GROWTH AND YIELD OF AROMATIC RICE AS INFLUENCED BY SEEDLING CLIPPING AND PLANTING DENSITY

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CERTIFICATE

This is to certify that the thesis entitled “**GROWTH AND YIELD OF AROMATIC RICE AS INFLUENCED BY SEEDLING CLIPPING AND PLANTING DENSITY**” *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 (MS) in AGRONOMY, embodies the results of a piece of bona fide research work carried out by ALFAZ UDDIN, Registration. No. 15-06591 under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

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

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Dhaka, Bangladesh

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GROWTH AND YIELD OF AROMATIC RICE AS INFLUENCED BY SEEDLING CLIPPING AND PLANTING DENSITY

ABSTRACT

A field experiment was carried out at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the period from July to December, 2022 to investigate the efficacy of seedling clipping and different planting geometry on the performance of an aromatic rice variety BRRI dhan80. The experiment comprised of two factors; Factor A: Seedling clipping (3) viz. C_1= Control (no clipping); C_2= 1/3rd top seedling clipping; C_3=1/2nd top seedling clipping and Factor B: Different planting geometry (4) viz. G_1= 25 cm x 20 cm, G_2= 20 cm x 20 cm, G_3= 20 cm x 15 cm, and G_4= 15 cm x 15 cm. The experiment was laid out in randomize complete block design with three replications. Results revealed that seedling and different planting geometry either individually or combined showed significant variations in most of the characteristics of aromatic rice. In case of seedling clipping, the effective tillers hill^{-1} (14.52), panicle length (26.14 cm), filled grains panicle^{-1} (171.09), total grains panicle^{-1} (190.07), 1000-grains weight (24.59 g), grain yield (4.14 t ha^{-1}), straw yield (7.94 t ha^{-1}), biological yield (12.09 t ha^{-1}) and harvest index (34.18 %) were observed in C_2 (1/3rd top seedling clipping) treatment. In case of different planting geometry, the maximum effective tillers hill^{-1} (15.31), panicle length (26.68 cm), filled grains panicle^{-1} (179.00), total grains panicle^{-1} (196.27), 1000-grains weight (25.30 g), grain yield (4.28 t ha^{-1}), straw yield (8.05 t ha^{-1}), biological yield (12.33 t ha^{-1}) and harvest index (34.65 %) were observed in G_3 (20 cm x 15 cm) treatment. In case of combined effect, the maximum effective tillers hill^{-1} (16.23), panicle length (27.41 cm), filled grains panicle^{-1} (189.05), total grains panicle^{-1} (204.48), 1000-grains weight (26.52 g), grain yield (4.62 t ha^{-1}), straw yield (8.14 t ha^{-1}), biological yield (12.76 t ha^{-1}) and harvest index (36.02 %) were observed in C_2G_3 treatment combination. Based on the findings it was concluded that treatment combination of 1/3rd top seedling clipping (C_2) along with 20 cm x 15 cm (G_3) planting geometry has positive influence on BRRI dhan80 to have maximum yield attributes of grain yield.

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LIST OF ACRONYMS

% = Percent
^{0}C = Degree Celsius
AEZ = Agro-Ecological Zone
AIS = Agriculture Information Service
B:C = Benefit Cost ratio
BARI = Bangladesh Agricultural Research Institute
BBS = Bangladesh Bureau of Statistics
Cm = Centi-meter
CV% = Percentage of coefficient of variance
cv. = Cultivar
DAS = Days after sowing
DF = Degree of freedom
EC = Emulsifiable Concentrate
et al. = And others
etc. = Etcetera
FAO = Food and Agriculture Organization
G = Gram
ha^{-1} = Per hectare
HI = Harvest Index
Hr = Hour
Kg = Kilogram
LAI = Leaf area index
LSD = Least significant difference
LSD = Least Significant Difference
M = Meter
Max = Maximum
Min = Minimum
Mm = Millimeter
MP = Muriate of Potash
N = Nitrogen
No. = Number
NPK = Nitrogen, Phosphorus and Potassium
NS = Non-significant
Ppm = Parts per million
RCBD = Randomized complete block design
SAU = Sher-e-Bangla Agricultural University
SRDI = Soil Resources and Development Institute
TSP = Triple Super Phosphate
viz. = Videlicet (namely)
WCE = Weed Control Efficiency
Wt. = Weight

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food crop and a primary food source for more than one-third of world's population (Sarkar *et al.,* 2017). Worldwide, rice provides 27% of dietary energy and 20% dietary protein (Kueneman, 2006). It constitutes 95% cereal consumed and supplies more than 80% calories and about 50% protein in the diet of the general people of Bangladesh (Yusuf, 1997). World's rice demand is projected to increase by 25% from 2001 to 2025 to keep pace with population growth (Maclean *et al.,* 2020), and therefore, meeting this ever increasing rice demand in a sustainable way with shrinking natural resources is a great challenge. In Bangladesh, majority of food grains comes from rice. Rice has tremendous influence on agrarian economy of the country. Annual production of rice in Bangladesh is about 36.28 million tons from 11.52 million ha of land (BBS, 2018). The country imported 200,000 tons of rice in the 2020-21 marketing year to ease food security tensions brought on by the COVID-19 pandemic situation (USDA, 2021).

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, 2021). 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 Aman season arising in July-November, and only a small contribution (6.60%) from Aus season arising in April-June (APCAS, 2016). Aman is the second most important rice growing season in Bangladesh.

Among three growing seasons (aus, aman and boro) aman rice occupies the highest area coverage. The aman rice crop occupies 67 per cent of the cropped area of 85.77 hectares. In 2020, the amount of land used for HYV varieties is 44.47 lakh (4.44 million) hectares, hybrid 2.40 lakh (0.24 million) hectares, local varieties 7.15 lakh (0.75 million) hectares and for broadcast aman 3.12 lakh (0.31 million) hectares of cultivable land. The total land under the aman crop was 57.14 lakh (5.71 million) hectares (Magzter, 2021). Almost 78 per cent of the land is occupied by the HYV varieties supported by the Department of Agricultural Extension with fertilizers and pesticides while only 12.5 per cent are local/traditional varieties cultivated by the farmers on their own initiatives in low lands (BBS, 2017).

There are two types of transplanted Aman rice: coarse and fine rice, including some fine rice varieties being aromatic. Aromatic rice is a special type of rice containing natural ingredient named 2-acetyl-1-pyrroline, which is responsible for their fragrant, taste and aroma (Gnanavel and Anbhazhagan, 2010) and had 15 times more 2-acetyl-1- pyrroline content than non - aromatic rice, ranges 0.14 - 0.009 ppm respectively (Singh, 2000). In addition, there are about 100 other volatile compounds, including 13 hydrocarbons, 14 acids, 13 alcohols, 16 aldehydes, 14 ketones, 8 esters, 5 phenols and some other compounds, which are associated with the aroma development in rice.

Most of the aromatic rice varieties in Bangladesh are traditional photo-period sensitive types and are grown during aman season (Chowdhury *et al.,* 2017). Cultivation of aromatic rice has been gaining popularity in Bangladesh over the recent years, because of its huge demand both for internal consumption and export (Das and Baqui, 2000). The popularity came at a time when Bangladesh has been struggling in aromatic rice export market due to lack of price competitiveness owing to low-yield potentials. Aromatic rice is there in Bangladesh's export basket since 2012 fetching a yearly earning of Tk 80 crore (the dailystar.net). But further growth is being hindered due to the farmers' reluctance in growing fragrant rice, which yields less compared to non-aromatic fine varieties.

Food security especially attaining self-sufficiency in rice production is a burning issue in Bangladesh. The average yield of rice is almost less than 50% of the world average rice grain yield. The national mean yield (2.60 t ha^{-1}) of rice in Bangladesh is lower than the potential national yield (5.40 t ha^{-1}) and world average yield (3.70 t ha^{-1}) (Pingali *et al.,* 2022). The lower yield of aromatic rice has been attributed to several reasons such as lack of high yielding cultivars, weed infestation, fluctuation of the market prices, lack of knowledge and proper agronomic management’s practices etc. In such condition, increasing rice production can play a vital role.

Therefore, attempts must be made to increase the yield per unit area by adopting modern rice cultivars, applying improved technology and agronomic management practices (such as clipping, irrigation, spacing, weed control, insect managements etc.). Rice crops can be either direct seeded or transplanted. In direct seeding, seeds are sown directly in the field. While in transplanting, seedlings are first raised in seedbeds before they are planted in the field.

Transplanting requires less seed but much more labor, and the crop takes longer to mature because of the transplanting shock.

Seedling top clipping had a better establishment, recover from transplanting shock sooner than non-clipped leaves (Georgias *et al.*, 2020). 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 growth. 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, 2016).

The yield potential of a variety can be realized only if full package of production practices is followed. The growth, development, yield and yield components of rice and the absolute density, weight and intensity of weed infestations are greatly influenced by planting geometry. Optimum planting geometry ensures the plants to grow properly with their aerial and underground parts utilizing more solar radiation and nutrients (Miah *et al.*, 2019). When the planting densities exceed an optimum level, competition among plants of same species for light or for nutrients become severe, consequently the plant growth slows down and grain yield decreases. Again, when the planting densities do not cover an optimum level, the remaining space will be filling up by the other plant species like weed species and the interplant competition is at a maximum level which ultimately slows down the crop growth and grain yield decreases. Therefore, this study aimed to examine the seedling clipping and planting geometry effect on growth, yield and yield contributing characters of aromatic rice. Considering the above facts, the present research work was undertaken to achieve the following objectives:

i. To determine the effect of seedling clipping on aromatic rice production.
ii. To evaluate the different planting geometry for maximum production and
iii. To find out the combined effect of seedling clipping along with planting geometry on plant growth, yield attributes 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 clipping and planting geometry 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 clipping and planting geometry on the growth and yield of rice have been discussed and presented under the following headings:

2.1 Impacts of seedling clipping on growth characters

Plant height

Karmaker and Karmakar (2019) carried out an experiment to investigate the influence of N-rates and leaf clipping on forage and grain yield and seed quality of transplant Aman (wet season) rice. Four nitrogen (N) rates (N_1=46, N_2=69, N_3=92 and N_4=115 kg N ha^{-1}) and four times of leaf clipping viz, C_0=no leaf clipping, C_1=leaf clipping at 25 DAT (Days after transplanting), C_2=40 and C_3=55 DAT were evaluated following split-plot design with three replications. They noticed from their experiment that the highest plant height (128.95 cm) was recorded at C_0 (No leaf clipping) and the lowest plant height (116.83 cm) was found in C_3 (leaf clipping time at 55 DAT). The results also showed that plant height was significantly decreased in later leaf cut treatments compared to those with no and early cuts.

Medhi *et al*. (2015) set up a field trial to study the impact of foliage pruning on growth and yield of two land rice varieties, TTB-303−1-42 (Dhansiri) and TTB6 303−1-23 (Difalu) under rain-fed low land condition (50–100 cm water profundity) during wet season. Test results showed that multiple times expulsion of foliage significantly decreased the plant height and prevented lodging.

Sherif *et al.* (2015) carried out an experiment during 2013-2015 to find out the effect of leaf removal on rice growth characteristics and yield. The experiment consisted of six level of defoliation viz: 0, 20, 40, 60, 80 and 100% were applied one month after transplanting. From the experiment they reported that the rice plants of the check (non-defoliated) plots exhibited, almost, the tallest plants; 92.60 and 91.55 cm, in the first and second seasons, respectively. Defoliation at 20 or 40% in the first season, and at 20, 40 or 60% in the second one induced slightly shorter rice plants, ranging between 91.80 and 92.64 cm and 89.50- 90.65 cm, respectively, but without significant differences compared to the check. However, the plant heights ranged 90.00-90.50 cm when 60, 80 or 100% of the leaves were removed in the first season, and ranged 87.00-87.05 cm when 80 or 100% of the rice plants were defoliated in the second season.

Ayutthaya (2011) stated that rice leaf cutting length of 30 cm had been suggested at 30–60 days after planting and prior to flowering. It tends to be cut on different occasions however the flag leaf should not be cut. Rice leaf cutting at 60 days subsequent to planting just one time had impact on uniform plant height and uniform flowering.

Roy and Pradhan (1992) observed that the no leaf cutting treatment resulted in the highest value of plant height at all observation dates. The lowest plant height values 6 were recorded at 28, 34, 42, and 49 DAT, as well as at maturity when the leaf cutting was done at 21, 28, 35, 35, and 35 DAT, respectively.

An experiment was conducted by Molla *et al.* (2002) to ascertain the feasibility of green fodder harvest without affecting the seed yield of transplant aman rice. Plant height, number of leaves hill^{-1}, number of tillers hill^{-1}, green fodder yield and seed yield were significantly differed due to different cultivar and leaf clipping height. Latishail produced the highest plant height, at all growth stages where BR10 showed the lowest among cultivers. There are two factors of this experiment, (A) cultivar: (i) C_1 = Latishail (ii) C_2 = BR 10 (iii) C_3 = BR 11 and (iv) C_4 = BRRI dhan32 and (B) leaf clipping heights: (i) H_1 = clipping at 10 cm (ii) H_2 = clipping at 15 cm (iii) H_3= clipping at 20 cm and (iv) H_4 = control (no clipping). The height of the rice plants was significantly different because of different cultivars and leaf clipping heights. The highest plant height was obtained from control plot at all growth stages where the lowest plant was recorded from leaf clipping at 10 cm height.

Total dry matter weight

Osunkoya *et al.* (1994) revealed that removing all leaves except the most apical expanded leaf resulted in a decrease in all parameters measured, with total biomass being around 20% of the control value. Although the leaf dry mass of seedlings with only three leaves or with one-third of all leaves (average of 7.8 leaves) was lower when compared to control values, total biomass was significantly higher for seedlings 8 in the one-third leaf treatment, but not significantly different from the control value in seedlings in the three-leaf treatment. Root dry mass increased significantly in response to the three-leaf and one-third leaf treatments, although stem dry mass was unaffected.

Sherif *et al.* (2015) carried out an experiment during 2013-2015 to find out the effect of leaf removal on rice growth characteristics and yield. The experiment consisted of six level of defoliation *viz*: 0, 20, 40, 60, 80 and 100% were applied one month after transplanting. From the experiment they showed that the biggest dry matter content were found in the check or 20% defoliation, with levels of 1215.00 and 1103.60 gm^{-2} in the first season. The corresponding values of dry matter in the second season were 1061.10 and 1164.94 gm^{-2}. The sharp reduction in dry matter content was observed in the first season at 80 or 100% defoliation (938.15 and 765.00 gm^{-2}, respectively). In the second season, defoliations at 60, 80 or 100% resulted in low levels of dry matter content; 866.11, 861.26 or 840.04 g m^{-2}, respectively.

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

However, rather than increasing stress tolerance, seedling vigor was more beneficial when post-transplant growth was not limited by nutrient or water stresses.

Misra (1986) demonstrated that leaf cuttings had a significant effect on, total dry matter (TDM) production of hybrid rice cultivar H_5 and inbred Egyptian local cultivar Sakha 103. Under the control condition, with no leaf cutting, all dry matter production showed their maximum value.

2.2 Impacts of seedling clipping on yield contributing characters

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}.

Hachiya (1989) reported that the maximum value of total tillers hill^{-1} for observations at 28, 35, 42, 48 DAT, and at maturity were obtained in the control, whereas the lowest at the same date of observations were obtained when leaf cutting was done at 21, 21, 28, 28, and 35 DAT, respectively.

Boonreund and Marsom (2015) conducted an experiments aimed at searching for the optimal length of cutting for Pathum Thani1 rice leaf for better yield. Length of rice leaf cutting was reported to have positive effecting on broadcasting Thai jasmine rice yield in Ponsai district, Roi Et province but not clarify in other variety .The experiments consist of 7 treatments, cutting lengths (0, 5, 10, 15, 20, 25 and 30 cm from the leaf tip was performed by sickle after 60 days after planting and 6 replications. The results found that tiller numbers was not significantly increased after cutting. So cutting of leaves had no significant effect on tiller number plant^{-1}.

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

Non-effective tillers hill^{-1}

Ahmed *et al.* (2001 a) directed a test to consider the impact of nitrogen rate and time of leaf cutting on green fodder as well as seed yield of rice. The test included two factors, (A) Nitrogen level – viz. I) N_1 – 50 kg N ha^{-1}, ii) N_2 – 75 kg N ha^{-1} and iii) N_3 – 100 kg N ha^{-1}, (B) Time of leaf cutting – viz. I) No cutting (control) – C_0, ii) Cutting at 21 DAT – C_1, iii) Cutting at 35 DAT – C_2 and iv) Cutting at 49 DAT – C_3. Greatest number of non-bearing turners hill^{-1} was recorded from no leaf cutting treatment, which was genuinely like leaf cutting at 21 DAT and the minimum was seen in leaf cutting at 49 DAT.

Panicle length

Das *et al.* (2017) reported that leaf clipping had non-significant effect on panicle length of modern variety and in local variety of rice.

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

Rahman *et al.* (2013) directed an investigation in order to explore the correlation analysis of flag leaf (FL) with yield in several rice cultivars. From their experiment they noticed that when FL length is high the panicle length is also high. In case of BR11 when the average FL length was 21.33, 25.90, 28.19, 37.33, 18.28, 37.84, 37.59, 25.90, 24.13, 35.50 cm, then the average panicle length was 18.03, 18.54, 20.32, 34.98, 17.52, 33.87, 33.36, 19.85, 22.60, 31.65 cm, respectively and in case of correlation analysis, a significant correlation was found between them. Similar significant result was found in case of BR28. Yield was significantly and positively associated with panicle length. They also found that flag leaf length was positively associated with panicle length, thereby indicating associated with grain yield.

Fatima (2019) carried out an experiment to study the effect of flag leaf clipping on growth yield, and yield attributes of hybrid rice varieties in Boro season. The experiment comprised of two factors. Factor A: Flag leaf clipping: T_1 = Flag leaf clipping at heading and T_2 = Control (without clipping). Factor B: Six hybrid rice varieties: V_1 = BRRI hybrid dhan1, V_2 = BRRI hybrid dhan2, V_3 = Heera2, V^4 = Heera4, V_5 = Nobin and V_6 = Moyna. The highest panicle length was recorded from Heera4 under control condition.

Grains panicle^{-1}

Karmaker and Karmakar (2019) observed that in BRRI dhan41 the highest mean number of grains panicle^{-1} (118) was found in C_0 (no leaf clipping) and the lowest number of grains panicle^{-1} (106) was obtained from C_3 when leaf clipped at 55 DAT and concluded that forage removal at later stages of crop growth reduce photosynthetic leaf area causing negative impact on carbohydrate accumulation which ultimately effect on producing grains panicle^{-1}.

Hossain (2017) conducted an experiment to evaluate the effect of leaf cutting on plant growth and yield of selected BRRI released Aman varieties.

The experiment comprised of two factors: Factor A: five varieties, V_1 = BRRI dhan32, V_2 = BRRI dhan33, V_3 = BRRI dhan39, V_4 = BRRI dhan62 and V_5 = BRRI dhan56 and Factor B: two leaf cutting, T_1 = Leaf cutting (aside from flag and penultimate leaves) T_2 = Control (no leaf cutting). Regardless of the all the varieties under study, the maximum grains panicle^{-1} (105.63) was obtained in no leaf cutting (control) treatment than leaf cutting treatment (94.73 grains panicle^{-1}).

Ahmed *et al.* (2001) carried out an experiment with four varieties: Latishail, BR10, BR11, and BRRI dhan32, as well as four leaf cuttings: no leaf cutting (T_1), leaf cutting at 21 DAT (T_2), leaf cutting at 28 DAT (T_3), and leaf cutting at 35 DAT (T_4). The effect of leaf cutting on grains panicle^{-1} at various days after transplantation was significant. The highest grains panicle^{-1}, sterile grains panicle^{-1} were obtained in no leaf cutting (control) which were observed in all investigated types. Leaf cutting reduces yield and yield contributing characteristics as compared to the control. At 35 DAT, Latishail leaf cutting resulted in considerably better forage production. The maximum grain yield was attained when no leaf cutting was used, which was statistically equivalent to leaf cutting at 21 and 28 DAT. It is possible to assume that leaf cutting at an early stage of crop growth could create almost identical grain or seed yields to regulate crops while also providing additional fodder production.

Filled grains panicle^{-1}

Das *et al.* (2017) study the effect of leaf clipping on yield attributes of modern and local rice varieties and observed that in Binadhan-8, the highest number of filled grain panicle^{-1} was found in without leaf cutting plants (104.00) which did not vary significantly from 2nd and 3rd leaf cut. Significant reduction in filled grains takes place 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) directed an experiment to study the effect of detopping on forage and grain yield of rice. The experiment consisted of six treatments viz., Control (T_1, no detopping), detopping at 22 DAT (T_2), detopping at 29 DAT (T_3), detopping at 36 DAT (T_4), detopping at 43 DAT (T_5), and detopping at 50 DAT (T_6). In respect of all the six treatments, the highest number of spikelets panicle^{-1} (106.8) and number of filled grains panicle^{-1} (90) were obtained from control (no detopping) treatment.

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

Mannan (1996) conducted an experiment and stated that panicle length varied among varieties. In comparison to BR10 and BRRI dhan32, BR11 had the highest grains $panicle^{-1}$ (97.21), 1000-grain weight (22.11 g), grain yield (4.84 t ha^{-1}), biological yield (10.16 t ha^{-1}) and harvest index (46.80%).

Ghosh and Sharma (1998) reported higher number of grains $panicle^{-1}$ from early leaf cutting than late leaf cutting. The lowest value for all crop characters were observed when the leaf was cut at 35 DAT. Ahmed (2001) also showed the effect of leaf cutting was found to be significant in respect of the crop characters except 1000-grain weight. The highest value found in control.

Ali *et al.* (2017) conducted pot experiments to evaluate the impact of five different types of leaf clipping on the yield attributes of modern (Binadhan-8) and local (Terebaile) rice variety. Following leaf clipping treatments were applied for both the experiments: L_0 - Control (without leaf cutting), L_1 - Flag leaf cut, L_2- 2nd leaf cut, L_3 - 3rd leaf cut, L_4 - Both flag leaf and 2nd leaf cut and L_5 - Flag leaf with 2nd and 3rd leaves cut together. Impact of five different types of leaf clipping on the yield attributes of modern (Binadhan-8) and local (Terebaile) rice variety was evaluated on pot experiments following a completely randomized design (CRD) with three replications. Leaves were cut according to the treatment.

Data were collected on panicle length (cm), filled grain $panicle^{-1}$, unfilled grain $panicle^{-1}$, thousand grain weight (g), grain weight $panicle^{-1}$ (g). In Binadhan-8, flag leaf alone or flag leaf with 2nd leaf and 2nd and 3rd leaves cutting showed profound reduction in grain number panicle-1 (35.14, 62.62, and 51.83%, respectively) cutting of 2nd leaf and 3rd leaf alone exert no significant impact compared to control.

Number of unfilled grains increased with higher intensity of leaf cutting. In Terebaile, only flag leaf cut showed non-significant impact on grain number panicle^{-1} and grain weight panicle-1. Profound impact was observed by cutting flag leaf with 2nd leaf (55.47 and 48.98%, respectively) and flag leaf with 2nd and 3rd leaf (58.96 and 63.13%, respectively). Leaf clipping had non-significant effect on thousand grain weight of modern variety Binadhan-8 while, it had significant effect in Terebaile.

Unfilled grains panicle^{-1}

Moballeghi *et al.* (2018) carried out an experiment in order to study the effect of source-sink limitations on agronomic traits and grain yield of different lines of rice.
The field experiment was carried out as factorial in a randomized complete block design with four replications in Chaparsar Rice Research station of Mazandaran province in 2013. Treatments of source-sink limitation in four levels (including cutting of flag leaf, cutting of one third the end of panicle, cutting of other leaves except flag leaf and control or without limitation) and lines of rice in four levels (line of No. 3, line of No. 6, line of No. 7 and line of No. 8) were the treatments. Among different source-sink limitation treatments, increased unfilled grain number per panicle and decreased the panicle fertility percentage, when all leaves except flag leaf removed.

Das *et al.* (2017) conducted an experiment to investigate the effect of leaf clipping on yield attributes of modern and local rice varieties and observed that in Binadhan-8, 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 in the control (33.99) which did not vary with 3rd leaf cut alone (39.57). Flag leaf cut and 2nd leaf cut showed the similar and moderate values.

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

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

Total grains panicle^{-1}

Usman *et al.* (2007) directed an experiment to study the effect of detopping on forage and grain yield of rice. The experiment consisted of six treatments viz., Control ($T_{1,}$ no detopping), detopping at 22 DAT (T_2), detopping at 29 DAT (T_3), detopping at 36 DAT (T_4), detopping at 43 DAT (T_5), and detopping at 50 DAT (T_6). In respect of all the six treatments, the highest number of spikelets panicle$^{−1}$ (106.8) and number of filled grains panicle$^{−1}$ (90) were obtained from control (no detopping) treatment. Ghosh and Sharma (1998) found that early leaf cutting yielded more grains panicle^{-1} than late leaf cutting. The lowest value for all crop attributes was observed when the leaf was cut at 35 DAT.

Aktar-uz-zaman (2006) led an examination to study on source-sink control and their impact on grain yield in rice of rainfed varieties. There were nine treatments in source-sink control: T_0 = Control, T_1 = Defoliation of flag leaf, T_2 = Defoliation of penultimate leaf, T_3 = Defoliation of tertiary leaf (Third leaf), T_4 = Defoliation of banner leaf and penultimate leaf, T_5 = Defoliation of banner leaf, penultimate leaf and tertiary leaf, T_6 = Defoliation, everything being equal, T_7 = Defoliation of all leaves without banner leaf, T_8 = Removal of half Spikelets. It was seen that the defoliation of flag leaf caused significant decrease on spikelets per panicle by 17.34 %. Likewise, the expulsion of penultimate leaf caused decrease of 10.98 % for spikelets per panicle.

Similarly, the defoliation of third leaf caused decrease of 7.20 % for spikelets per panicle. Likewise, the defoliation of flag leaf, penultimate leaf and third at a time caused reduction of 29.20 % for spikelets per panicle.

1000 grain weight

Fatima (2019) led an experiment to study the effect of flag leaf clipping on growth yield, and yield attributes of hybrid rice varieties in Boro season. The test involved two factors. Factor A: Flag leaf cutting: T_1 = Flag leaf cutting at heading and T_2 = Control (without cutting). Factor B: Six hybrid rice varieties: V_1 = BRRI hybrid dhan1, V_2 = BRRI hybrid dhan2, V_3 = Heera2, V_4 = Heera4, V_5 = Nobin and V_6 = Moyna. Chlorophyll content (SPAD value) in penultimate leaf following 15 days after heading, grain filling duration, yield contributing characters and yield were examined subsequent to cutting of flag leaf. Despite variety, all the studied parameters were shown predominance in control treatment. The maximum weight of 1000-grains was recorded from Heera4 under control condition. Das *et al.* (2017) reported that leaf clipping had non-significant effect on 1000 grains weight of modern variety while it was significant in local variety.

