78 cm at 20, 40 and 60 DAT, respectively) was observed in S_0L_0 treatment combination. At 80, 100 DAT and harvest, maximum plant height (133.90, 144.91 and 159.05 cm, respectively) was observed in S_0L_2 treatment combination. The maximum number of leaves hill^{-1} (59.50, 82.27, 101.40, 80.10 and 68.40 at 20, 40, 60, 80 and 100 DAT, respectively) was observed in S_2L_0 treatment combination. The maximum leaf area (30.24 cm^2) at 20 DAT was observed in S_2L_1 treatment combination. At 40 DAT the maximum leaf area (51.42 cm^2) was observed in S_0L_0 treatment combination. At 60, 80 and 100 DAT the maximum leaf area (70.68, 86.79 and 90.61 cm^2, respectively) was observed in S_2L_0 treatment combination. The maximum number of tillers hill^{-1} (17.00, 20.57, 22.53, 17.80, 15.20 and 14.60 at 20, 40, 60, 80, 100 DAT and harvest, respectively), above ground dry matter weight hill^{-1} (4.29, 14.65, 23.04, 38.92, 47.85 and 60.83 g at 20, 40, 60, 80, 100 DAT and harvest, respectively), number of effective tillers hill^{-1} (14.30) were observed in S_2L_0 treatment combination. The maximum number of non-effective tillers hill^{-1} (1.13) was observed in S_0L_4 treatment combination. The maximum panicle length (26.35 cm), number of the filled grains panicle^{-1} (100.80) were observed in S_2L_0 treatment combination. The maximum number of unfilled grains panicle^{-1} (28.07) was observed in S_0L_4 treatment combination. The maximum number of total grains panicle^{-1} (113.01), 1000 grains weight of Binadhan-13 (14.69 g), grain yield (3.73 t ha^{-1}) were observed in S_2L_0 treatment combination. The maximum straw yield of Binadhan-13 (7.77 t ha^{-1}) was observed in S_0L_0 treatment combination. The maximum biological yield of Binadhan-13 (11.43 t ha^{-1}) and harvest index of Binadhan-13 (32.59 %) were observed in S_2L_0 treatment combination.

On the other hand, the minimum plant height (49.89 cm) at 20 DAT was observed in S_2L_4 treatment combination. At 40 and 60 DAT the minimum plant height (80.15 and 98.59 cm, respectively) was observed in S_1L_4 treatment combination. At 80 and 100 DAT the minimum plant height (122.65 and 133.43 cm) was observed in S_0L_4 treatment combination. At harvest the minimum plant height (148.65 cm) was observed in S_1L_3 treatment combination. The minimum number of leaves hill^{-1} (49.93 and 73.60 at 20 and 40 DAT, respectively) was observed in S_0L_4 treatment combination. At 60 DAT the minimum number of leaves hill^{-1} (82.80) was observed in S_0L_3 treatment combination. At 80 DAT the minimum number of leaves hill^{-1} (66.00) was observed in S_2L_3 treatment combination. At 100 DAT the minimum number of leaves hill^{-1} (54.90) was observed in S_1L_4 treatment combination. The minimum leaf area (11.29 cm^2) was observed in S_1L_4 treatment combination. At 40 DAT the minimum leaf area (28.56 cm^2) was observed in S_0L_4 treatment combination. At 60, 80 and 100 DAT the minimum leaf area (53.41, 61.49 and 65.32 cm^2, respectively) was observed in S_1L_4 treatment combination. The minimum number of tillers hill^{-1} (14.27 and 18.40 at 20 and 40 DAT, respectively) was observed in S_0L_4 treatment combination. At 60 DAT the minimum number of tillers hill^{-1} (18.40) was observed in S_0L_3 treatment combination. At 80, 100 DAT and harvest the minimum number of tillers hill^{-1} (14.87, 12.20 and 11.73, respectively) was observed in S_1L_4 treatment combination. The minimum above ground dry matter weight hill^{-1} (2.31 g) at 20 DAT was observed in S_0L_4 treatment combination. At 40 and 60 DAT the minimum above ground dry matter weight hill^{-1} (9.12 and 18.26 g, respectively) was observed in S_1L_4 treatment combination. At 80, 100 DAT and harvest, the minimum above ground dry matter weight hill^{-1} (27.80, 36.63 and 48.26 g, respectively) was observed in S_1L_3 treatment combination. The minimum number of effective tillers hill^{-1} (10.80) was observed in S_1L_4 treatment combination. The minimum number of non-effective tillers hill^{-1} (0.10) was observed in S_2L_1 treatment combination. The minimum panicle length (24.43 cm), number of the filled grains panicle^{-1} (69.47) were observed in S_0L_4 treatment combination. The minimum number of unfilled grains panicle^{-1} (12.21) was observed in S_2L_0 treatment combination. The minimum number of total grains panicle^{-1} (97.53), 1000 grains weight of (13.04 g), grain yield (2.66 t ha^{-1}), straw yield (6.99 t ha^{-1}), biological yield (9.65 t ha^{-1}) and harvest index of Binadhan-13 (27.51 %) were observed in S_0L_4 treatment combination.

