INFLUENCE OF SEEDLING LEAF CLIPPING AND PLANT SPACING ON GROWTH AND YIELD OF BRRI Dhan80

MD. SAGAR HOSSAIN

DEPARTMENT OF AGRONOMY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

JUNE, 2022

INFLUENCE OF SEEDLING LEAF CLIPPING AND PLANT SPACING ON GROWTH AND YIELD OF BRRI Dhan80

BY

MD. SAGAR HOSSAIN

REGISTRATION NO. 20-11095

Mobile No. +8801585226636

Email: sagarhossain0011@gmail.com

A Thesis

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

IN

AGRONOMY

SEMESTER: JANUARY-JUNE, 2022

Approved by:

Prof. Dr. Md. Fazlul Karim **Supervisor**	**Prof. Dr. Tuhin Suvra Roy** **Co-Supervisor**

Prof. Dr. Md. Abdullahil Baque
Chairman
Examination Committee

DEPARTMENT OF AGRONOMY

Sher-e-Bangla Agricultural University

Sher-e-Bangla Nagar

Dhaka-1207

CERTIFICATE

*This is to certify that thesis entitled, "**INFLUENCE OF SEEDLING LEAF CLIPPING AND PLANT SPACING ON GROWTH AND YIELD OF BRRI Dhan80**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) in AGRONOMY**, embodies the result of a piece of bona-fide research work carried out by **MD. SAGAR HOSSAIN**, **Registration No. 20-11095** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Date:

Place: Dhaka, Bangladesh

Prof. Dr. Md. Fazlul Karim

Department of Agronomy

Sher-e-Bangla Agricultural University,

Dhaka-1207

DEDICATED TO

MY

BELOVED PARENTS

ACKNOWLEDGEMENTS

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

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

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

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

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

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

The author wish to extend his special thanks to his classmates and friends for their keen help as well as heartfelt co-operation and encouragement.

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

May Allah (SWT) bless and protect them all.

The Author

INFLUENCE OF SEEDLING LEAF CLIPPING AND PLANT SPACING ON GROWTH AND YIELD OF BRRI Dhan80

ABSTRACT

A field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the *Aman* season of June to November 2021, to the study influence of seedling leaf clipping and plant spacing on growth and yield of BRRI dhan80. The experiment was consisted of two factors, and followed Randomized Complete Block Design with three replications. The factors were as Factor A: Seedling leaf clipping (3) *viz;* C_0 = No seedling clipping, C_1 = Top $1/3^{rd}$ portion clipping, C_2 = Top $1/2^{nd}$ portion clipping and Factor B: Different plant spacing (4) *viz;* S_1 = 25 cm × 25 cm, S_2 = 25 cm × 20 cm, S_3 = 20 cm × 20 cm and S_4 = 20 cm × 15 cm. Experimental results revealed that, growth and yield of aromatic rice significantly influenced due to seedling leaf clipping. The highest panicle length (23.79 cm), filled grains panicle^{-1} (130.52), 1000-grain weight (24.43 g), grain yield (4.59 t ha^{-1}), straw yield (5.99 t ha^{-1}), biological yield (10.58 t ha^{-1}) and harvest index (43.29 %) were observed from C_0 (No seedling clipping) treatment. In the case of different plant spacings, the highest panicle length (24.01 cm), filled grains panicle^{-1} (134.10) and 1000-grain weight (24.82 g) were observed in S_1 (25 cm × 25 cm) treatment. However, the highest grain yield (4.61 t ha^{-1}), straw yield (6.04 t ha^{-1}), biological yield (10.66 t ha^{-1}) and harvest index (43.22 %) were observed in S_4 (20 cm × 15 cm) treatment. In the case of treatment combination, C_0S_4 (No seedling clipping along with 20 cm × 15 cm plant spacing) gave the highest grain yield (5.11 t ha^{-1}), straw yield (6.32 t ha^{-1}), biological yield (11.42 t ha^{-1}) and harvest index (44.71 %) whereas the lowest of these values were observed from C_2S_1 combination (Top $1/2^{nd}$ portion seedling clipping along with 20 cm × 15 cm plant spacing). Based on the above findings, it would be considered that no seedling leaf clipping treatment along with 20 cm × 15 cm plant spacing (C_0S_4) would be helpful to enhance better grain yield production of BRRI dhan80.

LIST OF CONTENTS

LIST OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Cont'd)

LIST OF APPENDICES

LIST OF ABBREVIATIONS

Full word	Abbreviations
Agriculture	Agr.
Agro-Ecological Zone	AEZ
Bangladesh Bureau of Statistics	BBS
Biology	Biol.
Biotechnology	Biotechnol.
Botany	Bot.
Cultivar	Cv.
Dry weight	DW
Editors	Eds.
Emulsifiable concentrate	EC
Entomology	Entomol.
Environments	Environ.
Food and Agriculture Organization	FAO
Fresh weight	FW
International	Intl.
Journal	J.
Least Significant Difference	LSD
Liter	L
Triple super phosphate	TSP
Science	Sci.
Soil Resource Development Institute	SRDI
Technology	Technol.
Serial	Sl.

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important cereal food crop which feeds the world's half of the population providing 35-60% of the total caloric requirements (Jahan *et al*., 2022). In Bangladesh, rice is consumed as staple food since it is the main source of food and has incredible influence on its agrarian economy (Paul *et al*., 2021). Approximately, 36.60 million tons of rice is produced from 11.42 million hectares of land in Bangladesh (BBS, 2020) of which *Aus, Aman,* and *Boro* rice covers 1.10, 5.56, and 4.76 million hectares of land with the production of 2.76, 14.20, and 19.65 million tons of rice, respectively (BBS, 2020).

Rice is classified as aromatic and non-aromatic rice by aroma. Aromatic rice is also named as fine rice, scented rice or fragrance rice which has great potential to attract rice consumer for its taste and deliciousness (Rathiya *et al*., 2017). Because of its aroma, grain dimension and cooking qualities, aromatic rice is preferred for consumption globally and fetches premium price in domestic and international markets which boosted up the economic condition of the rice growers (Singh *et al*., 2012). In Bangladesh, most of the photoperiod sensitive aromatic rice varieties are grown during *Aman* season (Kabir *et al*., 2004) and with low yield an average of 3.04 t ha^{-1} (Sinha *et al*., 2018) which covers 2% of the national rice acreage of Bangladesh (Roy *et al*., 2018). There are ways to increase its yield wich to be exploredby the researchers to find out suitable management practices of aromatic fine rice cultivation in *Aman* season. Therefore, effort should be made to improve the productivity of aromatic fine rice through agronomic manipulation with suitable cultivars for the highest productivity of aromatic fine rice.

Rice production is affected by a number of crucial variables, including climate, soil physical conditions, agronomic and management practices such as leaf clipping, and water management. Improved nutrient retention practice in the soil, use of the adequate level of nitrogen fertilizer and additional nutrients, proper seed rate, plant spacing and high yielding varieties all are considered key determinants of rice yield.

In Rice leaves are vitally important organs for photosynthesis, which is a major process influencing crop growth rates and is influenced by the number or area of the leaves. In Bangladesh, production must be increased vertically through the use of the leaf cutting method. Rice seedling leaf cutting is a farmer's wisdom for several reasons, including preventing wind damage from too heavy leaves, weed removal, easy pest management, lowering the cost of rice pests and weeding, uniform plant height and stimulating all plants to bloom at the same time and easy for harvesting. Leaf cuttings in transplanted seedlings may be able to translocate assimilate towards the root zone for early seedling establishment and increased plant growth (Paez *et. al.*, 1995). Seedling leaf clipping at transplanting does not immediately improve plant water status, but it may alleviate drought stress in clipped plants. Leaf clipping has also been reported to remove transpiring biomass while conserving soil moisture (Georgias *et al*., 1989). Misra and Misra (1991) (for pearl millet) and Mae (1997) (for rice) stated that the top three leaves translocate assimilate towards grain filling. The top three leaves an established plant have most contribution for the yield of grain (Yoshida, 1981; Misra, 1987). Seedling leaf cutting practiced in transplanted aman rice can reduce transplanting shock (Bardhan and Mandal, 1988). Leaf cutting during reproductive and ripening stages is directly related to biomass production and grain yield of rice crop (Ray *et al*,. 1983). However excessive leaf clipping creates negative impact on grain yield of rice production. By considering the importance of leaves for grain yield, it is necessary to analysis the morphological and the physiological characteristics of functional leaves to improve grain yield in rice (Yue *et al.* 2006).

Plant spacing is one of the crop management activities which governs all of the components of plant need for their growth and yield. Plant spacing directly affects normal physiological activities through intra-species competition (Halder *et al*., 2018). The number of productive tillers and total tillers per square meter were significantly affected by spacing. Wider spacing lowers the crop ability to compete with weeds by increasing the space available for weeds while limiting the crop competitive ability (Ramesh *et al*., 2009). To obtain a high yield, it is imperative to determine the optimum plant population per unit area, spacing, and nitrogen. One of the most significant non- monetary factors in rice yield maximization is adequate plant population in the proper planting geometry

(Siddiqui *et al*., 1999). Through efficient use of solar radiation and nutrients, optimal plant spacing ensures the improvement in plants physiology both above and below ground (Mahaddeshi *et al*, 2011) and hence improper plant spacing reduces the yield. As a result, it is imperative to examine the best planting geometry along with various seedling leaf clipping managements to obtain maximum rice crop yield. Transplanting is major method of crop establishment in case of rice cultivation in Bangladesh. However, traditional manual transplanting, which is normally performed by hired labour, is one of the most limiting factor affecting rice productivity because the plant density obtained is insufficient (15-20 hills m^{-2}) and far below the (33 hills m^{-2}) recommended density (Kumar, 2021). Furthermore, in most farmers' fields, transplanting is done at random (random geometry) with no defined plant to plant and row to row spacing. As a result, it's important to figure out how much yield loss is there due to improper plant spacing.

In Bangladesh few studies have been conducted with seedling leaf clipping and proper spacing of aromatic rice. Considering the above facts the present study was undertaken to find out the influence of seedling leaf clipping and plant spacing on growth and yield of aromatic rice with the following objectives:

i. To study the growth and yield of aromatic rice grown with seedling leaf clipping.

ii. To determine the optimum plant spacing for maximum growth and yield of aromatic rice.

iii. To assess the combined effect of seedling leaf clipping and plant spacing on aromatic rice cultivation.

CHAPTER II

REVIEW OF LITERATURE

In this section, an attempt was made to collect and study relevant information available regarding the influence of seedling leaf clipping and plant spacing on growth and yield of BRRI Dhan80, in order to gather knowledge useful in carrying out the current piece of work. Because the available literature on this crop is limited, literature on other related crops was gathered and reviewed under the following headings:

2.1 Effect of seedling leaf clipping

Ahsan (2020) conducted an experiment during the period from March to August 2019 at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to find out the influence of leaf clipping on the growth and yield of aus rice. The experiment comprised two factors; Factors A: three different seedling clipping viz. S0 = no seedling clipping (control), S_1 = 1/3rd seedling clipping and S_2 = 1/2nd seedling clipping and Factor B: four different leaf clipping before panicle initiation viz. L_0 = no leaf clipping (control), L_1 = Lower 1 + 2 leaves clipping, L_2 = Lower 2 + 3 leaves clipping and L_3 = Flag leaf clipping. Experimental result showed that in case of leaf clipping the highest plant height (109.60 cm),above ground dry matter (43.84 g) hill^{-1}, higher number of effective tiller hill^{-1} (24.13), filled grains panicle^{-1} (149.40), lowest unfilled grain panicle^{-1} (13.10),panicle length (32.71 cm), 1000 grains weight (23.21 g), grain yield (5.44 t ha^{-1}), and harvest index (57.29 %) were observed from no leaf clipping or control treatment. Whereas the corresponding lowest value of these parameters were observed from flag leaf clipping treatment.

Fatima *et al.* (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. Regardless of variety, all the studied parameters such as plant height, effective tiller hill^{-1}, filled grains panicle^{-1},panicle length, 1000 grains weight and grain yield, biological yield, straw yield and harvest index were found to be highest in without clipping treatment.

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), grains $panicle^{-1}$ (118), 1000- grains weight (22.72 g), grain yield (4.36 t ha^{-1}) and harvest index (44%) were found in C_0 (no leaf clipping) and the lowest of these parameters were obtained from C_3 when leaf clipped at 55 DAT.

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 the panicle length and unfilled grain number per panicle and decreased the panicle fertility percentage, when all leaves except flag leaf was removed.

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, 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) and grain weight $panicle^{-1}$ (29.18, 58.37 and 48.93%, respectively) while, cutting of 2nd leaf and 3rd leaf alone exert no significant impact compared to control. Number of unfilled grain 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.

Hossain (2017) conducted an experiment to evaluate the effect of leaf cutting on plant growth and yield of selected BRRI released Aman varieties. Experimental result showed that leaf cutting was observed with detrimental effect on the usual plant growth and yield performances. Leaf cutting at heading (except flag leaf and penultimate leaves) reduced average 10-20% loss of grain yield.

Boonreung and Marsom (2015) carried out a study aimed to search for the optimal length cutting of PathumThani1 rice leaf. The experimental design was randomized complete block design(RCBD). Treatment was 7 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. It was conducted in a research greenhouse and field of Agricultural Technology and Agro-industry, Rajamangala University of Technology Suvarnabhumi, Phra Nakhon Si Ayutthaya during November 2012 to February 2013. The results showed that no effect on plant height , tiller number per plant panicle length and yield but significantly higher number of grains per panicle and 1,000 grains weight. The optimal length of rice leaf cutting was15-30 cm.

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 TTB-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 however foliage pruning up to 100 days after germination (DAG) had no adverse impact on tillers of the crop.

Singh *et al.* (2013) studied the effect morphological modification through nipping of terminal bud by hand clipping (without nipping; and nipping at 25, 30 and 35 days crop stage) on the productivity of sesame (*Sesamum indicum* L.). Manual nipping significantly affected the plant height and primary branches/plant at harvest. In terminal nipping practice, the maximum plant height was recorded in without nipping treatment compared to nipping. Terminal clipping done at 30 days crop stage produced significantly higher number of primary branches/plant over other nipping schedule (without nipping and nipping at 25 days crop stage).

Safari *et al*. (2013) reported that maize crop without defoliation recorded significantly highest dry matter accumulation (3450.40 g m^{-2}) as compared to other treatments of defoliation.

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.

Daliri *et al.* (2009) completed a field trial to consider the impact of cutting time and cutting height on yield and yield components of ratoon rice (*Oryza sativa* L.) Tarom langrodi variety. Results showed that the impact of cutting time on number of effective tiller $hill^{-1}$ was found statistically significant. Cutting stature significantly effect on tiller number $hill^{-1}$ and number of effective tiller $hill^{-1}$. Interaction between cutting time and cutting height on number of tiller $hill^{-1}$ and number of viable tillers $hill^{-1}$ were significant.

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.

Kokilavani *et al.* (2007) investigated the influence of morphological modification through terminal clipping in sesame varieties and reported that in terminal clipping practice, the maximum plant height was noticed in without clipping treatment when compared to all manual terminal clipping treatments. Terminal clipping done at 35 DAS recorded more number of branches per plant, DMP and LAI. In plants, the development of auxiliary buds is inhibited normally by Indole Acetic Acid (IAA) produced in the apical meristem. If the source of auxin is removed by excising the apical meristem, the lateral branching gets accelerated. Moreover, under terminal clipping, the utilization of photosynthates by the crop for the production of lateral branches would be higher and this might be reason for increased number of branches.

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.

Chaudhary *et al*. (2005) reported that in maize no defoliation produced the maximum seed weight per cob and seed yield while, minimum seed weight per cob and seed yield were obtained in defoliation of all leaves below cob at two weeks after mid silking stage.

Ros *et al.* (2003) carried out an experiment to explore the concept of seedling vigour of transplanted rice and to determine what plant attributes conferred vigour on the seedlings. Seedling vigour treatments were established by subjecting seedlings to short-term submergence (0, 1 and 2 days week^{-1}) in one experiment and to leaf clipping or root pruning and water stress in another to determine their effect on plant growth after transplanting. Experimental result revealed that pruning 30% of leaves depressed shoot and root dry matter by 30% at PI, and root dry matter and straw and grain yield by 20% at maturity.

Ahmed *et al.* (2001) conducted an experiment with three nitrogen levels (N_1-50 kg N ha^{-1}, N_2-75 kg N ha^{-1}, N_3-100 kg N ha^{-1}) and four times of leaf cutting (C_0-no cutting, C_1-cutting at 21 DAT-Day After Transplanting, C_2-cutting at 35 DAT and C_3-cutting at 49 DAT) to find the possibility of production of rice for green fodder as well as seed. Experimental result revealed that the time of leaf cutting had significant influence on all the parameter studied. Plant height, number of total tillers hill^{-1}, cumulative straw yield, number of productive tillers hill^{-1}, number of non-bearing tillers hill^{-1}, number of total spikelets panicle^{-1}, number of grains panicle^{-1}, number of sterile spikelets panicle^{-1}, 1000-grain weight, grain yield and straw yield were found to be highest for no leaf cutting which was statistically similar to cutting at 21 DAT but 1000-grain weight was also similar to cutting at 35 DAT and lowest for cutting at 49 DAT. Amount of green forage and forage dry matter were highest for cutting at 49 DAT.

Biswas (2000) conducted an experiment on the effects of detoliation on cowpea and reported that plant height, number of branches per plant and number of inflorescence per plant were the highest in control and were decreased with the increasing degree (33%, 66% and 100%) of defoliation.

2.2 Effect of plant spacings

Koireng *et al.* (2019) conducted the field trail during the kharif season of 2016 to evaluate the effect of variety and spacing on the productivity of direct seeded rice and reported that the planting at 25 cm row spacing resulted in significantly higher number of tillers m^{-2}, number of effective tillers m^{-2}, panicle length, number of filled grain/panicle and grain yield as compared to 20 cm and 15 cm row spacing. However, plant height, number of unfilled spiklets $panicle^{-1}$ and straw yield were significantly higher with 15 cm row spacing.

Oyange *et al.* (2019) carried out a field trail to study the effect of planting density on growth and yield of nerica-1 rice variety and reported that number of tillers m^{-2}, number of panicles m^{-2}, number of filled grains $panicle^{-1}$ and grain yield were recorded maximum with the plant spacing 20 cm × 15 cm and also noted that plant height and panicle length were maximum from spacing 30 cm × 15 cm.