Hossain (2017) guided an experiment to evaluate the effect of leaf cutting on plant growth and yield of selected BRRI released Aman varieties. The experiment comprised of two factors: Factor A: five varieties, V_1 = BRRI dhan32, V_2 = BRRI dhan33, V_3 = BRRI dhan39, V_4 = BRRI dhan62 and V_5 = BRRI dhan56 and Factor B: two leaf cutting, T_1 = Leaf cutting (aside from flag and penultimate leaves) T_2 = Control (no leaf cutting). Regardless of the all the varieties under study, the maximum weight of 1000-grains was obtained in no leaf cutting (control) treatment. The yield and yield contributing characters was diminished by leaf cutting when compared with the control. 1000-grains weight was significantly reduced in plants those had the leaves cut compared with the plant in control treatment.

Sherif *et al.* (2015) reported that defoliation at 0, 20, 40 or 60% induced statistically the same values of 1000- grain weights, which ranged between 21.87 and 23.18 g in the first season (2013), and ranged between 27.47 and 29.21 g/1000 grains in the second season (2014). The least 1000- grain values were obtained at 80% (20.73 and 26.67 g) and at 100% (20.28 and 24.71 g) in the first and second seasons, respectively.

Mannan (1996) conducted an experiment and stated that panicle length varied among varieties. In comparison to BR10 and BRRI dhan32, BR11 had the highest 1000-grain weight (22.11 g).

Ahmed *et al.* (2001) revealed that the effect of leaf cutting was considerable in terms of crop characteristics except for 1000-grain weight. The control had the highest value of productive tillers hill^{-1} (9.19), panicle length (23.52 cm), sterile grains (18.68), grains panicle^{-1} (92.69), 1000-grain weight (22.72 g), grain yield (4.71 t ha^{-1}), straw yield (5.60 t ha^{-1}), biological yield (10.31 t ha^{-1}) and harvest index (45.59%). Hachiya (1989) carried out a field experiment to study on the effect of artificial leaf cutting on growth and yield of rice plants. The study revealed that compensatory response in rice growth, such as increases in the 1,000-grains weight, was observed.

Alejar *et al.* (1995) carried out an experiment to study the effect of source-sink imbalance on rice leaf senescence and yield. The planting materials for the experiment used were a slow senescing rice cultivar, Hankang and a rapid senescing cultivar, IR66; which were grown in waterlogged soil and at heading half the lamina of the flag, penultimate and 3rd leaves were cut transversely, half of the spikelets panicle^{-1} were removed or leaves and panicles were left intact. The slow senescing Hankang gave heavier 1000-grain weights compared with that of rapid senescing IR66.

2.3 Impact of seedling clipping on yield characters

Grain yield

Fatima (2019) set up an experiment to study the effect of flag leaf clipping on growth, yield and yield attributes of hybrid rice varieties in Boro season. The experiment consisted of two factors. Factor A: Flag leaf clipping: T_1 = Flag leaf clipping at heading and T_2 = Control (without clipping). Factor B: Six hybrid rice varieties: V_1 = BRRI hybrid dhan1, V_2 = BRRI hybrid dhan2, V_3 = Heera 2, V_4 = Heera 4, V_5 = Nobin and V_6 = Moyna. All the test varieties exhibited superiority in control condition. Chlorophyll content (SPAD value) in penultimate leaf after 15 days after heading, grain filling duration, yield contributing characters and yield were investigated after cutting of flag leaf. Regardless of variety, all the studied parameters were exhibited superiority in control treatment. Chlorophyll and nitrogen content (SPAD value) in penultimate (1.35% to 17.27%) and grain filling duration were increased (4.5 to 6.25 days) by virtue of clipping of flag leaf. The highest grain yield was recorded from Heera 4 under control condition. The clipping of the flag leaf reduced grain yield from 15.69% to 29.43% in the test Boro rice varieties.

Karmaker and Karmakar (2019) carried out an experiment to investigate the influence of N-rates and leaf clipping on forage and grain yield and seed quality of transplant Aman (wet season) rice. Four nitrogen (N) rates (N_1=46, N_2=69, N_3=92 and N_4=115 kg N ha^{-1}) and four times of leaf clipping viz, C_0=no leaf clipping, C_1=leaf clipping at 25 DAT (Days after transplanting), C_2=40 and C_3=55 DAT were evaluated following split-plot design with three replications. They noticed from their experiment that the highest mean grain yield (5.25 t ha^{-1}) was obtained from the treatment combination of 115 kg N ha^{-1} and no leaf clipping (N_4C_0) comparable to other treatment

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

Boonreund and Marsom (2015) carried out experiments aimed at searching for the optimal length of cutting for Pathum Thani1 rice leaf for better yield. Length of rice leaf cutting was reported to have positive effect on broadcasting Thai jasmine rice yield but was not clarified in other variety.

Treatments of the study was 7 cutting lengths (0, 5, 10, 15, 20, 25 and 30 cm from the leaf tip) which was performed by sickle after 60 days after planting. The results showed that cutting of leaves had no significant effect on yield. Grain yield was significantly increased after cutting. The optimal length of rice leaf cutting at 15–30 cm tended to obtain the highest grain yield.

Khatun *et al.* (2011) from their research work on influences of leaf cutting on growth and yield of rice and observed that the lowest grain yield of rice was produced from flag leaf cutting treatment. Prakash *et al.* (2011) found that the grain yield was positively related with flag leaf area in rice cultivars. Abou-Khalifa *et al*. (2008) stated that flag leaf contributed to 45% of grain yield and removal of flag leaf is the single most component for yield loss. Ros *et al.* (2003) found that pruning 30% of leaves depressed 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.

Mannan (1996) conducted an experiment and stated that panicle length varied among varieties. In comparison to BR10 and BRRI dhan32, BR11 had the highest grains panicle^{-1} (97.21), 1000-grain weight (22.11 g), grain yield (4.84 t ha^{-1}), biological yield (10.16 t ha^{-1}) and harvest index (46.80%). Das and Mukherjee (1992) conducted an experiment and reported that late leaf cutting reduce the grain yield.

Misra (1986) demonstrated that leaf cuttings had a significant effect on leaf area (cm^{2}) plant^{-1}, chlorophyll content (SPAD units), total dry matter (TDM) production, panicle length, spikelet number, number of grains per panicle, test weight (1000 grain weight), and grain yield (t ha^{-1}) of hybrid rice cultivar H5 and inbred Egyptian local cultivar Sakha 103. Under the control condition, with no leaf cutting, all of the parameters showed their maximum value.

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

Interaction effect of two factor showed that the highest grain yield (6531 kg ha^{-1}) was obtained in line of No.7 and control treatment. The lowest grain yield (4166.3 kg ha^{-1}) was observed in line of No.6 and cutting of leaves except flag leaf.

Sardana *et al.* (2006) conducted a field experiment to study the effect of extent and stage of foliage clipping on the grain yield of basmati rice (Basmati 386). The treatments were as follows: i) ⅓ of leaf clipping from top of the plant at 30 days after transplanting (DAT), ii) ½ of leaf clipping from top of the plant at 30 DAT, iii) ⅓ of leaf clipping from top of the plant at 45 DAT, iv) ½ of leaf clipping from top of the plant at 45 DAT, v) ⅓ of leaf clipping from top of the plant at 60 DAT, vi) ½ of leaf clipping from top of the plant at 60 DAT, vii) ⅓ of leaf clipping from top of the plant at 30 and 60 DAT, viii) ½ of leaf clipping from top of the plant at 30 and 60 DAT, ix) clipping of leaf just above growing point at the time of seedling transplanting and x) No leaf clipping. The extent (⅓ or ½) and stage (30, 45 or 30 and 60 DAT) of foliage clipping significantly influenced the grain yield through their marked influence on yield attributes. The maximum grain yield (2.90 t ha^{-1}) was registered in case of clipping of ⅓ foliage from the top at 30 DAT followed by clipping at the time of transplanting just above the growing point (2.50 t ha^{-1}). Grain yield linearly decreased with each successive delay in clipping from 30 to 60 DAT and the difference between 30 (2.60 t ha^{-1}) and 60 DAT (1.90 t ha^{-1}) was significant (mean of ⅓ and ½ foliage clipping). Similarly, foliage clipping only once (irrespective of the stage and extent of clipping) produced higher grain yield (1.90–2.90 t ha^{-1}) than clipping twice at 30 and 60 DAT (1.50 t ha^{-1}). Such reduction was significant as compared to clipping once at 30 (2.60 t ha^{-1}) or 45 DAT (2.30 t ha^{-1}). Similarly, foliage clipping of ⅓ portion from the top produced higher grain yield (2.20 t ha^{-1}) than clipping ½ foliage from top (2.0 t ha^{-1}). Clipping once at 60 DAT or twice at 30 and 60 DAT resulted in lower grain yield as compared to control where no foliage clipping was done.

Lower yield in case of clipping made at time of transplanting of seedlings as compared to that of 30 DAT might be due to lesser ability of plants to withstand clipping shock because the seedlings at this stage were also under transplanting shock. On the other hand, foliage clipping at 45 and 60 DAT might have adversely influenced the subsequent growth and possibly took more time to recover from such shock leading to reduced grain yield.

Clipping of only ⅓ of foliage from the top was found to be better than clipping to ½. It was concluded that partial foliage clipping up to ⅓ portion from top at 30 DAT has beneficial effect on traditional tall basmati rice.

Molla *et al.* (2002) conducted an experiment to ascertain the feasibility of green fodder harvest without affecting the seed yield of transplant aman rice. The experiment consists of two factors, (A) cultivar (i) C_1 = Latishail (ii) C_2 = BR 10 (iii) C_3 = BR 11 and (iv) C_4 = BRRI dhan32 and (B) leaf clipping heights (i) H_1 = clipping at 10 cm (ii) H_2 = clipping at 15 cm (iii) H3= clipping at 20 cm and (iv) H_4 = control (no clipping). Seed yield was significantly differed due to different cultivar and leaf clipping height. The highest value of all parameters except seed yield were obtained from control plot at all growth stage where the lowest were recorded from clipping at 10 cm height.

The plants, which were clipped at 20 cm height, produced an average green fodder yield in addition to higher seed yield, which was statistically similar to control. Therefore, it is possible to get green fodder by leaf clipping without seriously affecting the rice seed yield. Kupkanchanakul *et al.* (1990) conducted an experiment to observe the effect of leaf cutting for rice herbage on grain yield of deep-water rice. Leaf cutting for forage at 40, 70, 100 and 40 + 100 days after emergence gave grain yields of 2.13, 2.20, 2.24 and 1.94 ton ha^{-1} respectively, compared with 2.02 ton ha^{-1} without cutting.

Straw yield

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

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

Biological yield

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

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

Harvest index

Karmaker and Karmakar (2019) driven an experiment to investigate the influence of N-rates and leaf clipping on forage and grain yield and seed quality of transplant Aman (wet season) rice. Four nitrogen (N) rates (N_1=46, N_2=69, N_3=92 and N_4=115 kg N ha^{-1}) and four times of leaf clipping viz, C_0=no leaf clipping, C_1=leaf clipping at 25 DAT (Days after transplanting), C_2=40 and C_3=55 DAT were evaluated following split-plot design with three replications.

They noticed from their experiment that the highest mean harvest index (46%) was obtained from the treatment combination of 115 kg N ha^{-1} and no leaf clipping (N_4C_0) comparable to others treatment combinations.

Usman *et al.* (2007) set up an experiment to study the effect of detopping on forage and grain yield of rice. The experiment consisted of six treatments viz., Control (T_1, no detopping), detopping at 22 DAT (T_2), detopping at 29 DAT (T_3), detopping at 36 DAT (T_4), detopping at 43 DAT (T_5), and detopping at 50 DAT (T_6). In respect of all the six treatments, the highest harvest index (42.70%) were obtained from control (no detopping). Daliri *et al.* (2009) conducted an field experiment in order to study the effect of cutting time and cutting height on yield and yield components of ratoon rice (*Oryza sativa* L.) Taromlangrodi variety. Results showed that the effect of cutting time on harvest index was found statistically significant. Cutting height had a significant effect on harvest index. Remison and Omuti (1982) found the effects of N nutrition and leaf clipping after mid-silk of maize. Defoliation reduced weight of ears and harvest index. Crude protein was increased, especially with maximum clipping.

2.4 Impacts of planting geometry on growth characters

Plant height

Saha *et al.* (2020) conducted an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University during November 2016 to June 2017 to investigate the effect of spacing of planting on the yield performance of some aromatic rice varieties in Boro season. The experiment comprised three varieties viz. BRRI dhan50, Basmati and BRRI dhan63, six spacing of planting viz. 25 cm × 20 cm, 25 cm × 15 cm, 20 cm × 20 cm, 20 cm × 15 cm, 15 cm × 15 cm and 20 cm × 10 cm. The experiment was laid out in a randomized complete block design with three replications. Results of the experiment showed that plant spacing had significant effect on plant height. The tallest plant (73.73 cm) was obtained from the spacing of 25 cm × 20 cm which was at par 25 cm × 15 cm whereas the shortest plant (68.51 cm) was observed in 20 cm × 15 cm spacing which was at par with other spacing.

Paul *et al.* (2017) noticed that optimum plant spacing helps plants to grow well, using More solar radiation and soil nutrients. Ali *et al.* (2008) carried out an experiment at the Agronomy field, Sher-e-Bangla Agricultural University, Dhaka during the period from July to December, 2006 to evaluate the effect of integrated weed management and spacing on the weed flora and on the growth of transplanted aman rice and reported that plant height increased with the advancement of crop duration and with wider spacing. Haque (2002) conducted an experiment with 20 x 20cm, 30cm x 30cm and 40cm x 40cm spacing and found the tallest plant from wider spacing. Mia (2001) reported that plant height was influenced significantly due to spacing at all DAT except 15 DAT. It was observed that the widest spacing (20cm x 25cm) produced the tallest plant (120.80 cm) at 90 DAT and the shortest plant stature was (112.98 cm) in the closest spacing.

BRRI (1991) reported variation on plant height and maturity duration of BR 1, BR 3, BR 12, BR14 and BR 20 due to the plant densities where seedlings were planted with 25cm x 30cm, 25cm x 20 cm, 25cm x 10 cm and 15cm x 10cm respectively. Shah *et al.* (1991) reported that plant height of rice were maximum with 15 cm x 15 cm spacing. Miah *et al.* (1990) conducted an experiment where rice cultivars Nizersail and mutant lines Mut. NS 1 and Mut. NS 5 were transplanted at 15, 20, 25 and 30 cm row spacing. Plant heights were more in Mut. NS 1 than in Nizersail.

Akita and Tanaka (1992) found that panicle formation and plant height were more with 49 hills m^{-2} but at heading maturity the tallest IJialits were found at low plant density. When planted on square system the number of culm at panicle formation was the greatest at 100 hill nf 2 but at heading it was greatest at 64 hills n1, total dry weight increased with planting density and was highest when planted on the square and in rows with 64 and IOU hills m^{-2}. Respectively. Khisha (2002) stated that the highest plant height (122.52 cm) was obtained from 12 days old single seedling hill with 40 cm x 35 cm spacing and lowest plant height (109.9 cm) was found in normal practice which was thirty days old 2 seedlings hill^{-1} with 25 cm x 15 cm spacing.

Total dry matter weight

Mirza *et al.* (2009) studying the effect of tiller dynamics and dry matter production in transplanted rice as affected by spacing and number of seedlings per hill and observed that wider spacing coupled with higher number of seedlings per hill accumulated maximum amount of dry matter, emphasizing that productivity of tillers as well as dry matter yield was lower with closer spacing and transplanting single seedlings per hill. Total dry matter (TDM) production varies due to variation in plant density. In general, biological yield increased with increasing plant density in field crops because of increasing LAI (Haloi and Baldev, 1996).

Kang *et al.* (2001) conducted an experiment to know the influence of plant density (30, 50, 70 and 90 hills m^{-2}) on TDM production and found that TDM production $plant^{-1}$ decreased with increasing planting density but reverse trend was observed in case of unit area basis in rice. Khan (2007) worked with two rice cultivars and four plant densities of 20, 30, 40 and 50 hills m^{-2} and found that increasing plant density increased DM production per unit area but decreased DM $plant^{-1}$. Bashar (2007) conducted a field trial at BAU, Mymensingh to study the response of rice genotypes to plant densities and found that mean DM increased with increasing plant density up to 20 cm × 15 cm spacing.

2.5 Impacts of planting geometry on yield contributing characters

Effective tillers $hill^{-1}$

Salma *et al.* (2017) conducted an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh during Aman season from June to November 2016 to find out the effect of variety and planting density on weed dynamics and yield performance of transplant Aman rice. The experiment consisted of four varieties viz. Binadhan-7, BR25, BRRI dhan56 and BRRI dhan62 and four planting density viz. 25 cm × 15 cm, 25 cm × 10 cm, 20 cm × 15 cm and 20 cm × 10 cm. The experiment was laid out in a randomized complete block design with three replications. Result showed that the production of effective tillers $hill^{-1}$ was significantly influenced by spacing. The highest number of effective tillers $hill^{-1}$ (11.20) was obtained from 25 cm × 15 cm spacing and the lowest one (8.43) was found in 20 cm × 10 cm spacing. The highest number of total and effective tillers $hill^{-1}$ in wider spacing might be due to having more sunlight thus more photosynthesis more space for producing more number of tillers.

Ashraf *et al.* (2014) reported that the maximum productive tillers were found in widest plant spacing under weed free conditions while minimum was obtained from closest spacing under weedy treatments. It was also observed that closest spacing proved inefficient regarding tillering ability and provided lowest number of total tillers and productive tillers as well. Moreover, weed free conditions proved most effective and better regarding plant height and tillering ability as compared to weedy conditions and differed significantly.

Aziz and Hasan (2000) reported that the average number of tillers hill^{-1} and effective tillers hill^{-1} were 117 and 103, respectively in Parija variety at Rajshahi. The spacing 35 cm x 35 cm seemed more promising both in locally. On the other hand, farmers practice the average number of effective tillers m^{2} was 290 and 393 with 20cm x 20cm and 20cm x 15cm, respectively.

Non-effective tillers hill^{-1}

Akondo and Hossain (2019) conducted an experiment at the experimental farm of BINA Sub-station, Gopalganj to determine the effect of spacing on the yield and yield attributing parameters of rice. Four spacings viz. 15 cm × 15 cm, 20 cm × 15 cm, 20 cm × 20 cm and 25 cm × 20 cm were included in the study. The experimental design was a randomized completely block with three replications. Spacing's 15 cm × 15 cm, 20 cm × 15 cm, 20 cm × 20 cm and 25 cm × 20 cm were adopted 49, 42, 36 and 30 hills per square meter, respectively. Results revealed that different spacing performed significantly differed yield contributing characters. The 15 cm × 15 cm spacing (1.60) produced significantly higher non-effective tillers per stand than all the spacing (20 cm × 20 cm; 20 cm × 15 cm and 15 cm × 15 cm). The lowest number of non-effective tillers (0.80) per stand was recorded under 20 cm × 15 cm spacing.

Moro *et al.* (2016) reported that growth attributes were significantly affected by spacing. Mirza *et al.* (2009) also observed that closer spacing reduced the number of effective tillers and increased tiller mortality, hence lower number of panicles.

Total tillers hiil^{-1}

Halder *et al.* (2018) conducted an experiment was at the Agronomy Field of Patuakhali Science and Technology University, Dumki, Patuakhali from June to December, 2013 to find out the effect of variety and planting density on the yield and yield attributing characters of local aromatic rice. The experiment was laid out in a factorial randomized complete block design with three replications, which consisted of three local aromatic rice varieties (Chinigura, Shakhorkhora and Kalizira) and four planting densities were viz. S1 (25 cm × 20 cm), S2 (20 cm × 20 cm), S3 (20 cm × 15 cm) and S4 (20 cm × 10 cm). The results revealed that the higher number of tillers per hill (14.8), number of grains per panicle (140 nos.) were found in 20 cm × 20 cm spacing with higher grain yield.

Rashid and Khan (2006) made an experiment to study the tillering dynamics and the productivity of rice cv. BRRI dhan 44 under four spacing viz. 20cm x 15cm, 25cm x 15cm, 20cm x 20cm and 25cm x 25cm in Gazipur, Bangladesh. The highest number of tillers hill^{-1} was recorded at 25cm x 25cm spacing and decreased with a decrease in spacing. The effectivity index of tillers was highest in 25cm x 25cm spacing (58.12%), which was comparable to 20cm x 20cm spacing (52.38%) and significantly higher than spacing at 25cm x 15cm (46.62%) and 20cm x 15cm (50.63%).

Karim *et al.* (2002) conducted an experiment on SRI in Boro season 2000-2001. In that experiment, the spacing trail of 30 cm x 30cm, 35cm x 35cm and 40 cm x 40cm was tested for seedling age of 12 to 15 days. Results of the experiment showed that SRI performed the best in respect of total tillers hill^{-1} in wider spacing of 35 cm x 35 cm or 40cm x 40 cm. Chris (2002) stated that among three plant spacing (20cm x 20cm, 30cm x 30cm and 40cm x 40cm), the highest number of tillers hill^{-1} (60) was recorded in case of 20cm x 20cm spacing.

Sarker (2001) reported that row spacing exerted significant effect on the production of tillers hill^{-1} at all sampling dates. There was an increasing trend of tillers production with the increase in spacing on all the dates of observation. Srinivasan and Purushothaman (1990) observed that in rice cv.

Ponni and Bhavanis when transplanted at 15cm, 20cm or 25cm x 10cm the increased number of productive tillers at higher plant density in main and ratoon crops. Uddin (2003) planted rice *cv*. BRRI dhan39 at 25 cm x 25 cm, 25 cm x 20 cm, 25 cm x 15 cm and 25 cm x 10 cm spacing's and reported that the number of tillers hill^{-1} decreased with increasing plant density.

Haque and Nasiruddin (1988) conducted an experiment with deep water rice at densities of 50, 100, 150, 200, 225 and 350 seedlings m^{-2} and reported that tiller number decreased with increasing plant density. Muhammad *et al*. (1987) planted rice *cv*. Basmoti 370 with 2 seedlings hill^{-1} and maintained of 6, 11, 25 and 44 hills m^{-2} and reported that the number of total tillers hill^{-1} decreased with increasing plant density.

Panicle length

Ninad *et al*. (2017) conducted an experiment to know the effect of spacing and seedling per hill on the performance of aus rice var. performance of aus rice var. BRRI dhan48 and reported that closer spacing decreased panicle length.The longest panicle length (23.35 cm) was produced by 20 cm × 25 cm spacing and the shortest one (20.97 cm) by 20cm × 10 cm.

Kalita *et al.* (1997) observed that closer spacing decreased yield components including grains panicle^{-1}, panicle length and panicle weight but increased panicle numbers m^{-2}. Rekhashri *et al.* (1997) reported that closer spacing decreased yield components including Panicle length increased grain yield.

Liou (1987) reported that rice cultivars with closer spacing markedly decreased the panicle length, when grown at spacing 12.5 cm x 12.5 cm, 25 cm x 25 cm or 50 cm x 50 cm. Shirakawa *et al*. (1992) reported that in rice *cv.* Koshinikari, plant height and panicle length decreased with a decreased grain yield as plant density increased from 6-32 plants m^{-2}.

Filled grains panicle^{-1}

Rajesh and Thanunathan (2003) reported that the use of wider spacing led to lesser below and above ground competition for better grain filling, higher grain weight and more number of filled grains panicle^{-1}.

Unfilled grains panicle^{-1}

Saju *et al.* (2019) conducted a field study was during the late Samba (September-January) season of 2018-19 at Wetland farms, TNAU, Coimbatore to study the effect of high-density planting on growth and yield of rice (Oryza sativa L.) under modified system of rice intensification. The treatments comprised of T_1 - 25 x 25cm with 100% Recommended Dose of Fertiliser (RDF) (SRI), T_2 - 25 x 20cm with 100% RDF, T_3 - 25 x 15cm with 100% RDF, T_4 - 25 x 15cm with 125% RDF, T_5 - 20 x 20cm with 100% RDF, T_6 - 20 x 15cm with 100% RDF, T_7 - 20 x 15cm with 125% RDF and T_8 - Conventional cultivation with 100% RDF.

The experiment was laid out in Randomised Complete Block Design with three replications. The results revealed that the spacing levels had a significant influence on number of unfilled grains/panicle, which was recorded higher under 20 x 10cm (50.0 panicle^{-1}), followed by 20 x 15cm (48.1 panicle^{-1}). The number of unfilled grains in a panicle were lower under 25 x 25cm (29.3), which was statistically identical to 25 x20 cm (31.6) and 25 x15 cm (33.8). The higher number of unfilled grains panicle^{-1} under closer spacing levels is due to higher competition for utilization of resources due to increased plant population.

Total grains panicle^{-1}

Ninad *et al*. (2017) reported that the highest number of grains panicle^{-1} (128.79) was observed in 20 cm × 25 cm spacing while lowest number of grains panicle^{-1} (104.17) in 20 cm × 10 cm spacing. Reduction in the number of grains panicle^{-1} under closer spacing might be due to increased number of plants per unit area. This increased number of plants per unit area exerted competition among plants for nutrients and light that might have caused lower crop growth rate with consequently a reduction in the number of filled grains panicle^{-1}.

Rekhashri *et al.* (1997) stated that rice cv. Kapilee was grown at 20cm x 20cm, 10cm x 10cm, 15cm x 10cm and 10cm x 10cm spacing. Closer spacing decreased yield components including number of grains panicle^{-1}, panicle lengths and panicle weight but increased panicle numbers m^{-2} and slightly increased grain yield.

Rao *et al.* (1990) reported that grain yield was the highest at 20cm x 25cm spacing and decreased with closer spacing due to the unfilled spikelets panicle^{-1} and lower panicle weight and yield was also found to be decreased at wider spacing despite of slightly increased of panicle weight. Ghosh *et al.* (1998) obtained the highest number of grains per panicle at spacing of 30cm x 30 cm than those of closer spacing of 20 cm x 20cm and 20cm x 25 cm, respectively. Tsai (1987) conducted an experiment where rice cv.

Pegonil and Tainung 67 were grown at spacing of 30 cm x 15cm or 30cm x 7.5 cm with 1 or 4 to 6 plants hill^{-1} with the wider spacing and several seedlings hill^{-1} headed earlier and produced lower tillers and panicle numbers than Tainung 67 while closer planting tended to decrease panicle number hill^{-1} but significantly increase panicle number unit area^{-1}.