Conclusion

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

Treatment 1/2nd seedling top clipping (S_2) along with no leaf clipping (L_0) treatment combination (S_2L_0) is proved to be the optimum management for improving yield of aromatic rice Binadhan-13.

Recommendations

However, further investigation with same treatment combinations is necessary at different rice growing areas of Bangladesh covering different environment to confirm the present findings.

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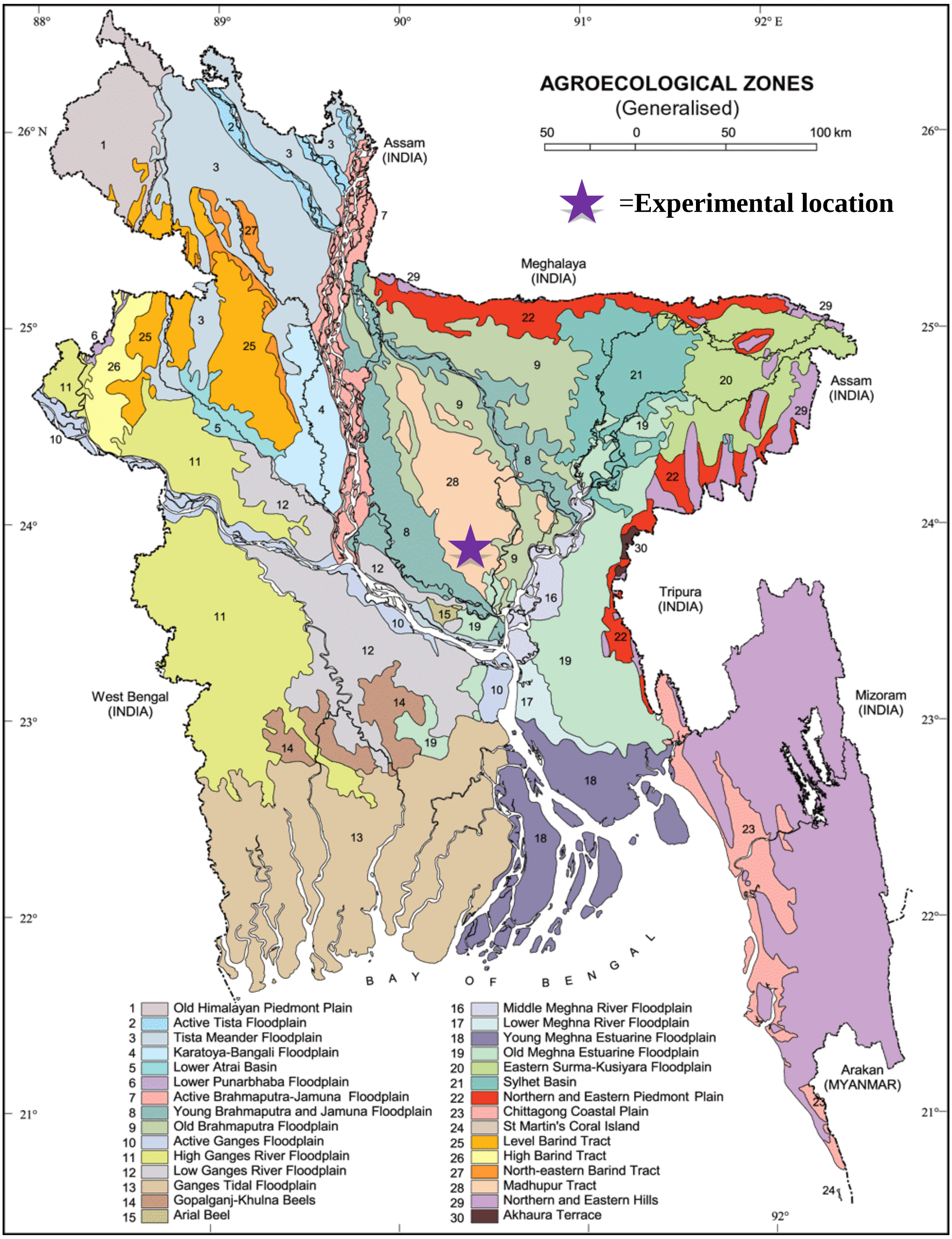
APPENDICES