Shel *et al.* (2019) carried out a field investigation to study the effect of row spacing on the performance of three short duration transplant Aman rice varieties and reported that tallest plant and highest number of effective tillers $hill^{-1}$ were obtained from 35 cm × 15 cm row spacing. similarly, they noted that the highest number of grains/panicle, 1000-grain weight, grain yield and harvest index were recorded maximum at row spacing 25 cm × 15 cm. They also reported that the interaction effect of variety (BRRI dhan 49) with the row spacing of 25 cm ×15 cm recorded the higher grain yield and harvest index.

Das *et al.* (2017) conducted the field trail to evaluate growth and yield potential of direct seeded hybrid rice cultivars with different crop geometry and revealed that amongst hybrid rice cultivars, Arize 6444 recorded significantly higher plant height, number of tillers m^{-2}, dry matter accumulation, leaf area index, panicle weight, effective tillers m^{-2}, number of grains/panicle, test weight and grain yield in comparison to other cultivars. They also noted that closer plant spacing 20 cm × 10 cm was recorded maximum number of tillers m^{-2}, dry matter accumulation and leaf area index in comparison to wider spacing 25 cm × 25 cm at all the growth stages. similarly, panicle length, effective tillers m^{-2}, number of grains $panicle^{-1}$ and test weight were observed maximum at wider spacing 25 cm × 25 cm in comparison to narrow row spacing 20 cm × 10 cm.

Sampath *et al.* (2017) conducted a field experiment on a sandy clay loam soil at college farm of Professor Jayashankar Telangana State Agricultural University, Rajendranagar, Hyderabad, Telangana during the *Kharif* seasons of 2014 and 2015 to study the nutrient uptake of rice varieties as influenced by combination of plant densities and fertilizers under late sown condition. Study revealed that significantly higher grain yield (6494, 6647 and 6570 kg ha^{-1}) and straw yield ((8036, 8252 and 8144 kg ha^{-1}) were obtained in (T_9) *viz*., P_3 (15 cm × 10 cm) in combination with F_3 (195-86-90, N, P_2O_5 and K_2O) which was at par with (T8) *viz*.,P_3 (15 cm × 10 cm) in combination with F_2 (153-59-68, N, P_2O_5 and K_2O) (6341, 6532 and 6437 kg ha^{-1}) with respect to rest of the treatments. Significantly the lowest grain yield (4092, 4239 and 4165 kg ha^{-1}) and straw yield (5252, 5389 and 5321 kg ha^{-1}) were obtained with (T_1) *viz*., P_1 (20 cm × 20 cm) in combination with F_1 (111-32-45, N, P_2O_5 and K_2O) when compared to other treatments.

To evaluate the performance of DSR with different plant spacing, Joshi *et al.* (2016) carried out field experiment and found that the plant height, dry matter accumulation, total number of tillers and number of productive tillers varied significantly due to plant spacing.

Khalil *et al.* (2016) conducted the field experiment to evaluate the effect of plant spacing on growth and yield of aromatic rice varieties and found that plant height, total tillers $hill^{-1}$, effective tillers/hill, panicle length, total spikelet/panicle, filled grains $panicle^{-1}$ and 1000-grain weight were observed maximum with the spacing 25 cm × 25 cm and also noted that non filled grains/panicle and grain yield were recorded maximum under the spacing 20 cm × 15 cm.

Moro *et al.* (2016) studied the effect of plant spacing on rice varieties, and concluded that transplanting at a wider spacing of 20 cm × 20 cm resulted in significantly more panicles per m^{-2} and higher individual panicle weights (2.66 g) than transplanting at a closer spacing.

Singh *et al*. (2015) concluded that the planting geometry of 20 cm × 25 cm recorded maximum number of effective tillers $hill^{-1}$ which was at par with 20 cm × 20 cm and significantly superior over 20 cm × 15 cm and 20 cm × 10 cm. The planting geometry 20 cm x 25 cm recorded more filled grains than 20 cm × 20 cm, 20 cm × 15 cm and 20 cm x 10 cm, respectively. The highest grain yield of 5.07 t ha^{-1} was recorded in moderate wider planting geometry of 20 cm × 20 cm which was at par with 20 cm × 15 cm (4.75 t ha^{-1}) and significantly superior over 20 cm × 10 cm (4.50 t ha^{-1}) and 20 cm × 25 cm (3.98 t ha^{-1}). The harvest index was recorded higher in planting geometry 20 cm × 25 cm which is 1.6 %, 12.78 % and 26.26 % more than 20 cm × 20 cm, 20 cm × 15 cm and 20 cm × 10 cm, respectively.

Chakrabortty *et al.* (2014) conducted the field trail to study the growth and yield of boro rice as affected by planting geometry under system of rice intensification and found that maximum dry matter, number of tillers $hill^{-1}$, number of effective tillers $hill^{-1}$, number of filled grains $panicle^{-1}$, 1000-grains weight, grain yield, straw yield, biological yield and harvest index were registered maximum from 40 cm × 40 cm plant spacing.

Mohan and Pillai (2014) carried out field experiment during Sep- Dec, 2012 at the Cropping Systems Research Centre, Karamana, Thiruvananthapuram, Kerala for assessing the production potential of hybrid rice in relation to spacing, seedling density and nutrient management. They observed that number of spikelets panicle-1 (144.14) was significantly higher at wider spacing of 20 cm × 15 cm than closer spacing of 20 cm × 10 cm (141.97) and sterility percentage was remarkably lower at wider spacing of 20 cm × 15 cm.

Ram *et al*. (2014) performed a field experiment for different rice genotypes under SRI with two spacings (25 cm × 25 cm and 30 cm × 30 cm). They found that spacing of 30 cm × 30 cm resulted in more tillers per hill (22.7), panicles per hill (21.9) and grains per panicle (168.1) than spacing of 25 cm × 25 cm. However, closer spacing of 25 cm × 25 cm resulted in higher plant height (116 cm), net monetary returns and yield (grain and straw). A higher number of panicles per unit area resulted in a higher grain and straw yield. When compared to broader spacing, closer spacing resulted in a 12.30% higher grain yield.

Thawait *et al*. (2014) carried out a field experiment at Raipur and reported that planting of 2-3 seedlings hill^{-1} transplanted in the spacing of 25 cm × 25 cm recorded significantly higher plant height, number of tillers, dry matter accumulation, yield attributes, grain yield and straw yield of rice.

Baskar *et al.* (2013) carried out experiment with different plant spacing *viz*., 25 cm × 25 cm, 30 cm × 30 cm and 35 cm × 35 cm and concluded that the number of tillers hill^{-1} at all growth stages was higher under 35 cm × 35 cm plant spacing than of 30 cm × 30 and 25 cm × 25 cm, but the closer spacing 25 cm × 25 cm recorded more number of tillers m^{-2} than remaining spacing.

Das *et al.* (2013) in Bangladesh carried out an experiment with two planting geometry (20 cm × 20 cm and 20 cm × 25 cm) and three nitrogen doses of 46, 68 and 91 kg ha^{-1}. They reported that the impact of spacing on yield and the plant characteristics was significant. The number of panicles per hill and the number of grains per panicle were found to be higher when the spacing was 20 cm × 25 cm. The 20 cm × 20 cm spacing resulted in higher grain and straw yields. However, in terms of harvest index, both spacings showed nearly identical results. The highest yield (4.82 t ha^{-1}) was obtained from a combination of 20 cm × 20 cm and 68 kg N ha^{-1}, while the lowest yield (3.75 t ha^{-1}) was obtained from a combination of 20 cm × 25 cm and 46 kg N ha^{-1}. At 68 kg N ha^{-1}, more panicles per hill, more grains per panicle, and higher grain and straw yields were obtained.

Mondal *et al*. (2013) performed an experiment during the period of December, 2011 to May, 2012 at the field laboratory of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensignh, Bangladesh to evaluate the effect of spacing on assimilate availability, yield attributes and yield of modern rice varieties. Results revealed that number of effective tillers (65.8 m^{-2}) and grain number (101.0 panicle^{-1}) being the highest in the spacing of 20 cm × 20 cm. On the other hand, the lowest number of effective tillers (46.6 m^{-2}) and grain number (86.4 $panicle^{-1}$) was recorded in closer spacing of 20 cm × 10 cm, resulted in the lowest grain yield (31.6 g $hill^{-1}$ and 6.47 t ha^{-1}). Likely, the highest grain weight (39.1 g $hill^{-1}$ and 8.53 t ha^{-1}) was observed in wider spacing of 20 cm × 20 cm due to superiority in yield contributing characters.

Rasool *et al.* (2013) conducted field experiment during *Kharif*, 2005 at the Agronomy Farm of Sher-e Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar. They reported that the plant spacing of 20 × 20 cm significantly recorded higher panicle length, panicle weight more spikelets $panicle^{-1}$, grain $panicle^{-1}$ as compared to 15× 20 cm and 15 × 15 cm spacing. However, plant spacing 15 × 15 cm gave significantly more grain 95 (67.1 q ha^{-1}) and straw yield (92.8 q ha^{-1}) than 15 × 20 cm and 20 × 20 cm spacing.

Uddin *et al*. (2013) also conducted a trial on three nitrogen doses (150, 200 and 250 kg ha^{-1}) and different planting geometry (25 cm × 10 cm, 25 cm × 15 cm, 25 cm × 20 cm and 25 cm × 25 cm) and found that 25 cm × 15 cm gave the maximum grain yield (7.58 t ha^{-1}).

Three high yielding varieties *viz.* BRRI dhan-32, BRRI dhan-33, and BR-11,were tested by Alam *et al*. (2012) with four different spacing 10 cm × 25 cm, 15 cm × 25 cm, 20 cm × 25 cm, and 25 cm × 25 cm. They found that the spacing 15 cm × 25 cm had the maximum plant height (115.36 cm) as compared to other plant spacings.

Dass and Chandra (2012) reported that in rice wider planting geometry of 25 cm × 25 cm contributed to significantly maximum no. of fertile tillers $plant^{-1}$ in comparison with narrow spacing of 20 cm × 20 cm, because the plants got enough space above the ground (shoots) and below the ground (roots) for proper growth, as well as increased light transmission in the canopy.

Sultana *et al*. (2012) investigated the effects of row to row spacing (20 and 25 cm) and intra row spacing (2.5, 5, 10, 15, and 20 cm) on boro rice (BRRI dhan45) and found that spacing of 25 cm × 20 cm resulted in the maximum number of fertile tillers $hill^{-1}$.

Results obtained by a field trial conducted by Banerjee and Pal (2011) during two consecutive wet seasons of 2007 and 2008 at Regional Research Sub-station, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal on sandy clay loam soil showed that transplanting of hybrid rice at different spacing had a significant influence on both yield attributing characters and yield of rice. Hybrid rice seedling planted at closer spacing (15cm × 15cm) recorded maximum number of effective tillers m^{-2} (313) but filled grains $panicle^{-1}$ was lower (131). However, the grain and straw yield was significantly superior (6.02 and 7.46 t ha^{-1}, respectively) than wider spacing 20 × 20 cm (4.23 and 5.84t ha^{-1}, respectively) and 20 × 15 cm (5.53 and 7.27 t ha^{-1}, respectively) due to more number of plant population per unit area.

Bozorgi *et al.* (2011)) investigated the impact of planting geometry on rice yield and yield attributes. The rice cultivar, Hashemi' was evaluated with three different spacings of 15 cm × 15 cm, 20 cm × 20 cm and 25 cm × 25 cm and three different numbers of seedlings hill $^{-1}$ *viz*. 1, 3, and 5 seedling $hill^{-1}$. The highest grain yield (3415 kg ha^{-1}) was obtained with a plant spacing of 15 cm × 15 cm.

Sarkar *et al*. (2011) carried out an field experiment at Bangladesh and noticed the interaction effect of planting geometry and variety (BR-23) and reported that grain yield, biological yield, panicle length, total number of spikelets $panicle^{-1}$, number of grains $panicle^{-1}$, 1000- grain weight and harvest index were maximum when transplanted two seedlings $hill^{-1}$ with the spacing 25 cm within the rows.

In a study it was carried out in Shivamogga, Karnataka by Sridhara *et al*. (2011) with two planting geometry of 45 cm × 20 cm and 30 cm × 30 cm under different methods of establishment. They found that grain yield was 9.79% higher under spacing of 30 cm × 30 cm than spacing of 45 cm × 20 cm because of higher dry matter accumulation, number of panicles per hills and 1000 grain weight.

Mahaddesi *et al*. (2011) in Iran carried out an experiment with with four spacing treatments (11 cm × 30 cm, 15 cm × 30 cm, 20 cm× 20 cm and 25 cm × 25 cm) and found that the 20 cm x 20 cm spacing treatment produced the highest grain yield (8619.1 kg ha-1). The grain yield increased as the spacing was increased up to 20 cm × 20 cm, then decreased as the spacing was increased further.

A trial was conducted in Ludhiana, Punjab by Sharma *et al.* (2011) with two spacing treatments (20 cm × 15 cm and 30 cm × 10 cm) at different sowing dates. They found that the "PAU 201" rice genotype, transplanted on June 15 at 30 cm × 10 cm spacing, produced the more tillers per plant and the maximum yield.

Sridhara *et al*. (2011) carried out a field experiment on different rice cultivar with two plant spacing (45 cm × 20 cm and 30 cm × 30 cm) under different methods of establishment in Shivamoga, Karnataka and revealed that there was increase in grain yield about 9.79 % in 30 cm x 30 cm plant spacing than 45 cm × 20 cm. This was due to higher dry matter accumulation, number of panicles plant^{-1} and test weight at plant spacing of 30 cm × 30 cm.

A study was carried out by Basavaraja *et al*. (2010) with different spacings of 20 cm × 10 cm, 25 cm × 25 cm and 45 cm × 20 cm, in aerobic rice. They found that spacing of 45 cm × 20 cm resulted in longer panicle length and more no. of grains per panicle.

Jena *et al.* (2010) conducted field experiment at Central Research Station, Orissa University of Agriculture & Technology, Bhubaneswar during the dry season of 2003-04 and 2004-05 to evaluate the performance of rice hybrid vis -a- vis the ruling HYV with respect to time of planting and optimum spacing. The study resulted that the planting at 20 cm × 10 cm recorded maximum plant height (69.7 cm) and leaf area index (5.37) whereas, effective tillers clum^{-1} (7.84) and dry matter production (33.85 g) were maximum with wider spacing of 20 cm × 15 cm. However, the 15 cm × 15 cm spacing registered significantly maximum grain yield of 4.83 t ha^{-1}.

Hasanuzzaman *et al*. (2009) investigated the impact of three different plant spacings and four different seedling counts on transplanted rice. The results indicated that the plant spacing of 25 cm × 20 cm, provided the most dry matter in all growth stages, as well as more number of fertile tillers hill^{-1}.

Salahuddin *et al.* (2009) conducted a field experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh to study the response of nitrogen and plant spacing of transplanted aman rice and reported that higher grain yield (4.22 t ha^{-1})

was obtained at closer spacing (25 cm × 10 cm) followed by 25 cm × 15 cm (4.21 t ha^{-1}) and the lowest (3.90 t ha^{-1}) from 25 cm × 20 cm.

Thavapraprakash *et al.* (2008) experimented a field research trial comprising four levels of square geometry (25 cm × 25 cm, 30 cm × 30 cm, 40 cm × 40 cm and 50 cm × 50 cm) under SRI (System of Rice Intensification) and conventional method of planting (20 cm × 10 cm). They reported that number of productive tillers hill^{-1} was significantly more with the 50 cm × 50 cm followed by treatments 40 cm × 40 cm, 30 cm × 30 cm and 25 cm × 25cm *vis-à-vis* the conventional system of planting.

Effect of varying levels of fertilizer and spacing on medium duration rice (*Oryza sativa* L.) in Tarai Zone of West Bengal was studied by Mahato *et al.* (2007) during rainy season of 2000 and 2001 at Instructional Farm of the Uttar Banga Krishi Vishwavidyalaya. Data revealed that closer spacing of 15 × 15 cm produced the significantly higher grain yield (38.45 q ha^{-1}) as compared to wider spacing of 20 × 15 cm (35.37 q ha^{-1}).

Mobasser *et al.* (2007) conducted a field experiment at field of Ghaemshahr Azad University in north of Iran to study the effects of seedling age and planting spaces on yield and yield components of rice (Neda variety). They stated that greatest panicle number m^{-2} (427.3) and the highest rice grain yield (1129 g m^{-2}) were obtained in 15 × 15 cm planting spacing.

To identify the effect of spacing and fertilizer level, Rautaray (2007) planned an experiment at Gerua and Kamrup, Assam on grain yield of rice in rice-rice cropping system and reported that the optimum row spacing and fertilizer dose have significant effect on grain yield of rice by leaving one row after each three rows at spacing of 15 cm × 15 cm and gave highest grain yield of 5.27 t ha-1 during the dry season and 4.51 t ha^{-1} during the wet season.

Jacob and Syriac (2005) conducted the field experiment to study the effects of spacing and weed management practices on transplanted scented rice during the winter season of 2001-2002 and reported that Pusa basmati-1 transplanted with the spacing 20 cm × 10 cm registered the maximum productive tillers hill^{-1}, grain yield and straw yield.

Amin *et al.* (2004) carried out a study to investigate the effect of increased plant spacing and nitrogen dose on yield of rice variety IR-6 at the farm of Faculty of Agriculture, Gomal University Dera Ismail Khan. They found that increased plant spacing significantly increased straw yield, and number of panicles per square meter while increased dose of nitrogen increased plant height, normal kernels, and test weight. Interaction of increased plant spacing and nitrogen dose was found non-significant in respect of plant height, dry matter accumulation and no. of tillers except straw yield.

An experiment conducted by Nayak *et al*. (2003) at Bhubaneswar on rice hybrid PA 6201 and concluded that total and effective tillers hill^{-1} and dry matter accumulation clump-1 were maximum at wider spacing of 20 cm × 15 cm than closer spacing of 20 cm ×10 cm and 15 cm × 15 cm. The grain yield (42.83 q ha^{-1}) at spacing 20 cm × 10 cm was significantly higher than wider spacing of 20 cm × 15 cm (42.23 q ha^{-1}).

Rajesh and Thanunathan (2003) conducted field experiment at Annamalai University Experimental Farm, Annamalainagar during Samba season of 2000 to find out the optimum age of seedlings, number of seedlings hill^{-1} and plant population for a long duration traditional rice *viz.,* „Kambanchamba and investigated that wider spacing of 20 × 15 cm produced significantly higher rice grain yield (2.40 and 2.27 t ha^{-1}) and straw yield (5.68 and 5.53 t ha^{-1}) over closer spacing of 20 × 10 cm and 15 × 15 cm in experiments I and II.