Thangamuthu and Subramanian (1983) studied the effect of population on yield and yield components of rice cv. C_O-43 and found that 20cm x 15cm spacing produced the highest grain yield 5.2 and 6.6 t ha^{-1} during the wet and dry seasons, respectively. The number of panicle m^{-2} was higher in a conventional planting at 15 cm x 10 cm spacing during the wet season but was higher at 20 cm x 15 cm spacing during the dry season. Murty and Murty (1981) stated that the number of spikelets panicle^{-1} was decreased in plants with closer spacing of 10cm x 10cm and 15cm x 15cm from those of plants cultivated with spacing of 20 cm x 20cm and 30 cm x 30 cm. Hwu and Thseng (1982) also expressed similar results that increasing spacing increased the number of spikelet panicle^{-1}

1000 grains weight

Anwari *et al.* (2019) carried out a field experiment at the experimental station of the Agricultural Faculty of Kunduz University in 2016 to evaluate the effect of planting distance on yield and agro-morphological characteristics of Bara variety (local variety of rice). Randomized Completely Block Design (RCBD) with four replications was used in the experiment. Transplanting distances with four levels viz. 10x10 cm, 15x15 cm, 20x20 cm, and 25x25 cm were used as treatment. Results showed that 1000 grains weight was significantly affected by spacing the results indicated that with the increase in spacing the thousand grains weight also increased significantly.

The highest 1000 grains weight (27.27g) was obtained when the crop was transplanted at 20x20 cm spacing and the lowest (26.47 g) at 10x10 cm spacing. Higher plant density was noted in narrow spacing than other spacing and this higher plant density was accompanied by strong intra and inter-row competition that might have caused the decrease in 1000 grains weight.

Biswas *et al.* (2015) reported that highest thousand-grain weight was obtained in wider spacing (30 x 20 cm) than narrow spacing (15 x20 cm). Yan (2002) reported that rice var. Yaza 1 gave a maximum yield of 12.79 t ha^{-1}, had 240 effective panicles m^{-2} and 198 grains $panicle^{-1}$ with a 1000 grain weight of 27.5 g when plant spacing was 50 cm x 50cm in SRI technique.

Wang *et al.* (2002) reported that in SRI Technique 1000 grain weights were 26.33, 26.27, 26.96 and 26.27 g with spacing distance of 25cm x 25cm, 25cmx 15cm, 30cmx 30cm, 30cm x 15cm, respectively. Alam (2004) conducted an experiment with BINA dhan4 at 25 cm x 20 cm, 20 cm x 20 cm, 25 cm x 15 cm and 20 cm x 15 cm spacings and reported that 1000-grain weight was not influenced by spacing. On the other hand, Karim *et al*. (1992) found that plant spacing had effect of grain size and reported that 1000-grain weight decreased with increasing plant density in rice. Rao *et al*. (1990) in an experiment with rice to know the effect of spacing on yield and yield related traits and reported that spacing had slight effect of grain size. The 1000-grain weight was greater in wider spacing (20 cm x 20 cm) than in closer spacing 20 cm x 10 cm) but non-significant different with each other.

2.6 Impact of planting geometry on yield characters

Grain yield

Dass *et al*. (2017) documented that narrower plant spacing in puddled transplanted rice resulted in higher productivity with minimum weed infestations. Bhowmik *et al.* (2012) reported that optimum plant spacing ensures optimum number of plants per unit area which lead to proper growth, yield components and ultimately grain yield.

Rashid *et al.* (2010) carried out a field experiment was at the Agronomy Field Laboratory, Department of Agronomy during February to June, 2008 to evaluate the effect of row to row and hill to hill spacing on the yield performance and yield of boro rice cv. BRRI dhan36 under aerobic system of cultivation. The experiment consists of three row to row spacing viz.; 20.0 cm, 25.0 cm and 30.0 cm and five hill to hill spacings viz. 2.5 cm, 5.0 cm, 10.0 cm, 20.0 cm and 30.0 cm. The trial was laid out in a randomiz complete block design with 3 replications. The result revealed that the crop with 20.0 cm row to row spacing and 20.0 cm hill to hill spacing produced the highest grain yield (4.90 t ha^{-1}), whereas the lowest grain yield (2.55 t ha^{-1}) was found with 20.0 cm × 2.5 cm.

Verma *et al.* (2002) conducted a field experiment in Raipur, Madhya Pradesh, India, during the rainy season of 1998-99 to study the effect of spacing 20cm x 20cm, 20cm x15cm and 20cm x 10cm and crop density or transplanted rice hybrid Proagro 6201. They found that seedlings planted at 20cm x 20cm and 20cm x 15cm produced higher number of productive tillers, grain yield and harvest index than seedlings planted at 20cm x 10cm. Closer spacing (20cm x10cm) gave higher sterility percentage than wider spacing. Patel (1999) also reported that maximum yield and yield related attributes in rice transplanted was obtained from 20 cm × 20cm planting distance as compared to narrower spacing than this.

Mobasser *et al.* (2007) conducted an experiment in Iran, to see the effects of seedling age (25, 35 or 45 days) and spacing (15x15, 20x20, 25x25 or 30x30 cm) on the yield and yield components of rice (cv. Neda). For this cultivar, transplanting of 25 days old seedlings at a spacing of 15cm x15 cm is optimum with regard to yield attributes. A field experiment was conducted by Bali (2006) during the kharif (rainy) seasons of 1999 and 2000 in India, to test the performance of scented rice (Mushk budgi)under various planting geometry and fertility levels. Plant geometry of 20 cm x 10 cm gave higher yield and economic returns than dense or wider spaced crop.

Dongarwar *et al.* (2005) conducted field experiments in Maharashtra, India, during the 1996, 1997 and 1998 wet seasons, to study the effect of spacing (20 x 5, 20 x 10 and 15 x 15 cm) on the grain yield of three scented rice cultivars. Three years pooled data on grain yield revealed that scented rice planted at 15 cm x15 cm (44 hills m^{-2}) spacing gave significantly higher yield compared to the 20cm x 15cm (33 hills m^{-2}) and 20cm x 10cm (50 hills m^{-2}). The overall performance of BRRI dhan 38 at the spacing of 20cm x 15cm was found to be the best and it produced the highest grain yield of 4.27 t ha^{-1} and the second highest grain was in BRRI dhan 37 at the same spacing (Khalil, 2001).

Reddy *et al.* (2001) reported that planting of rice at a closer spacing of 15cm x 10cm resulted in higher grain yields (40.66 and 50.33 q ha^{-1} during 1996 and 1997, respectively) as compared to normal planting at a spacing of 20 cm x 10cm (35.39 and 48.11 q ha^{-1} during 1996 and 1997, respectively) and recorded a mean increase of 7.6 % higher grain yield over the normal spacing.

Among the yield components, number of panicles unit $area^{-1}$ and grains $panicle^{-1}$ appeared to have been increased significantly by closer planting. Closer planting of seedlings (15cm x 10cm) also significantly increased the number of grains $panicle^{-1}$ (463) compared to the other treatments.

Yang *et al.* (1999) studied growth and yield of rice cv. Jinongda 3 at plant spacing of 30cm x 40cm, 30cm x 17cm and 30cm x 10cm, respectively and reported that tillers number and growth period increased as plant density increased. The optimum plant density was 20 hills m^{-2} (30cm x 17cm) at which yield reached the highest of 8.7 t ha^{-1} Siddique *et al.* (1999) grew rice cv. Mahamaya, Kranti, R-296-260 and Suraksha at spacing of 10cm x 10cm or 10cm x 20cm and reported that grain yield of rice under closer spacing (10cm x 10cm) was significantly higher than the wider spacing (20 cm x 10 cm).

Geethadevi *et al.* (2000) conducted an experiment by 15cm x10cm and 20cm x 10cm spacing to find out the effect on the growth and yield of hybrid rice. They found that maximum grain yield (5.14 t ha^{-1}) was obtained with 20 cm x10 cm spacing. Zhao *et al.* (1998) conducted an experiment with five planting densities (16.7cm x 13.3cm, 20cm x 13.3cm, 23.3 cm x 13.3cm, 26.7cm x 13.3cm and 30.3cm x 13.3cm) and observed that grain yield with the medium density (23.3cm x 13.3cm) was significantly higher than the highest density or the lowest density.

Straw yield

Saha *et al.* (2020) conducted an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University during November 2016 to June 2017 to investigate the effect of spacing of planting on the yield performance of some aromatic rice varieties in Boro season. The experiment comprised three varieties viz. BRRI dhan50, Basmati and BRRI dhan63, six spacing of planting viz. 25 cm × 20 cm, 25 cm × 15 cm, 20 cm × 20 cm, 20 cm × 15 cm, 15 cm × 15 cm and 20 cm × 10 cm.

The experiment was laid out in a randomized complete block design with three replications. Result showed that planting spacing significantly effect on grain and straw yield and among different planting spacing 20 cm × 10 cm gave the highest grain (4.54 t ha^{-1}) and straw (5.92 t ha^{-1}) yields compared to other spacing.

Mustapha (2000) claimed that the differences in population density in rice cv. IET 3137 and ITA 306 gave relatively similar grain between 20 cm x 20cm and 30cm x 30cm spacing. Straw yield increased with an increase in spacing, but that did not correspond to an increase in yield. Transplanting at a spacing of 40cm x 40cm gave the highest straw mass but the grain yield was the lowest.

Plant spacing has remarkable effect on straw yield. BRRI (1999) conducted an experiment with three rice varieties at different Regional Research Stations under different spacings of 10 cm x 10 cm to 30 cm x 30 cm using normal cultural practices and reported that straw yield was varied significantly. Straw yield varied from 4.6 to 6.08 t ha^{-1} in closer spacing with an average of 6.12 t ha^{-1} whereas the yield varied from 4.80 to 8.94 t ha^{-1} in wider spacing with an average of 7.76 t ha^{-1}. Most of the varieties gave higher straw yield in wider spacing. Chandra *et al.* (1997) conducted an experiment on 12 Basmati rice varieties in wet season with 20 cm x 20 cm, 20 cm x 15 cm and 15 cm x 15 cm spacing and reported that 15 cm x 15 cm gave greater straw yield in unit area basis over 20 cm x 20 cm spacing due to higher number of tillers per unit area although total tillers hill^{-1} was fewer than wider spacing.

Chavan *et al.* (1989) found from an experiment on different spacing that grain yield and grain straw: ratio increased with wider spacing. Sarkar *et al.* (1988) observed that straw yield was significantly higher with 5 cm hill spacing. Uddin (2003) conducted an rice experiment with four spacing’s of 25 cm x 25 cm, 25 cm x 20 cm, 25 cm x 15 cm and 25 cm x 10 cm and reported that 25 cm x 15 cm spacing recorded the highest straw yield plot^{-1} although the straw yield hill^{-1} was not greater than other two wider spacing’s, 25 cm x 25 cm and 25 cm x 20 cm.

Biological yield

Dass *et al.* (2017) documented that narrower plant spacing in puddled transplanted rice resulted in higher biological yield comparable to widest spacing. The yield performance at a spacing of 20cm x 20cm was significant and recorded 16.1% and 16.4% and 6.5% and 5.7% higher grain and straw over the spacing of 20cm x 10cm and 20cm x 15 cm, respectively. Nitrogen uptake by grain significantly increased with increasing plant spacing, while it was reverse for N uptake by straw (Gautam *et al.*, 2005).

Harvest index

Saju *et al.* (2019) concluded from their study that higher harvest index was recorded under 20 x 20cm spacing (0.46) which was statistically similar to 25 x 25cm (0.44), 25 x 15cm at 100% RDF (0.43) and 125% RDF (0.44) and 25 x 20cm (0.44). Harvest index recorded was lower under conventional planting system (0.37) which is on par with 20 x 15cm at 100% RDF (0.38) and 125% RDF (0.39).

Higher harvest index might be due to greater partitioning of photosynthesis towards the production of straw and higher grain ratio in total biological yield. Hossain (2002) conducted a field trial during aman season with cv. BRRI dhan 32 and results revealed that the highest harvest index (48.62 %) was obtained from SRI planting method, which was 15 days old seedlings with the spacing 25cm x 25cm and the lowest harvest index (45.94) obtained from conventional method, which was 25 days old seedlings coupling with 25cm x 15cm.

Bhab *et al.* (1987) said that the harvest index was maximum with 25m x 15cm spacing. Kim *et al*. (1990) found that harvest index increased by dense planting in rice. Similar result was also reported by Uddin (2003) in rice. Shah *et al.* (1991) reported that harvest index was the highest in 15 cm x 15 cm spacing compared to other wider spacing's. On the other hand, Aktar (2004) reported that plant spacing had no effect on harvest index in rice. Similar result was also reported by Alam (2004) in rice.

CHAPTER III

MATERIALS AND METHODS

This chapter presents a concise depiction about experimental period, site description, climatic condition, crop or planting materials that were being used in the experiment, treatments, experimental design and layout, crop growing technique, fertilizers application, uprooting of seedlings, intercultural operations, data collection and statistical analysis.

3.1 Location of the experimental site

3.1.1 Geographical location

The experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar Agargong, Dhaka, 1207. The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level.

3.1.2 Agro-Ecological Zone

The experimental field belongs to the Agro-ecological zone (AEZ) of “The Modhupur Tract”, AEZ-28. This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain for better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I.

3.2 Experimental Duration

The experiment was conducted during the period from July to December, 2022 in Transplanting aman season.

3.3 Soil characteristics of the experimental field

Soil of the experimental site was silty clay loam in texture belonging to Tejgaon series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ No. 28) with pH 5.8–6.5, ECE-25–28.

Soil samples from 0- 15 cm depths were collected from the experimental field. The analytical data of the soil sample collected from the experimental area were analyzed in the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and have been presented in Appendix II.

3.4 Climate condition of the experimental field

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

3.5 Crop / planting material

BRRI dhan80 was being used as test crops for this experiment.

3.6 Description of the planting material

Variety: **BRRI dhan80**	
Main Features of the Variety	
Developed by	Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh
Method of development/origin	Hybridization
Year of release	2017
Main characteristics	High yielding aromatic variety, plant height 120 cm, grain straw color, very long, slender, aromatic, white, weight of 1000-grain (26.2 g), life time 130 days
Planting season and time	Aman, seedling in seed bed 5-25 July
Harvesting time	15-25 November
Yield	4.5-5.0 t ha^{-1}
Quality of product	Amylose 23.6% in rice

3.7 Seed collection and sprouting

BRRI dhan80 rice variety was collected from BRRI (Bangladesh Rice Research Institute), Joydebpur, Gazipur. Healthy and disease-free seeds were selected following standard technique. Seeds were immersed in water in a bucket for 24 hours. These were then taken out of water and kept in gunny bags. The seeds started sprouting after 48 hrs which were suitable for sowing in 72 hours.

3.8 Raising of the seedlings

A typical system was followed in raising of seedlings in the seedbed. The nursery bed was set up by puddling with continued ploughing followed by laddering. The sprouted seeds were planted as uniformly as possible. Irrigation was delicately given to the bed as and when required. No fertilizers were used in the nursery bed.

3.9 Preparation of experimental field

The experimental field was first opened on 11 July, 2022 with the help of a power tiller, later the land was irrigated and prepared by three successive ploughings and cross-ploughings. Each ploughing was followed by laddering, to have a good puddled field. Various kind of weeds and developments of pest crop were disposed of from the field. After final land preparation the field layout was made on 24 July 2022. Each plot was cleared in and finally leveled out with the help of wooden board.

3.10 Fertilizer management

The following doses of fertilizer were applied for cultivation of (BRRI dhan80) (BRRI, 2000).

Fertilizers	**Quantity (kg ha^{-1})**
Urea	180
TSP	75
MoP	98
Gypsum	68
Zinc sulphate	9

Plant nutrients (*viz*. nitrogen, phosphorus, potash, sulfur, zinc) for rice were given through urea, triple super phosphate, muriate of potash, gymsum, and zinc sulphate respectively. All of the fertilizers except urea were applied as basal dose at the time of final land preparation. Urea (180 kg ha^{-1}) was applied in equal three splits.

The first dose of urea was applied at 12 days after transplanting (DAT). The second dose of urea was added as top dressing at 30 days (active vegetative stage) after transplanting and third dose was applied at 45 days (panicle initiation stage) after transplanting recommended by BRRI.

3.11 Experimental design and layout

The experiment was laid out in Randomize Complete Block Design having 3 replications. There were 12 treatment combinations and 36-unit plots. The unit plot size was 5.76 m^2 (2.4 m × 2.4 m). The blocks and unit plots were separated by 1.0 m and 0.50 m spacing, respectively. The layout of the experimental field was shown in Appendix III.

3.12 Experimental details

Seed bed preparation Date: 30 June 2022

Seed Sowing Date: 30 June 2022

Fertilizer application Date: All the fertilizers were applied at 24 July 2022 during final land preparation except total urea

Transplanting Date: 30 July 2022

Harvesting Date: 5 December 2022

3.13 Experimental treatments

The experiment consisted of two factors as mentioned below:

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

C_1= Control (no clipping)

C_2= 1/3rd top seedling clipping

C_3= 1/2nd top seedling clipping

Factor B: Planting geometry (4) *viz:*

G_1= 25 cm x 20 cm

G_2= 20 cm x 20 cm

G_3= 20 cm x 15 cm

G_4= 15 cm x 15 cm

3.14 Experimental treatment combinations

Treatment Combination	
C_1G_1	(No seedling clipping) x (25 cm x 20 cm)
C_1G_2	(No seedling clipping) x (20 cm x 20 cm)
C_1G_3	(No seedling clipping) x (20 cm x 15 cm)
C_1G_4	(No seedling clipping) x (15 cm x 15 cm)
C_2G_1	(1/3rd top seedling clipping) x (25 cm x 20 cm)
C_2G_2	(1/3rd top seedling clipping) x (20 cm x 20 cm)
C_2G_3	(1/3rd top seedling clipping) x (20 cm x 15 cm)
C_2G_4	(1/3rd top seedling clipping) x (15 cm x 15 cm)
C_3G_1	(1/2nd top seedling clipping) x (25 cm x 20 cm)
C_3G_2	(1/2nd top seedling clipping) x (20 cm x 20 cm)
C_3G_3	(1/2nd top seedling clipping) x (20 cm x 15 cm)
C_3G_4	(1/2nd top seedling clipping) x (15 cm x 15 cm)

3.15 Intercultural operations

3.15.1 Clipping

Seedling clipping were done according to the treatment requirement.

3.15.2 Gap filling

Died off seedlings in some hills, were replaced by vigor and healthy seedling from same source within 7 days of transplantation.

3.15.3 Application of irrigation water

Irrigation water was added to each plot according to the critical stage. Irrigation was done up to 5 cm.

3.15.4 Method of water application

The experimental plots were irrigated through irrigation channels. Centimeter marked sticks were installed in each plot which were used to measure depth of irrigation water.

3.15.5 Weeding

Two hand weeding were done during plant growth period. First weeding was done at 20 DAT (Days after transplanting) followed by second weeding at 38 DAT.

3.15.6 Plant protection measures

The crop was attacked by yellow rice stem borer (*Scirpopagain certulas*) at the panicle initiation stage which was successfully controlled with Sumithion @ 1.5 t ha^{-1}. Yet to keep the crop growth in normal, Basudin was applied at tillering stage @ 17 kg ha^{-1} while Diazinon 60 EC @ 850 ml ha^{-1} were applied to control rice bug and leaf hopper. Crop was protected from birds during the grain filling period by using net and covering the experimental field.

3.15.7 General observations of the experimental field

Regular observations were made to see the growth and visual different of the crops, due to application of different treatment were applied in the experimental field. In general, the field looked nice with normal green plants. Incidence of stem borer, green leaf hopper, leaf roller was observed during tillering stage and there were also some rice bugs were present in the experimental field. But any bacterial and fungal disease was not observed. The flowering was uniform.

3.15.8 Harvesting and post-harvest operation

The rice plant was harvested depending upon the maturity of grains and harvesting was done manually from each plot. Maturity of crop was determined when 80–90% of the grains become golden yellow in color. Ten (10) pre-selected hills per plot from which different data were collected and 1.00 m^2 areas from middle portion of each plot was separately harvested and bundled, properly tagged and then brought to the threshing floor. Threshing was done by pedal thresher. The grains were cleaned and sun dried to moisture content of 14%. Straw was also sun dried properly. Finally grain and straw yields plot^{-1} were recorded and converted to t ha^{-1}.

3.16 Data collection

The data were recorded on the following parameters

1. Crop growth characters

i. Plant height at 25 days interval
ii. Number of tillers hill^{-1} at 25 days interval
iii. Above ground dry matter weight of plant at 25 days interval

2. Yield contributing characters

iv. Effective tillers hill^{-1}
v. Non-effective tillers hill^{-1}
vi. Panicle length
vii. Filled grains panicle^{-1}
viii. Unfilled grains panicle^{-1}
ix. Total grains panicle^{-1}
x. Weight of 1000- grain

3. Yield

xi. Grain yield
xii. Straw yield
xiii. Biological yield
xiv. Harvest index

3.17 Procedure of recording data

3.17.1 Plant height

The height of the randomly selected 5 plant was determined by measuring the distance from the soil surface to the tip of the leaf at 25 DAT interval and harvest respectively. Mean plant height of rice plant were calculated and expressed in cm.

3.17.2 Tillers hill^{-1}

Tillers hill^{-1} (no.) were counted at 25 days interval up to harvest from pre-selected hills and finally averaged as their number hill^{-1}. Only those tillers having three or more leaves were considered for counting.

3.17.3 Above ground dry matter weight hill^{-1}

Total above ground dry matter weight hill^{-1} was recorded at 25 days interval and harvest respectively by drying plant sample. The sample plants were oven dried for 72 hours at 70°C and then data were recorded from plant samples hill^{-1} plot^{-1} selected at random from the outer rows of each plot leaving the border line and expressed in gram.

3.17.4 Panicle length

Measurement of panicle length was taken from basal node of the rachis to apex of each panicle. Panicle length was measured with a meter scale from 5 selected panicles and average value was recorded.

3.17.5 Effective tillers hill^{-1}

The total effective tillers hill^{-1} (no.) was counted as the number of panicle bearing tillers per hill. Data on effective tiller per hill were recorded from 5 randomly selected hill at harvesting time and average value was recorded.

3.17.6 Non-effective tillers hill^{-1}

The total non-effective tillers hill^{-1} (no.) was counted as the tillers, which have no panicle on the head. Data on non-effective tiller per hill were counted from 5 preselected (used in effective tiller count) hill at harvesting time and average value was recorded.

3.17.7 Filled grains panicle^{-1}

The total filled grains (no.) were collected randomly from selected 5 plants of a plot and then average filled grains (no.) per panicle was recorded.

3.17.8 Unfilled grains penicle^{-1}

The total unfilled grains (no.) were collected randomly from selected 5 plants of a plot based on, no or partially developed grain in spikelet and then average number of unfilled grains per panicle was recorded.

3.17.9 Total grains panicle^{-1}

The fertile grains panicle^{-1} (no.) alone with the number of sterile grains panicle^{-1} gave the total grains panicle^{-1} (no.).

3.17.10 Weight of 1000-grain

One thousand cleaned dried seeds were counted randomly from each sample and weighed by using a digital electric balance at the stage the grain retained 12% moisture and the mean weight were expressed in gram.

3.17.11 Grain yield

Grain yield was adjusted at 14% moisture. Grains obtained from each unit plot were sun-dried and weighed carefully. The dry weight of grains of central 1m^{2} area was measured and then record the final grain yield of each plot^{-1} and finally converted to t ha^{-1} in both locations. The grain yield t ha^{-1} was measured by the following formula:

$$\text{Grain yield (t ha}^{-1}\text{)} = \frac{\text{Grain yield per unit plot (kg)} \times 10000}{\text{Area of unit plot in m}^{2} \times 1000}$$

3.17.12 Straw yield

After separating the grains, straw yield was determined 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}. The straw yield t ha^{-1} was measured by the following formula:

$$\text{Straw yield (t ha}^{-1}\text{)} = \frac{\text{Straw yield per unit plot (kg)} \times 10000}{\text{Area of unit plot in m}^{2} \times 1000}$$

3.17.13 Biological yield

The summation of grain yield and above ground straw yield was the biological yield.

Biological yield =Grain yield + straw yield.

3.17.14 Harvest index

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

$$\text{Harvest index (\%)} = \frac{\text{Grain yield (t ha}^{-1}\text{)}}{\text{Biological yield (t ha}^{-1}\text{)}} \times 100$$

Here, Biological yield = Grain yield + straw yield

3.18 Data analysis technique

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program name Statistic 10 data analysis software and the mean differences were adjusted by Least Significant Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

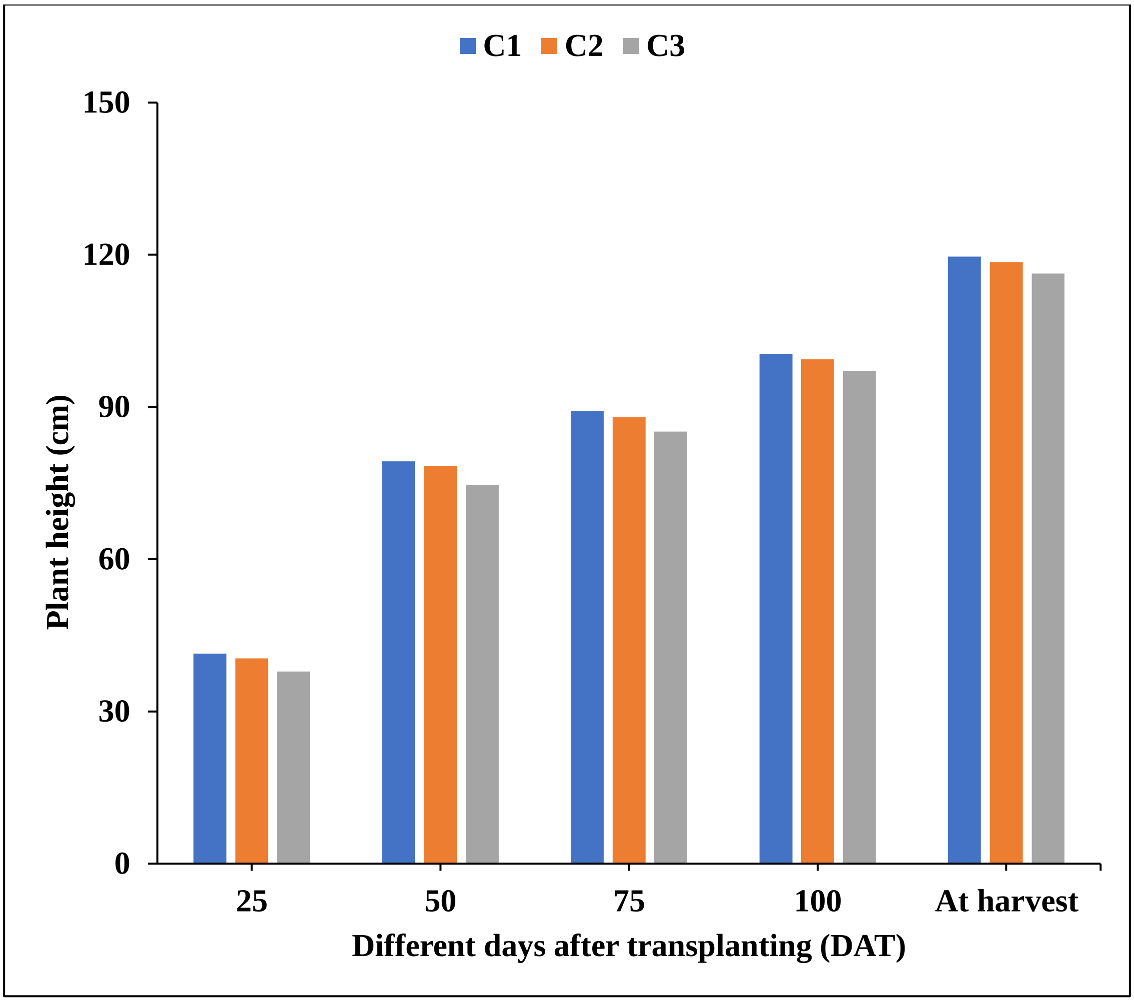
This chapter comprised presentation and discussion of the results obtained from the study on growth and yield response of aromatic rice to seedling clipping and different planting geometry. The analyses of variance (ANOVA) of the data on different growth parameters and yield of aromatic rice are presented in Appendix V-X. The results have been presented and discussed in the different tables and graphs and possible interpretations are given under the following headings:

4.1 Growth parameters

4.1.1 Plant height

4.1.1.1 Seedling clipping

Plant height is one of the most effective characters for better yield of aromatic rice which was also directly allied to straw yield. Plant height was recorded at 25, 50, 75, 100 DAT (days after transplanting) and harvest showed statistically significant variations due to seedling clipping (Appendix V and Fig.1). At 25, 50, 75, 100 DAT and harvest, the tallest plant (41.38, 79.32, 89.28, 100.50 and 119.68 cm, respectively) was observed in C_1 (Control, no clipping) treatment that was followed by C_2 (1/3rd top seedling clipping) and the shortest plant (37.87, 74.61, 85.17, 97.15 and 116.33 cm respectively) was found in C_3 (1/2nd top seedling clipping) treatment. It's possible that this is due to inherent characteristics of the variety that aren't greatly affected by cultural treatment. 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.