Appendix I. Map showing the experimental location under study



Appendix II. Monthly meteorological information during the period from July, 2019 to December, 2019

Year	Month	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2019	July	32.6	26.8	81	114
	August	32.6	26.5	80	106
	September	32.4	25.7	80	86
	October	31.2	23.9	76	52
	November	29.6	19.8	53	00
	December	28.8	19.1	47	00

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix III. Soil characteristics of the experimental field

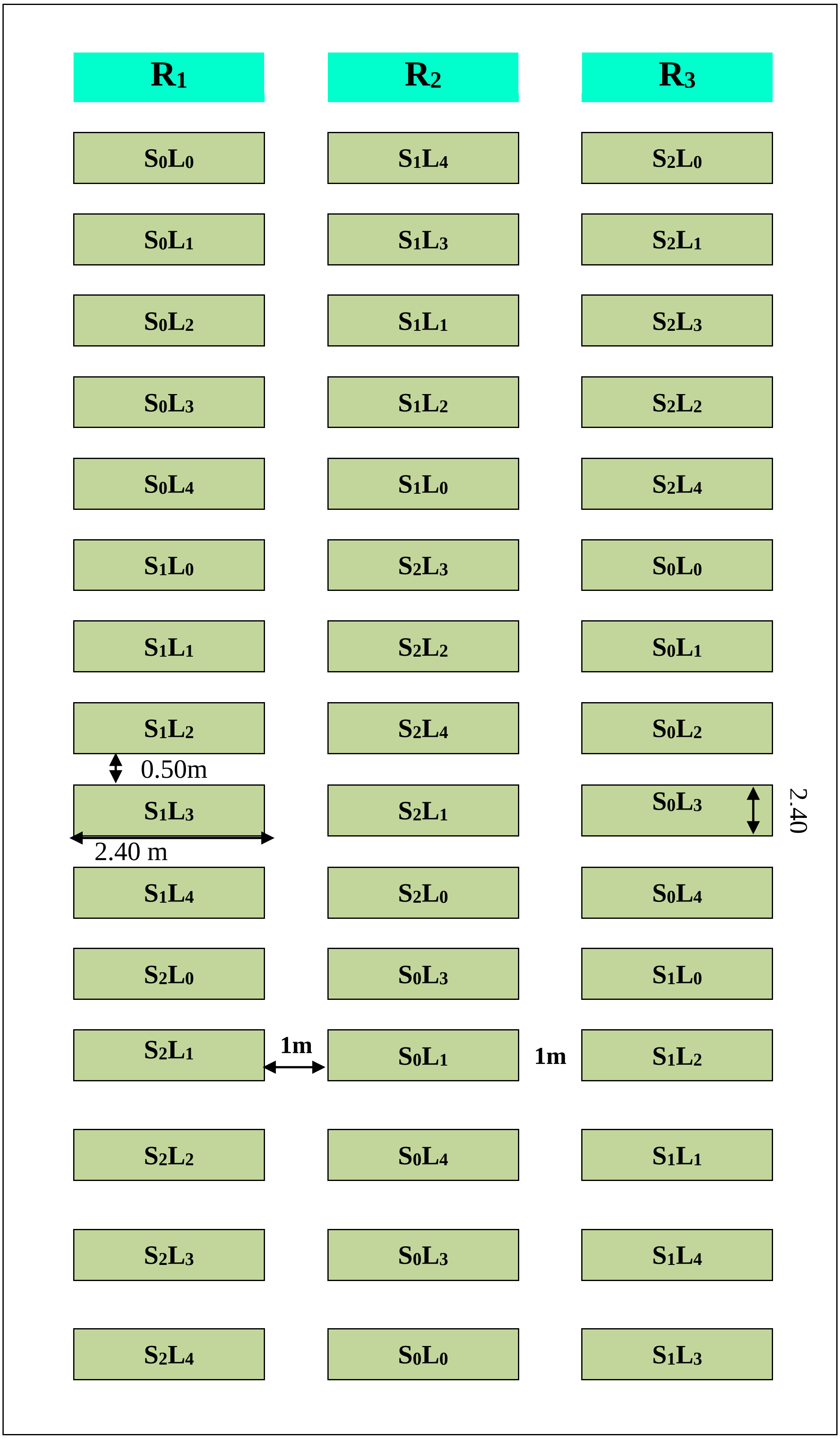
A. Morphological features of the experimental field