Shivay and singh (2003) conducted the field trail at IARI New Delhi to study the effect of planting geometry and nitrogen level on growth, yield and nitrogen-use efficiency of scented hybrid rice and reported that the plant height, panicle length, 1000-grain weight, grain weight panicle^{-1}, grain yield and straw yield were recorded maximum from plant spacing 20 cm × 15 cm. Singh *et al*. (2003) carried out a field experiment and reported that the spacing and number of seedlings hill^{-1} could not influence significantly the number of filled grains panicle^{-1}, 1000-grain weight, grain yield and straw yield.

From the above literature studies it may be opined that seedling leaf clipping was emerged as good management practice to improve plant establishment on main field. Thereby increasing rice yield with no clipping also proved importance in some cases. Plant spacing showed its significant practices for better yield harvest of rice plant.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh to study on the influence of seedling clipping and plant spacing on growth and yield of BRRI Dhan80. Materials used and methodologies followed in the present investigation have been described in this chapter.

3.1 Experimental period

The experiment was conducted during the period from June to November 2021 in *Aman* season.

3.2 Description of the experimental site

3.2.1 Location

The research was carried out during the rabi season at the Sher-e-Bangla Agricultural University Farm, Sher-e-Bangla Nagar, Dhaka-1207, from February to August 2021. It is located at latitude 90.2^0N and longitude 23.5^0E. The precise location of the experimental site is depicted on a map (Appendix -I)

3.2.2 Soil

According to Bangladesh soil classification, the soil in the experimental field was from the Tejgaon series of AEZ No. 28, Madhupur Tract and was classified as Shallow Red Brown Terrace Soils. A composite sample was prepared prior to the experiment by collecting dirt from various locations across the field at depths ranging from 0 to 15 cm. Before testing for physical and chemical properties, the soil was air-dried, crushed, and sieved through a 2 mm sieve. Appendix II describes some of the soil's early physical and chemical characteristics.

3.2.3 Climatic condition

The experimental site's climate is subtropical, with three distinct seasons: the monsoon season from November to February, the pre-monsoon period or hot season from March to

April, and the monsoon season from May to October. Appendix III shows the monthly average temperature, humidity, and rainfall during the crop growing season as collected from Weather Yard, Bangladesh Meteorological Department.

3.3 Planting material

BRRI dhan80 was used as the plant material for conducting the experiment. BRRI dhan80 is a high yielding aromatic variety of fine rice developed by the Bangladesh Rice Research Institute (BRRI), Gazipur, Bangladesh. The variety was released in 2017 by the authorization of National Seed Board. It takes about 110-120 days to mature in *Aman* season. Seed sown in the seed bed between 25 June -10 July and harvesting was done at the last week of November. Plant are stout, tiller dense on the base of plant, not lodging, grain medium slender, and 1000 grain weight is 26.2 g. This variety gives yield of maximum 5 t ha^{-1} and average 4.5 t ha^{-1}. This is one of the best varieties so far released by BARI.

3.4 Experimental treatment

There were two factors in the experiment namely seedling leaf clipping and plant spacing as mentioned below:

Factor A: Seedling leaf clipping (3) denoted as;

C_0 = No Seedling clipping (Control)
C_1 = Top 1/3 portion seedling clipping
C_2 = Top 1/2 portion seedling clipping

Factor B: Different plant spacing (4) denoted as;

S_1 = 25 cm × 25 cm
S_2 = 25 cm × 20 cm
S_3 = 20 cm × 20 cm
S_4 = 20 cm × 15 cm

3.5 Seed collection and sprouting

BRRI dhan80 rice variety seed was collected from BRRI (Bangladesh Rice Research Institute), Joydebpur, Gazipur. Healthy and disease free seeds were selected by following standard technique. Seeds were immersed in water in a bucket for 24 hrs. 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 hrs.

3.6 Raising of the T. *Aman* 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.

3.7 Experimental design and layout

The present experiment was laid out by using Randomized block design with three replications. The layout consisted of 36 experimental units in three replications with 12 experimental units in each replication. The unit plot size was 5.1 m^2 (3 m × 1.7 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 done after final land preparation.

3.8 Field preparation

The experiment plot was opened with a power tiller in the 1st July, 2021 and left exposed to the sun for a week. After one week, the land was harrowed, ploughed, and cross-ploughed several times before laddering to achieve good tilth. Weeds and stubbles were removed, and a desirable tilth of soil was obtained for seedling transplantation. Drainage channels were built around the land to avoid water logging caused by rainfall during the study period. When the plot was finally ploughed, the soil was treated with Furadan 5G at a rate of 15 kg ha^{-1} to protect the young seedlings from cut worm attack.

3.9 Transplanting of seedlings

Twenty seven days old seedlings were uprooted from nursery and transplanted in the main field. The seedlings were transplanted after its top clipping according to treatments requirements and maintaining plant spacing of 25 cm × 25 cm, 25 cm × 20 cm, 20 cm × 20 cm and 20 cm × 15 cm at random, respectively with two seedlings per hill.

3.10 Fertilizer management

Plant nutrients *viz*. N, P, K, S, and Zn for rice were given through urea (150 kg ha^{-1}), triple superphosphate (100 kg ha^{-1}), muriate of potash (70 kg ha^{-1}), gypsum (60 kg ha^{-1}), and zinc sulphate (10kg ha^{-1}), respectively. Based on the soil test the following doses of fertilizers were applied according to the recommendation by BRRI for the cultivation of T. *aman* rice. All of the fertilizers except urea were applied as basal dose at the time of final land preparation. Urea (150 kg ha^{-1}) was applied in equal three splits. The first dose of urea was applied at 21 days after transplanting (DAT). The second dose of urea was added as top dressing at 45 days (active vegetative stage) after transplanting and the third dose was applied at 60 days (panicle initiation stage) after transplanting recommended by BRRI.

3.11 Intercultural operations

3.11.1 Gap filling

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

3.11.2 Water management

Optimum water level (8-10 cm) was maintained at transplanting and after that shallow level of water was maintained for a week. To maintain the soil moisture near saturation frequent irrigations were given by keeping the rainfall in consideration throughout the growth period of crop. Irrigation was stopped as crop turned towards maturity.

3.11.3 Weed control

Butachlor @ 1.5 kg ha^{-1} was applied after mixing with sand in the field at 2 DAT. Later on, one hand weeding was done at 35 DAT to remove weeds from the plots.

3.11.4 Plant protection measure

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

3.12 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 bug were present in the experimental field. But any bacterial and fungal disease was not observed.

3.13 Harvesting and threshing

The rice plant was harvested depending upon the maturity of grains and harvesting was done manually from each plot. The maturity of the crop was determined when 80–90% of the grains become golden yellow. Five (5) pre-selected hills per plot from which different data were collected and 1.00 m^2 areas from the middle portion of each plot were separately harvested and bundled, properly tagged, and then brought to the threshing floor. Threshing was done by a pedal thresher. The grains were cleaned and sun-dried to a moisture content of 12%. Straw was also sun-dried properly. Finally grain and straw yields $plot^{-1}$ were recorded and converted to t ha^{-1}.

3.14 Data collection

The data were recorded on the following parameters

a. Growth parameters

i. Plant height (cm)
ii. Number of tillers $hill^{-1}$
iii. Above ground dry matter weight of $plant^{-1}$ (g)

iv. Number of effective tillers hill^{-1}

v. Number of non-effective tillers hill^{-1}

b. Yield contributing characters

i. Panicle length (cm)

ii. Number of filled grains panicle^{-1}

iii. Number of unfilled grains panicle^{-1}

iv. 1000- grain weight (g)

c. Yield

i. Grain yield (t ha^{-1})

ii. Straw yield (t ha^{-1})

iii. Biological yield (t ha^{-1})

iv. Harvest index (%)

3.15 Procedure of recording data

i. Plant height (cm)

Height of plant was documented of the tagged hills in all the plots at 30, 60 DAT and at harvest stage. Height was recorded by measuring the longest tiller from the base of the plant to highest terminal point with a meter scale. Then average of all five plants was taken to find out the mean plant height of the plot for analysis.

ii. Number of tillers hill^{-1}

Number of tillers hill^{-1} were counted at 30, 60 DAT and at harvest stage from pre-selected hills and finally averaged as their number hill^{-1}. Only those tillers having three or more leaves were considered for counting.

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

Above ground dry matter hill^{-1} in grams was assessed at 30, 60 DAT and at harvest stage. Randomly three hills in each plot were cut down from ground level, then sun dried and later dried in an oven at 70^0 C for 48 hours. After averaging dry matter obtained from these three hills, mean dry matter accumulation hill^{-1} was calculated for each plot for statistical analysis.

iv. Number of effective tillers hill^{-1}

The total number of effective tillers hill^{-1} was counted as the number of panicle bearing tillers hill^{-1}. Data on effective tiller hill^{-1} were recorded from 5 randomly selected hill at harvesting time and average value was recorded.

v. Number of non-effective tillers hill^{-1}

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

vi. Panicle length (cm)

Panicle length was measured from five panicles collected from each plot at the time of harvesting. The length of each panicle was taken from the base of the panicle to the terminal point with the help of a meter rod. Length of five panicles was averaged to determine panicle length for each plot.

vii. Numbers of filled grains panicle

At the time of harvesting number of filled grains were counted from ten randomly selected effective panicles taken from each plot. Then for each plot mean number of filled grains panicle^{-1} was computed by averaging the number of filled grains in all selected panicles.

viii. Numbers of unfilled grains panicle

At the time of harvesting number of unfilled grains were counted from ten randomly selected effective panicles taken from each plot. Then for each plot mean number of unfilled grains per panicle was computed by averaging the number of unfilled grains in all selected panicles.

ix. 1000-grain weight (g)

From each plot weight of 1000 grains was documented after drying them to a 12-14% moisture level.

x. Grain yield (t ha^{-1})

After harvesting, paddy was threshed separately in each plot and then weighted separately (at 14% moisture level) which was then converted to grain yield (t ha^{-1}).

xi. Straw yield (t ha^{-1})

The straw from threshed crop of each plot was dried in the sun for three days and weighed. The yield of straw per plot was then converted to straw yield in ton per hectare.

xii. Biological yield (t ha^{-1})

All the above ground biomass of experimental crop of each plot was harvest sun dried and weighed in kg plot^{-1} and finally converted in to t ha^{-1}.

xiii. Harvest index (%)

The ratio of grain to biological yield (dry matter) was considered as harvest index which expressed in percentage and calculated with the help of following formula.

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

3.16 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 Statistix 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

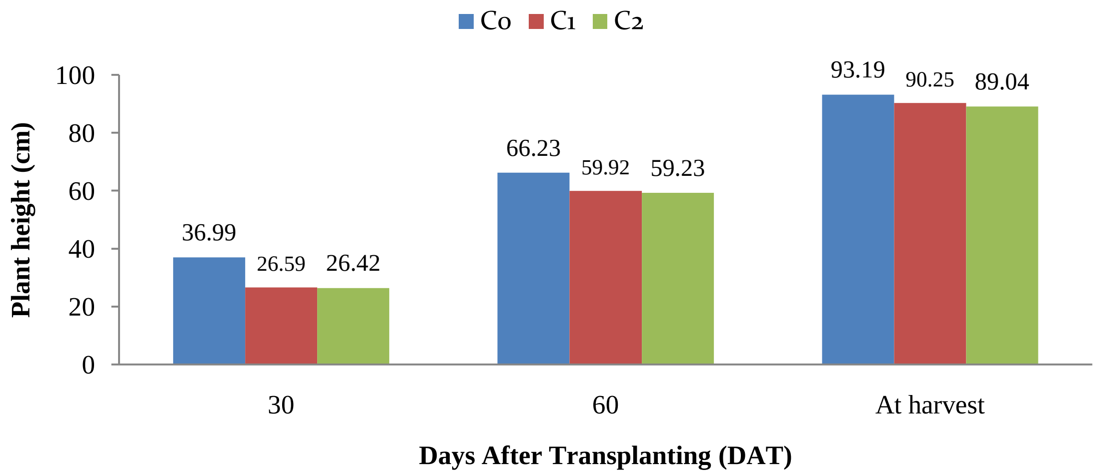
This section contains a presentation and discussion of the study's findings on the influence of seedling leaf clipping and plant spacing on growth and yield of BRRI Dhan80. The information was presented in various tables and figures. The findings had been discussed, and possible interpretations were provided under the headings listed below.

4.1 Plant growth characters

4.1.1 Plant height (cm)

Effect of seedling leaf clipping

No leaf clipping at seedling stage had shown significant effect on plant height of aromatic rice at different days after transplanting (Fig. 1). According to the experimental findings the highest plant height (36.99, 66.23 and 93.19 cm at 30, 60 DAT and at harvest, respectively) was observed in C_0 treatment while the lowest plant height (26.42, 59.23 and 89.04 cm at 30, 60 DAT and harvest, respectively) of aromatic rice was observed in C_2 treatment which was statistically similar to C_1 treatment (26.59, 59.92 and 90.25 cm) 30, 60 DAT and harvest, respectively. Photosynthesis takes place in mesophyll cells of specialized organs like leaves. The rigid cell wall that encases photosynthetic cells regulates cell expansion and distribution within photosynthetic tissues. Leaf area influences the relationship between photosynthesis and plant growth. Clipping leaves reduces photosynthesis area, which reduces photosynthesis and has an impact on plant dry matter accumulation; as a result, plant height becomes shorter when compared to non-clipped plants. The findings of the present study corroborate with the findings of Karmaker and Karmakar (2019) reported 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).

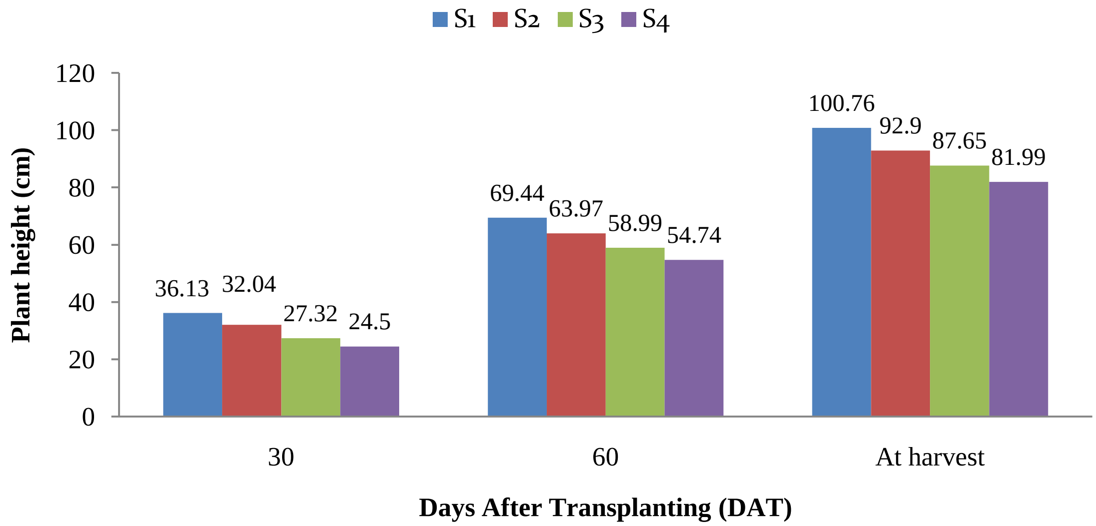


Here, C_0 = No seedling leaf clipping, C_1 = Top 1/3 portion seedling leaf clipping, C_2 = Top 1/2 portion seedling leaf clipping.

Figure. 1. Effect of seedling leaf clipping on plant height at different days after transplanting of aromatic rice ($LSD_{0.05}$ = 1.46, 2.48 and 2.63 at 30, 60 DAT and harvest, respectively).

Effect of plant spacings

Plant height is an essential character of the vegetative stage of the crop plant and indirectly impacts on yield of crop plants. Different plant spacings significantly influenced on plant height of aromatic rice at different days after transplanting (DAT). It was seen that height increased gradually with the age of the crop (Fig. 2). Experimental result revealed that the highest plant height (36.13, 69.44 and 100.76 cm at 30, 60 DAT and harvest, respectively) was observed in S_1 (25 cm × 25 cm) treatment, whereas, the lowest plant height (24.50, 54.74 and 81.99 at 30, 60 DAT and harvest, respectively) was observed in S_4 (20 cm × 15 cm) treatment. In general, height was increased as the plant spacing was increased indicating tendency of plant to grow tall under adequate space which might be due to less competition for light and CO_2 between plants. The result obtained from the present study was similar with the findings of Oyange *et al.* (2019) reported that the growth characters such as plant height, was significantly higher at 30 cm × 15 cm wider plant spacing than 20 cm × 15 cm spacing level.



Here, S_1 = 25 cm × 25 cm, S_2 = 25 cm × 20 cm, S_3 = 20 cm × 20 cm and S_4 = 20 cm × 15 cm.

Figure. 2. Effect of plant spacings on plant height at different days after transplanting of aromatic rice ($LSD_{0.05}$ = 1.68, 2.87 and 3.03 at 30, 60 DAT and harvest, respectively).

Combined effect of seedling leaf clipping and plant spacings

The combined effect of seedling leaf clipping and plant spacings caused significant variation in respect of aromatic rice plant height at different days after transplanting (Table 1). Experimental result showed that, the highest plant height (43.93, 73.48 and 103.04 cm at 30, 60 DAT and harvest, respectively) was observed in C_0S_1 treatment combination, which was statistically similar with C_0S_2 (69.47 cm) and C_1S_1 (69.38 cm) at 60 DAT and with C_1S_1 (100.71 cm) and C_2S_1 (98.52 cm) treatment combination harvest, respectively. While the lowest plant height (20.41, 51.85 and 80.29 cm at 30, 60 DAT and harvest, respectively) was observed in C_2S_4 treatment combination which was statistically similar with C_1S_4 (20.56, 52.76 and 81.96 cm) at 30, 60 DAT and harvest, respectively and with C_0S_4 (83.71 cm) treatment combination harvest, respectively.