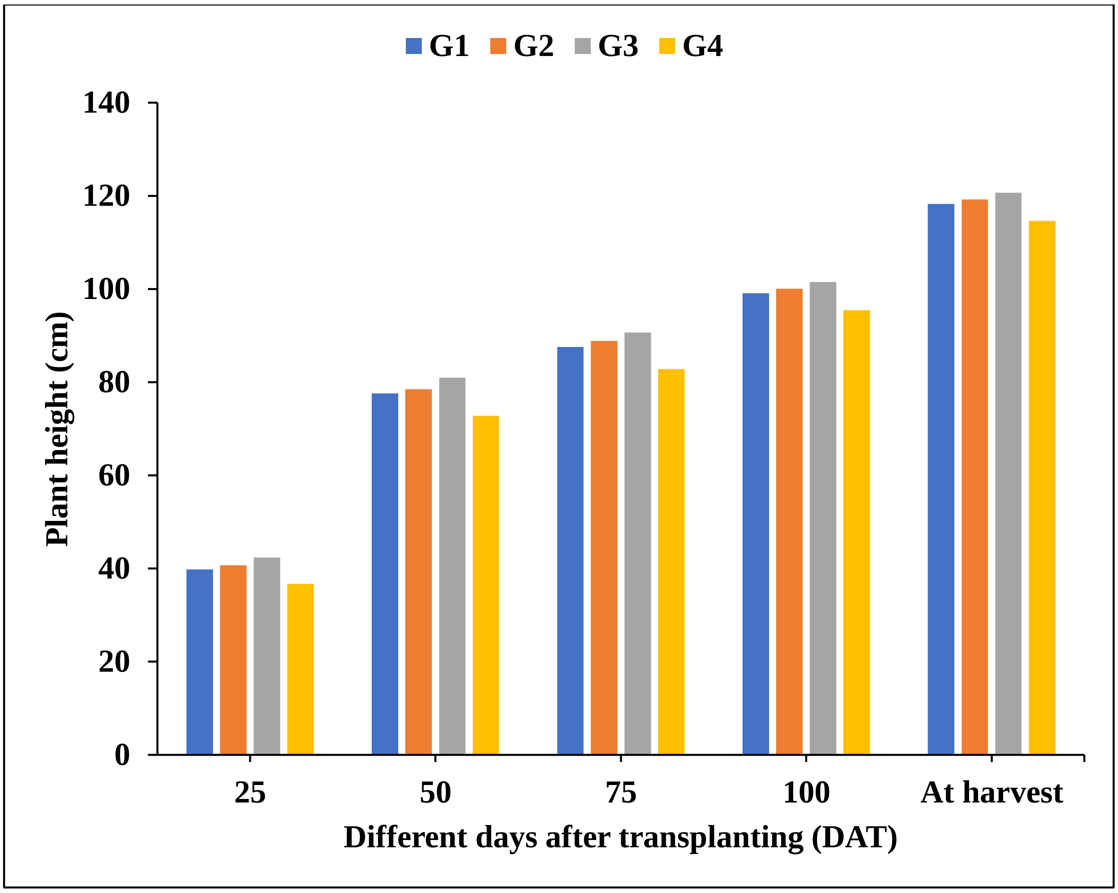


Here, C_1= Control (no clipping), C_2= 1/3rd top seedling clipping and C_3= 1/2nd top seedling clipping.

Figure 1. Effect of seedling clipping on plant height (cm) of aromatic rice at different days after transplanting (DAT) (LSD $_{0.05}$ = 0.66, 0.98, 1.70, 1.44, 1.86 at 25, 50, 75, 100 DAT and harvest, respectively).

4.1.1.2 Different planting geometry

Plant height was varied significantly at different stages due to variation in different planting geometry (Appendix V and Fig.2). At 25, 50, 75, 100 DAT and harvest, the tallest plant (42.34, 80.94, 90.66, 101.52 and 120.70 cm, respectively) was observed in G_3 (20 cm x 15 cm) which was statistically similar with G_2 (20 cm x 20 cm) treatment. whereas the shortest plant height (36.73, 72.81, 82.84, 95.47 and 114.65 cm, respectively) was found in G_4 (15 cm x 15 cm) treatment. Similar result was found by Haque (2002) who reported that wider hill spacing produced the tallest plants than did closer hill spacing.



Here, G_1= 25 cm x 20 cm, G_2= 20 cm x 20 cm, G_3= 20 cm x 15 cm and G_4= 15 cm x 15 cm.

Figure 2. Effect of different planting geometry on plant height (cm) of aromatic rice at different days after transplanting (DAT) (LSD $_{0.05}$ = 0.76, 1.13, 1.96, 1.66, 2.15 at 25, 50, 75, 100 DAT and harvest, respectively).

4.1.1.3 Combination effect of seedling clipping and different panting geometry

Interaction effect of seedling clipping and different planting geometry showed significant differences for plant height (Appendix V and Table 1). at 25, 50, 75, 100 DAT and harvest, the tallest plant (45.11, 84.63, 92.86, 103.75 and 122.93 cm respectively) was observed in C_1G_3 (Control, no clipping and 20 cm x 15 cm) and the second highest plant height (42.8, 81.78, 91.64, 102.14 and 121.32 cm) was observed in C_2G_3 while the shortest plant height (35.87, 71.67, 81.29, 94.44 and 113.62 cm, respectively) was recorded in C_3G_4 (1/2nd top seedling clipping and 15 cm x 15 cm).

Table 1. Combination effect of seedling clipping and different planting geometry on plant height at different days after transplanting (DAT)

Treatment combinations	Plant height (cm) at different days after transplanting (DAT)				
	25	**50**	**75**	**100**	**At harvest**
C_1G_1	40.98 cd	79.16 c	88.95 b-d	100.19 b-e	119.37 a-e
C_1G_2	42.17 bc	80.34 bc	90.48 a-c	101.36 a-c	120.54 a-c
C_1G_3	45.11 a	84.63 a	92.86 a	103.75 a	122.93 a
C_1G_4	37.25 f	73.78 f	84.81 ef	96.71 f-h	115.89 e-g
C_2G_1	40.46 d	78.53 c	88.14 c-e	99.52 b-f	118.7 b-e
C_2G_2	41.4 cd	79.83 bc	89.86 a-c	100.81 b-d	119.99 a-d
C_2G_3	42.8 b	81.78 b	91.64 ab	102.14 ab	121.32 ab
C_2G_4	37.06 fg	72.99 fg	82.43 fg	95.26 gh	114.44 fg
C_3G_1	37.92 ef	74.35 ef	85.56 d-f	97.55 e-g	116.73 d-g
C_3G_2	38.58 e	76.02 de	86.33 de	97.94 d-g	117.12 c-g
C_3G_3	39.1 e	76.41 d	87.48 c-e	98.66 c-f	117.84 b-f
C_3G_4	35.87 g	71.67 g	81.29 g	94.44 h	113.62 g
LSD $_{(0.05)}$	**1.32**	**1.96**	**3.40**	**2.88**	**3.72**
CV (%)	**1.96**	**1.49**	**2.29**	**1.72**	**1.86**

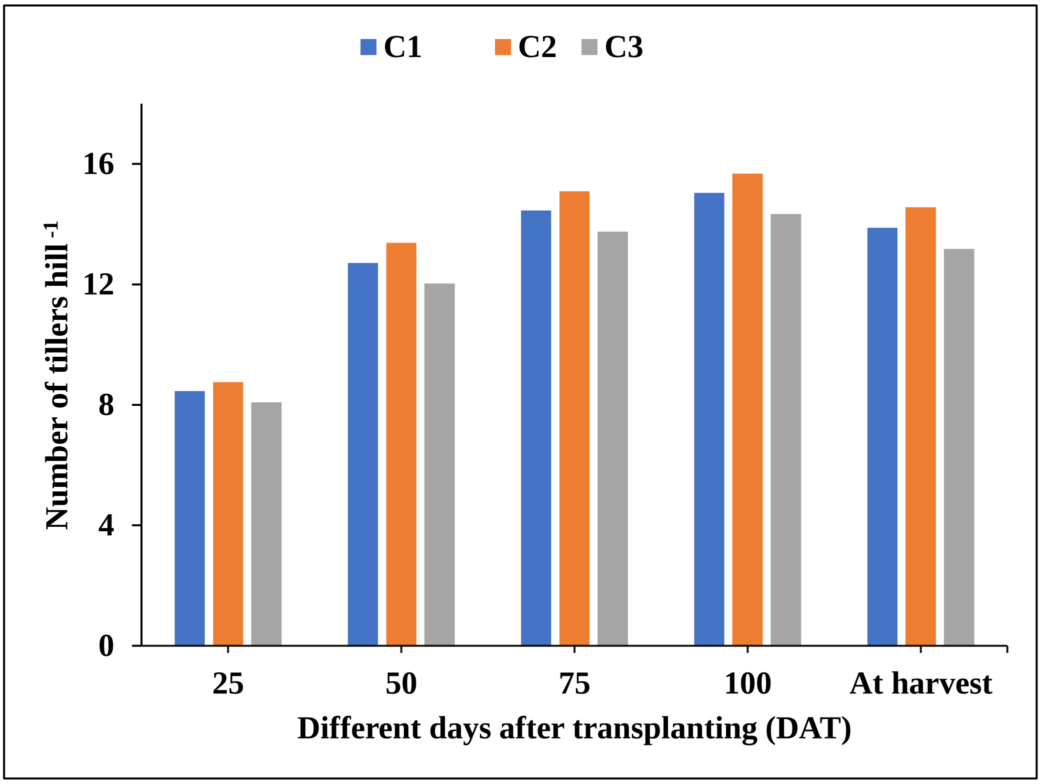
In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance

Here, C_1= Control (no clipping); C_2= 1/3rd top seedling clipping; C_3= 1/2nd top seedling clipping; G_1= 25 cm x 20 cm; G_2= 20 cm x 20 cm; G_3= 20 cm x 15 cm and G_4= 15 cm x 15 cm.

4.1.2 Tillers hill^{-1}

4.1.2.1 Seedling clipping

A significant variation in number of tillers hill^{-1} were observed due to variation in seedling clipping at 25, 50, 75, 100 DAT and harvest (Appendix VI and Fig. 3). At 25, 50, 75, 100 DAT and harvest, the highest no. of tillers (8.76, 13.38, 15.10, 15.68 and 14.56, respectively) was observed in C_2 (1/3rd top seedling clipping) that was followed by C_1 and lowest no. of tillers (8.09, 12.03, 13.76, 14.34 and 13.18 respectively) was observed in C_3 (1/2nd top seedling clipping). Fukushima (2019) observed that tiller no. can vary due to varietal differences. 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).

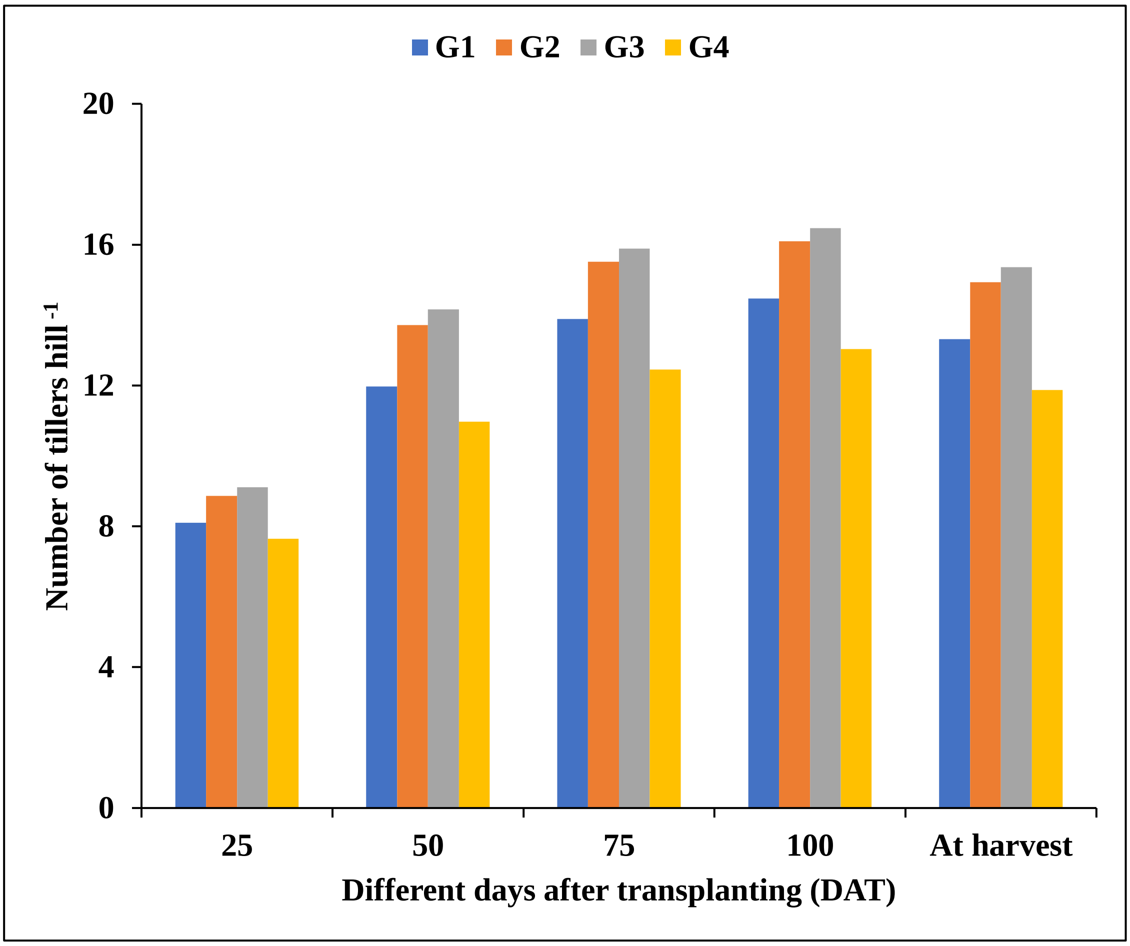


Here, C_1= Control (no clipping), C_2= 1/3rd top seedling clipping and C_3= 1/2nd top seedling clipping.

Figure 3. Effect of seedling clipping on number of tillers hill^{-1} of aromatic rice at different days after transplanting (DAT) (LSD $_{0.05}$ = 0.19, 0.37, 0.29, 0.33, 0.32 at 25, 50, 75, 100 DAT and harvest, respectively).

4.1.2.2 Different planting geometry

Different planting geometry showed different no. of tillers hill^{-1} which varied significantly (Appendix VI and Fig. 4). At 25, 50, 75, 100 DAT and at harvest, the highest no. of tillers (9.11, 14.16, 15.89, 16.47 and 15.36 respectively) was observed in G_3 (20 cm x 15 cm) which was followed by (8.86, 13.72, 15.51, 16.09 and 14.93, respectively) in G_2 (20 cm x 20 cm). The lowest no. of tillers (7.65, 10.97, 12.45, 13.03 and 11.87, respectively) was observed in G_4 (15 cm x 15 cm) treatment which was followed by G_1 treatment. The result corroborates with the findings of Mustapha (2002) who reported that the widest spacing produces the highest number of tillers hill^{-1} and the lowest number of tillers hill^{-1} was founded in closer spacing.



Here, G_1= 25 cm x 20 cm, G_2= 20 cm x 20 cm, G_3= 20 cm x 15 cm and G_4= 15 cm x 15 cm.

Figure 4. Effect of different planting geometry of tillers hill^{-1} of aromatic rice at different days after transplanting (DAT) (LSD $_{0.05}$ = 0.21, 0.43, 0.34, 0.38, 0.37 at 25, 50, 75, 100 DAT and harvest, respectively).

4.1.2.3 Combination effect of seedling clipping and different panting geometry

Interaction effect of seedling clipping and different planting geometry showed significant differences in tillers number hill^{-1} (Appendix VI and Table 2). At 25, 50, 75, 100 DAT and harvest, the highest no. of tillers (9.64, 15.03, 16.81, 17.39 and 16.40, respectively) were produced from the 1/3rd top seedling clipping and 20 cm x 15 cm planting geometry (C_2G_3) that is followed by the tillers no. (9.32, 14.73, 16.33, 126.91 and 15.75, respectively) produced from the 1/3rd top seedling clipping and 20 cm x 20 cm planting geometry (C_2G_2). At 25, 50, 75, 100 DAT and harvest, the lowest no. of tillers (7.49, 10.56, 11.96, 12.54 and 11.38, respectively) was observed where 1/2nd top seedling clipping + 15 cm x 15 cm (C_3G_4) treatment combination. 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 20 cm x 15 cm planting geometry 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 2. Combination effect of seedling clipping and different planting geometry on number of tillers hill^{-1} at different days after transplanting (DAT)

Treatment combinations	Number of tillers hill^{-1} at different days after transplanting (DAT)				
	25	50	75	100	At harvest
C_1G_1	8.11 e-g	11.96 gh	13.87 fg	14.45 fg	13.29 fg
C_1G_2	8.91 c	13.62 cd	15.63 c	16.21 c	15.05 c
C_1G_3	9.16 bc	14.26 bc	15.89 bc	16.47 bc	15.31 bc
C_1G_4	7.64 hi	11.02 ij	12.44 ij	13.02 ij	11.86 ij
C_2G_1	8.24 d-f	12.43 fg	14.29 ef	14.87 ef	13.71 ef
C_2G_2	9.32 ab	14.73 ab	16.33 ab	16.91 ab	15.75 b
C_2G_3	9.64 a	15.03 a	16.81 a	17.39 a	16.40 a
C_2G_4	7.82 g-i	11.34 hi	12.96 hi	13.54 hi	12.38 hi
C_3G_1	7.96 f-h	11.53 hi	13.52 gh	14.10 gh	12.94 gh
C_3G_2	8.36 de	12.81 ef	14.58 de	15.16 de	14.00 de
C_3G_3	8.54 d	13.20 de	14.96 d	15.54 d	14.38 d
C_3G_4	7.49 i	10.56 j	11.96 j	12.54 j	11.38 j
LSD (0.05)	**0.37**	**0.74**	**0.59**	**0.65**	**0.64**
CV (%)	**2.59**	**3.44**	**2.41**	**2.56**	**2.71**

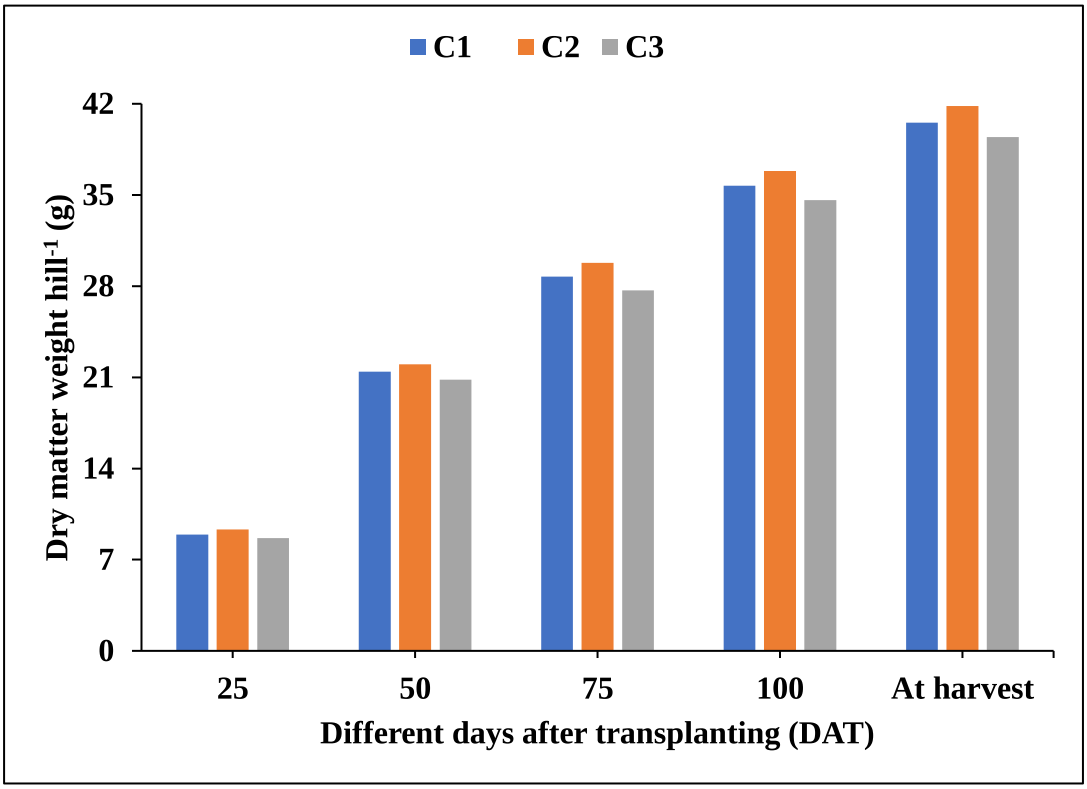
In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance

Here, C_1= Control (no clipping); C_2= 1/3rd top seedling clipping; C_3= 1/2nd top seedling clipping; G_1= 25 cm x 20 cm; G_2= 20 cm x 20 cm; G_3= 20 cm x 15 cm and G_4= 15 cm x 15 cm.

4.1.3 Above ground dry matter weight hill^{-1}

4.1.3.1 Seedling clipping

Significant variations were observed in above ground dry matter weight hill^{-1} study as influenced due to seedling clipping (Appendix VII and Fig. 5). Results showed that at 25, 50, 75, 100 DAT and harvest, the highest above ground dry matter weight hill^{-1} (9.32, 22.01, 29.80, 36.83 and 41.82 g, respectively) was observed in C_2 (1/3rd top seedling clipping) that was followed by the treatment C_1 (Control, no clipping) and lowest above ground dry matter weight hill^{-1} (8.66, 20.83, 27.67, 34.61 and 39.43 g, respectively) was observed in C_3 (1/2nd top seedling clipping). 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.

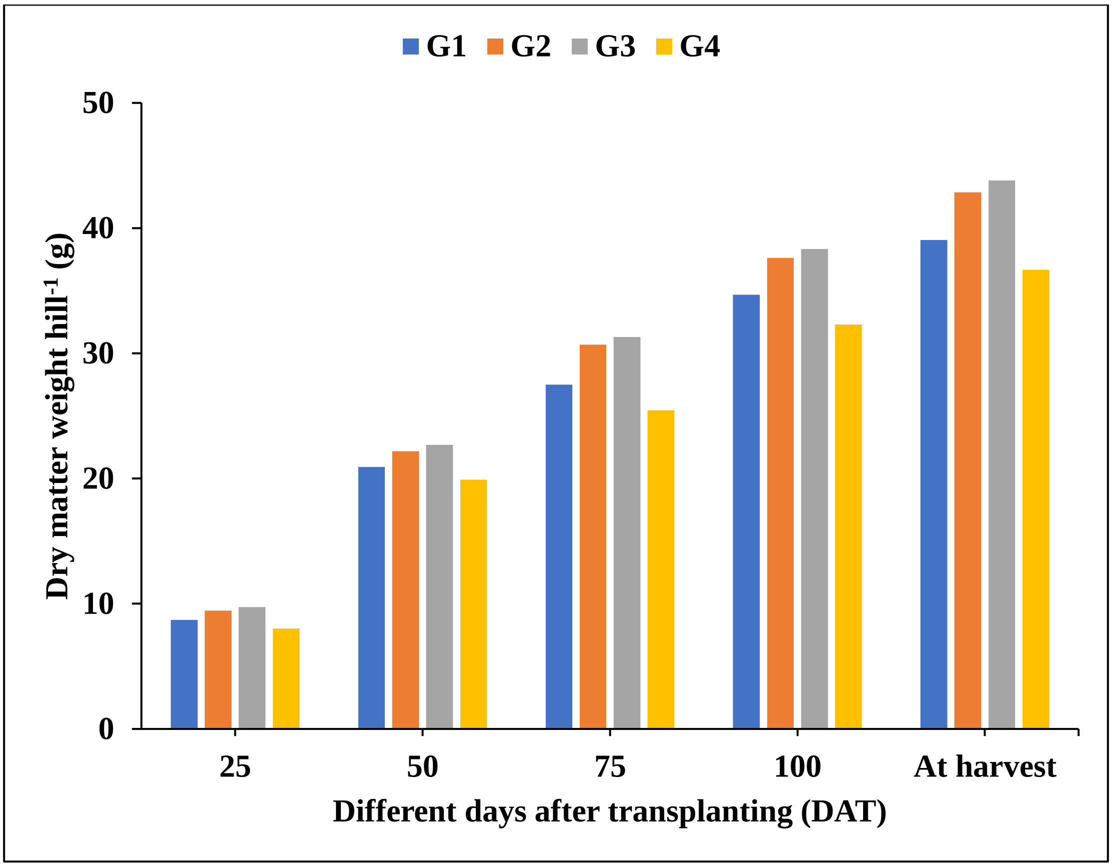


Here, C_1= Control (no clipping), C_2= 1/3rd top seedling clipping and C_3= 1/2nd top seedling clipping.