Morphological features	Characteristics
Location	Sher-e-Bangla Agricultural University Agronomy research field, Dhaka
AEZ	AEZ-28, Modhupur Tract
General Soil Type	Shallow Red Brown Terrace Soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. The initial physical and chemical characteristics of soil of the experimental site (0 -15 cm depth)

Physical characteristics	
Constituents	Percentage
Sand	26 %
Silt	45 %
Clay	29 %
Textural class	Silty clay
Chemical characteristics	
Soil characteristics	Value
pH	5.8
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total nitrogen (%)	0.03
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10

Appendix IV. Layout of the experimental field



LEGENDS

S_0= Control (no seedling top clipping)

S_1 =1/3rd top clipping

S_2= 1/2nd clipping

L_0= Control (no clipping),

L_1= Lower 1+2 leaves clipping,

L_2= Lower 2+3 leaves clipping,

L_3= Lower 3+4 leaves clipping,

L_4= Flag leaf clipping

Appendix V. Analysis of variance of the data of plant height of aromatic rice at different days after transplanting

Mean square of plant height of aromatic at						
Source	Df	20 DAT	40 DAT	60 DAT	80 DAT	Harvest
Replication (A)	2	9.94	30.56	0.29	2.22	6.49
Seedling clipping (S)	2	64.59*	55.24^{NS}	134.21*	12.93^{NS}	73.42^{NS}
Error (A×S)	4	6.17	18.04	5.92	12.22	21.82
Leaf Clipping (L)	4	50.56*	59.32*	148.07*	78.41*	100.19*
S×L	8	3.82*	17.93*	22.44*	51.11*	49.43*
Error (A×S×L)	24	1.99	6.82	4.04	17.22	20.27
Total	44					

NS: Non significant
*: Significant at 0.05 level of probability

Appendix VI. Analysis of variance of the data of number of leaves hill^{-1} of aromatic rice at different days after transplanting

Mean square of number of leaves hill^{-1} of aromatic at					
Source	Df	20 DAT	40 DAT	60 DAT	80 DAT
Replication (A)	2	1.36	1.40	1.62	1.87
Seedling clipping (S)	2	4.92^{NS}	4.99^{NS}	0.13^{NS}	2.28^{NS}
Error (A×S)	4	1.16	3.40	0.69	2.27
Leaf Clipping (L)	4	34.16*	56.64*	39.43*	69.70*
S×L	8	1.95*	2.66*	5.01*	2.75*
Error (A×S×L)	24	0.89	2.73	1.42	2.13
Total	44				

NS: Non significant
*: Significant at 0.05 level of probability

Appendix VII. Analysis of variance of the data of leaf area hill^{-1} of aromatic rice at different days after transplanting

Mean square of leaf area hill^{-1} of aromatic at					
Source	Df	20 DAT	40 DAT	60 DAT	80 DAT
Replication (A)	2	0.47	2.82	28.69	1.16
Seedling clipping (S)	2	40.15*	4.13^{NS}	107.43*	313.24*
Error (A×S)	4	0.77	6.42	3.69	6.76
Leaf Clipping (L)	4	464.25*	612.94*	88.22*	1116.56*
S×L	8	26.15*	36.57*	51.75*	46.06*
Error (A×S×L)	24	0.67	5.22	9.52	4.89
Total	44				