Table 1. Combined effect of seedling leaf clipping and plant spacings on plant height at different days after transplanting of aromatic rice

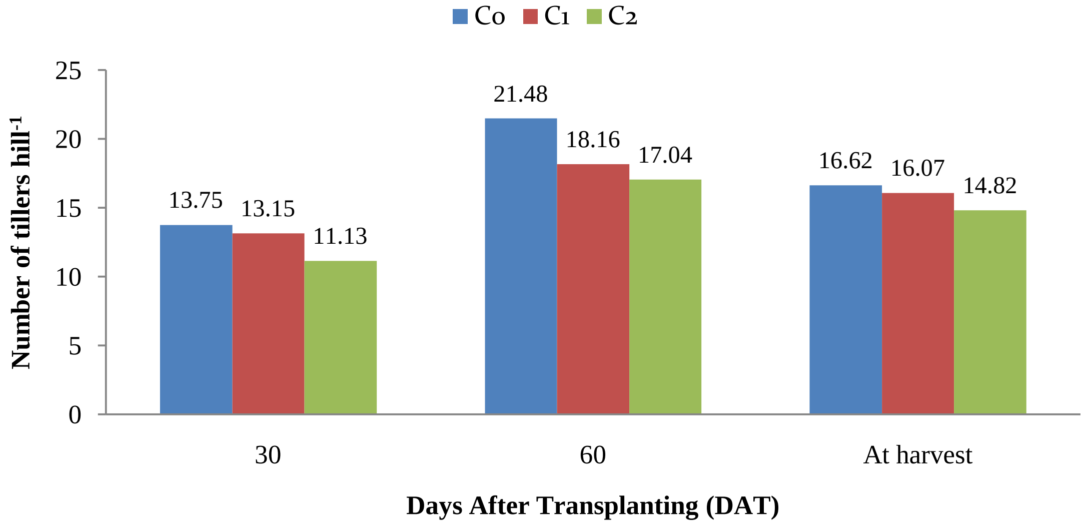
Treatment combinations	Plant height (cm) at		
	30 DAT	**60 DAT**	**At harvest**
C_0S_1	43.93 a	73.48 a	103.04 a
C_0S_2	40.85 b	69.47 ab	95.09 bc
C_0S_3	30.64 de	62.28 cd	90.92 c-e
C_0S_4	32.53 cd	59.62 de	83.71 fg
C_1S_1	35.05 c	69.38 ab	100.71 a
C_1S_2	25.66 f	60.60 c-e	92.54 c
C_1S_3	25.09 f	56.93 ef	85.77 ef
C_1S_4	20.56 g	52.76 fg	81.96 fg
C_2S_1	29.42 e	65.47 bc	98.52 ab
C_2S_2	29.62 de	61.84 c-e	91.06 cd
C_2S_3	26.23 f	57.75 de	86.27 d-f
C_2S_4	20.41 g	51.85 g	80.29 g
$LSD_{0.05}$	2.92	4.97	5.26
CV%	5.76	4.76	3.42

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, C_0 = No Seedling leaf clipping, C_1 = Top 1/3 portion seedling leaf clipping, C_2 = Top 1/2 portion seedling leaf clipping, S_1 = 25 cm × 25 cm, S_2 = 25 cm × 20 cm, S_3 = 20 cm × 20 cm and S_4 = 20 cm × 15 cm.

4.1.2 Number of tillers hill^{-1}

Effect of seedling leaf clipping

No leaf clipping at the seedling stage had a significant effect on aromatic rice tillers number hill^{-1} at different days after transplanting (Fig. 3). According to the experimental findings, the highest number of tillers hill^{-1} of aromatic rice (13.75, 21.48 and 16.62 at 30, 60 DAT and harvest, respectively) was observed in C_0 treatment which was statistically similar with C_1 (16.07) treatment harvest respectively, while the lowest number of tillers hill^{-1} of aromatic rice (11.13, 17.04 and 14.82 at 30, 60 DAT and harvest, respectively) was observed in C_2 treatment. The result was similar with the findings of Moballeghi *et al.* (2018).

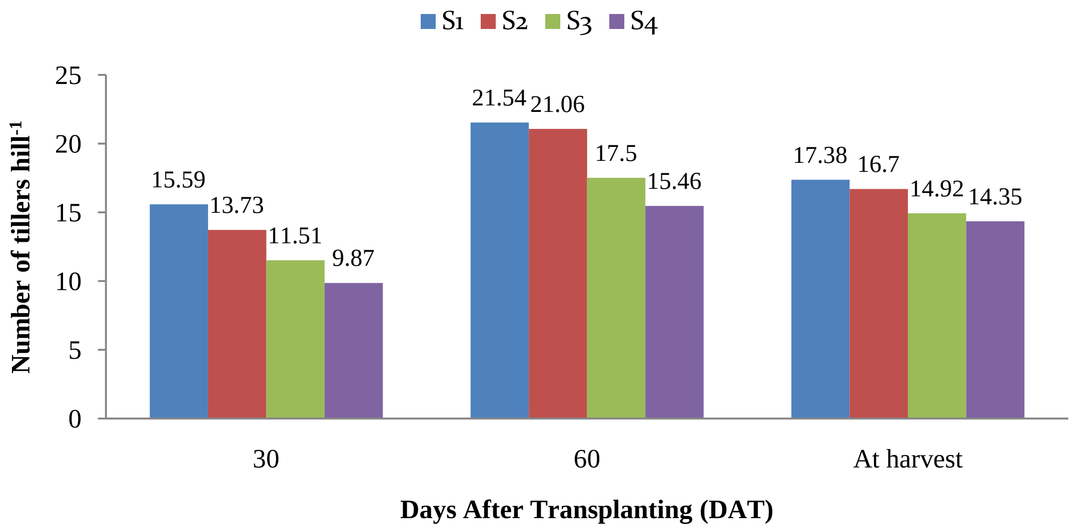


Here, C_0 = No seedling leaf clipping, C_1 = Top 1/3 portion seedling leaf clipping, C_2 = Top 1/2 portion seedling leaf clipping.

Figure. 3. Effect of seedling leaf clipping on number of tillers hill^{-1} at different days after transplanting of aromatic rice ($LSD_{0.05}$ = 0.28, 0.73 and 0.76 at 30, 60 DAT and harvest, respectively).

Effect of plant spacings

Various plant spacing showed significant effect on tillers number hill^{-1} at different days after transplanting (Fig. 4). The results of the experiment showed that the S_1 treatment had the highest number of tillers hill^{-1} of aromatic rice (15.59, 21.54 and 17.38 at 30, 60 DAT and harvest, respectively) which was statistically similar with S_2 (21.06 and 16.70) at 60 DAT and harvest, respectively treatment. While the S_4 treatment had the lowest number of tillers hill^{-1} of aromatic rice (9.87, 15.46 and 14.35 at 30, 60 DAT and harvest, respectively) which was statistically similar with S_3 (14.92) treatment harvest, respectively. Joshi *et al.* (2016) also found similar result which supported the present finding and reported that wider spacing increasing tillers number hill^{-1} comparable to closest spacing.



Here, S_1 = 25 cm × 25 cm, S_2 = 25 cm × 20 cm, S_3 = 20 cm × 20 cm and S_4 = 20 cm × 15 cm.

Figure. 4. Effect of plant spacings on number of tillers hill^{-1} at different days after transplanting of aromatic rice ($LSD_{0.05}$ = 0.68, 0.84 and 0.88 at 30, 60 DAT and harvest, respectively).

Combined effect of seedling leaf clipping and plant spacings

The combined effect of seedling leaf clipping and plant spacings, had shown significant variation in respect of tillers number hill^{-1} of aromatic rice at different days after transplanting (Table 2). The results of the experiment revealed that the C_0S_1 treatment combination had the highest number of number of tillers hill^{-1} of aromatic rice (17.33, 23.97 and 18.70 at 30, 60 DAT and harvest, respectively), which was statistically comparable to C_0S_2 (18.10) combination treatments harvest, respectively. While the C_2S_4 combination treatment showed the lowest number of tillers hill^{-1} of aromatic rice (9.20, 13.86 and 13.10 at 30, 60 DAT and harvest, respectively) which was statistically comparable to C_2S_3 (10.33, 14.86 and 14.10) at 30, 60 DAT and harvest, respectively and with C_0S_4 (14.43) harvest, respectively.

Table 2. Combined effect of seedling leaf clipping and plant spacings on number of tillers hill^{-1} at different days after transplanting of aromatic rice

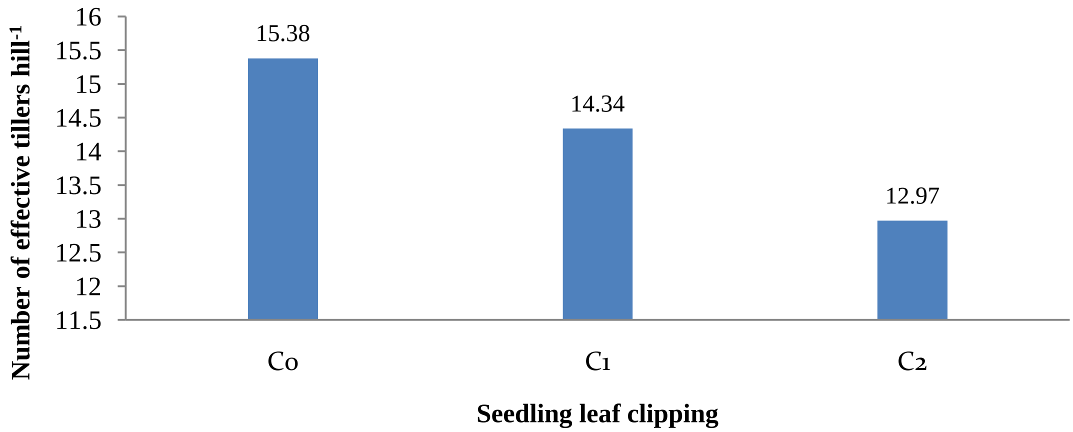
Treatment combinations	Number of tillers hill^{-1} at		
	30 DAT	**60 DAT**	**At harvest**
C_0S_1	17.33 a	23.97 a	18.70 a
C_0S_2	15.67 b	23.97 a	18.10 ab
C_0S_3	12.00 d	20.76 bc	15.23 d-f
C_0S_4	10.00 ef	17.20 e	14.43 e-g
C_1S_1	16.77 ab	21.33 b	17.10 bc
C_1S_2	13.20 c	19.10 d	16.23 cd
C_1S_3	12.20 cd	16.87 e	15.43 d-f
C_1S_4	10.42 e	15.33 f	15.53 d-f
C_2S_1	12.67 cd	19.33 cd	16.33 cd
C_2S_2	12.33 cd	20.10 b-d	15.76 c-e
C_2S_3	10.33 ef	14.86 fg	14.10 fg
C_2S_4	9.20 f	13.86 g	13.10 g
$LSD_{0.05}$	1.19	1.46	1.52
CV%	5.56	4.59	5.69

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, C_0 = No Seedling leaf clipping, C_1 = Top 1/3 portion seedling leaf clipping, C_2 = Top 1/2 portion seedling leaf clipping, S_1 = 25 cm × 25 cm, S_2 = 25 cm × 20 cm, S_3 = 20 cm × 20 cm and S_4 = 20 cm × 15 cm.

4.1.3 Number of effective tillers hill^{-1}

Effect of seedling leaf clipping

Different seedling leaf clipping practices had shown significant influenced on the number of effective tillers hill^{-1} of aromatic rice (Fig. 5). According to the experimental findings, the highest the number of effective tillers hill^{-1} of aromatic rice (15.38) was observed in C_0 treatment, while the lowest number of effective tillers hill^{-1} of aromatic rice (15.05) was observed in C_2 (12.97) treatment. The result was similar with the finding of Fatima *et al.* (2019) who reported that the highest number of effective tillers hill^{-1} was recorded from Heera 4 under control (without leaf cutting) condition.

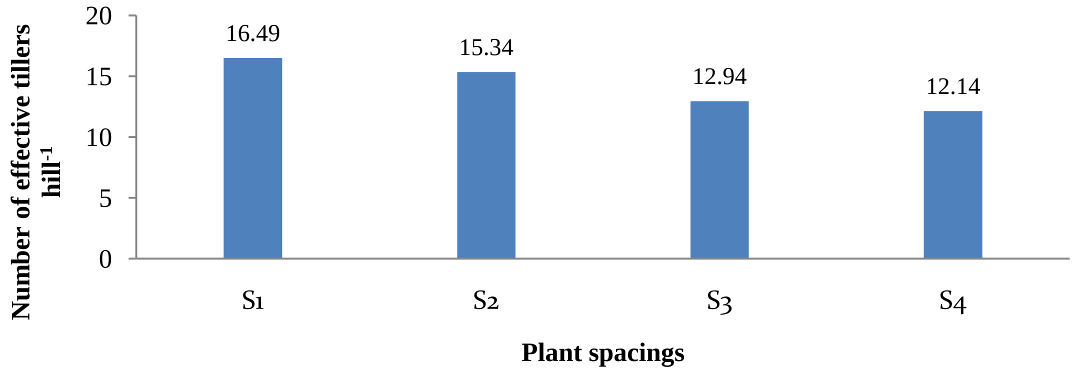


Here, C_0 = No seedling leaf clipping, C_1 = Top 1/3 portion seedling leaf clipping, C_2 = Top 1/2 portion seedling leaf clipping.

Figure. 5. Effect of seedling leaf clipping on number of effective tillers hill^{-1} of aromatic rice at harvest ($LSD_{0.05}$ = 0.76).

Effect of plant spacings

Different plant spacings had shown significant impact on the number of effective tillers hill^{-1} of aromatic rice (Fig. 6). The results of the experiment showed that the S_1 treatment had the highest number of effective tillers hill^{-1} of aromatic rice (16.49) which was statistically similar with S_2 (15.34) treatment. While the S_4 treatment had the lowest number of effective tillers hill^{-1} of aromatic rice (12.14) which was statistically similar with S_3 (12.94) treatment. The highest number of effective tillers hill^{-1} was observed in wider spacing could be due to having more sunlight, which leads to more photosynthesis and thus more space for producing a greater number of effective tillers hill^{-1}. Moro *et al.* (2016) also found similar result which support the present study and reported that the production of effective tillers hill^{-1} was significantly influenced by spacing. Thawait *et al*. (2014) also reported that planting of 2-3 seedlings hill^{-1} transplanted in the spacing of 25 cm × 25 cm recorded significantly number of effective tillers hill^{-1} of rice.



Here, S_1 = 25 cm × 25 cm, S_2 = 25 cm × 20 cm, S_3 = 20 cm × 20 cm and S_4 = 20 cm × 15 cm.

Figure. 6. Effect of plant spacings on number of effective tillers hill^{-1} of aromatic rice at harvest ($LSD_{0.05}$ = 0.88).

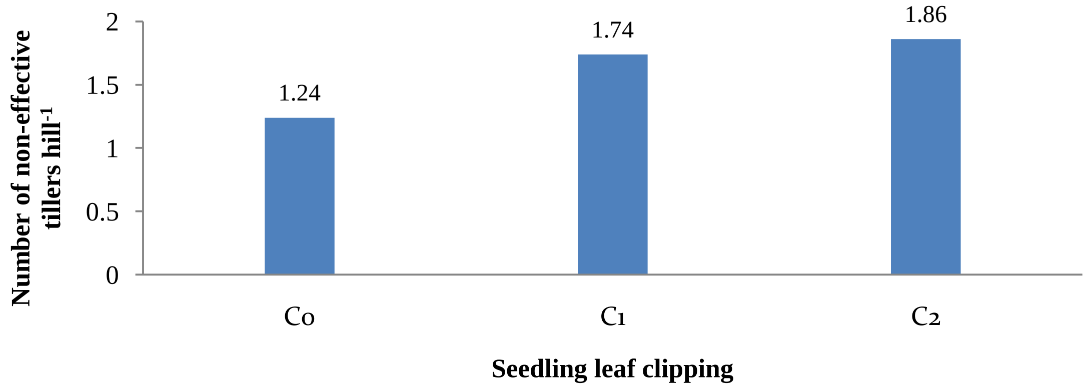
Combined effect of seedling leaf clipping and plant spacing

Due to the combined effect of seedling leaf clipping and plant spacing, the number of effective tillers hill^{-1} of aromatic rice significantly varied at harvest (Table 3). The results of the experiment revealed that the C_0S_1 treatment combination had the highest number of effective tillers hill^{-1} of aromatic rice (18.37), which was statistically comparable to C_0S_2 (17.23) combination treatments. While the C_2S_4 combination treatment showed the lowest number of effective tillers hill^{-1} of aromatic rice (10.43).

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

Effect of seedling leaf clipping

The number of non-effective tillers hill^{-1} of aromatic rice was significantly influenced by different seedling leaf clipping practices (Fig. 7). According to the experimental results, the C_2 treatment had the highest number of non-effective tillers hill^{-1} of aromatic rice (1.86), while the C_0 treatment had the lowest number of effective tillers hill^{-1} of aromatic rice (1.24).

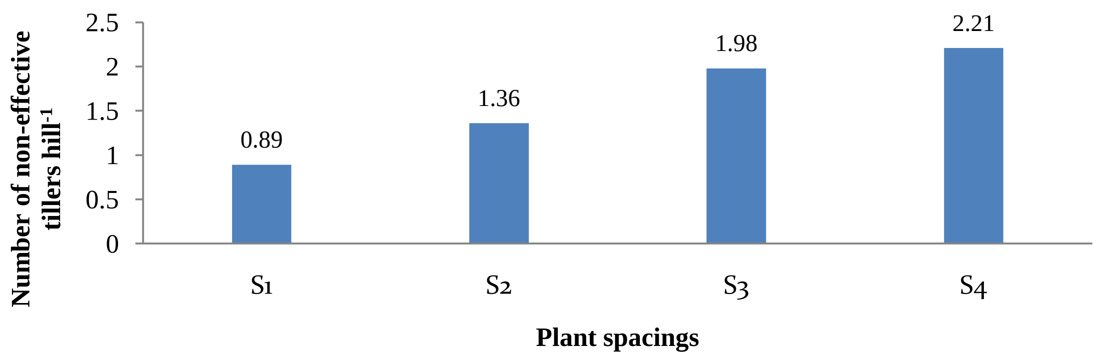


Here, C_0 = No seedling leaf clipping, C_1 = Top 1/3 portion seedling leaf clipping, C_2 = Top 1/2 portion seedling leaf clipping.

Figure. 7. Effect of seedling leaf clipping on number of non-effective tillers hill^{-1} of aromatic rice at harvest ($LSD_{0.05}$ = 0.07).

Effect of plant spacings

The number of non-effective tillers hill^{-1} of aromatic rice was significantly affected by plant spacing (Fig. 8). The experiment results showed that the S_4 treatment had the highest number of non-effective tillers hill^{-1} of aromatic rice (2.21). While the S_1 treatment had the lowest number of non-effective tillers hill^{-1} of aromatic rice (0.89).



Here, S_1 = 25 cm × 25 cm, S_2 = 25 cm × 20 cm, S_3 = 20 cm × 20 cm and S_4 = 20 cm × 15 cm.

Figure. 8. Effect of plant spacings on number of non-effective tillers hill^{-1} of aromatic rice at harvest ($LSD_{0.05}$ = 0.08).