Figure 5. Effect of seedling clipping on above ground dry matter weight hill^{-1} of aromatic rice at different days after transplanting (DAT) (LSD $_{0.05}$ = 0.19, 0.39, 0.65, 0.61, 0.77 at 25, 50, 75, 100 DAT and harvest, respectively).

4.1.3.2 Different planting geometry

Above ground dry matter weight hill^{-1} varied significantly due to different planting geometry treatments (Appendix VII and Fig. 6). It was observed at 25, 50, 75, 100 DAT and harvest, G_3 treatment (20 cm x 15 cm) showed highest above ground dry matter weight hill^{-1} (9.72, 22.68, 31.30, 38.32 and 43.80 g, respectively) that is closely followed (9.44, 22.19, 30.68, 37.61 and 42.86 g, respectively) by G_2 (20 cm x 20 cm). On the other hand, results obtained by G_4 (15 cm x 15 cm) showed the lowest above ground dry matter weight hill^{-1} (8.01, 19.89, 25.45, 32.29 and 36.68 g, respectively). On the other hand, production of dry matter was lower in early stages of growth and it was much higher in the later stage. It was also observed the rate of increase in dry matter production was more rapid in the later stage than earlier stage. The result was in consistent with the findings of Sarker (2003).



Here, G_1= 25 cm x 20 cm, G_2= 20 cm x 20 cm, G_3= 20 cm x 15 cm and G_4= 15 cm x 15 cm.

Figure 6. Effect of different planting geometry on above ground dry matter weight hill^{-1} of aromatic rice at different days after transplanting (DAT) (LSD $_{0.05}$ = 0.22, 0.45, 0.75, 0.71, 0.89 at 25, 50, 75, 100 DAT and harvest, respectively).

4.1.3.3 Combination effect of seedling clipping and different panting geometry

Interaction effect of seedling clipping and different planting geometry had significant influence on above ground dry matter weight hill^{-1} at different growth stages of aromatic rice (Appendix VII and Table 3). Result indicated that at 25, 50, 75, 100 DAT and harvest, the highest above ground dry matter weight hill^{-1} (10.36, 23.63, 32.76, 39.81 and 45.73 g, respectively) was found in the 1/3rd top seedling clipping and 20 cm x 15 cm planting geometry (C_2G_3) that was closely followed (9.75, 23.06, 32.15, 38.92 and 44.17 g respectively) by the 1/3rd top seedling clipping and 20 cm x 20 cm planting geometry (C_2G_2) which was statistically similar with C_1G_3. On the other hand, C_3G_4 (1/2nd top seedling clipping + 15 cm x 15 cm) showed the lowest above ground dry matter weight hill^{-1} (7.67, 19.38, 24.82, 31.47 and 35.86 g at 25, 50, 75, 100 DAT and at harvest, respectively) which was statistically similar with C_1G_4.

Table 3. Combination effect of seedling clipping and different planting geometry on above ground dry matter weight hill^{-1} at different Days after transplanting (DAT)

Treatment combinations	Above ground dry matter weight hill^{-1} (g) at different days after transplanting (DAT)				
	25	50	75	100	At harvest
C_1G_1	8.72 f	20.97 fg	27.34 fg	34.56 fg	38.95 fg
C_1G_2	9.43 b-d	22.13 cd	30.88 bc	37.76 bc	43.01 bc
C_1G_3	9.54 bc	22.61 bc	31.34 b	38.27 b	43.52 bc
C_1G_4	8.02 hi	20.00 hi	25.34 hi	32.29 ij	36.68 hi
C_2G_1	8.84 ef	21.04 e-g	28.09 ef	35.49 ef	39.88 ef
C_2G_2	9.75 b	23.06 ab	32.15 ab	38.92 ab	44.17 b
C_2G_3	10.36 a	23.63 a	32.76 a	39.81 a	45.73 a
C_2G_4	8.33 gh	20.30 gh	26.19 gh	33.11 hi	37.50 gh
C_3G_1	8.56 fg	20.76 f-h	27.05 fg	33.95 gh	38.34 g
C_3G_2	9.13 de	21.38 d-f	29.01 de	36.14 de	41.39 de
C_3G_3	9.27 cd	21.80 de	29.81 cd	36.89 cd	42.14 cd
C_3G_4	7.67 i	19.38 i	24.82 i	31.47 j	35.86 i
LSD (0.05)	**0.38**	**0.78**	**1.30**	**1.23**	**1.53**
CV (%)	**2.48**	**2.15**	**2.68**	**2.03**	**2.23**

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance

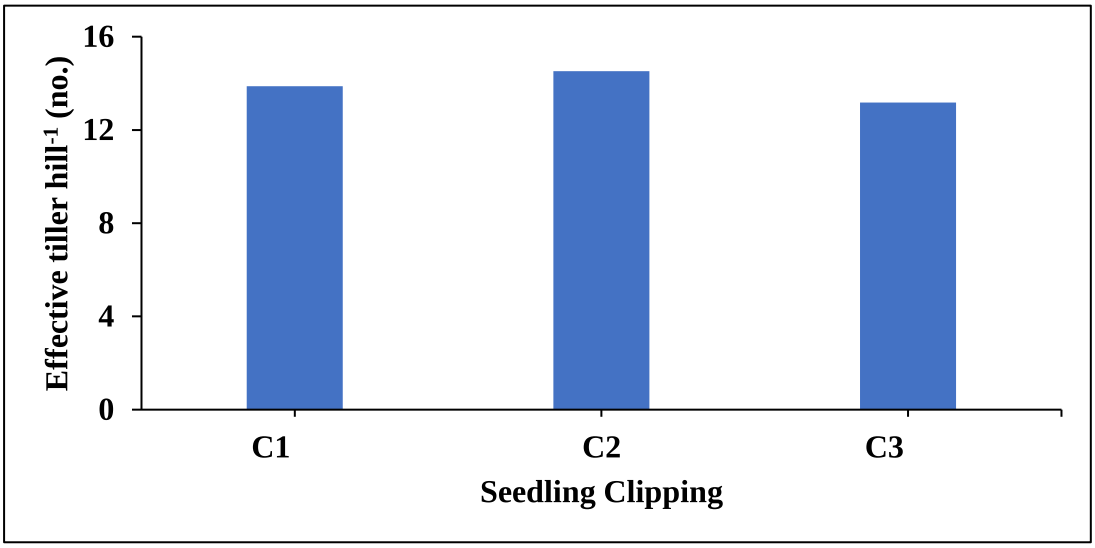
Here, C_1= Control (no clipping); C_2= 1/3rd top seedling clipping; C_3= 1/2nd top seedling clipping; G_1= 25 cm x 20 cm; G_2= 20 cm x 20 cm; G_3= 20 cm x 15 cm and G_4= 15 cm x 15 cm.

4.2. Yield contributing characters

4.2.1 Effective tillers hill^{-1}

4.2.1.1 Seedling clipping

Number of effective tillers hill^{-1} of aromatic rice varied significantly due to variation of seedling clipping (Appendix VIII and Fig. 7). The highest number of effective tillers hill^{-1} (14.52) was found from C_2 (1/3rd top seedling clipping). whereas the lowest number (13.18) was observed from C_3 (1/2nd top seedling clipping) which was followed by effective tillers hill^{-1} (13.88) from C_1 (Control, no clipping)**.** 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).

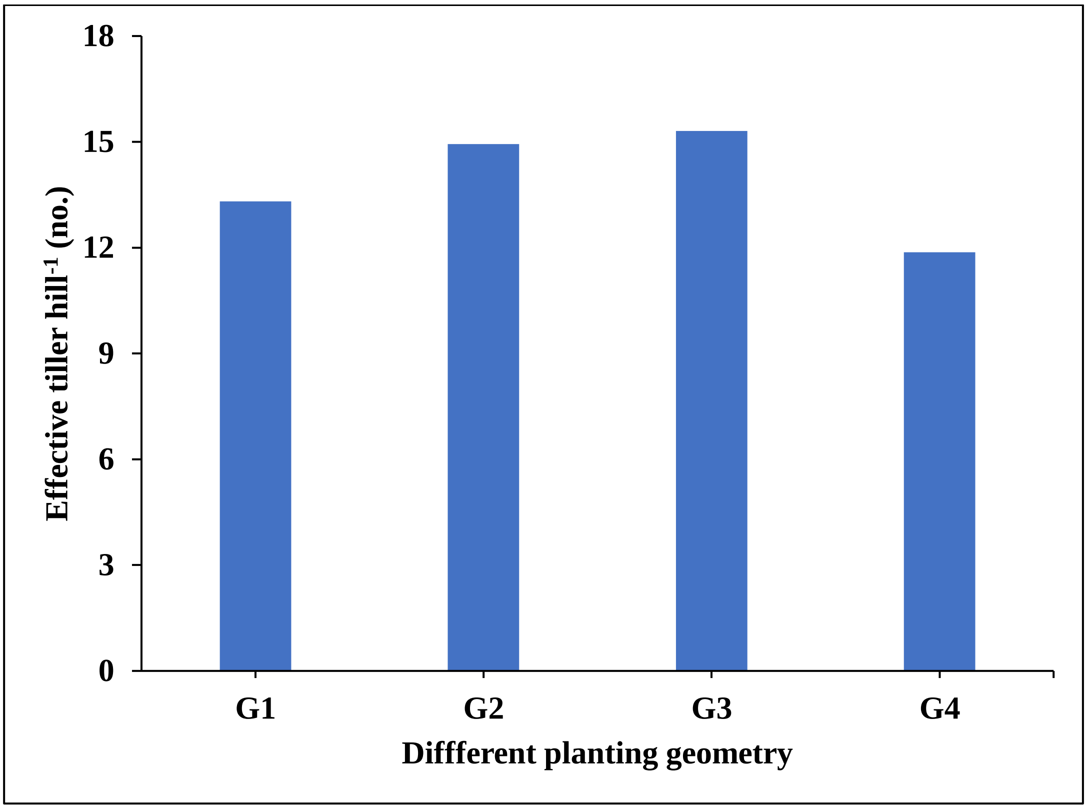


Here, C_1= Control (no clipping), C_2= 1/3rd top seedling clipping and C_3= 1/2nd top seedling clipping.

Figure 7. Effect of seedling clipping on number of effective tillers hill^{-1} of aromatic rice at harvest (LSD $_{0.05}$ = 0.29).

4.2.1.2 Different planting geometry

Different levels of planting geometry showed significant variations in terms of effective tillers hill^{-1} of aromatic rice (Appendix VIII and Fig. 8). The highest number of effective tillers hill^{-1} (15.31) was recorded from G_3 (20 cm x 15 cm) that was followed by effective tillers hill^{-1} (14.93 and 13.31) from G_2 and G_1 and they were statistically similar, while the lowest number recorded (11.87) from G_4 (15 cm x 15 cm) treatment. The trend of effective tillers hill' was that the widest spacing showed the highest number of effective tillers hill' and then tiller number showed a decreasing trend with reduced spacing. The closest spacing showed the lowest number of effective tillers hill'. The competition among the plants for nutrient, air, space and light might be the main reasons for decreasing tillers production in closer spacing. This result was in agreement with the findings of Miah *et at*, (1990), who reported that highest number effective tillers were produced in wider spacing and lowest in closer spacing.



Here, G_1= 25 cm x 20 cm, G_2= 20 cm x 20 cm, G_3= 20 cm x 15 cm and G_4= 15 cm x 15 cm.

Figure 8. Effect of different planting geometry on number of effective tillers hill^{-1} of aromatic rice at harvest (LSD $_{0.05}$ = 0.34).

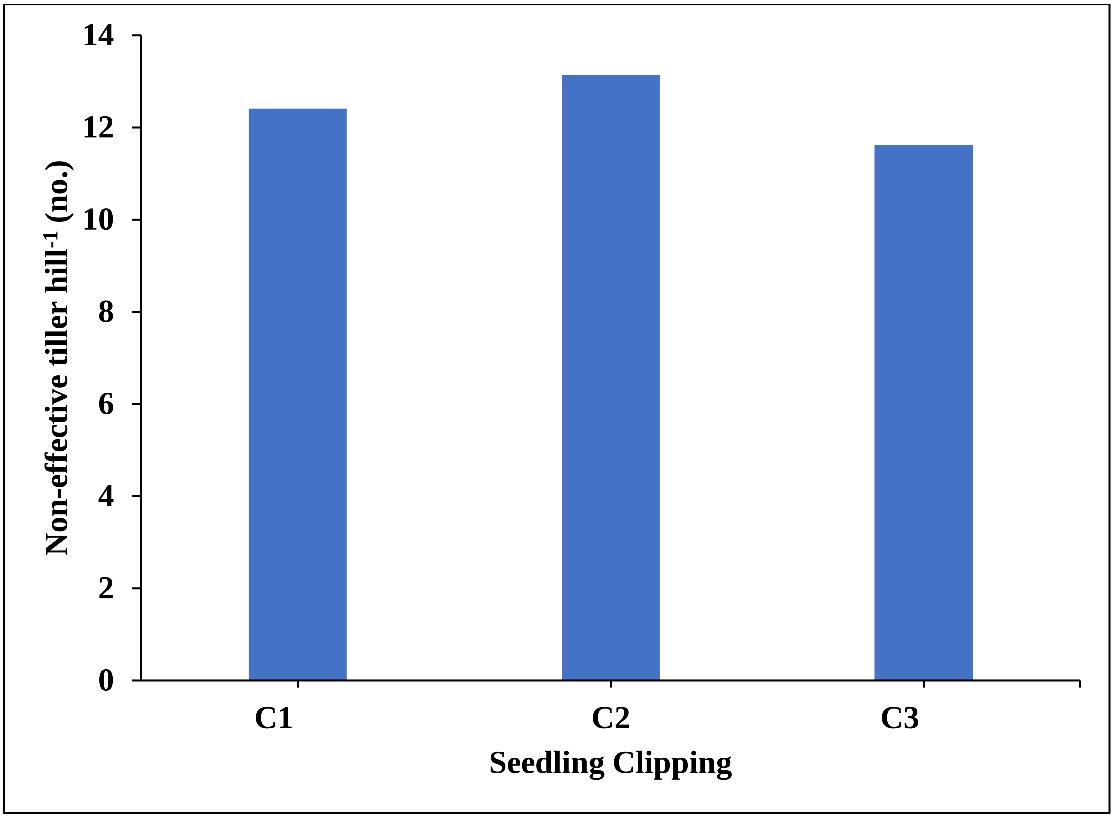
4.2.1.3 Combination effect of seedling clipping and different panting geometry

Statistically significant variation was recorded on number of effective tillers hill^{-1} of aromatic rice due to the combined effect of seedling clipping and different planting geometry (Appendix VIII and Table 4). The highest number of effective tillers hill^{-1} (16.23) was recorded from C_2G_3 (1/3rd top seedling clipping and 20 cm x 15 cm planting geometry) that was followed (15.75 and 15.31) by C_2G_2 (1/3rd top seedling clipping and 20 cm x 20 cm planting geometry) and C_1G_3 (control, no clipping) and (20 cm x 15 cm planting geometry) and the lowest number (11.38) was found from C_3G_4 (1/2nd top seedling clipping + 15 cm x 15 cm planting geometry) that was statistically similar to C_1G_4.

4.2.2 Non-effective tillers hill^{-1}

4.2.2.1 Seedling clipping

Number of non-effective tillers hill^{-1} of aromatic rice varied significantly due to variation of seedling clipping (Appendix VIII and Fig. 9). The highest number of non-effective tillers hill^{-1} (13.14) was found from C_2 (1/3rd top seedling clipping). whereas the lowest number (11.63) was observed from C_3 (1/2nd top seedling clipping) which was followed by non-effective tillers hill^{-1} (12.41) from C_1 (Control, no clipping). 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.

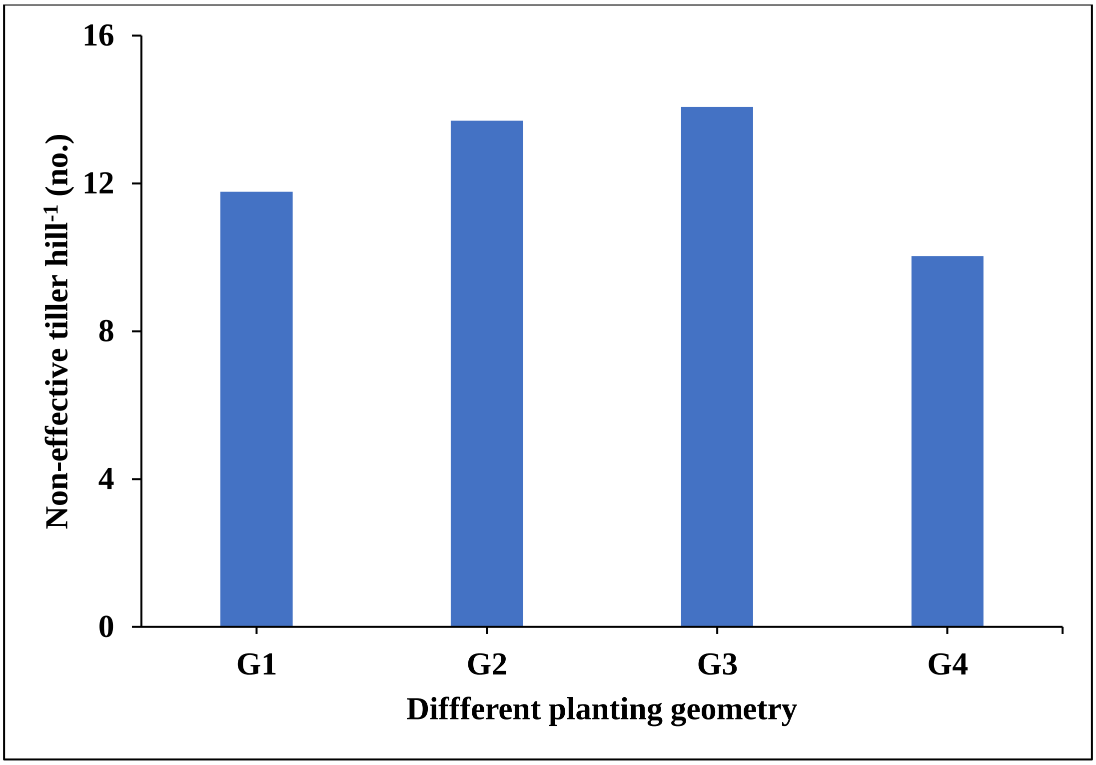


Here, C_1= Control (no clipping), C_2= 1/3rd top seedling clipping and C_3= 1/2nd top seedling clipping.

Figure 9. Effect of seedling clipping on number of non-effective tillers hill^{-1} of aromatic rice at harvest (LSD $_{0.05}$ = 0.31).

4.2.2.2 Different planting geometry

Different levels of planting geometry showed significant variations in terms of non-effective tillers hill^{-1} of aromatic rice (Appendix VIII and figure 10). The highest number of non-effective tillers hill^{-1} (14.07) was recorded from G_3 (20 cm x 15 cm) that was followed by non-effective tillers hill^{-1} (13.69) from G_2 treatment, while the lowest number recorded (10.03) from G_4 (15 cm x 15 cm) treatment. in wider spacing, plants received more nutrient, moisture and light which resulted on a smaller number of non-effective tiller hill^{-1} Mustapha (2002) had similar observation.



Here, G_1= 25 cm x 20 cm, G_2= 20 cm x 20 cm, G_3= 20 cm x 15 cm and G_4= 15 cm x 15 cm.

Figure 10. Effect of different planting geometry on number of non-effective tillers hill^{-1} of aromatic rice at harvest (LSD $_{0.05}$ = 0.35).

4.2.2.3 Combination effect of seedling clipping and different planting geometry

Statistically significant variation was recorded on number of non-effective tillers hill^{-1} of aromatic rice due to the combined effect of seedling clipping and different planting geometry (Appendix VIII and Table 4). The highest number of non-effective tillers hill^{-1} (15.08) was recorded from C_2G_3 (1/3rd top seedling clipping and 20 cm x 15 cm planting geometry) that was followed (14.55 and 14.03) by C_2G_2 (1/3rd top seedling clipping and 20 cm x 20 cm planting geometry) and C_1G_3 (control, no clipping) and (20 cm x 15 cm planting geometry) and the lowest number (9.46) was found from C_3G_4 (1/2nd top seedling clipping + 15 cm x 15 cm planting geometry) that was statistically similar to C_1G_4.

Table 4. Combination effect of seedling clipping and different planting geometry on number effective and non-effective tillers hill^{-1} of aromatic rice

Treatment combinations	Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)
C_1G_1	13.29 fg	11.76 fg
C_1G_2	15.05 c	13.84 c
C_1G_3	15.31 bc	14.03 bc
C_1G_4	11.86 ij	10.02 hi
C_2G_1	13.71 ef	12.31 ef
C_2G_2	15.75 ab	14.55 ab
C_2G_3	16.23 a	15.08 a
C_2G_4	12.38 hi	10.61 h
C_3G_1	12.94 gh	11.26 g
C_3G_2	14.00 de	12.69 de
C_3G_3	14.38 d	13.10 d
C_3G_4	11.38 j	9.46 i
LSD (0.05)	**0.59**	**0.61**
CV (%)	**2.51**	**2.93**

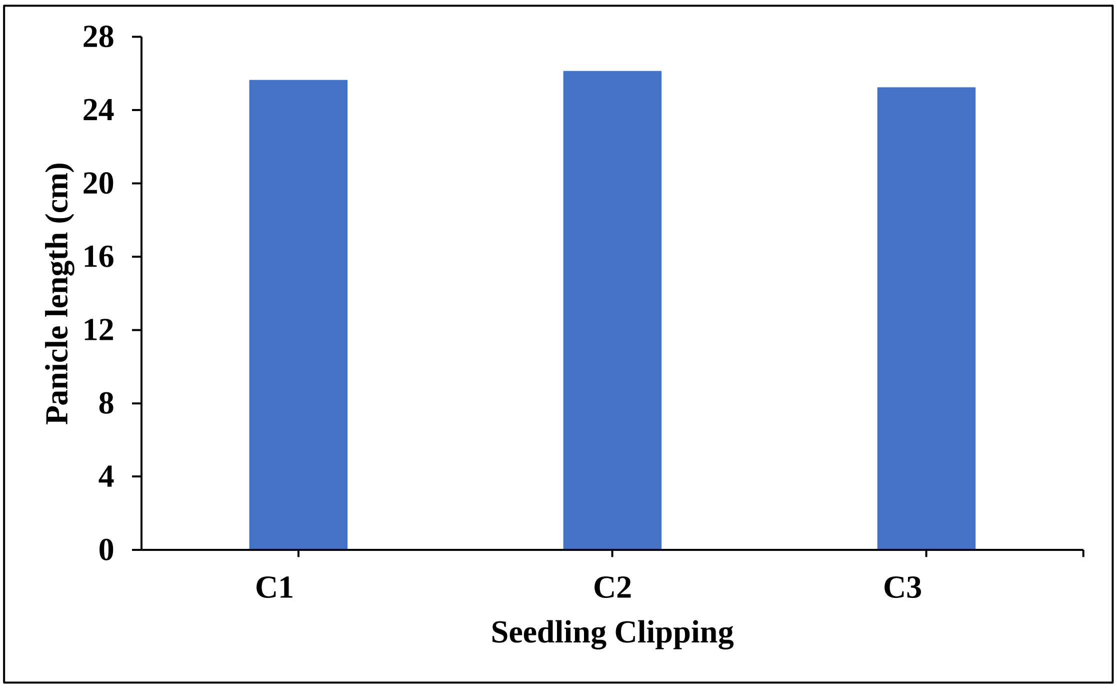
In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance

Here, C_1= Control (no clipping); C_2= 1/3rd top seedling clipping; C_3= 1/2nd top seedling clipping; G_1= 25 cm x 20 cm; G_2= 20 cm x 20 cm; G_3= 20 cm x 15 cm and G_4= 15 cm x 15 cm.

4.2.3 Panicle length

4.2.3.1 Seedling clipping

Different seedling clipping varied significantly in terms of panicle length of aromatic rice (Appendix IX and Fig. 11). The maximum panicle length (26,14) was observed from C_2 (1/3rd top seedling clipping). whereas the minimum (25.25) was recorded from C_3 (1/2nd top seedling clipping) which was followed (25,65) by C_1 (Control, no clipping). 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).

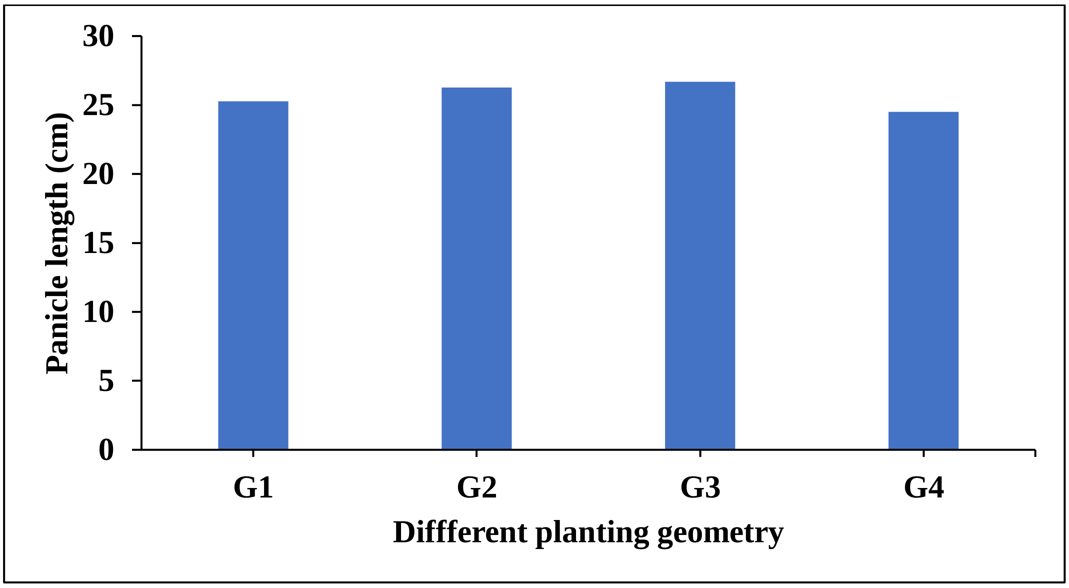


Here, C_1= Control (no clipping), C_2= 1/3rd top seedling clipping and C_3= 1/2nd top seedling clipping.