NS: Non significant
*: Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data of number of tillers hill^{-1} of aromatic rice at different days after transplanting

Mean square of number of tillers hill $^{-1}$ of aromatic at						
Source	Df	20 DAT	40 DAT	60 DAT	80 DAT	Harvest
Replication (A)	2	0.05	0.05	0.13	0.02	0.05
Seedling clipping (S)	2	0.009^{NS}	1.95*	1.05*	0.43*	4.48*
Error (A×S)	4	0.08	0.08	0.103	0.01	0.08
Leaf Clipping (L)	4	0.69*	11.87*	0.29*	1.26*	8.34*
S×L	8	0.05*	0.26*	0.26*	0.03*	0.47*
Error (A×S×L)	24	0.02	0.08	0.11	0.02	0.07
Total	44					

NS: Non significant
*: Significant at 0.05 level of probability

Appendix IX. Analysis of variance of the data of above ground dry matter weight hill^{-1} of aromatic rice at different days after transplanting

Mean square of above ground dry matter weight hill $^{-1}$ of aromatic at						
Source	Df	20 DAT	40 DAT	60 DAT	80 DAT	Harvest
Replication (A)	2	0.04	0.04	0.39	1.63	10.52
Seedling clipping (S)	2	0.10*	1.99*	7.89*	53.52*	54.17*
Error (A×S)	4	0.02	0.29	0.59	3.67	2.11
Leaf Clipping (L)	4	0.62*	18.81*	7.84*	69.41*	86.09*
S×L	8	0.17*	0.28*	1.61*	11.78*	9.66*
Error (A×S×L)	24	0.03	0.32	0.62	3.02	3.52
Total	44					

*: Significant at 0.05 level of probability

Appendix X. Analysis of variance of the data of number of effective and non-effective tillers hill^{-1} of aromatic rice at harvest

Mean square of			
Source	Df	Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)
Replication (A)	2	0.14	0.00056
Seedling clipping (S)	2	8.82*	0.632*
Error (A×S)	4	0.23	0.00076
Leaf Clipping (L)	4	17.52*	1.82*
S×L	8	1.15*	0.13*
Error (A×S×L)	24	0.19	0.00069
Total	44		

*: Significant at 0.05 level of probability

Appendix XI. Analysis of variance of the data of panicle length, filled grains panicle^{-1}, unfilled grains panicle^{-1}, total grains panicle^{-1} and weight of 1000-grains of aromatic rice at harvest respectively

Mean square of						
Source	Df	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	Total grains panicle^{-1} (no.)	Weight of 1000-grains (g)
Replication (A)	2	0.69	27.42	2.54	34.67	0.26
Seedling clipping (S)	2	7.29*	244.57*	5.15*	184.62*	3.95*
Error (A×S)	4	0.29	26.66	0.59	19.80	0.27
Leaf Clipping (L)	4	39.75*	920.16*	249.18*	232.22*	6.23*
S×L	8	1.37*	63.67*	7.71*	45.37*	1.28*
Error (A×S×L)	24	0.26	17.09	2.199	18.92	0.26
Total	44					

*: Significant at 0.05 level of probability

Appendix XII. Analysis of variance of the data of grain yield, straw yield, biological yield and harvest index of aromatic rice at harvest respectively

Mean square of					
Source	Df	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication (A)	2	0.03	0.01	0.08	0.42
Seedling clipping (S)	2	1.32*	0.15*	2.36*	23.27*
Error (A×S)	4	0.019	0.02	0.06	0.23
Leaf Clipping (L)	4	0.62*	0.71*	1.76*	17.78*
S×L	8	0.12*	0.27*	0.52*	3.58*
Error (A×S×L)	24	0.01	0.07	0.07	1.39
Total	44				

*: Significant at 0.05 level of probability

PLATES

Plate 1: Prepared main field

Plate 2: Tillering stage of Binadhan-13

Plate 3: Flowering stage of Binadhan-13

Plate 4: Ripening stage of Binadhan-13