Combined effect of seedling leaf clipping and plant spacings

The number of non-effective tillers hill^{-1} of aromatic rice varied significantly at harvest due to the combined effect of seedling leaf clipping and plant spacing (Table 3). The experiment results showed that the C_2S_4 treatment combination had the highest number of non-effective tillers hill^{-1} of aromatic rice (2.67), on the other hand, the number of non-effective tillers hill^{-1} of aromatic rice (0.33) C_2S_4 treatment combination.

Table 3. Combined effect of seedling leaf clipping and plant spacings on effective tillers hill^{-1} and non-effective tillers hill^{-1} of aromatic rice

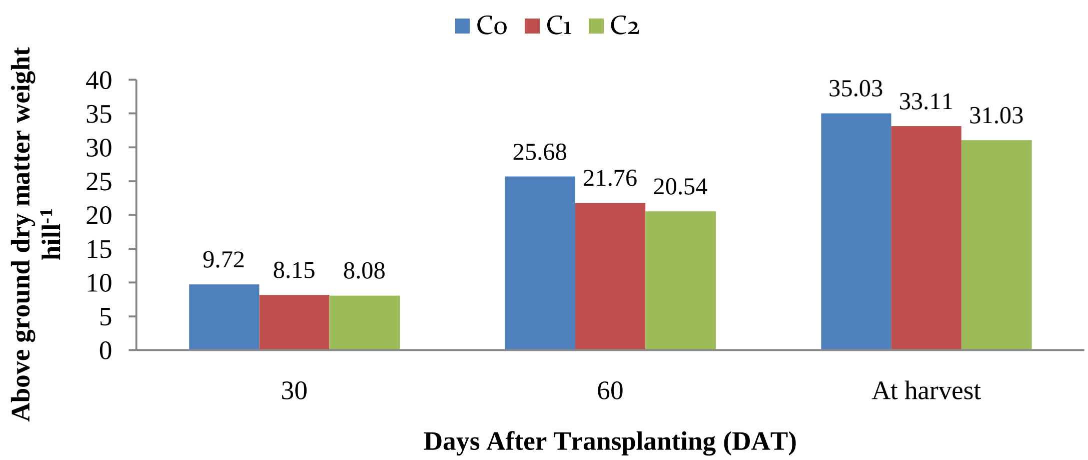
Treatment Combinations	Effective tillers hill^{-1} (no.)	Non-effective tillers hill^{-1} (no.)
C_0S_1	18.37 a	0.33 f
C_0S_2	17.23 ab	0.87 e
C_0S_3	13.36 ef	1.87 c
C_0S_4	12.56 f	1.87 c
C_1S_1	16.10 bc	1.00 e
C_1S_2	14.36 de	1.87 c
C_1S_3	13.46 ef	1.97 bc
C_1S_4	13.43 ef	2.10 b
C_2S_1	15.00 cd	1.33 d
C_2S_2	14.43 de	1.33 d
C_2S_3	12.00 f	2.10 b
C_2S_4	10.43 g	2.67 a
$LSD_{0.05}$	1.53	0.14
CV%	5.14	5.36

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, C_0 = No Seedling leaf clipping, C_1 = Top 1/3 portion seedling leaf clipping, C_2 = Top 1/2 portion seedling leaf clipping, S_1 = 25 cm × 25 cm, S_2 = 25 cm × 20 cm, S_3 = 20 cm × 20 cm and S_4 = 20 cm × 15 cm.

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

Effect of seedling leaf clipping

Seedling leaf clipping had shown significant effect on above ground dry matter weight hill^{-1} at different days after transplanting (Fig. 9). According to the experimental findings the highest above ground dry matter weight hill^{-1} (9.72, 25.68 and 35.03 and g hill^{-1} at 30, 60 DAT and at harvest respectively), was observed in C_0 treatment, while the lowest above ground dry matter weight hill^{-1} (8.08, 20.54 and 31.03 and g hill^{-1} at 30, 60 DAT and at harvest respectively), was observed in C_2 treatment which was statistically similar with C_1 (8.15) treatment at 30 DAT. Plant dry matter accumulation increases when photosynthesis exceeds respiration, allowing the plant to grow and develop. However, leaf clipping reduces leaf area, resulting in less photosynthesis, which has an impact on plant development when compared to a non-clipped plant. The result was similar with the findings of Safari *et al*. (2013) who reported that maize crop without defoliation recorded significantly highest dry matter accumulation (3450.40 g m^{-2}) as compared to other treatments of defoliation.

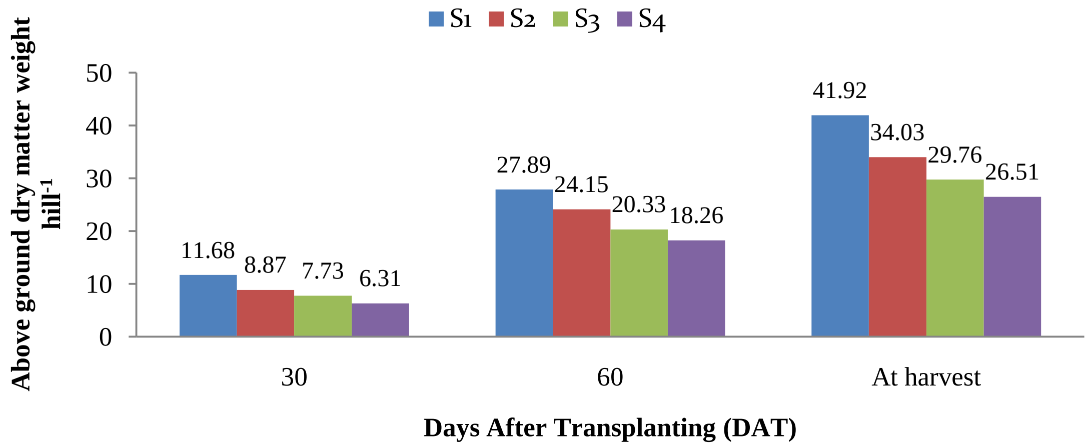


Here, C_0 = No seedling leaf clipping, C_1 = Top 1/3 portion seedling leaf clipping, C_2 = Top 1/2 portion seedling leaf clipping.

Figure. 9. Effect of seedling leaf clipping on above ground dry matter weight hill^{-1} at different days after transplanting of aromatic rice ($LSD_{0.05}$ = 0.48, 0.98, and 1.31 at 30, 60 DAT and harvest, respectively).

Effect of plant spacings

The above ground dry matter weight hill^{-1} of aromatic rice was significantly affected by various plant spacing (Fig. 10). The results of the experiment showed that the S_1 treatment had the highest above ground dry matter weight hill^{-1} aromatic rice (11.68, 27.89 and 41.92 g hill^{-1} at 30, 60 DAT and at harvest respectively), while the S_4 treatment had the lowest above ground dry matter weight hill^{-1} aromatic rice (6.31, 18.26 and 26.51 g hill^{-1} at 30, 60 DAT and at harvest respectively). The variation of above ground dry matter weight hill^{-1} of aromatic rice among different treatment due to availability of more space for plant spread, getting more sunlight and CO_2 for better growth and development of the plant. The current study's findings were similar to those of Thawait *et al*. (2014) who reported that planting of 2-3 seedlings hill^{-1} transplanted in the spacing of 25 cm × 25 cm recorded significantly higher plant height, number of tillers, dry matter accumulation, yield attributes, grain yield and straw yield of rice.



Here, S_1 = 25 cm × 25 cm, S_2 = 25 cm × 20 cm, S_3 = 20 cm × 20 cm and S_4 = 20 cm × 15 cm.

Figure. 10. Effect of plant spacings on above ground dry matter weight hill^{-1} at different days after transplanting of aromatic rice ($LSD_{0.05}$ = 0.56, 1.13 and 1.51 at 30, 60 DAT and harvest, respectively).

Combined effect of seedling leaf clipping and plant spacings

The above ground dry matter weight hill^{-1} of aromatic rice significantly varied due to the combined effect of seedling leaf clipping and plant spacing at different days after transplanting (Table 4). Experimental result showed that, the highest above ground dry matter weight hill^{-1} of aromatic rice (12.43, 30.31 and 44.15 g hill^{-1} at 30, 60 DAT and at harvest respectively) was observed in C_0S_1 treatment combination, which was statistically similar with C_2S_1 (11.56 g hill^{-1}) at 30 DAT and with C_1S_1 (28.80 and 41.87 g hill^{-1}) at 60 DAT and at harvest respectively. While the lowest above ground dry matter weight hill^{-1} of aromatic rice (5.54, 16.52 and 24.74 g hill^{-1} at 30, 60 DAT and at harvest respectively) was observed in C_2S_4 treatment combination which was statistically similar with C_1S_4 (5.90, 17.30 and 27.05 g hill^{-1}) treatment combination at 30, 60 DAT and at harvest respectively and with C_1S_3 (18.13 g hill^{-1}) treatment combination at 60 DAT (Table 4).

Table 4. Combined effect of seedling leaf clipping and plant spacing on above ground dry matter weight hill^{-1} at different days after transplanting of aromatic rice

Treatment combinations	Above ground dry matter weight hill^{-1} at		
	30 DAT	60 DAT	At harvest
C_0S_1	12.43 a	30.31 a	44.15 a
C_0S_2	10.35 c	27.45 b	36.21 c
C_0S_3	8.60 de	24.00 cd	32.00 de
C_0S_4	7.48 f	20.95 e	27.74 fg
C_1S_1	11.06 bc	28.80 ab	41.87 ab
C_1S_2	8.80 d	22.79 c-e	33.67 cd
C_1S_3	6.84 fg	18.13 fg	29.85 ef
C_1S_4	5.90 gh	17.30 fg	27.05 gh
C_2S_1	11.56 ab	24.55 c	39.73 b
C_2S_2	7.45 f	22.20 de	32.21 de
C_2S_3	7.76 ef	18.87 f	27.42 fg
C_2S_4	5.54 h	16.52 g	24.74 h
$LSD_{0.05}$	0.97	1.97	2.63
CV%	6.68	5.15	4.70

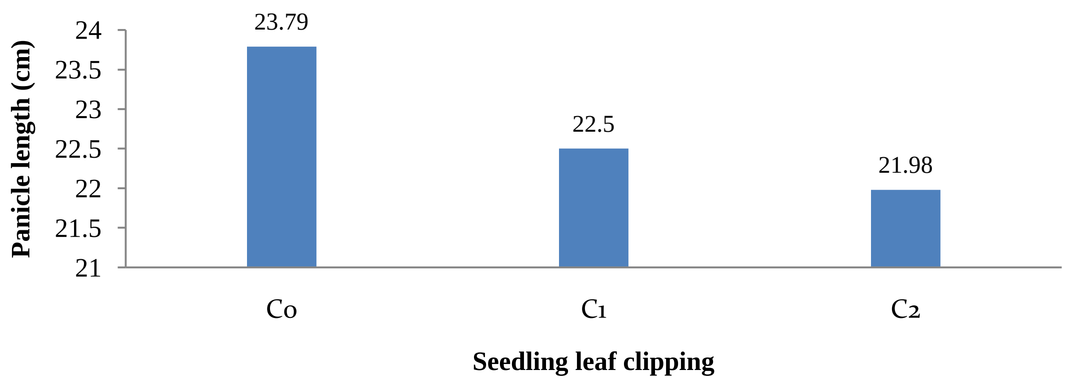
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, C_0 = No Seedling leaf clipping, C_1 = Top 1/3 portion seedling leaf clipping, C_2 = Top 1/2 portion seedling leaf clipping, S_1 = 25 cm × 25 cm, S_2 = 25 cm × 20 cm, S_3 = 20 cm × 20 cm and S_4 = 20 cm × 15 cm.

4.2 Yield contributing characters

4.2.1 Panicle length (cm)

Effect of seedling leaf clipping

Different levels of seedling leaf clipping practices had shown significant effect on panicle length of aromatic rice (Fig. 11). Experimental result showed that the highest panicle length of aromatic rice (23.79 cm) was found in C_0 treatment. Whereas the lowest panicle length of aromatic rice (21.98 cm) was found in C_2 treatment which was statistically similar with C_1 (22.50 cm) treatment. Clipping of seedling leaves has an impact on phenology, morphology, dry mass production, and partitioning of plant products. In aromatic rice crop, the leaf is the primary source of assimilate supply for developing vegetative organs, as well as cob production and grain yield. Depending on the magnitude of leaf clipping, leaf removal may influence yield and yield contributing characters via photosynthetic production and distribution into plant parts. The result was similar with the findings of Boonreund and Marsom (2015) who observed that panicle length of rice was varied due to different seedling clipping treatments.

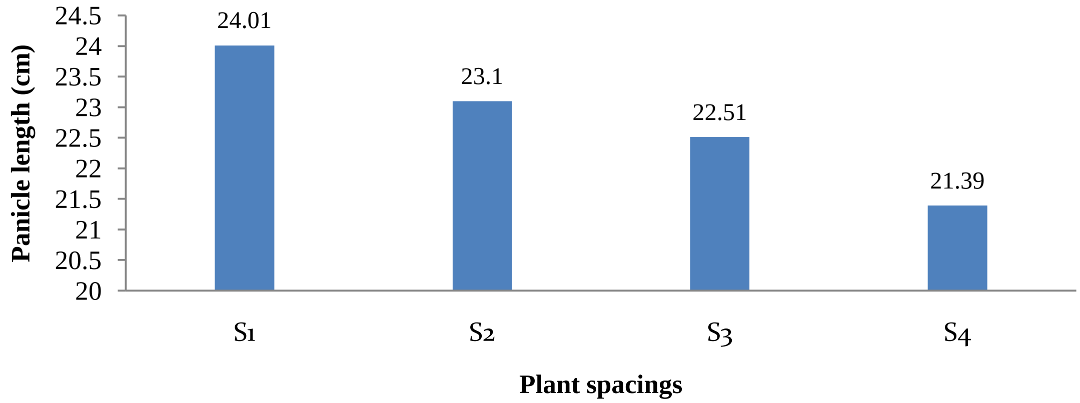


Here, C_0 = No seedling leaf clipping, C_1 = Top 1/3 portion seedling leaf clipping, C_2 = Top 1/2 portion seedling leaf clipping.

Figure. 11. Effect of seedling leaf clipping on panicle length of aromatic rice at harvest ($LSD_{0.05}$ = 0.71).

Effect of plant spacings

The panicle length of aromatic rice was significantly influenced by different plant spacings (Fig. 12). Experimental result revealed that the highest panicle length of aromatic rice (24.01 cm) was found in S_1 treatment. Whereas the lowest panicle length of aromatic rice (21.39 cm) was found in S_4 treatment. Increased panicle length may be due to less competition between plants as well as adequate nutrient availability, which resulted in increased photosynthesis, which promotes metabolic activity, increases cell division, and ultimately increases panicle length plant^{-1}. The result was similar wtth the findings of Rasool *et al.* (2013) who reported that wide plant spacing significantly influenced panicle length of rice compared to close plant spacing.



Here, S_1 = 25 cm × 25 cm, S_2 = 25 cm × 20 cm, S_3 = 20 cm × 20 cm and S_4 = 20 cm × 15 cm.

Figure. 12. Effect of plant spacings on panicle length of aromatic rice at harvest ($LSD_{0.05}$ = 0.82).

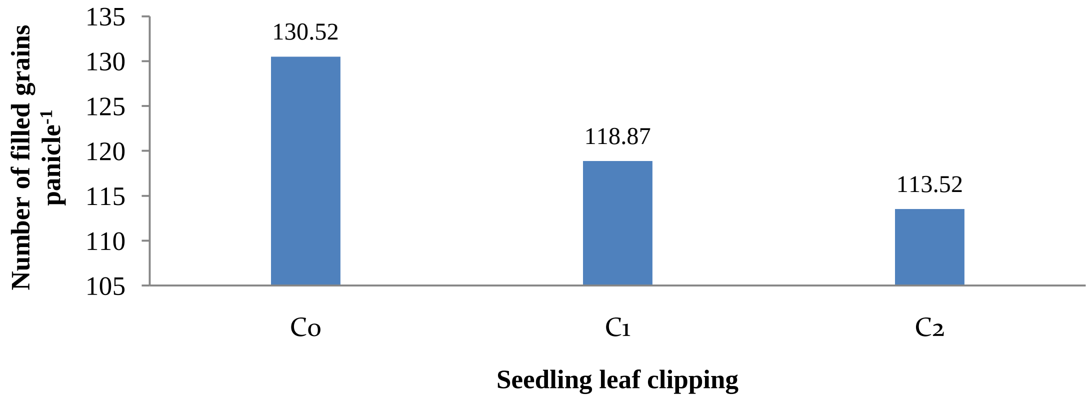
Combined effect of seedling leaf clipping and plant spacings

The panicle length of aromatic rice significantly varied due to the combined effect of seedling leaf clipping and plant spacing. Experimental result showed that, the highest panicle length of aromatic rice (25.74 g) was observed in C_0S_1 treatment combination. While the lowest panicle length of aromatic rice (20.74 cm) was observed in C_2S_4 treatment combination which was statistically similar with C_2S_3 (22.10 cm) and C_1S_4 (13.32 cm) treatment combination (Table 5).

4.2.2 Number of filled grains panicle^{-1}

Effect of seedling leaf clipping

The number of filled grains panicle^{-1} of aromatic rice significantly influenced due to effect of seedling leaf clipping (Fig. 13). The result of the experiment revealed that, the highest number of filled grains panicle^{-1} (130.52) was observed in C_0 treatment, while the lowest number of filled grains panicle^{-1} (113.52) was observed in C_2 treatment. This is because leaves are responsible for photosynthesis, which is the process by plants that convert sunlight into energy. When leaves are clipped, the plant's ability to photosynthesize is reduced, which can lead to a decrease in the number of grains that are filled. The amount of reduction in filled grains will depend on the number of leaves that are clipped. This finding was consistent with the findings of Fatima *et al.* (2019), who discovered that seedling clipping regime had a significant effect on filled grains panicle^{-1} of rice.