Figure 11. Effect of seedling clipping on panicle length of aromatic rice at harvest (LSD $_{0.05}$ = 0.45).

4.2.3.2 Different planting geometry

Statistically significant variations were recorded in terms of panicle length of aromatic rice due to different planting geometry (Appendix IX and Fig. 12). The maximum panicle length (26.68) was found from G_3 (20 cm x 15 cm) that was statistically similar (26.27) to G_2. While the minimum (24.49) was from G_4 (15 cm x 15 cm) which was followed by G_1 (25,28) that was statistically similar. The plants grown in widest spacing got lighter, space. air and nutrient facilities which stimulated positively towards panicle development than in closer spacing. Similar results were observed by Rekhashri *et al.*, (1997) and Liou (1987) who stated that closer spacing decreased panicle length.



Here, G_1= 25 cm x 20 cm, G_2= 20 cm x 20 cm, G_3= 20 cm x 15 cm and G_4= 15 cm x 15 cm.

Figure 12. Effect of different planting geometry on panicle length of aromatic rice at harvest (LSD $_{0.05}$ = 0.52).

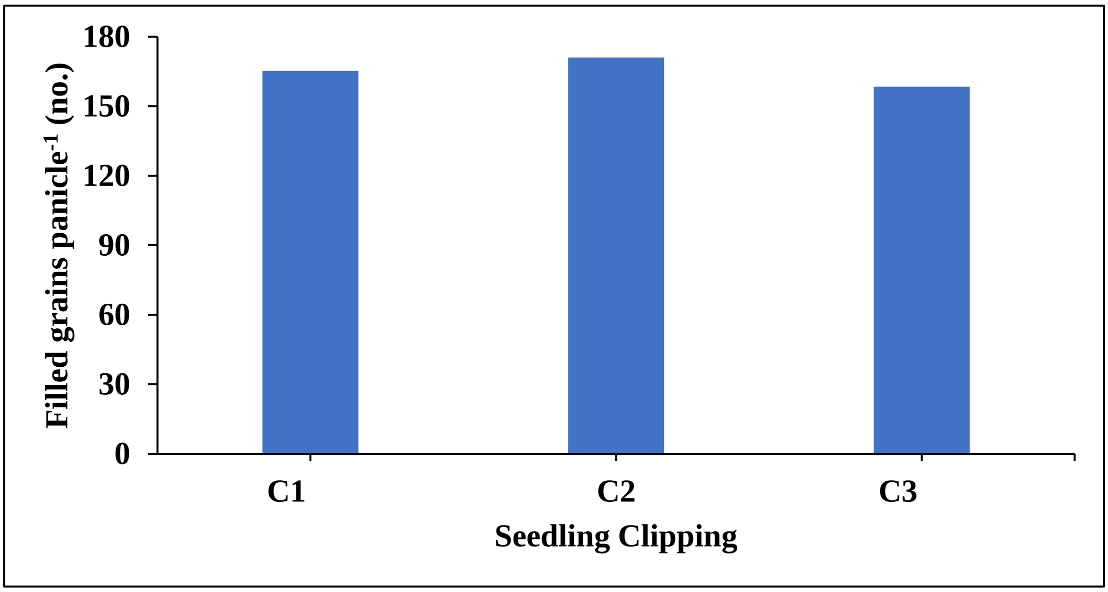
4.2.3.3 Combination effect of seedling clipping and different planting geometry

Statistically significant variation was recorded on panicle length of aromatic rice due to the combined effect of seedling clipping and different planting geometry (Appendix IX and Table 5). The maximum panicle length (27.41) was recorded from C_2G_3 (1/3rd top seedling clipping and 20 cm x 15 cm planting geometry) that was followed (26.67 and 26.55) by C_2G_2 (1/3rd top seedling clipping and 20 cm x 20 cm planting geometry) and C_1G_3 (control (no clipping) and 20 cm x 15 cm planting geometry) and the minimum (24.13) was found from C_3G_4 (1/2nd top seedling clipping + 15 cm x 15 cm planting geometry) that was statistically similar to C_1G_4.

4.2.4 Filled grains panicle^{-1}

4.2.4.1 Seedling clipping

Number of filled grains panicle^{-1} of aromatic rice varied significantly due to variation of seedling clipping (Appendix IX and Fig. 13). The highest number of filled grains panicle^{-1} (171.09) was found from C_2 (1/3rd top seedling clipping). whereas the lowest number (158.42) was observed from C_3 (1/2nd top seedling clipping). 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).

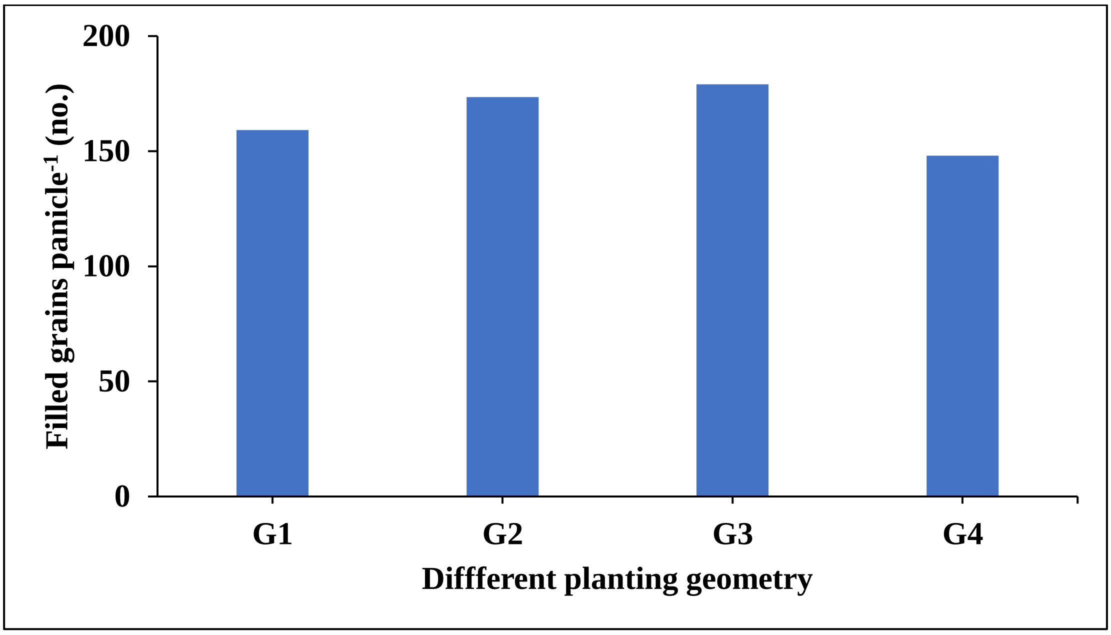


Here, C_1= Control (no clipping), C_2= 1/3rd top seedling clipping and C_3= 1/2nd top seedling clipping.

Figure 13. Effect of seedling clipping on number of filled grains panicle^{-1} of aromatic rice at harvest (LSD $_{0.05}$ = 2.74).

4.2.4.2 Different planting geometry

Different levels of planting geometry showed significant variations in terms of filled grains panicle^{-1} of aromatic rice (Appendix IX and Fig. 14). The highest number of filled grains panicle^{-1} (179.00) was recorded from G_3 (20 cm x 15 cm) that was followed by filled grains panicle^{-1} (173.49) from G_2 treatment, while the lowest number recorded (148.03) from G_4 (15 cm x 15 cm) treatment. The result was supported by Ghosh *et al.*, (1988) and Uddin (1996) that wider spacing produced higher number of filled grains panicl^{-1}.



Here, G_1= 25 cm x 20 cm, G_2= 20 cm x 20 cm, G_3= 20 cm x 15 cm and G_4= 15 cm x 15 cm.

Figure 14. Effect of different planting geometry on number of filled grains panicle^{-1} of aromatic rice at harvest (LSD $_{0.05}$ = 3.71).

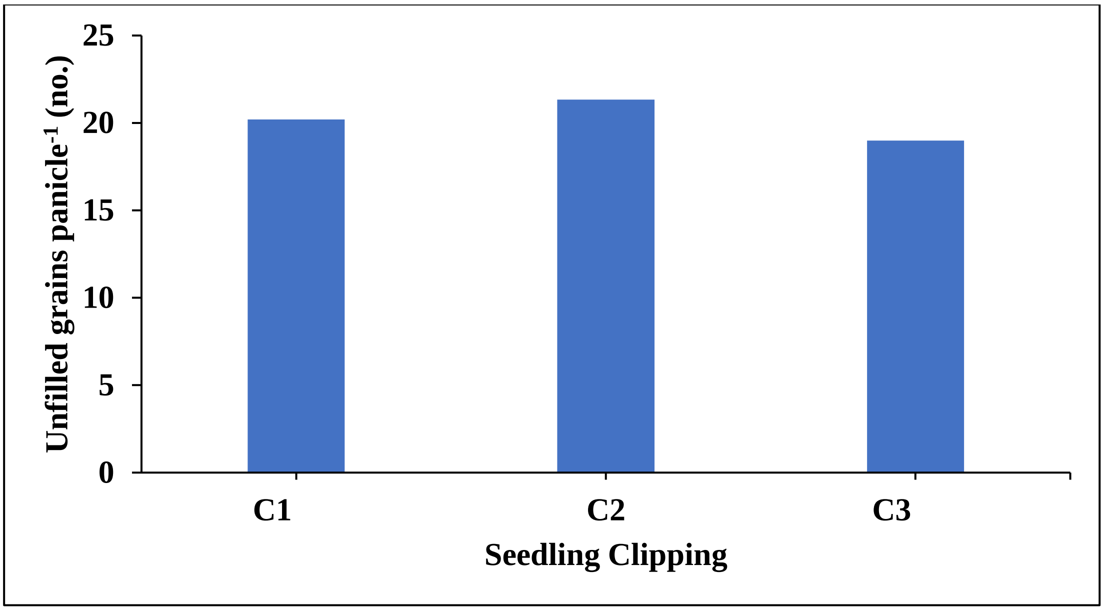
4.2.4.3 Combination effect of seedling clipping and different planting geometry

Statistically significant variation was recorded on number of filled grains panicl^{-1} of aromatic rice due to the combined effect of seedling clipping and different planting geometry (Appendix IX and Table 5). The highest number of filled grains panicl^{-1} (189.05) was recorded from C_2G_3 (1/3rd top seedling clipping and 20 cm x 15 cm planting geometry). the lowest number (143.17) was found from C_3G_4 (1/2nd top seedling clipping + 15 cm x 15 cm planting geometry) that was statistically similar to C_1G_4.

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

4.2.5.1 Seedling clipping

Number of unfilled grains panicle^{-1} of aromatic rice varied significantly due to variation of seedling clipping (Appendix IX and Fig. 15). The highest number of unfilled grains panicle^{-1} (21.34) was found from C_2 (1/3rd top seedling clipping) which was followed by unfilled grains panicle^{-1} (20.21) from C_1 (Control, no clipping), whereas the lowest number (18.98) was observed from C_3 (1/2nd top seedling clipping). 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}.



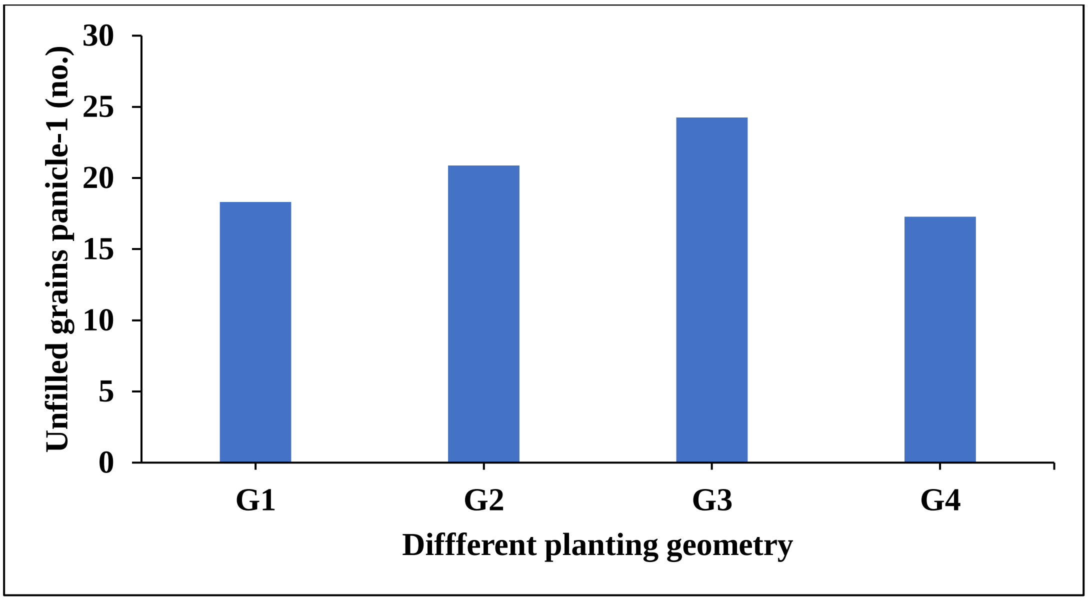
Here, C_1= Control (no clipping), C_2= 1/3rd top seedling clipping and C_3= 1/2nd top seedling clipping.

Figure 15. Effect of seedling clipping on number of unfilled grains panicle^{-1} of aromatic rice at harvest (LSD $_{0.05}$ = 0.71).

4.2.5.2 Different planting geometry

Different levels of planting geometry showed significant variations in terms of unfilled grains panicle^{-1} of aromatic rice (Appendix IX and Fig. 16). The highest number of unfilled grains panicle^{-1} (24.26) was recorded from G_3 (20 cm x 15 cm). while the lowest number recorded (17.27) from G_4 (15 cm x 15 cm) treatment. Competition of the plants for nutrient, air, space and light might be the reasons for increasing unfilled grains production in the closer spacing. The result corroborates with the findings of

Verma *et al.*, (2002) that closer spacing produces higher sterility percentage than wider spacing.



Here, G_1= 25 cm x 20 cm, G_2= 20 cm x 20 cm, G_3= 20 cm x 15 cm and G_4= 15 cm x 15 cm.

Figure 16. Effect of different planting geometry on number of unfilled grains panicle^{-1} of aromatic rice at harvest (LSD $_{0.05}$ = 0.82).

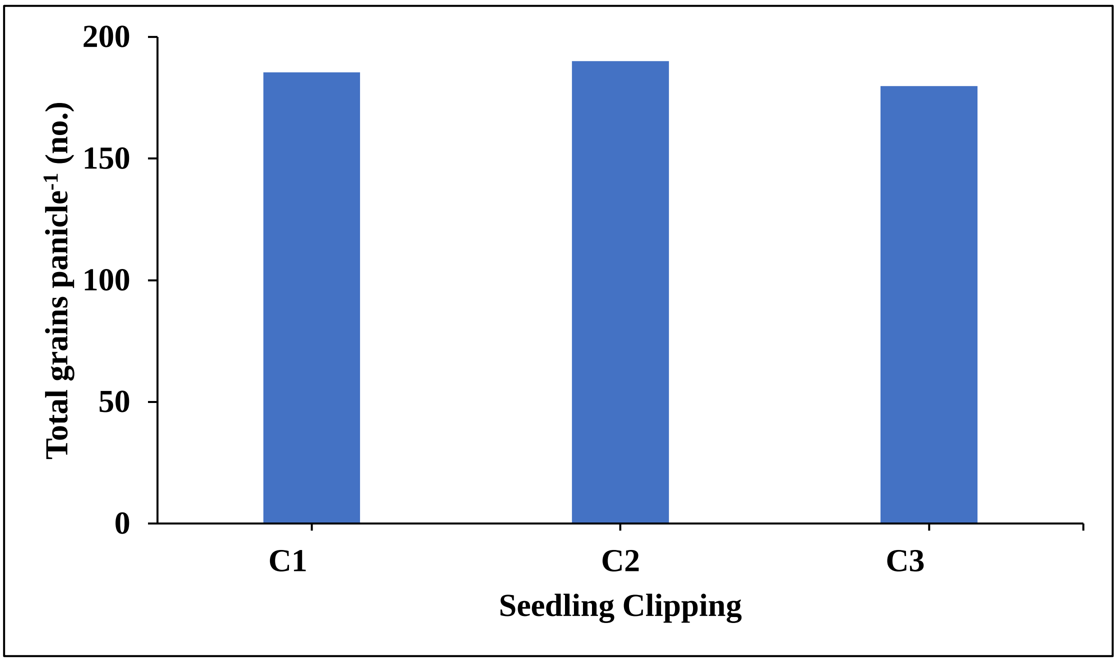
4.2.5.3 Combination effect of seedling clipping and different planting geometry

Statistically significant variation was recorded on number of unfilled grains panicle^{-1} of aromatic rice due to the combined effect of seedling clipping and different planting geometry (Appendix IX and Table 5). The highest number of unfilled grains panicle^{-1} (25.29) was recorded from C_2G_3 (1/3rd top seedling clipping and 20 cm x 15 cm planting geometry) that was followed (24.37) by C_2G_2 (1/3rd top seedling clipping and 20 cm x 20 cm planting geometry) and the lowest number (15.43) was found from C_3G_4 (1/2nd top seedling clipping + 15 cm x 15 cm planting geometry) that was statistically similar to C_1G_4.

4.2.6 Total grains panicle^{-1}

4.2.6.1 Seedling clipping

Number of total grains panicle^{-1} of aromatic rice varied significantly due to variation of seedling clipping (Appendix IX and Fig. 17). The highest number of total grains panicle^{-1} (190.07) was found from C_2 (1/3rd top seedling clipping) which was followed by total grains panicle^{-1} (185.50) from C_1 (Control, no clipping), whereas the lowest number (179.76) was observed from C_3 (1/2nd top seedling clipping). 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}.

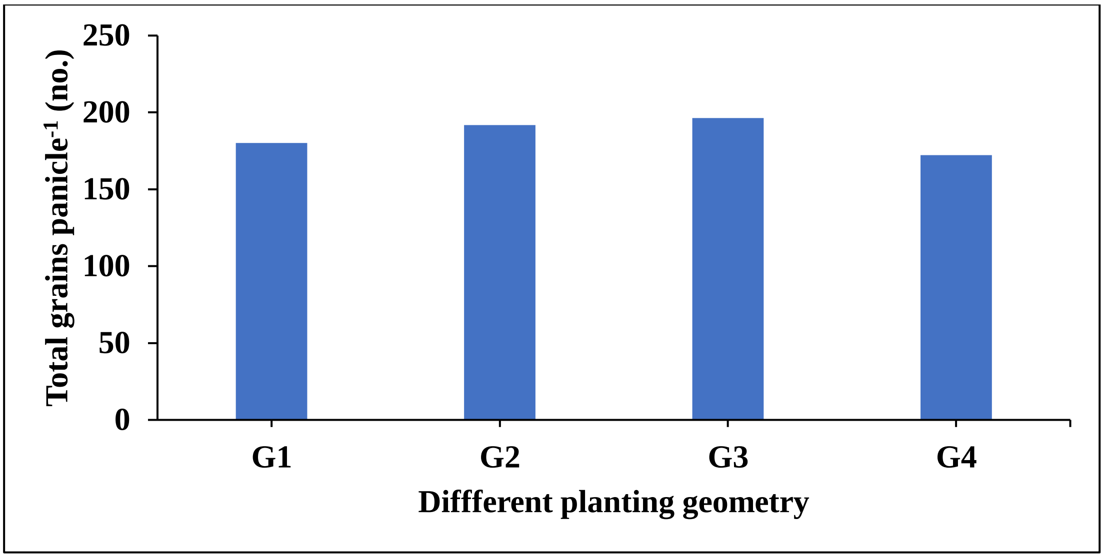


Here, C_1= Control (no clipping), C_2= 1/3rd top seedling clipping and C_3= 1/2nd top seedling clipping.

Figure 17. Effect of seedling clipping on number of total grains panicle^{-1} of aromatic rice at harvest (LSD $_{0.05}$ = 2.92).

4.2.6.2 Different planting geometry

Different levels of planting geometry showed significant variations in terms of total grains panicle^{-1} of aromatic rice (Appendix IX and Fig. 18). The highest number of total grains panicle^{-1} (196.27) was recorded from G_3 (20 cm x 15 cm). while the lowest number recorded (172.29) from G_4 (15 cm x 15 cm) treatment. Competition of the plants for nutrient, air, space and light might be the reasons for increasing total grains production in the closer spacing. The result corroborates with the findings of Verma *et al.*, (2002) that closer spacing produces higher sterility percentage than wider spacing.



Here, G_1= 25 cm x 20 cm, G_2= 20 cm x 20 cm, G_3= 20 cm x 15 cm and G_4= 15 cm x 15 cm.

Figure 18. Effect of different planting geometry on number of total grains panicle^{-1} of aromatic rice at harvest (LSD $_{0.05}$ = 3.37).

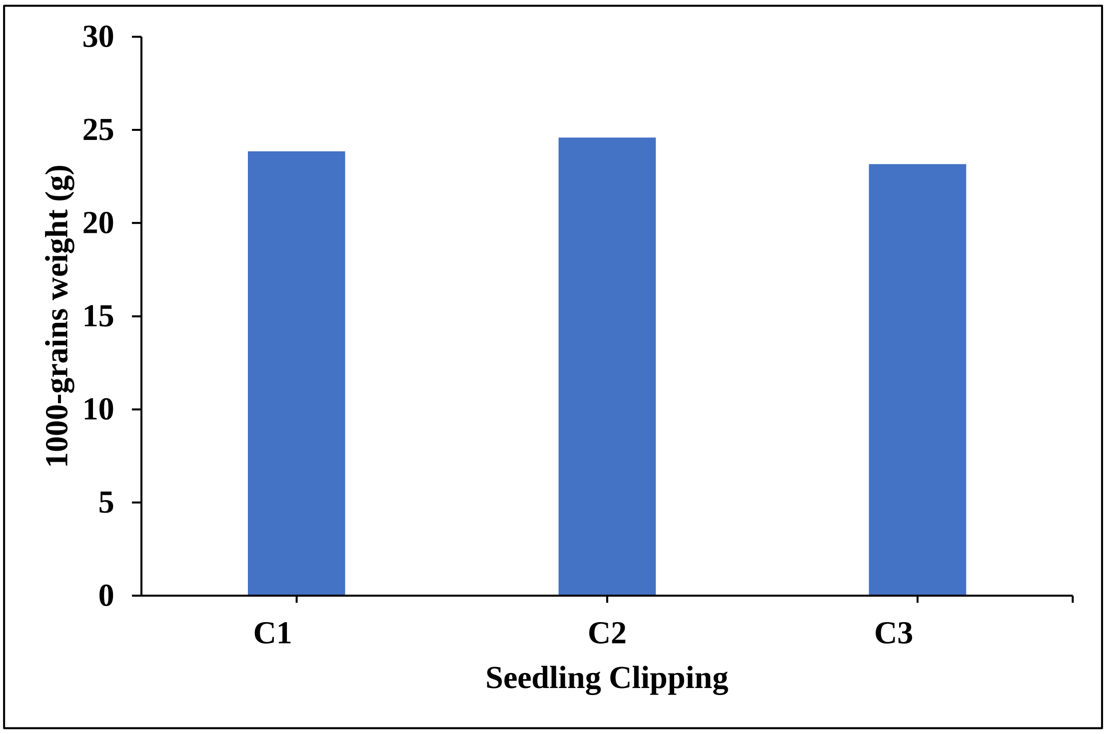
4.2.6.3 Combination effect of seedling clipping and different planting geometry

Statistically significant variation was recorded on total grains panicle^{-1} of aromatic rice due to the combined effect of seedling clipping and different planting geometry (Appendix IX and Table 5). The highest number of total grains panicle^{-1} (204.48) was recorded from C_2G_3 (1/3rd top seedling clipping and 20 cm x 15 cm planting geometry) that was followed (199.39 and 196.10) by C_2G_2 (1/3rd top seedling clipping and 20 cm x 20 cm planting geometry) and C_1G_3 (control (no clipping) and 20 cm x 15 cm planting geometry) and the lowest number (173.77) was found from C_3G_4 (1/2nd top seedling clipping + 15 cm x 15 cm planting geometry) that was statistically similar to C_1G_4.

4.2.7 1000-grains weight

4.2.7.1 Seedling clipping

Different seedling clipping varied significantly in terms of weight of 1000 grains of aromatic rice (Appendix IX and Fig. 19). The highest weight of 1000 grain of aromatic rice was recorded (24.59g) from C_2 (1/3rd top seedling clipping). whereas the lowest number (23.17g) was recorded from C_3 (1/2nd top seedling clipping) which was followed (23.85g) by C_1 (Control, no clipping). 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.

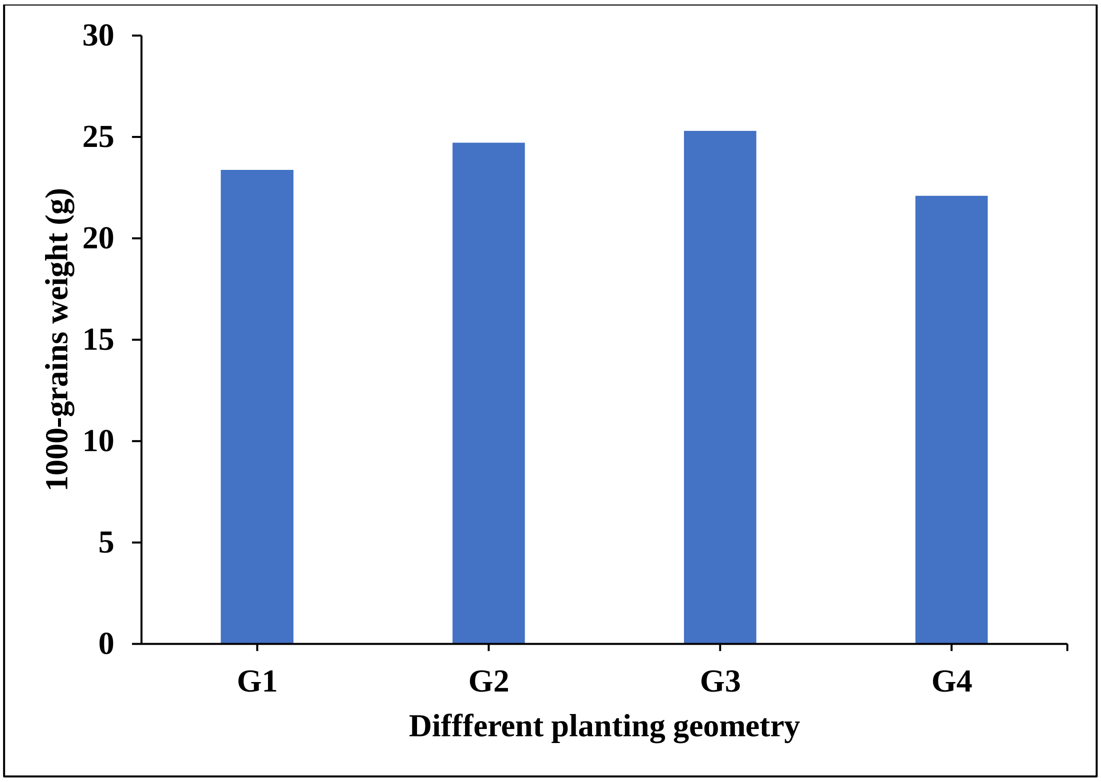


Here, C_1= Control (no clipping), C_2= 1/3rd top seedling clipping and C_3= 1/2nd top seedling clipping.

Figure 19. Effect of seedling clipping on 1000-grains weight of aromatic rice at harvest (LSD $_{0.05}$ = 0.45).

4.2.7.2 Different planting geometry

Statistically significant variations were recorded in terms of weight of 1000 grains of aromatic rice due to different planting geometry (Appendix IX and Fig. 20). The highest weight of 1000 grain (25.30g) was found from G_3 (20 cm x 15 cm) that was statistically similar (24.71g) to G_2. While the lowest (22.09g) was from G_4 (15 cm x 15 cm) which was followed by G_1 (23.37g) that was statistically similar. These results revealed that the weight of rice grain of the studied variety was partially affected due to plant spacing. The present finding was confirmed by Wang *et al.*, (2002) that thousand grains weight did not affect by spacing.



Here, G_1= 25 cm x 20 cm, G_2= 20 cm x 20 cm, G_3= 20 cm x 15 cm and G_4= 15 cm x 15 cm.

Figure 20. Effect of different planting geometry on 1000-grains weight of aromatic rice at harvest (LSD $_{0.05}$ = 0.52).

4.2.7.3 Combination effect of seedling clipping and different planting geometry

Statistically significant variation was recorded on weight of 1000 grains of aromatic rice due to the combined effect of seedling clipping and different planting geometry (Appendix IX and Table 5). The highest weight of 1000 grain (26.52g) was recorded from C_2G_3 (1/3rd top seedling clipping and 20 cm x 15 cm planting geometry) that was followed (25.66g and 25.10g) by C_2G_2 (1/3rd top seedling clipping and 20 cm x 20 cm planting geometry) and C_1G_3 (control (no clipping) and 20 cm x 15 cm planting geometry) and the lowest (21.57g) was found from C_3G_4 (1/2nd top seedling clipping + 15 cm x 15 cm planting geometry) that was statistically similar to C_1G_4.

Table 5. Combination effect of seedling clipping and different planting geometry on panicle length, filled grains panicle^{-1}, unfilled grains panicle^{-1}, total grains panilce^{-1} and weight of 1000-grains of aromatic rice.

Treatment combinations	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	Total grains panicle^{-1} (no.)	Weight of 1000 grain (g)
C_1G_1	25.21 d-f	159.70 fg	18.71 fg	180.33 f-h	23.43 ef
C_1G_2	26.29 bc	173.67 cd	21.84 cd	191.82 cd	24.62 cd
C_1G_3	26.55 a-c	178.43 bc	23.11 bc	196.10 bc	25.10 bc
C_1G_4	24.56 fg	149.40 i	17.25 h	173.77 ij	22.24 gh
C_2G_1	25.69 c-e	161.64 fg	19.52 ef	181.78 fg	23.71 ef
C_2G_2	26.67 ab	182.14 b	24.37 ab	199.39 ab	25.66 ab
C_2G_3	27.41 a	189.05 a	25.29 a	204.48 a	26.52 a
C_2G_4	24.79 e-g	151.52 hi	17.67 gh	174.63 hi	22.47 g
C_3G_1	24.94 e-g	156.35 gh	18.15 f-h	178.19 g-i	22.98 fg
C_3G_2	25.85 b-d	164.66 ef	20.14 e	184.18 ef	23.85 d-f
C_3G_3	26.09 b-d	169.52 de	20.63 de	188.23 de	24.28 c-e
C_3G_4	24.13 g	143.17 j	15.43 i	168.46 j	21.57 h
LSD $_{(0.05)}$	**0.90**	**5.49**	**1.42**	**5.84**	**0.89**
CV (%)	**2.08**	**1.96**	**4.16**	**1.86**	**2.21**

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance

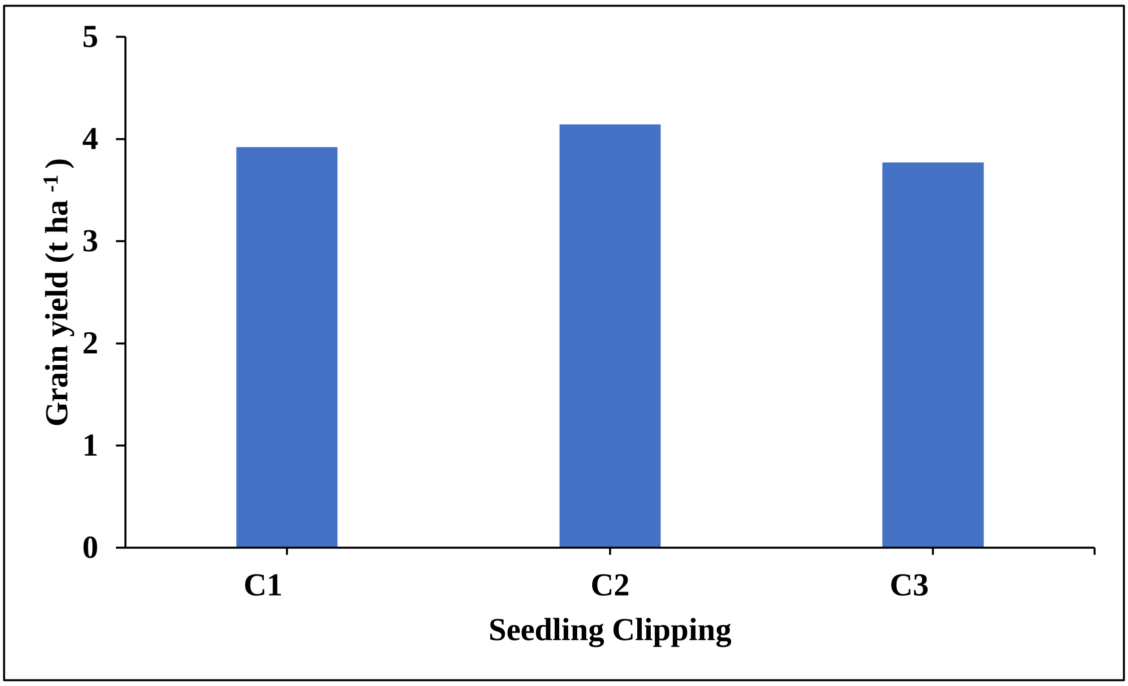
Here, C_1= Control (no clipping); C_2= 1/3rd top seedling clipping; C_3= 1/2nd top seedling clipping; G_1= 25 cm x 20 cm; G_2= 20 cm x 20 cm; G_3= 20 cm x 15 cm and G_4= 15 cm x 15 cm.

4.3 Yield characters

4.3.1 Grain yield

4.3.1.1 Seedling clipping

Different seedling clipping varied significantly in terms of grain yield of aromatic rice (Appendix X and Fig. 21). The maximum grain of aromatic rice was recorded (4.14 t ha^{-1}) from C_2 (1/3rd top seedling clipping). whereas the minimum grain yield (3.77 t ha^{-1}) was recorded from C_3 (1/2nd top seedling clipping) which was followed (3.92 t ha^{-1}) by C_1 (Control, no clipping). 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).

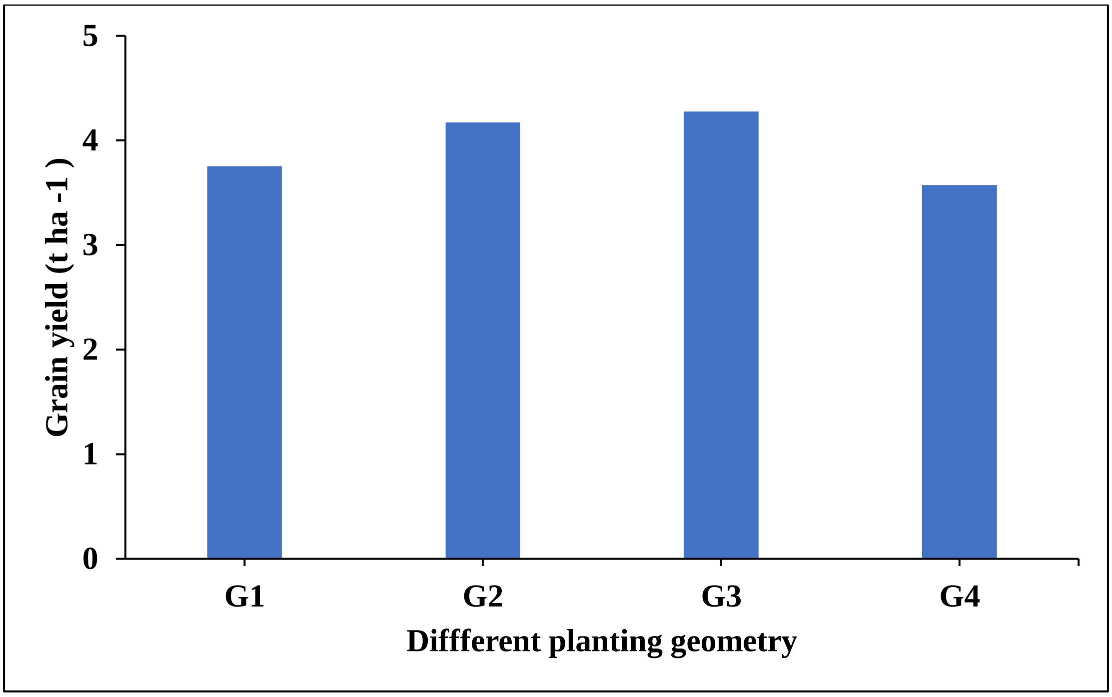


Here, C_1= Control (no clipping), C_2= 1/3rd top seedling clipping and C_3= 1/2nd top seedling clipping.

Figure 21. Effect of seedling clipping on grain yield of aromatic rice at harvest (LSD $_{0.05}$ = 0.06).

4.3.1.2 Different planting geometry

Statistically significant variations were recorded in terms of grain yield of aromatic rice due to different planting geometry (Appendix X and Fig. 22). The maximum grain yield (4.28 t ha^{-1}) was found from G_3 (20 cm x 15 cm) that was statistically similar (4.17 t ha^{-1}) to G_2. While the minimum grain yield (3.57 t ha^{-1}) was from G_4 (15 cm x 15 cm) which was followed by G_1 (3.75 t ha^{-1}) that was statistically similar. The findings of Azad *et al*., (1995), Patel (1999) and BRRI (2000) agreed with the present result.



Here, G_1= 25 cm x 20 cm, G_2= 20 cm x 20 cm, G_3= 20 cm x 15 cm and G_4= 15 cm x 15 cm.

Figure 22. Effect of different planting geometry on grain yield of aromatic rice at harvest (LSD $_{0.05}$ = 0.07).

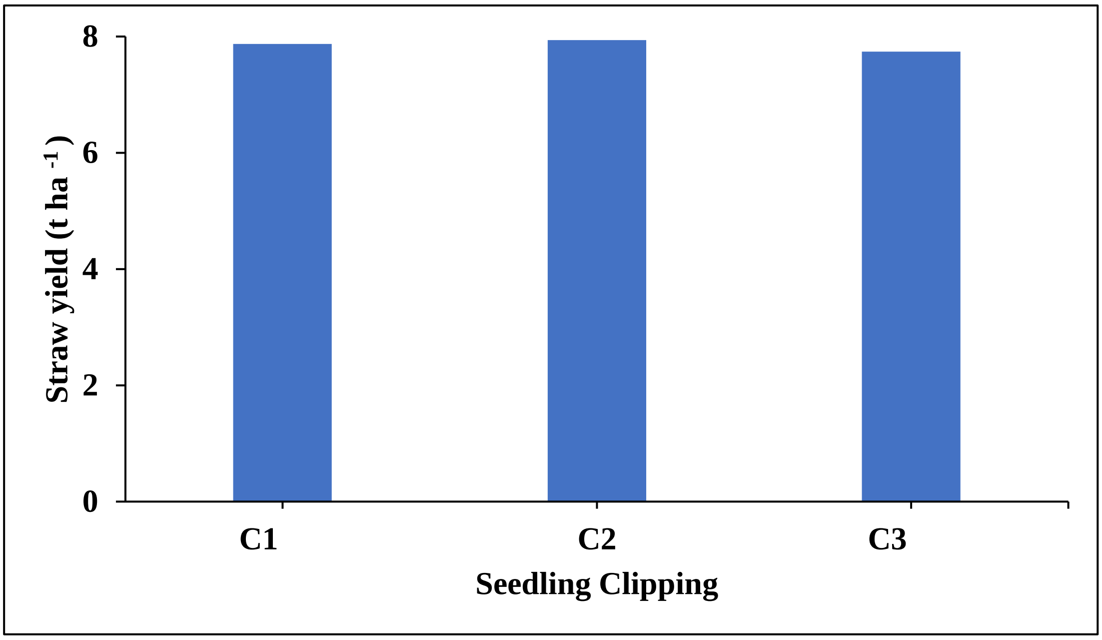
4.3.1.3 Combination effect of seedling clipping and different planting geometry

Statistically significant variation was recorded on grain yield of aromatic rice due to the combined effect of seedling clipping and different planting geometry (Appendix X and Table 6). The maximum grain yield (4.62 t ha^{-1}) was recorded from C_2G_3 (1/3rd top seedling clipping and 20 cm x 15 cm planting geometry) that was followed (4.48 t ha^{-1}) by C_2G_2 (1/3rd top seedling clipping and 20 cm x 20 cm planting geometry) the minimum grain yield (3.48 t ha^{-1}) was found from C_3G_4 (1/2nd top seedling clipping + 15 cm x 15 cm planting geometry) that was statistically similar to C_1G_4.

4.3.2 Straw yield

4.3.2.1 Seedling clipping

Different seedling clipping varied significantly in terms of straw yield of aromatic rice (Appendix X and Fig. 23). The maximum straw of aromatic rice was recorded (7.94 t ha^{-1}) from C_2 (1/3rd top seedling clipping). whereas the minimum grain yield (7,74 t ha^{-1}) was recorded from C_3 (1/2nd top seedling clipping) which was followed (7.87 t ha^{-1}) by C_1 (Control (no clipping)). 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.



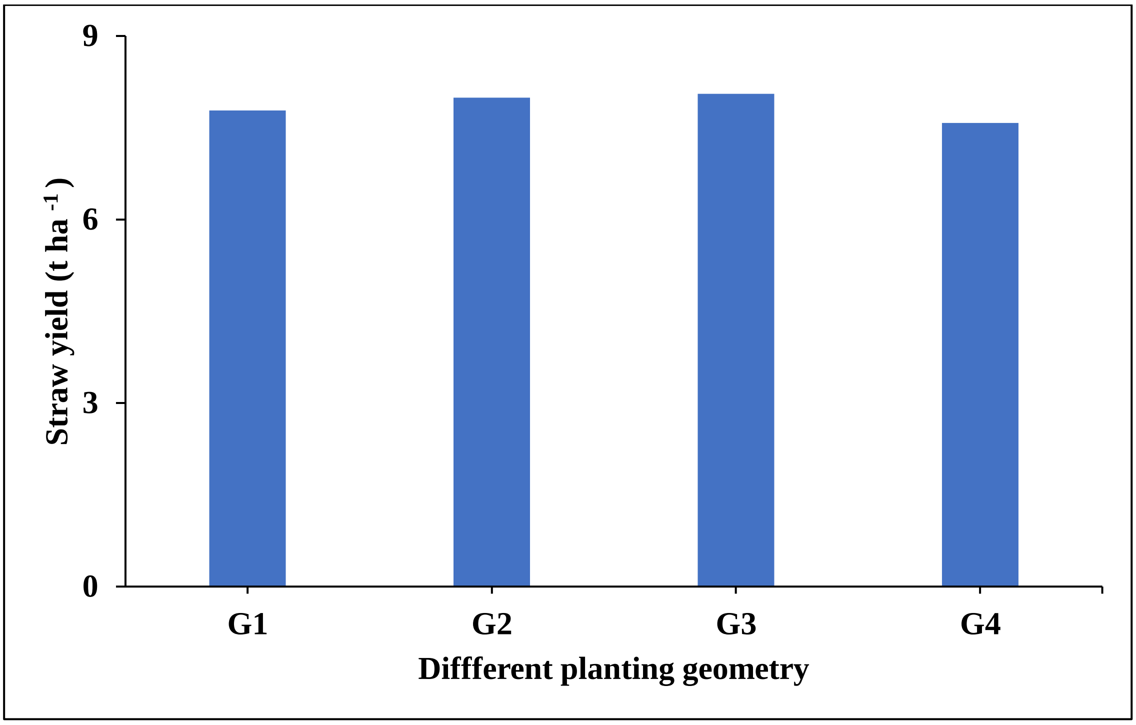
Here, C_1= Control (no clipping), C_2= 1/3rd top seedling clipping and C_3= 1/2nd top seedling clipping.

Figure 23. Effect of seedling clipping on straw yield of aromatic rice at harvest (LSD $_{0.05}$ = 0.15).

4.3.2.2 Different planting geometry

Statistically significant variations were recorded in terms of straw yield of aromatic rice due to different planting geometry (Appendix X and Fig. 24).

The maximum straw yield (8.05 t ha^{-1}) was found from G_3 (20 cm x 15 cm) that was statistically similar (7.99 t ha^{-1}) to G_2. While the minimum straw yield (7.58 t ha^{-1}) was from G_4 (15 cm x 15 cm) which was followed by G_1 (7.78 t ha^{-1}) that was statistically similar. Highest straw yield in closely spaced treatment might be attributed to higher number of plants in closely spaced plots. The result was supported by Islam *et al.,* (1994) and Chavan *et at.,* (1989) that straw yield increase with closer spacing.



Here, G_1= 25 cm x 20 cm, G_2= 20 cm x 20 cm, G_3= 20 cm x 15 cm and G_4= 15 cm x 15 cm.

Figure 24. Effect of different planting geometry on straw yield of aromatic rice at harvest (LSD $_{0.05}$ = 0.17).

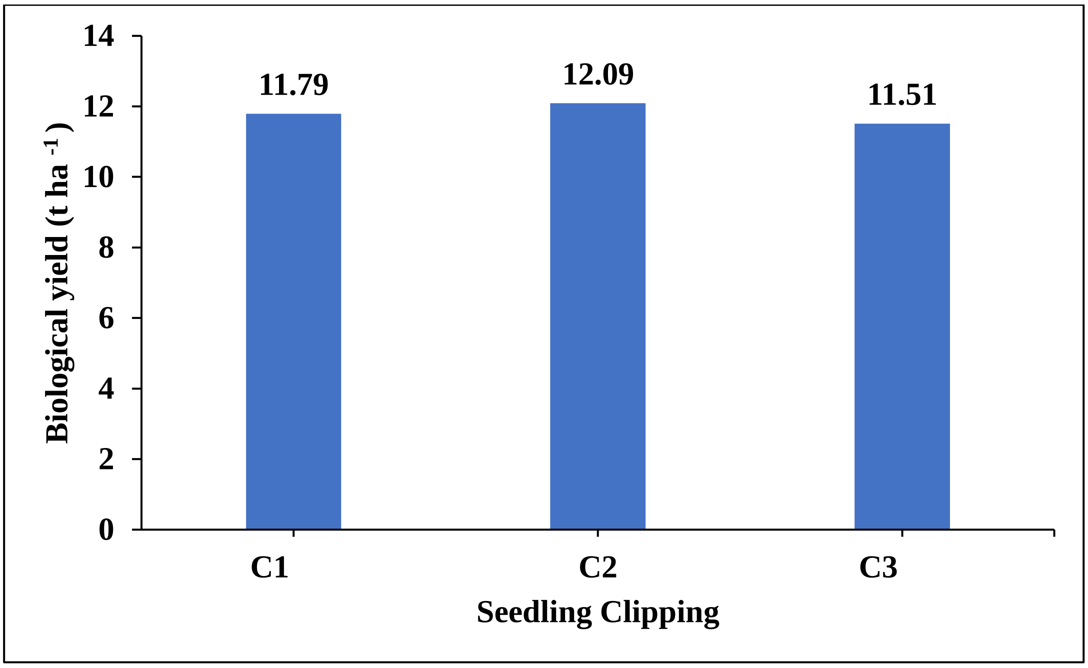
4.3.2.3 Combination effect of seedling clipping and different planting geometry

Statistically significant variation was recorded on straw yield of aromatic rice due to the combined effect of seedling clipping and different planting geometry (Appendix X and Table 6). The maximum straw yield (8.14 t ha^{-1}) was recorded from C_2G_3 (1/3rd top seedling clipping and 20 cm x 15 cm planting geometry) that was followed (8.12 t ha^{-1}) by C_2G_2 (1/3rd top seedling clipping and 20 cm x 20 cm planting geometry) the minimum straw yield (7.47 t ha^{-1}) was found from C_3G_4 (1/2nd top seedling clipping + 15 cm x 15 cm planting geometry) that was statistically similar to C_1G_4.

4.3.3 Biological yield

4.3.3.1 Seedling clipping

Different seedling clipping varied significantly in terms of biological yield of aromatic rice (Appendix X and Fig. 25). The maximum biological yield of aromatic rice was recorded (12.09 t ha^{-1}) from C_2 (1/3rd top seedling clipping). whereas the minimum biological yield (11.51 t ha^{-1}) was recorded from C_3 (1/2nd top seedling clipping) which was followed (11.79 t ha^{-1}) by C_1 (Control (no clipping)). 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.

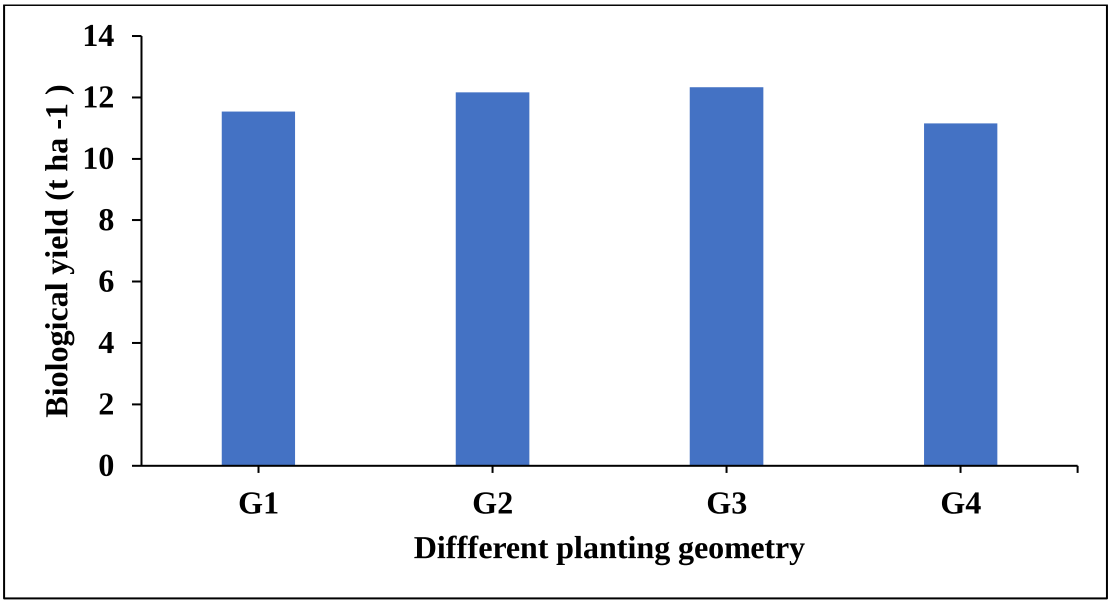


Here, C_1= Control (no clipping), C_2= 1/3rd top seedling clipping and C_3= 1/2nd top seedling clipping.

Figure 25. Effect of seedling clipping on biological yield of aromatic rice at harvest (LSD $_{0.05}$ = 0.14).

4.3.3.2 Different planting geometry

Statistically significant variations were recorded in terms of biological yield of aromatic rice due to different planting geometry (Appendix X and Fig. 26). The maximum biological yield (12.33 t ha^{-1}) was found from G_3 (20 cm x 15 cm) that was statistically similar (12.17 t ha^{-1}) to G_2. While the minimum biological yield (11.15 t ha^{-1}) was from G_4 (15 cm x 15 cm) which was followed by G_1 (11.54 t ha^{-1}) that was statistically similar. Haque (2002) and Hossain (2002) found similar results that closer spacing produced the higher biological yield compare than wider spacing.



Here, G_1= 25 cm x 20 cm, G_2= 20 cm x 20 cm, G_3= 20 cm x 15 cm and G_4= 15 cm x 15 cm.

Figure 26. Effect of different planting geometry on biological yield of aromatic rice at harvest ($LSD_{0.05}$ = 0.16).

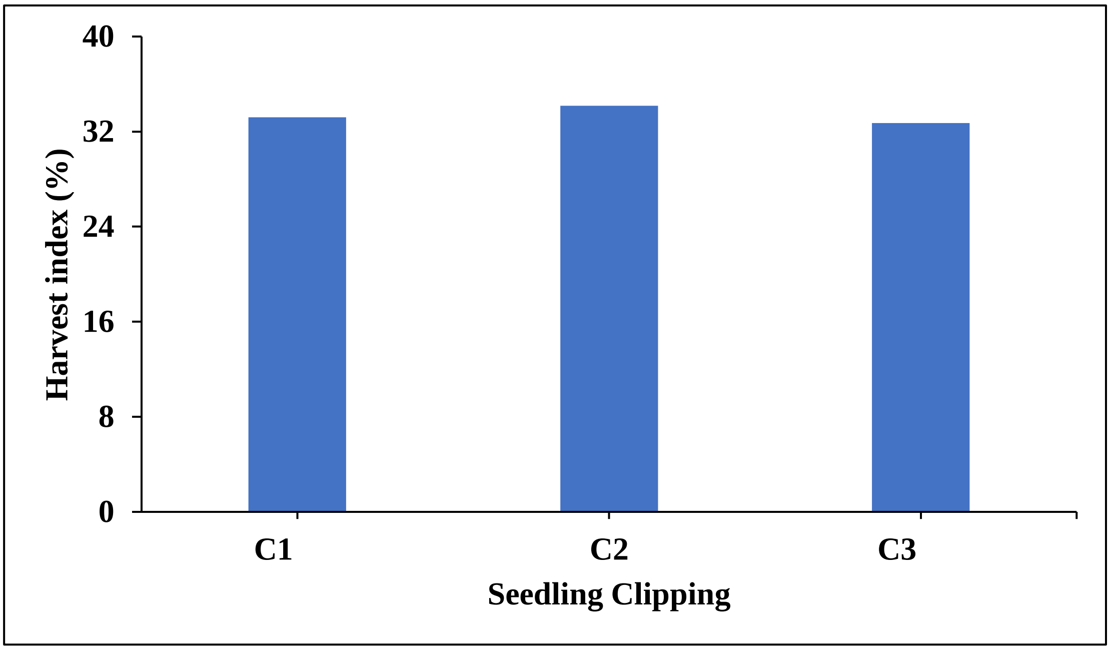
4.3.3.3 Combination effect of seedling clipping and different planting geometry

Statistically significant variation was recorded on biological yield of aromatic rice due to the combined effect of seedling clipping and different planting geometry (Appendix X and Table 6). The maximum biological yield (12.76 t ha^{-1}) was recorded from C_2G_3 (1/3rd top seedling clipping and 20 cm x 15 cm planting geometry) that was followed (12.58 t ha^{-1} and 12.33 t ha^{-1}) by C_2G_2 (1/3rd top seedling clipping and 20 cm x 20 cm planting geometry) and C_1G_3 (control (no clipping) and 20 cm x 15 cm planting geometry) and the minimum (10.95 t ha^{-1}) was found from C_3G_4 (1/2nd top seedling clipping + 15 cm x 15 cm planting geometry) that was statistically similar to C_1G_4.