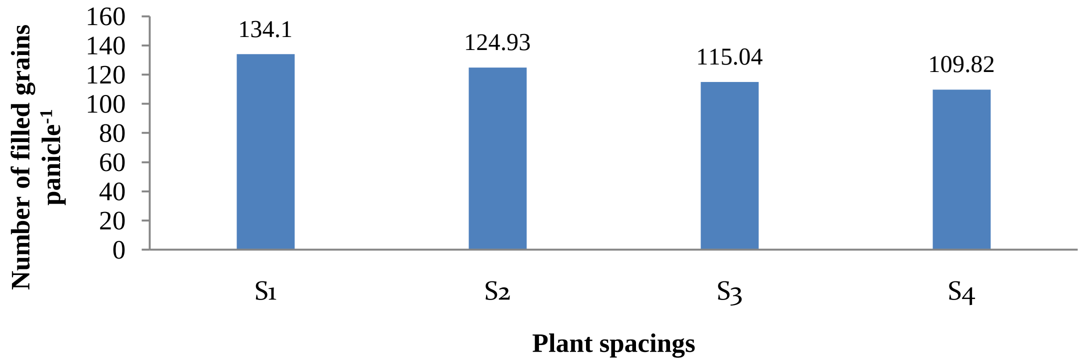


Here, C_0 = No seedling leaf clipping, C_1 = Top 1/3 portion seedling leaf clipping, C_2 = Top 1/2 portion seedling leaf clipping.

Figure. 13. Effect of seedling leaf clipping on number of filled grains panicle^{-1} of aromatic rice at harvest ($LSD_{0.05}$ = 5.05).

Effect of plant spacings

The number of filled grains panicle^{-1} of aromatic was significantly affected by various plant spacings (Fig. 14). The results of the experiment showed that the S_1 treatment had the highest number of filled grains panicle^{-1} (134.10). While the S_4 treatment had the lowest number of filled grains panicle^{-1} (109.82) which was statistically similar with S_3 (115.04) treatment. Seedlings transplanted at wider spacing got sufficient space to grow and also utilized the resources in better way and hence performed better as individual plants result in higher number of filled grains panicle^{-1} of rice. The current study's findings were similar to those of Rajesh and Thanunathan (2003), who reported that wider spacing resulted in less below and above ground competition for better grain filling, higher grain weight, and a greater number of filled grains panicle^{-1} of rice.



Here, S_1 = 25 cm × 25 cm, S_2 = 25 cm × 20 cm, S_3 = 20 cm × 20 cm and S_4 = 20 cm × 15 cm.

Figure. 14. Effect of plant spacings on number of filled grains panicle^{-1} of aromatic rice at harvest ($LSD_{0.05}$ = 5.84).

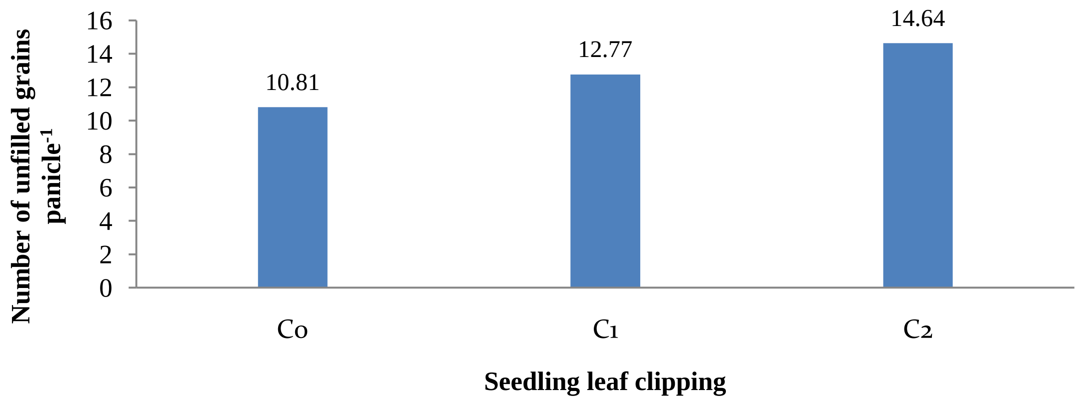
Combined effect of seedling leaf clipping and plant spacings

The combined effects of seedling leaf clipping and plant spacing caused a significant variation in the number of filled grains panicle^{-1} of aromatic rice. According to the experimental findings, the C_0S_1 combination treatment had the highest number of filled grains panicle^{-1} of aromatic rice (142.70) which was statistically similar with C_0S_2 (137.50) treatment combination. While the C_2S_4 combination treatment showed the lowest number of filled grains panicle^{-1} of aromatic rice (99.57) which was statistically similar with C_2S_3 (107.94) and C_1S_4 (108.41) treatment combination (Table 5).

4.2.3 Number of unfilled grains panicle^{-1}

Effect of seedling leaf clipping

The effect of seedling leaf clipping on the number of unfilled grains panicle^{-1} of aromatic rice was significant (Fig. 15). The experiment revealed that the C_2 treatment had the highest number of unfilled grains panicle^{-1} (14.64), while the C_0 treatment had the lowest number of unfilled grains panicle^{-1} (10.81). The present study's findings were similar to those of Das *et al*. (2017), who reported that in the case of rice, unfilled grain number increased with higher intensity of leaf cutting and lowest unfilled grain was observed in the control or without leaf cutting of rice.

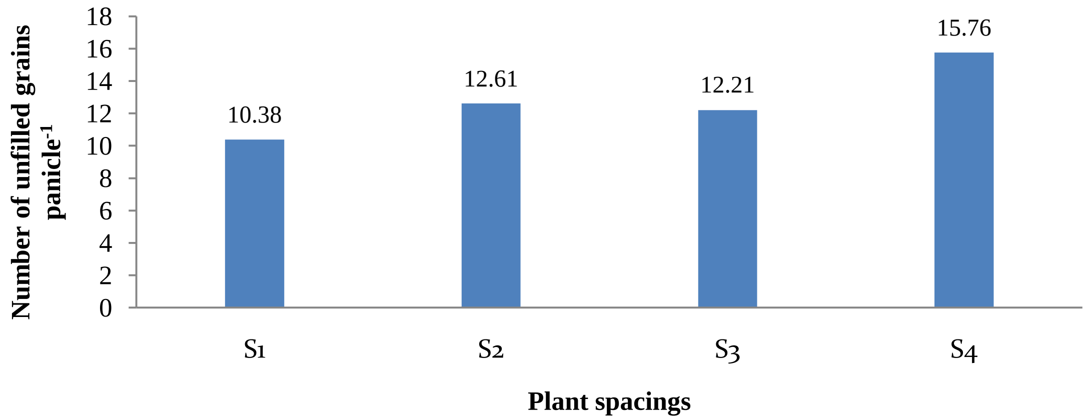


Here, C_0 = No seedling leaf clipping, C_1 = Top 1/3 portion seedling leaf clipping, C_2 = Top 1/2 portion seedling leaf clipping.

Figure. 15. Effect of seedling leaf clipping on number of unfilled grains panicle^{-1} of aromatic rice at harvest ($LSD_{0.05}$ = 0.57).

Effect of plant spacings

The number of filled grains panicle^{-1} of aromatic was significantly affected by plant spacings (Fig. 16). According to the experimental findings, the S_4 treatment had the highest number of unfilled grains panicle^{-1} (15.76), while the S_1 treatment had the lowest number of unfilled grains panicle^{-1} (10.38). Appropriate spacing promotes plant growth and development, whereas closer spacing influences plant population, increasing competition for nutrients; as a result, closer spacing produced the most unfilled grains panicle^{-1} compared to wider spacing.



Here, S_1 = 25 cm × 25 cm, S_2 = 25 cm × 20 cm, S_3 = 20 cm × 20 cm and S_4 = 20 cm × 15 cm.

Figure. 16. Effect of plant spacings on number of unfilled grains panicle^{-1} of aromatic rice at harvest ($LSD_{0.05}$ = 0.66).

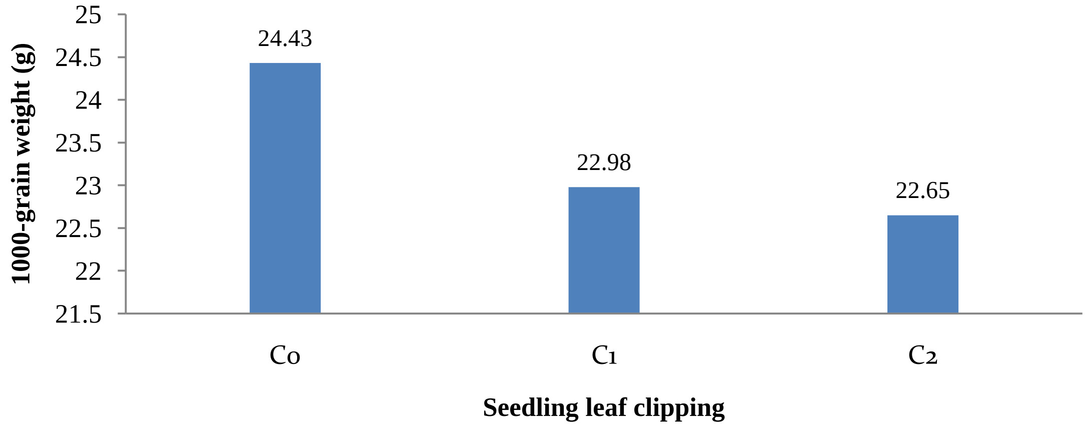
Combined effect of seedling leaf clipping and plant spacing

The combined effects of seedling leaf clipping and plant spacing caused a significant variation in the number of filled grains panicle^{-1} of aromatic rice. According to the experimental findings, the C_0S_1 combination treatment had the highest number of filled grains panicle^{-1} of aromatic rice (142.70) which was statistically similar with C_0S_2 (137.50) treatment combination. While the C_2S_4 combination treatment showed the lowest number of filled grains panicle^{-1} of aromatic rice (99.57) which was statistically similar with C_2S_3 (107.94) and C_1S_4 (108.41) treatment combination (Table 5).

4.2.4 1000-grain weight (g)

Effect of seedling leaf clipping

The 1000-grain weight of aromatic rice was significantly influenced by seedling leaf clipping (Fig. 17). According to the experimental results, the C_0 treatment had the highest 1000-grain weight of aromatic rice (24.43 g). While the C_2 treatment, on the other hand, had the lowest 1000-grain weight of aromatic rice (22.65 g) which was statistically similar with C_2 (22.98 g) treatment. The result was quite similar with the findings of Karmaker and Karmakar (2019) who revealed that significantly higher 1000-grain weight of rice was observed in control or no leaf clipping treatment whereas the lowest 1000-grain weight of rice was obtained from C_3 treatment when leaf clipped at 55 DAT.

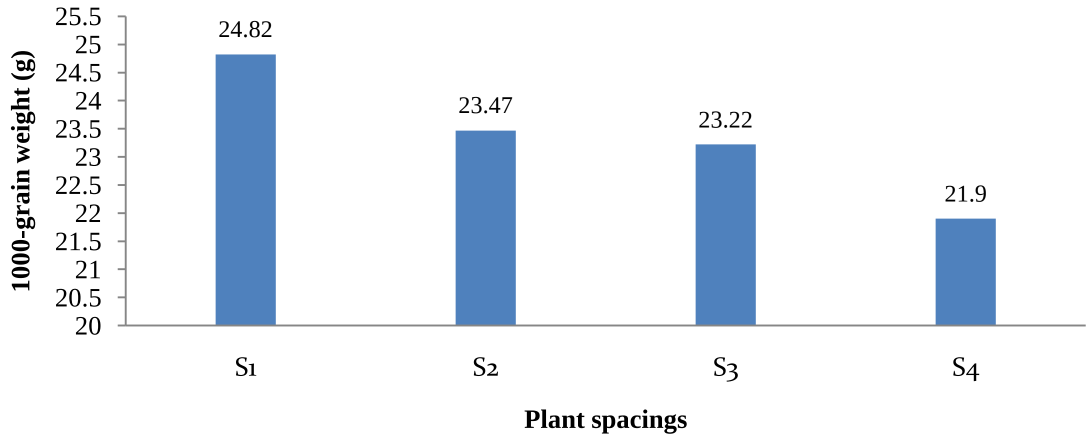


Here, C_0 = No seedling leaf clipping, C_1 = Top 1/3 portion seedling leaf clipping, C_2 = Top 1/2 portion seedling leaf clipping.

Figure. 17. Effect of seedling leaf clipping on 1000-grain weight of aromatic rice at harvest ($LSD_{0.05}$ = 0.73).

Effect of plant spacings

Different plant spacings significantly influenced 1000-grain weight of aromatic rice. Experimental result showed that, the highest 1000-grain weight of aromatic rice (24.82 g) was observed in S_1 treatment, while the lowest 1000-grain weight of aromatic rice (21.90 g) was observed in S_4 treatment (Fig. 18). The current study's findings were similar to those of Koireng *et al.* (2019), who reported that 1000 grains weight of rice was significantly affected by spacing. The results showed that as the spacing increased, the weight of the thousand grains increased significantly. Plant density was higher in narrow spacing than in other spacing, and this higher plant density was accompanied by strong intra and inter-row competition, which may have caused the decrease in 1000 grains weight. Chakrabortty *et al.* (2014) reported that highest 1000 grains weight of rice was obtained in wider spacing than narrow spacing.



Here, S_1 = 25 cm × 25 cm, S_2 = 25 cm × 20 cm, S_3 = 20 cm × 20 cm and S_4 = 20 cm × 15 cm.

Figure. 18. Effect of plant spacings on 1000-grain weight of aromatic rice at harvest ($LSD_{0.05}$ = 0.85).

Combined effect of seedling leaf clipping and plant spacings

Due to the combined effects of seedling leaf clipping and plant spacing, the 1000-grain weight of aromatic rice significantly varied (Table 5). The experimental results show that the C_0S_1 treatment combination had the highest 1000-grain weight of aromatic rice (26.47 g), while the C_2S_4 combination treatment showed the lowest 1000-grain weight of aromatic rice (21.09 g) which was statistically similar with C_1S_4 (21.74 g) combination treatment.

Table 5. Combined effect of seedling leaf clipping and plant spacing on panicle length, filled, unfilled and 1000 grain weight of aromatic rice

Treatments combinations	Panicle length (cm)	Filled grains panicle^{-1} (no.)	Unfilled grains panicle^{-1} (no.)	1000 grain weight (g)
C_0S_1	25.74 a	142.70 a	8.27 g	26.47 a
C_0S_2	23.67 b	137.50 ab	11.00 f	24.33 b
C_0S_3	23.33 bc	120.40 de	11.47 ef	24.03 bc
C_0S_4	22.40 b-d	121.47 c-e	12.50 de	22.87 b-d
C_1S_1	23.51 bc	130.88 bc	10.88 f	24.33 b
C_1S_2	23.34 bc	119.41 de	13.48 cd	23.05 b-d
C_1S_3	22.11 c-e	116.77 ef	11.11 f	22.81 cd
C_1S_4	21.04 de	108.41 fg	15.61 b	21.74 de
C_2S_1	22.77 bc	128.71 b-d	12.00 ef	23.67 bc
C_2S_2	22.30 b-d	117.88 ef	13.34 cd	23.04 b-d
C_2S_3	22.10 c-e	107.94 fg	14.04 c	22.82 cd
C_2S_4	20.74 e	99.57 g	19.17 a	21.09 e
$LSD_{0.05}$	1.43	10.11	1.15	1.47
CV%	3.71	4.94	5.33	3.74

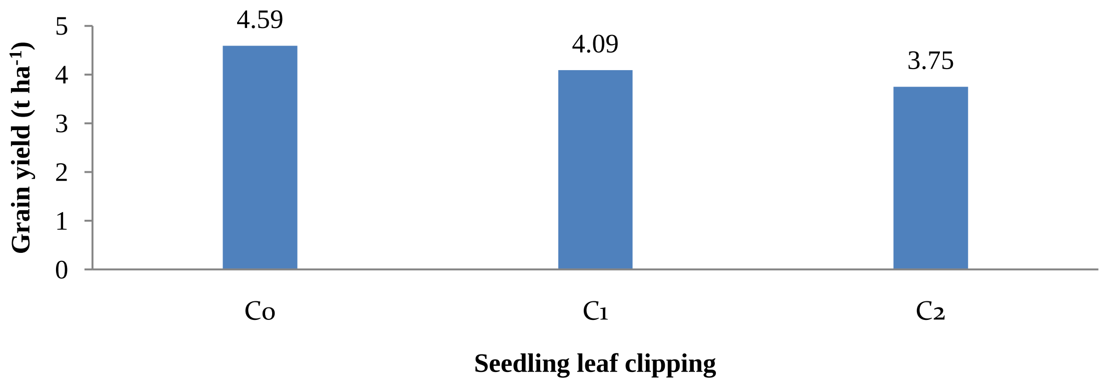
In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, C_0 = No Seedling leaf clipping, C_1 = Top 1/3 portion seedling leaf clipping, C_2 = Top 1/2 portion seedling leaf clipping, S_1 = 25 cm × 25 cm, S_2 = 25 cm × 20 cm, S_3 = 20 cm × 20 cm and S_4 = 20 cm × 15 cm.

4.3 Yield

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

Effect of seedling leaf clipping

Different levels of seedling leaf clipping significantly influenced grain yield of aromatic rice (Fig. 19). According to the experimental findings, the highest grain yield of aromatic rice (4.59 t ha^{-1}) was observed in C_0 treatment while the lowest grain yield of aromatic rice (3.75 t ha^{-1}) was observed in C_2 treatment. The highest grain yield attributed due to increase number of effective tillers hill^{-1}, panicle length, filled grains panicle^{-1} and 1000-grains weight. The result was similar with the findings of Hossain (2017) who observed that the reduction of grain yield was minimum in BRRI dhan39 with leaf cutting than that of the rest varieties. Ros *et al.* (2003) found that pruning 30% of rice leaves depressed grain yield by 20%.

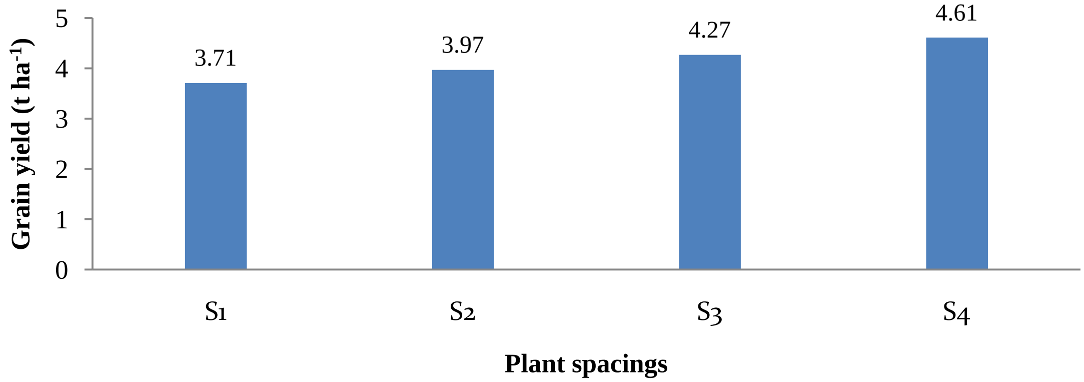


Here, C_0 = No seedling leaf clipping, C_1 = Top 1/3 portion seedling leaf clipping, C_2 = Top 1/2 portion seedling leaf clipping.