4.3.4 Harvest index

4.3.4.1 Seedling clipping

Different seedling clipping varied significantly in terms of biological yield of aromatic rice (Appendix X and Fig. 27). The maximum harvest index of aromatic rice was recorded (34.18 %) from C_2 (1/3rd top seedling clipping). whereas the minimum harvest index (32.72 %) was recorded from C_3 (1/2nd top seedling clipping) which was followed (33.33 %) by C_1 (Control, no clipping). 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.



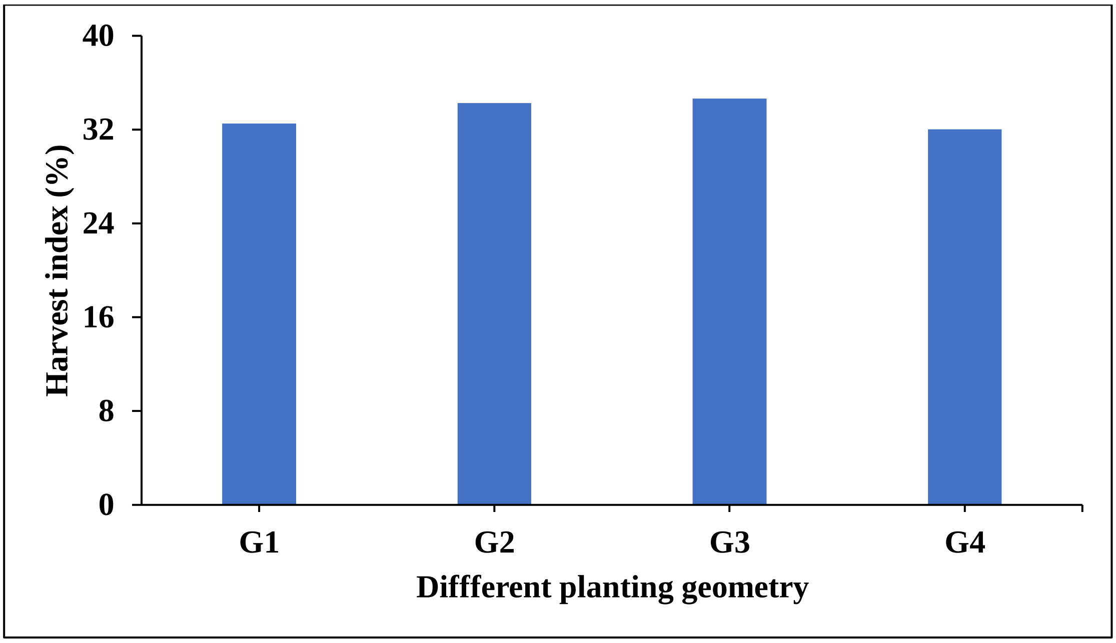
Here, C_1= Control (no clipping), C_2= 1/3rd top seedling clipping and C_3= 1/2nd top seedling clipping.

Figure 27. Effect of seedling clipping on harvest index of aromatic rice at harvest (LSD $_{0.05}$ = 0.55).

4.3.4.2 Different planting geometry

Statistically significant variations were recorded in terms of harvest index of aromatic rice due to different planting geometry (Appendix X and Fig. 28).

The maximum harvest index (34.65 %) was found from G_3 (20 cm x 15 cm) that was statistically similar (34.37 %) to G_2. While the minimum harvest index (32.03 %) was from G_4 (15 cm x 15 cm) which was followed by G_1 (32.52 %) that was statistically similar. Similar trend of harvest index was also reported by Bhab *et al.*, (1987) and Kim *et al.*, (1990).



Here, G_1= 25 cm x 20 cm, G_2= 20 cm x 20 cm, G_3= 20 cm x 15 cm and G_4= 15 cm x 15 cm.

Figure 28. Effect of different planting geometry on harvest index of aromatic rice at harvest (LSD $_{0.05}$ = 0.63).

4.3.4.3 Combination effect of seedling clipping and different planting geometry

Statistically significant variation was recorded on harvest index of aromatic rice due to the combined effect of seedling clipping and different planting geometry (Appendix X and Table 6). The maximum harvest index (36.20 %) was recorded from C_2G_3 (1/3rd top seedling clipping and 20 cm x 15 cm planting geometry) that was followed (35.61 % and 34.14 %) by C_2G_2 (1/3rd top seedling clipping and 20 cm x 20 cm planting geometry) and C_1G_3 (control (no clipping) and 20 cm x 15 cm planting geometry) and the minimum harvest index (31.78 %) was found from C_3G_4 (1/2nd top seedling clipping + 15 cm x 15 cm planting geometry) that was statistically similar to C_1G_4.

Table 6. Combination effect of seedling clipping and different planting geometry on grain yield, straw yield, biological yield and harvest index of aromatic rice.

Treatment combinations	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
C_1G_1	3.75 fg	7.77 c-e	11.52 f-h	32.55 c-e
C_1G_2	4.13 c	8.01 a-c	12.14 cd	34.02 b
C_1G_3	4.21 c	8.10 ab	12.33 bc	34.14 b
C_1G_4	3.59 hi	7.59 ef	11.18 ij	32.11 de
C_2G_1	3.82 ef	7.84 b-e	11.68 e-g	32.70 c-e
C_2G_2	4.48 b	8.12 ab	12.58 ab	35.61 a
C_2G_3	4.62 a	8.14 a	12.76 a	36.20 a
C_2G_4	3.65 gh	7.68 d-f	11.33 hi	32.21 de
C_3G_1	3.69 gh	7.73 c-f	11.42 g-i	32.31 de
C_3G_2	3.91 de	7.87 a-e	11.78 ef	33.19 b-d
C_3G_3	4.00 d	7.90 a-d	11.90 de	33.61 bc
C_3G_4	3.48 i	7.47 f	10.95 j	31.78 e
LSD $_{(0.05)}$	**0.13**	**0.29**	**0.28**	**1.09**
CV (%)	**1.93**	**2.19**	**1.41**	**1.93**

In a column mean values having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly as per 0.05 level of significance

Here, C_1= Control (no clipping); C_2= 1/3rd top seedling clipping; C_3= 1/2nd top seedling clipping; G_1= 25 cm x 20 cm; G_2= 20 cm x 20 cm; G_3= 20 cm x 15 cm and G_4= 15 cm x 15 cm.

CHAPTER V

SUMMARY AND CONCLUSION

5.1 Summary

The field experiment was carried out at the Agronomy field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh, during the time period from July to December-2022, to investigate the efficacy of seedling clipping and leaf different planting geometry on growths, yield and yield contributing characters of BRRI dhan80. The experiment comprised of two factors, Factor A: Seedling clipping (3) viz. C_1= Control (no clipping), C_2 =1/3rd top seedling clipping and C_3= 1/2nd top seedling clipping and Factor B: Different planting geometry (4) viz. G_1= 25 cm x 20 cm, G_2= 20 cm x 20 cm, G_3= 20 cm x 15 cm and G_4= 15 cm x 15 cm. The experiment was laid out in Randomize complete block design with three replications. The total numbers of unit plots were 36. The size of unit plot was 5.76 m^2 (2.4 m × 2.4 m). Data on different growth parameters, yield contributing characters and yield parameters were recorded to find out the efficacy of seedling clipping and different planting geometry for the production of highest grain yield of aromatic rice. Seedling clipping and different planting geometry either individually or combined showed significant variations in most of the characters of BRRI dhan80. In respect of seedling clipping, the maximum plant height (41.38, 79.32, 89.28, 100.50 and 119.68 cm at 25, 50, 75, 100 DAT and harvest, respectively) were observed in C_1 treatment. The maximum number of tillers $hill^{-1}$ (8.76, 13.38, 15.10, 15.68 and 14.56 at 25, 50, 75, 100 DAT and harvest, respectively), above ground dry matter weight $hill^{-1}$ (9.32, 22.01, 29.80, 36.83 and 41.82 g at 25, 50, 75, 100 DAT and harvest, respectively), effective tillers $hill^{-1}$ (14.52) were observed in C_2 treatment. The maximum number of non-effective tillers $hill^{-1}$ (13.14) was observed in C_2 treatment. The maximum panicle length (26.14 cm), maximum number of filled grains $panicle^{-1}$ (171.09) were observed in C_2 treatment. The maximum number of unfilled grains $panicle^{-1}$ (21.34) was observed in C_2 treatment. The maximum number of total grains $panicle^{-1}$ (190.07), 1000 grains weight of BRRI dhan80 (24.59 g), grain yield (4.14 t ha^{-1}), straw yield (7.94 t ha^{-1}), biological yield (12.09 t ha^{-1}) and the maximum harvest index (34.18 %) were observed in C_2 treatment.

On the other hand, the minimum plant height (37.87, 74.61, 85.17, 97.15 and 116.33 cm at 25, 50, 75, 100 DAT and harvest, respectively) was observed in C_3 treatment. The minimum number of tillers hill^{-1} (8.09, 12.03, 13.76, 14.34 and 13.18 at 25, 50, 75, 100 DAT and harvest, respectively) was observed in C_3 treatment. The minimum above ground dry matter weight hill^{-1} (8.66, 20.83, 27.67, 34.61 and 39.43 at 25, 50, 75, 100 DAT and harvest, respectively) was observed in C_3 treatment. The minimum number of effective tillers hill^{-1} was observed in C_3 (13.18) treatment. The minimum number of non-effective tillers hill^{-1} was observed in C_3 (11.63) treatment. The minimum panicle length (25.25 cm), number of filled grains panicle^{-1} (158.42) were observed in C_3 treatment. The minimum number of unfilled grains panicle^{-1} (18.98) was observed in C_3 treatment. The minimum number of total grains panicle^{-1} (179.76), 1000 grains weight of aromatic rice BRRI dhan80 (23.17 g), grain yield (3.77 t ha^{-1}), straw yield (7.74 t ha^{-1}), biological yield (11.51 t ha^{-1}) and harvest index (32.72 %) were observed in C_3 treatment.

In respect of different planting geometry, the maximum plant height (42.34, 80.94, 90.66, 101.52 and 120.70 cm at 25, 50, 75, 100 DAT and harvest, respectively) were observed in G_3 treatment. The maximum number of tillers hill^{-1} (9.11, 14.16, 15.89, 16.47 and 15.36 at 25, 50, 75, 100 DAT and harvest, respectively), above ground dry matter weight hill^{-1} (9.72, 22.68, 31.30, 38.32 and 43.80 g at 25, 50, 75, 100 DAT and harvest, respectively), effective tillers hill^{-1} (15.31) were observed in G_3 treatment. The maximum number of non-effective tillers hill^{-1} (14.07) was observed in G_3 treatment. The maximum panicle length (26.68 cm), maximum number of filled grains panicle^{-1} (179.00) were observed in G_3 treatment. The maximum number of unfilled grains panicle^{-1} (24.26) was observed in G_3 treatment. The maximum number of total grains panicle^{-1} (196.27), 1000 grains weight of BRRI dhan80 (25.30 g), grain yield (4.28 t ha^{-1}), straw yield (8.05 t ha^{-1}), biological yield (12.33 t ha^{-1}) and the maximum harvest index (34.65 %) were observed in G_3 treatment. On the other hand, the minimum plant height (36.73, 72.81, 82.84, 95.47 and 114.65 cm at 25, 50, 75, 100 DAT and harvest, respectively) was observed in G_4 treatment. The minimum number of tillers hill^{-1} (7.65, 10.97, 12.45, 13.03 and 11.87 at 25, 50, 75, 100 DAT and harvest, respectively) was observed in G_4 treatment. The minimum above ground dry matter weight hill^{-1} (8.01, 19.89, 25.45, 32.29 and 36.68 at 25, 50, 75, 100 DAT and harvest, respectively) was observed in G_4 treatment.

The minimum number of effective tillers hill^{-1} was observed in G_4 (11.87) treatment. The minimum number of non-effective tillers hill^{-1} was observed in G_4 (10.03) treatment. The minimum panicle length (24.49 cm), number of filled grains panicle^{-1} (148.03) were observed in G_4 treatment. The minimum number of unfilled grains panicle^{-1} (17.27) was observed in G_4 treatment. The minimum number of total grains panicle^{-1} (172.29), 1000 grains weight of aromatic rice BRRI dhan80 (22.09 g), grain yield (3.57 t ha^{-1}), straw yield (7.58 t ha^{-1}), biological yield (11.15 t ha^{-1}) and harvest index (32.03 %) were observed in G_4 treatment.

In respect of combined effect, the maximum plant height (45.11, 84.63, 92.86, 103.75 and 122.93 cm at 25, 50, 75, 100 DAT and harvest, respectively) were observed in C_1G_3 treatment combination. The maximum number of tillers hill^{-1} (9.64, 15.03, 16.81, 17.39 and 16.40 at 25, 50, 75, 100 DAT and harvest, respectively), above ground dry matter weight hill^{-1} (10.36, 23.63, 32.76, 39.81 and 45.73 g at 25, 50, 75, 100 DAT and harvest, respectively), effective tillers hill^{-1} (16.23) were observed in C_2G_3 treatment combination. The maximum number of non-effective tillers hill^{-1} (15.08) was observed in C_2G_3 treatment combination. The maximum panicle length (27.41 cm), maximum number of filled grains panicle^{-1} (189.05) were observed in C_2G_3 treatment combination. The maximum number of unfilled grains panicle^{-1} (25.29) was observed in C_2G_3 treatment combination. The maximum number of total grains panicle^{-1} (204.48), 1000 grains weight of BRRI dhan80 (26.52 g), grain yield (4.62 t ha^{-1}), straw yield (8.14 t ha^{-1}), biological yield (12.76 t ha^{-1}) and the maximum harvest index (36.20 %) were observed in C_2G_3 treatment combination. On the other hand, the minimum plant height (35.87, 71.67, 81.29, 94.44 and 113.62 cm at 25, 50, 75, 100 DAT and harvest, respectively) was observed in C_3G_4 treatment combination. The minimum number of tillers hill^{-1} (7.49, 10.56, 11.96, 12.54 and 11.38 at 25, 50, 75, 100 DAT and harvest, respectively) was observed in C_3G_4 treatment combination. The minimum above ground dry matter weight hill^{-1} (7.67, 19.38, 24.82, 31.47 and 35.86 at 25, 50, 75, 100 DAT and harvest, respectively) was observed in C_3G_4 treatment combination. The minimum number of effective tillers hill^{-1} was observed in C_3G_4 (11.38) treatment combination. The minimum number of non-effective tillers hill^{-1} was observed in C_3G_4 (9.46) treatment combination. The minimum panicle length (24.13 cm), number of filled grains panicle^{-1} (143.17) were observed in C_3G_4 treatment combination. The minimum number of unfilled grains panicle^{-1} (15.43) was observed in C_3G_4 treatment combination. The minimum number of total grains panicle^{-1} (168.46), 1000 grains weight of aromatic rice BRRI dhan80 (21.57 g), grain yield (3.48 t ha^{-1}), straw yield (7.47 t ha^{-1}), biological yield (10.95 t ha^{-1}) and harvest index (31.78 %) were observed in C_3G_4 treatment combination.

5.2 Conclusion

Based on the results of the present experiment, the following conclusion can be drawn: Treatment 1/3rd seedling top clipping along with planting geometry (20 cm x 15 cm) treatment combination (C_2G_3) is proved to be the optimum management for improving yield of aromatic rice BRRI dhan80.

Recommendation

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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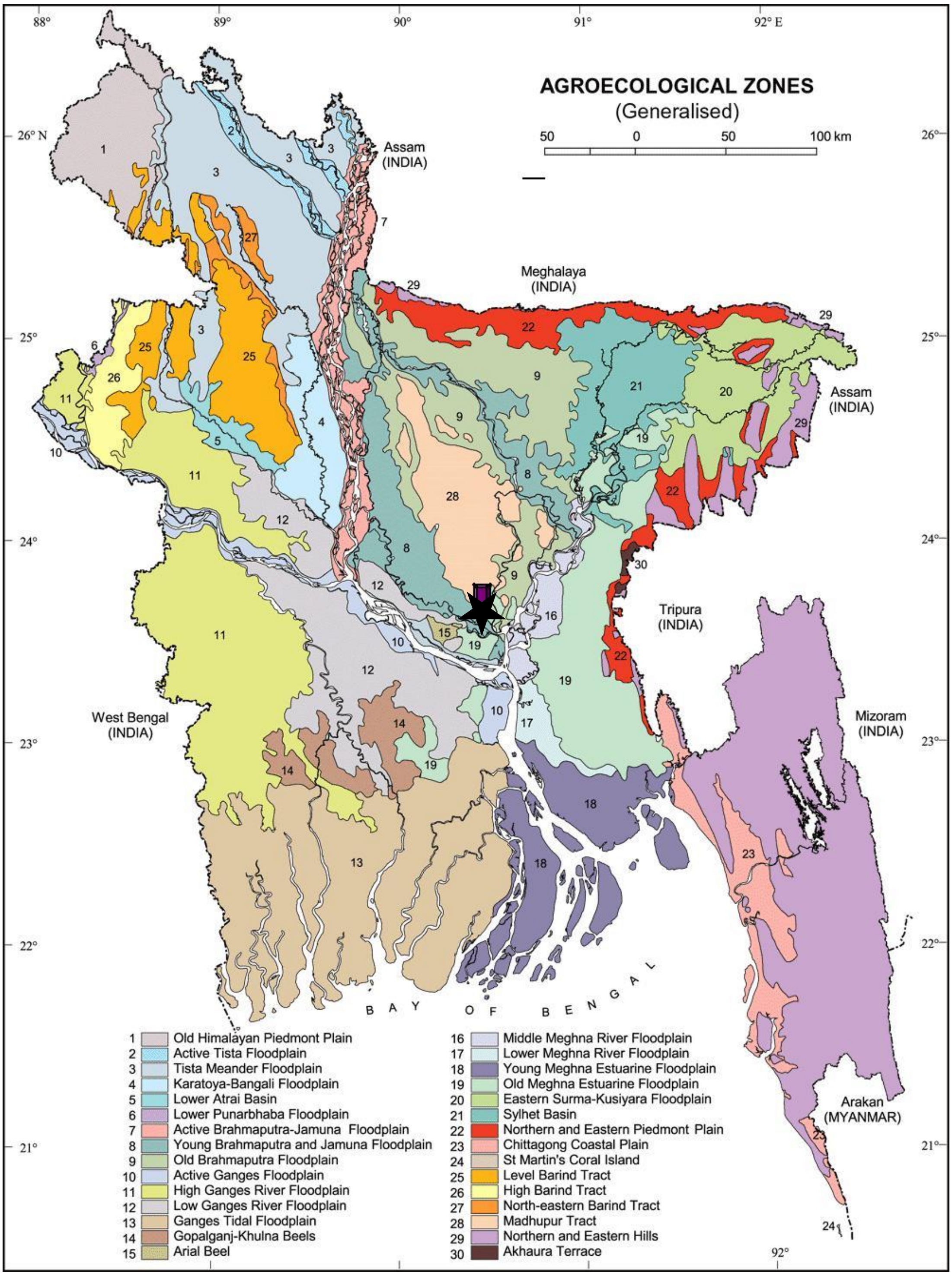
APPENDICES

Appendix I. Map showing the experimental location under study



★ The experimental side under the study

Appendix II. Soil characteristics of experimental field as analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Experimental field, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	26
% Silt	43
% Clay	31
Textural class	Silty clay
pH	5.9
Catayon exchange capacity	2.64 meq 100 g/soil
Organic matter (%)	1.15
Total N (%)	0.03
Available P(ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Appendix III: Layout of the experiment

R_1	R_2	R_3
C_2G_1	C_1G_1	C_3G_4
C_2G_2	C_1G_4	C_3G_2
C_2G_3	C_1G_3	C_3G_1
C_2G_4	C_1G_2	C_3G_3
C_1G_3	C_3G_2	C_2G_3
C_1G_4	C_3G_3	C_2G_4
C_1G_2	C_3G_4	C_2G_2
C_1G_1	C_3G_1	C_2G_1
C_3G_1	C_2G_2	C_1G_1
C_3G_4	C_2G_3	C_1G_3
C_3G_3	C_2G_4	C_1G_4
C_3G_2	C_2G_1	C_1G_2

Factor A: Seedling clipping (3)	**Factor B: Planting geometry (4)**
C_1 = Control (no clipping)	G_1 = 25 cm x 20 cm
C_2 = 1/3rd top seedling clipping	G_2 = 20 cm x 20 cm
C_3 = 1/2nd top seedling clipping	G_3 = 20 cm x 15 cm
	G_4 = 15 cm x 15 cm

Appendix IV. Monthly records of air temperature, relative humidity and total rainfall during the period from July 2022 to December 2022.

Month	RH (%)	Air temperature (C)			Total rainfall (mm)
		Max.	Min.	Mean	
July	81	32.6	26.8	26	114
August	80	32.6	26.5	22	106
September	80	32.4	25.7	18	86
October	76	31.2	23.9	25.42	52
November	53	29.6	19.8	28	00
December	47	28.8	19.1	28	00

Appendix V. Analysis of variance of the data on plant height of aromatic rice as influenced by combined effect of seedling clipping and different planting geometry.

Source of variation	d.f	Mean square of plant height (cm) at different days after transplanting (DAT)				
		25	50	75	100	At harvest
Replication	2	38.52	48.25	90.75	150.52	165.02
Seedling clipping (A)	2	39.57*	75.17^{NS}	53.22^{NS}	35.24^{NS}	35.24^{NS}
Planting geometry (B)	3	50.06*	104.43^{NS}	100.81^{NS}	59.62^{NS}	59.62^{NS}
Seedling clipping (A) X Planting geometry (B)	6	2.81*	6.69*	1.59^{NS}	1.59^{NS}	1.59*
Error	22	0.61	1.34	4.02	2.88	4.84

*Significant at 5% level of significance

^{NS} Non significant

Appendix VI. Analysis of variance of the data on number of tillers hill^{-1} of aromatic rice as influenced by combined effect of seedling clipping and different planting geometry.

Source of variation	d.f	Mean square of tillers hill^{-1} (no.) at different days after transplanting (DAT)				
		25	50	75	100	At harvest
Replication	2	0.98	5.75	4.94	5.33	5.24
Seedling clipping (A)	2	1.34*	5.53*	5.41*	5.41*	5.76*
Planting geometry (B)	3	4.11*	20.08*	22.47*	22.47*	22.98*
Seedling clipping (A) X Planting geometry (B)	6	0.14*	0.29*	0.23*	0.23*	0.28*
Error	22	0.05	0.19	0.12	0.15	0.14

*Significant at 5% level of significance

^{NS} Non significant

Appendix VII. Analysis of variance of the data on dry matter weight hill^{-1} of aromatic rice as influenced by combined effect of seedling clipping and different planting geometry.

Source of variation	d.f	Mean square of dry matter weight hill^{-1} (g) at different days after transplanting (DAT)				
		25	50	75	100	At harvest
Replication	2	1.53	5.60	9.67	10.55	12.09
Seedling clipping (A)	2	1.33*	4.16*	13.54*	14.78*	17.13*
Planting geometry (B)	3	5.35*	14.27*	68.15*	69.63*	99.18*
Seedling clipping (A) X Planting geometry (B)	6	0.10 ^{NS}	0.40 ^{NS}	0.92*	0.43 ^{NS}	0.79*
Error	22	0.049	0.21	0.59	0.52	0.82

*Significant at 5% level of significance

^{NS} Non significant

Appendix VIII. Analysis of variance of the data on number of effective tillers hill^{-1} and non-effective tillers hill^{-1} of aromatic rice as influenced by combined effect of seedling clipping and different planting geometry.

Source of variation	d.f	Mean square at different days after transplanting (DAT)	
		Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)
Replication	2	4.94	6.02
Seedling clipping (A)	2	5.41*	6.84*
Planting geometry (B)	3	22.47*	31.39*
Seedling clipping (A) X Planting geometry (B)	6	0.23*	0.19^{NS}
Error	22	0.12	0.13

*Significant at 5% level of significance

^{NS} Non significant

Appendix IX. Analysis of variance of the data on panicle length, filled grains panicle^{-1}, unfilled grains panicle^{-1}, total grains panilce^{-1} and weight of 1000-grains of aromatic rice as influenced by combined effect of seedling clipping and different planting geometry.

Source of variation	d.f	Mean square at different days after transplanting (DAT)				
		Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	Total grains panicle^{-1} (no.)	Weight of 1000 grain (g)
Replication	2	3.73	331.14	34.34	564.91	2.88
Seedling clipping (A)	2	2.37 ^{NS}	482.20*	16.68*	319.96*	6.05*
Planting geometry (B)	3	8.77 ^{NS}	1767.96*	87.22*	1076.34*	18.46*
Seedling clipping (A) X Planting geometry (B)	6	0.08 ^{NS}	37.25*	0.52 ^{NS}	31.63*	0.44^{NS}
Error	22	0.28	10.50	0.70	11.89	0.28

*Significant at 5% level of significance

^{NS} Non significant

Appendix X. Analysis of variance of the data on grain yield, straw yield, biological yield and harvest index of aromatic rice as influenced by combined effect of seedling clipping and different planting geometry.

Source of variation	d.f	Mean square at different days after transplanting (DAT)			
		Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	0.083*	0.070	0.15*	41.18*
Seedling clipping (A)	2	0.42*	0.12*	0.99*	6.62*
Planting geometry (B)	3	1.01*	0.42*	2.70*	14.89*
Seedling clipping (A) X Planting geometry (B)	6	0.05*	0.005*	0.068*	1.27 *
Error	22	0.005	0.029	0.027	0.42

*Significant at 5% level of significance