Figure. 19. Effect of seedling leaf clipping on grain yield of aromatic rice at harvest ($LSD_{0.05}$ = 0.24).

Effect of plant spacings

Different plant spacings had shown significant variation in respect of grain yield of aromatic rice (Fig. 20). According to the experimental findings the highest grain yield of aromatic rice (4.61 t ha^{-1}) was observed in S_4 treatment while the lowest grain yield of aromatic rice (3.71 t ha^{-1}) was observed in S_1 treatment, which was statistically similar with S_2 (3.97 t ha^{-1}) treatment. The possible reason for the lowest grain yield at widest spacing might be due to the presence of less number of plants per unit area. An increase in the grain yields under the spacing of 20 cm × 15 cm was due to the fact that less spacing provided more number of plants per unit area which resulted in more yield per unit area as compared to the wider spacing. On the contrary, the lower grain yields under spacing of 25 cm × 25 cm was due to the less plant population which resulted in reduction of grain and straw yields. Oyange *et al.* (2019) reported that number of tillers m^{-2}, number of panicles m^{-2}, number of filled grains panicle^{-1} and grain yield were recorded maximum with the plant spacing 20 cm × 15 cm. Khalil *et al.* (2016) also reported that at wider spacing number of effective tiller m^{-2}, filled grains panicle^{-1} and 1000-grain weight recorded higher but produced lower yield due to lesser number of plants m^{-2} as compared to the closer spacing. Bozorgi *et al.* (2011)) reported that the highest grain yield of rice (3415 kg ha^{-1}) was obtained with closer plant spacing plant spacing of 15 cm × 15 cm compared to other plant spacings.



Here, S_1 = 25 cm × 25 cm, S_2 = 25 cm × 20 cm, S_3 = 20 cm × 20 cm and S_4 = 20 cm × 15 cm.

Figure. 20. Effect of plant spacings on grain yield of aromatic rice at harvest ($LSD_{0.05}$ = 0.28).

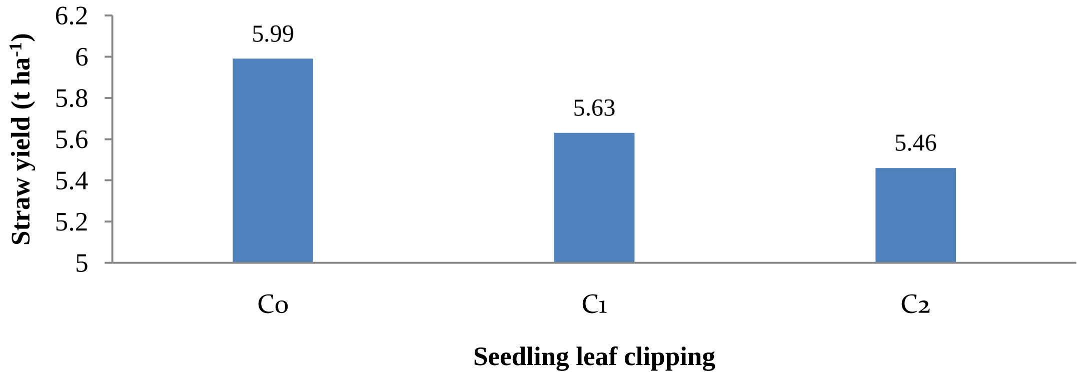
Combined effect of seedling leaf clipping and plant spacings

The grain yield of aromatic rice at harvest varied significantly due to the combined effects of seedling leaf clipping and plant spacing (Table 6). The C_0S_4 treatment combination had the highest grain yield of aromatic rice (5.11 t ha^{-1}), which was statistically similar with C_0S_3 (4.90 t ha^{-1}) treatment combination and was significantly differed from all other treatments. While the C_2S_1 combination treatment had the lowest grain yield of aromatic rice (3.21 t ha^{-1}), it was statistically comparable to the C_2S_2 (3.69 t ha^{-1}) treatment combination.

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

Effect of seedling leaf clipping

Different levels of seedling leaf clipping had shown significant impact on aromatic rice straw yield (Fig. 21). According to the experimental results, the C_0 treatment had the highest straw yield of aromatic rice (5.99 t ha_{-1}), while the C_2 treatment had the lowest straw yield of aromatic rice (5.46 t ha^{-1}) which was statistically similar with C_2 treatment. The result was similar with the findings of Hossain (2017), who reported that the highest straw yield of rice was obtained in no leaf cutting (control) regardless of the *Aman* rice varieties under study.

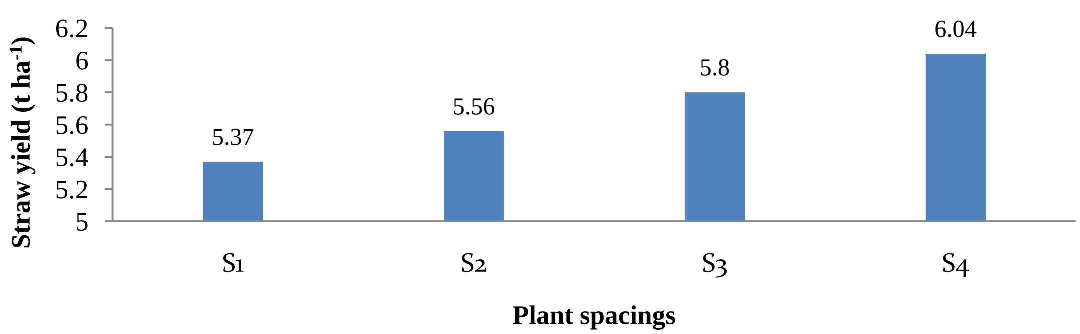


Here, C_0 = No seedling leaf clipping, C_1 = Top 1/3 portion seedling leaf clipping, C_2 = Top 1/2 portion seedling leaf clipping.

Figure. 21. Effect of seedling leaf clipping on straw yield of aromatic rice at harvest ($LSD_{0.05}$ = 0.17).

Effect of plant spacings

Different plant spacing varied significantly in terms of aromatic rice straw yield (Fig. 22). The results of the experiment showed that the S_4 treatment produced the highest straw yield of aromatic rice (6.04 t ha^{-1}), whereas the S_1 treatment produced the lowest straw yield of aromatic rice (5.37 t ha^{-1}) which was statistically similar with S_2 (5.56 t ha^{-1}) treatment. Joshi *et al.* (2016) reported that straw and grain yields of rice were significantly increased with increasing plant density, as plant density is influenced by spacing, wide spacing cause low plant density and narrow spacing cause high plant density which ultimately impact on straw and grain yield of the crop.



Here, S_1 = 25 cm × 25 cm, S_2 = 25 cm × 20 cm, S_3 = 20 cm × 20 cm and S_4 = 20 cm × 15 cm.

Figure. 22. Effect of plant spacings on straw yield of aromatic rice at harvest ($LSD_{0.05}$ = 0.20).

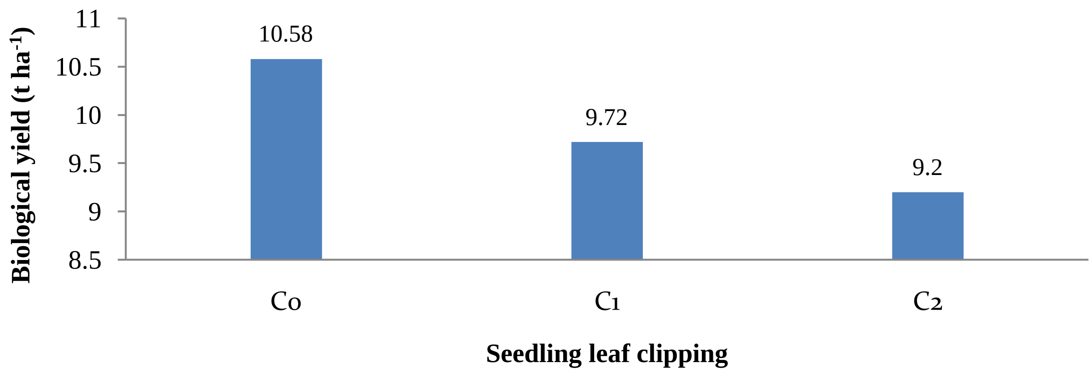
Combined effect of seedling leaf clipping and plant spacings

The combined effects of seedling leaf clipping and plant spacing resulted in significant variations in the straw yield of aromatic rice at harvest (Table 6). The C_0S_4 treatment combination had the highest straw yield of aromatic rice (6.32 t ha^{-1}), which was statistically similar with C_0S_3 (6.30 t ha^{-1}) and C_1S_4 (6.06 t ha^{-1}) treatment combination and was significantly differed from all other treatments. While the C_2S_1 treatment combination had the lowest straw yield of aromatic rice (5.09 t ha^{-1}) and it was statistically comparable to C_1S_3 (5.44 t ha^{-1}) and C_2S_2 (5.33 t ha^{-1}) treatment combination.

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

Effect of seedling leaf clipping

Seedling leaf clipping had a significant impact on the biological yield of aromatic rice at harvest (Fig. 23). The experimental results showed that the C_0 treatment had the highest biological yield of aromatic rice (10.58 t ha^{-1}). While the lowest biological yield of aromatic rice was recorded by the C_2 treatment (9.20 t ha^{-1}), which was statistically similar to the C_1 (9.72 t ha^{-1}) treatment (Figure 22). Leaf clipping causes leaf injury and reduces leaf area in seedlings, which has a negative impact on the plant's ability to photosynthesize, leading to decreased dry matter production and, ultimately, yield. Because biological yield is made up of the combined yields of grains and stover, excessive leaf removal at the seedling stage has an effect on plant growth and development, which in turn has an impact on the characters that contribute to yield, thereby reducing biological yield of aromatic rice. The result was similar with the findings of Usman *et al.* (2007) who reported that the highest biological yield was obtained from no leaf cutting treatment.

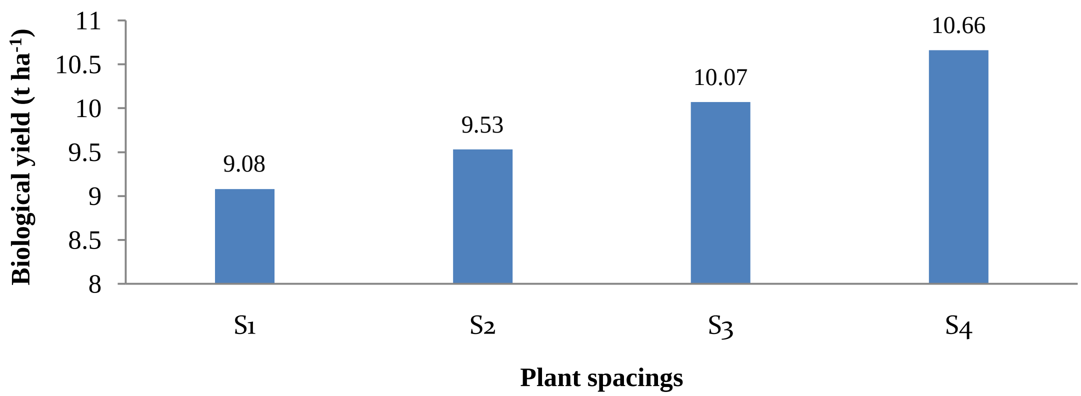


Here, C_0 = No seedling leaf clipping, C_1 = Top 1/3 portion seedling leaf clipping, C_2 = Top 1/2 portion seedling leaf clipping.

Figure. 23. Effect of seedling leaf clipping on straw yield of aromatic rice at harvest ($LSD_{0.05}$ = 0.53).

Effect of plant spacings

The biological yield of aromatic rice varied significantly across different plant spacings (Fig. 24). The results of the experiment showed that the S_4 treatment produced the highest biological yield of aromatic rice (10.66 t ha^{-1}) which was statistically similar with S_3 (10.07 t ha^{-1}) treatment, whereas the S_1 treatment produced the lowest biological yield of aromatic rice (9.08 t ha^{-1}) which was statistically similar with S_2 (9.53 t ha^{-1}) treatment. The possible reason for the lowest biological yield at widest spacing might be due to the presence of less number of plants per unit area. The findings were similar to those of Ram *et al.* (2014), who reported that when compared to wider spacing, closer spacing increased biological yield of rice due to higjer plant population per unit area.



Here, S_1 = 25 cm × 25 cm, S_2 = 25 cm × 20 cm, S_3 = 20 cm × 20 cm and S_4 = 20 cm × 15 cm.

Figure. 24. Effect of plant spacings on straw yield of aromatic rice at harvest ($LSD_{0.05}$ = 0.61).

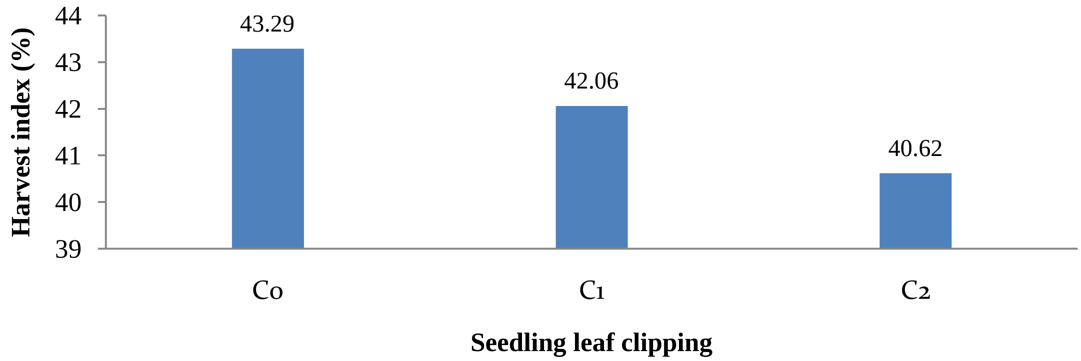
Combined effect of seedling leaf clipping and plant spacings

The biological yield of aromatic rice at harvest showed significant variations as a result of the combined effects of seedling leaf clipping and plant spacing (Table 6). The C_0S_4 treatment combination had the highest biological yield of aromatic rice (11.43 t ha^{-1}), which was statistically similar with C_0S_3 (11.20 t ha^{-1}) and C_1S_4 (10.65 t ha^{-1}) treatment combination and was significantly differed from all other treatments. While the C_2S_1 combination treatment had the lowest biological yield of aromatic rice (8.30 t ha^{-1}) and it was statistically comparable to the C_2S_2 (9.02 t ha^{-1}) combination treatment.

4.3.4 Harvest index (%)

Effect of seedling leaf clipping

At harvest, seedling leaf clipping had shown significant effect on the harvest index of aromatic rice (Fig. 25). The experimental results revealed that the C_0 treatment had the highest harvest index of aromatic rice (43.29 %). The C_2 treatment, on the other hand had the lowest harvest index of aromatic rice (40.62 %). The result was similar with the findings of Karmaker and Karmakar (2019), who reported that the highest harvest index of rice was found in no clipping treatment of rice.

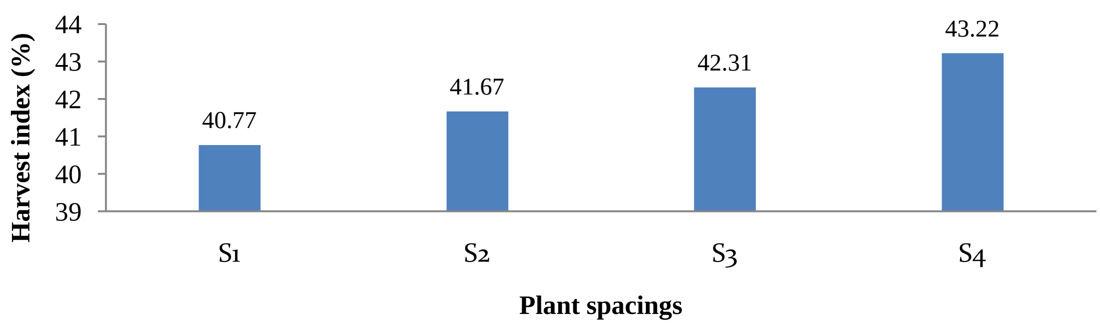


Here, C_0 = No seedling leaf clipping, C_1 = Top 1/3 portion seedling leaf clipping, C_2 = Top 1/2 portion seedling leaf clipping.

Figure. 25. Effect of seedling leaf clipping on harvest index of aromatic rice at harvest ($LSD_{0.05}$ = 0.72).

Effect of plant spacings

Various plant spacing had shown significant effect on the harvest index of aromatic rice (Fig. 26). The results of the experiment showed that the S_4 treatment recorded the highest harvest index of aromatic rice (43.22 %), whereas the S_1 treatment recorded the lowest highest harvest of aromatic rice (40.77 %). Jena *et al.* (2010) found similar result that supported the present finding and concluding that a higher harvest index was recorded under 20 cm 10 cm spacing (close spacing) compared to wider spacing of 20 cm × 15 cm. Higher harvest indexes could be attributed to greater photosynthesis partitioning toward straw production and a higher grain ratio in total biological yield.



Here, S_1 = 25 cm × 25 cm, S_2 = 25 cm × 20 cm, S_3 = 20 cm × 20 cm and S_4 = 20 cm × 15 cm.

Figure. 26. Effect of plant spacings on harvest index of aromatic rice at harvest ($LSD_{0.05}$ = 0.83).

Combined effect of seedling leaf clipping and plant spacings

The harvest index of aromatic rice at harvest showed significant variations as a result of the combined effects of seedling leaf clipping and plant spacing (Table 6). The C_0S_4 treatment combination had the highest harvest index of aromatic rice (44.71 %) which was statistically similar with C_0S_4 (43.75 %) treatment combination. While the C_2S_1 combination treatment had the lowest harvest index of aromatic rice (38.67 %).

Table 6. Combined effect of seedling leaf clipping and plant spacing on grain yield, straw yield, biological yield and harvest index

Treatments combinations	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
C_0S_1	4.07 de	5.49 de	9.56 de	42.59 bc
C_0S_2	4.27 cd	5.87 bc	10.14 b-d	42.11 cd
C_0S_3	4.90 ab	6.30 a	11.20 ab	43.75 ab
C_0S_4	5.11 a	6.32 a	11.43 a	44.71 a
C_1S_1	3.85 de	5.53 c-e	9.38 de	41.04 d
C_1S_2	3.96 de	5.47 de	9.43 de	41.99 cd
C_1S_3	3.96 de	5.44 d-f	9.40 de	42.13 cd
C_1S_4	4.59 bc	6.06 ab	10.65 a-c	43.09 bc
C_2S_1	3.21 f	5.09 f	8.30 f	38.67 e
C_2S_2	3.69 ef	5.33 ef	9.02 ef	40.91 d
C_2S_3	3.94 de	5.66 c-e	9.60 c-e	41.04 d
C_2S_4	4.14 c-e	5.75 b-d	9.89 c-e	41.86 cd
$LSD_{0.05}$	0.48	0.35	1.06	1.44
CV%	6.97	3.69	6.37	2.03

In a column means having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 5% level of probability. Here, C_0 = No seedling leaf clipping, C_1 = Top 1/3 portion seedling leaf clipping, C_2 = Top 1/2 portion seedling leaf clipping, S_1 = 25 cm × 25 cm, S_2 = 25 cm × 20 cm, S_3 = 20 cm × 20 cm and S_4 = 20 cm × 15 cm.

CHAPTER V

SUMMARY AND CONCLUSION

A field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from June to November 2021 in *Aman* season, to study influence of seedling leaf clipping and plant spacing on growth and yield of BRRI Dhan80. The experiment consisted of two factors, and followed Randomized Complete Block Design with three replications. Factor A: Seedling leaf clipping (3) *viz;* C_0 = No seedling clipping, C_1 = Top 1/3 portion seedling clipping, C_2 = Top 1/2 portion seedling clipping and Factor B: Different plant spacing (4) *viz;* S_1 = 25 cm × 25 cm, S_2 = 25 cm × 20 cm, S_3 = 20 cm × 20 cm and S_4 = 20 cm × 15 cm. For the purpose of evaluating the experimental outcomes, data on various parameters were evaluated. The analysis of various parameter data revealed significant differences in respect of aromatic rice growth and yield, as a result of seedling leaf clipping, plant spacing and their combined treatment.

In case of different seedling leaf clipping treatment, the highest the highest plant height (36.99, 66.23 and 93.19 cm at 30, 60 DAT and at harvest, respectively), number of tillers hill^{-1} of aromatic rice (13.75, 21.48 and 16.62 at 30, 60 DAT and harvest, respectively), effective tillers hill^{-1} (15.38), above ground dry matter weight hill^{-1} (9.72, 25.68 and 35.03 and g hill^{-1} at 30, 60 DAT and at harvest respectively), panicle length (23.79 cm), filled grains panicle^{-1} (130.52), 1000-grain weight (24.43 g), grain yield (4.59 t ha^{-1}), straw yield (5.99 t ha$_{-1}$), biological yield (10.58 t ha^{-1}) and harvest index (43.29 %) were observed from C_0 (No seedling clipping) treatment. While the lowest plant height (26.42, 59.23 and 89.04 cm at 30, 60 DAT and harvest, respectively), number of tillers hill^{-1} of aromatic rice (11.13, 17.04 and 14.82 at 30, 60 DAT and harvest, respectively), effective tillers hill^{-1} (15.05), above ground dry matter weight hill^{-1} (8.08, 20.54 and 31.03 and g hill^{-1} at 30, 60 DAT and at harvest respectively), panicle length (21.98 cm), filled grains panicle^{-1} (113.52), 1000-grain weight (22.65 g), grain yield (3.75 t ha^{-1}), straw yield (5.46 t ha^{-1}), biological yield (9.20 t ha^{-1}), and harvest index (40.62 %) were observed from C_2 (Top 1/2 portion seedling clipping) treatment.

Growth and yield of aromatic rice was significantly influenced due to the effect of different plant spacing. Experimental result revealed that highest plant height (36.13, 69.44 and 100.76 cm at 30, 60 DAT and harvest, respectively), number of tillers hill^{-1} of aromatic rice (15.59, 21.54 and 17.38 at 30, 60 DAT and harvest, respectively), effective tillers hill^{-1} (16.49), above ground dry matter weight hill^{-1} (11.68, 27.89 and 41.92 g hill^{-1} at 30, 60 DAT and harvest, respectively), panicle length (24.01 cm), number of filled grains panicle^{-1} (134.10) and 1000-grain weight of aromatic rice (24.82 g) was observed in S_1 treatment. However the highest grain yield (4.61 t ha^{-1}), straw yield (6.04 t ha^{-1}), biological yield (10.66 t ha^{-1}) and harvest index of aromatic rice (43.22 %) were observed in S_4 treatment. While the lowest plant height (24.50, 54.74 and 81.99 at 30, 60 DAT and harvest, respectively), number of tillers hill^{-1} of aromatic rice (9.87, 15.46 and 14.35 at 30, 60 DAT and harvest, respectively), effective tillers hill^{-1} (12.14), above ground dry matter weight hill^{-1} (6.31, 18.26 and 26.51 g hill^{-1} at 30, 60 DAT and harvest, respectively), panicle length (21.39 cm), number of filled grains panicle^{-1} (109.82) and 1000-grain weight of aromatic rice (21.90 g) was observed in S_4 treatment. However the lowest grain yield (3.71 t ha^{-1}), straw yield (5.37 t ha^{-1}), biological yield (9.08 t ha^{-1}) and harvest index of aromatic rice (40.77 %) were observed in S_1 treatment.

In case of combination, C_0S_1 combination treatment gave the highest plant height (43.93, 73.48 and 103.04 cm at 30, 60 DAT and harvest, respectively), number of tillers hill^{-1} of aromatic rice (17.33, 23.97 and 18.70 at 30, 60 DAT and harvest, respectively), effective tillers hill^{-1} (18.37), above ground dry matter weight hill^{-1} of aromatic rice (12.43, 30.31 and 44.15 g hill^{-1} at 30, 60 DAT and harvest respectively), panicle length (25.74 g), number of filled grains panicle^{-1} (142.70) and 1000-grain weight of aromatic rice (26.47 g). However, C_0S_4 combination treatment gave the highest grain yield (5.11 t ha^{-1}), straw yield (6.32 t ha^{-1}), biological yield (11.42 t ha^{-1}) and harvest index of aromatic rice (44.71 %).Whereas the lowest grain yield (3.21 t ha^{-1}), straw yield (5.09 t ha^{-1}), biological yield (8.30 t ha^{-1}) and harvest index of aromatic rice (38.67 %) were observed from C_2S_1 combination treatment.

Conclusion

Based on the, experimental results it revealed that different levels of seedling leaf clipping and plant spacings significantly influenced the growth and yield of aromatic rice BRRI dhan80. However, considering above all facts, it may be concluded that seedlings without leaf clipping transplanted by 20 cm × 15 cm plant spacing and their combination (C_0S_4) appears good for increasing growth and yield of this variety over the other treatment combinations.

Recommendations

Considering the results of the experiment, further studies in the following areas are suggested:

- ✓ Different levels of leaf clipping, spacings and agronomic managements practices on aromatic rice cultivation may be taken for further experiments to get more accurate result.
- ✓ Studies of similar nature of experiment could be carried out in different agro-ecological zones (AEZ) in different seasons of Bangladesh for the evaluation of zonal adaptability.

REFERENCES

Abou-khalifa, A.A.B., Misra, A.N., El-Azeem, A. and Salem, K.M. (2008). Effect of leaf cutting on physiological traits and yield of two rice cultivars. *African. J. Pl. Sci.* **2**(12): 147–150.

Ahmed, M., Ahmed, F., Molla, M.S.H., Hossain M.D. and Rahman, B.M.Z. (2001). Effect of nitrogen rate and time of leaf cutting on green fodder as well as seed yield of rice. *Pakistan J. Biol. Sci*. **4**(8): 937-939.

Ahsan, M.N. (2020). Influence of leaf clipping on the growth and yield of Aus rice. M.S. thesis. Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka. pp. 1-2.

Alam, M.S., Baki, M.A., Sultana, M.S., Ali, K.J. and Islam, M.S. (2012). Effect of variety, spacing and number of seedlings per hill on the yield potentials of transplant Aman rice. *Intl. J. Agron. Agric. Res.* **2**: 10-15.

Amin, M., Khan, M.A., Khan, E.A. and Ramzan, M. (2004). Effect of increased plant density and fertilizer dose on the yield of rice variety IR-6. *J. Res. Sci. Bahauddin Zakariya Uni. Multan, Pakistan*. **15**(1): 9-16.

Banerjee, H. and Pal, S. (2011). Effect of planting geometry and different levels of nitrogen on hybrid rice. *Oryza,* **48**(3):274-275.

Bardhan, S.K. and Mandal, B.K. (1988). Effect of leaf cutting for herbage in deep water Rice. *Intl. Rice. Res. Newsl.* **12**: 16-19.

Basavaraja, M.K., Murali, K., Siddaram, Y.M., Ramesha, Y.H. and Prakash, H. (2010). Effect of spacing and genotype on growth and yield of aerobic rice. *Intl. J. Agric. Sci.* **6**(2): 485-487.

Baskar, P., Siddeswaran, K. and Thavaprakaash, N. (2013). Tiller dynamics, light interception percentage and yield of rice cultivars under system of rice intensification (SRI) as influenced by nursery techniques and spacing. *Madras Agric. J.* **100** (1-3): 131-134.

BBS. (Bangladesh Bureau of Statistics) (2020). The Yearbook of Agricultural Statis-tics of Bangladesh. Statistics Division, Ministry of Planning, Government of People's Republic of Bangladesh, Dhaka. pp. 02-40.

Biswas, J.C., Maniruzzaman, M., Nahar, U.A., Zahan, T., Haque, M.M., Ali, M.H., Kabir, N.K. and Rahnamayan, S. (2019). Prospect of Developing Soil Health Index in Bangladesh. *Curr. Inves. Agri. Curr. Res.* **6**(2): 799-807.

Boonreung, C and Marsom, K. (2015). Effect of rice leaf cutting length on rice yield. M.S. thesis. Faculty of Agricultural Technology and Agro-Industry. Rajamangala University of Technology Suvarnabhumi PhraNakhon SiAyutthaya, Thailand 13000. pp. 1-2.

Bozorgi, H.R., Faraji, A., Danesh, R.K., Keshavarz, A., Azarpour, E. and Tarighi, F. (2011). Effect of planting density on yield and yield components of rice. *World App. Sci. J.* **12**(11): 2053-2057.

Chakrabortty, S., Biswas, P.K., Roy, T.S., Mahmud, M.A.A and Mehraj, H and Jamal, U.A.F.M. (2014). Growth and yield of boro rice (BRRI Dhan 50) as affected by planting geometry under system of rice intensification. *J. Bio. Agric. Res*. **2**(1): 36-43.

Chaudhary, A.N., Latif, M.I., Haroon, Ur-Rasheed, M. and Ghulam, J. (2005). Profitability increase in maize production through fertilizer management and defoliation under rain fed cropping. *Intl. J. Bio. Biotech.* **2**(4) : 1007-1012.

Daliri, M.S., Eftekhari, A., Mobasser, H.R., Tari, D.B. and Porkalhor, H. (2009). Effect of cutting time and cutting height on yield and yield components of ratoon rice (*Tarom Langrodi* Variety). *Asian J. Pl. Sci*. **8**(1): 89-91.

Das, A., Singh, M.K., Mishra, J., Yadav, D. and Sadhukhan, R. (2017). Crop geometrical effect on growth and yield under direct seeded hybrid rice cultivars. *Inl. Quarterly J. Life Sci.* **12**(1): 265-268.

Das, S., Chaki, A.K., Sarker, A.R., Mondal, S., Sarker, M.M.R. and Moniruzzaman, M. (2013). Effect of spacing of transplanting, rate and depth of placement of urea super granules (USG) on the yield of Boro rice. *Bull. Inst. Tropical Agric. Kyushu Uni.* **36**: 85- 94.

Das, S.R., Ali, M. Y. and Islam, M.M. (2017). Effect of leaf clipping on yield attributes of modern and local rice varieties. *Bangladesh Rice J.* **21**(1): 101-104.

Dass, A. and Chandra, S. (2012). Effect of different components of SRI on yield, quality, nutrient accumulation and economics of rice *(Oryza sativa* L.) in tarai belt of Northern India. *Indian J. Agron.* **57** (3): 250-254.

Fatima, S. (2019). Effect of flag leaf clipping on growth, yield and yield attributes of hybrid rice in Boro season. M. S. Thesis. Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka−1207, Bangladesh. pp. 1-3.

Georgias, N.J., Ruess, R.W., Mcnaughton, S.J. and Western, D. (1989). Ecological conditions that determine when grazing stimulates grass production. *Oecologia.* **81**: 316–322.

Gomez, M.A. and Gomez, A. A. (1984). Statistical procedures for Agricultural Research. John Wiley and sons. New York, Chichester, Brisbane, Toronto. pp. 97-215.

Halder, J., Rokon, G.M., Islam, M.A., Salahin, N. and Alam, M.K. (2018). Effect of planting density on yield and yield attributes of local aromatic rice varieties. *Bangladesh J. Agril. Res.* **43**(3): 489-497.

Hasanuzzaman, M., Nahar, K., Roy, T.S., Rahman, M.L., Hossain, M.Z. and Ahmed, J.U. (2009). Tiller dynamics and dry matter production of transplanted rice as affected by plant spacing and number of seedling per hill. *Academic J. Pl. Sci.* **2**(3):162-168.

Hossain, M.J. (2017). Effect of leaf cutting on growth and yield of modern aman rice varieties. M.S. Thesis, Department of Agricultural Botany, Sher-e-Bangla Agricultural University, Dhaka−1207, Bangladesh. pp. 1-2.

Jacob, D. and syriac, E.K. (2005). Performance of transplanted scented rice under different spacing and weed management regimes in southern Kerala. *J. Trop. Agric.* **43**(1-2): 71-73.

Jahan, A., Islam, A., Sarkar, M.I.U., Iqbal, M., Ahmed, M.N. and Islam, M.R. (2022). Nitrogen response of two high yielding rice varieties as influenced by nitrogen levels and growing seasons. *Geo. Eco. Land*. **6**(1): 24-31.

Jena, S., Annie, P. and Nayak, B.C. (2010). Response of hybrid rice to time of planting and planting density. *Oryza.* **47**(1): 48-52.

Joshi, N., Singh, V.P., Dhyani, V.C., Singh, S.P. and Pratap, T. (2016). Effect of planting geometry and weed management practices on crop growth and yield of direct seeded (aerobic) rice (*Oryza sativa* L.). *Eco. Environ. Conser.* **22**: 371-376.

Kabir, M.E., Kabir, M.R., Jahan, M.S. and Das, G.G. (2004). Yield performance of three aromatic fine rices in a coastal medium high land. *Asian J. Pl. Sci.* **3**: 561-563.

Karmaker, B. and Karmakar, B. (2019). Effect of nitrogen rates and leaf clipping on forage and grain yield, and seed quality of transplant aman rice. *Bangladesh Rice J.* **23**(2) : 49-57.

Khalil, M.E., Chowdhury, K., Sabagh, A.E.L., Barutcular, C. and Islam, M.S. (2016). Effect of planting geometry on yield and yield attributes of aromatic rice genotypes. *Agric. Adv.* **5**(9): 349-357.

Khatun, M.M., Ali, M.H. and Mateo, L.G. (2011). Influences of leaf cutting on growth and yield of rice. *J. bio-sci.* **19**: 99–100.

Koireng, R.J., Devi, M.N., Devi, P., Gogoi, K.M. and Rolling, A.P.S. (2016). Effect of variety and spacing on the productivity of direct seeded rice (*Oryza sativa* L.) under Manipur Condition. *Indian J. Pure App. Bio. Sci.* **7**(5): 335-341.

Kokilavani, S., Jagannathan, R., Selvaraju, R., and Thavaprakaash, N. (2007). Influence of terminal clipping on growth and yield of sesame varieties. *Asian J. Agric. Res.* **1**(3): 142-145.

Kumar, P. (2021). Response of transplanted rice (*Oryza sativa* L.) to nitrogen levels and planting geometry. M.S. thesis submitted to the Chaudhary Charan Singh Haryana Agricultural University. pp. 1-2.

Mae, T. (1997). Physiological nitrogen efficiency in rice Nitrogen utilization, photosynthesis and yield potential. *Pl. Soil J.* **196**: 201–210.

Mahaddeshi, A.A., Abbasian, A., Bakhshipour, S. and Aminpanah, H. (2011). Effect of different levels of nitrogen and plant spacing on yield, yield components and physiological indices in high yield rice. *American-Euracian J. Agric. Environ. Sci.***10**: 893-900.

Mahato, P., Gunri, S.K., Chanda, K. and Ghosh, M. (2007). Effect of varying levels of fertilizer and spacing on medium duration rice (*Oryza sativa* L.) in Tarai Zone of West Bengal. *Karnataka J. Agric. Sci.* **20**(2): 363-365.

Medhi, A.K., Dey, P.C., Chetia, S.K. and Ghose, T.J. (2015). Effect of foliage pruning on vegetative growth and grain yield of rice under rainfed low land situation (50–100 cm water depth). *Environ. Eco.* **33**(3A): 1335–1338.

Misra, A.N. (1987). Physiological aspects of grain formation in sorghum and pearl millet. In: Production technology for sorghum and pearl millet.ICAR/Sukhadia University, Jaipur, India. pp. 1-6.

Misra, A.N. and Misra, M. (1991). Physiological responses of pearl millet to agro climatic conditions. In: Prakash R., Ali. A. (Eds) Environmental Contamination and Hygiene, jagmandir Books, New Delhi, India. pp. 165-175.

Moballeghi, M., Kheyri, N., Hatami, S., Mohaddesi, A. (2018). Effect of source-sink limitation on agronomic traits and grain yield of different lines of rice (*Oryza sativa* L.). *Agron. Res. Semi Desert Regions.* **13**(3): 241-251.

Mobasser, H.R., Tari, D.B., Vojdani, M., Abadi, R.S. and Eftekhari, A. (2007). Effect of seedling age and planting space on yield and yield components of rice (Neda variety). *Asian J. Pl. Sci.,* **6**(2): 438-440.

Mohan, S.S. and Pillai, S.P. (2014). Effect of spacing, seedling density and nutrient management on the performance of hybrid rice (*Oryza sativa* L.) in Southern Kerala. *Curr. Adv. Agric. Sci.,* **6**(2):193-195.

Mondal, M.M.A, Puteh, A.B., Ismail, M.R. and Rafii, M.Y. (2013). optimizing plant spacing for modern rice varieties. *Intl. J. Agric. Biol.* **15**(1):175-178.

Moro, B., Nuhu, I. and Martin, E. (2016). Effect of spacing on grain yield and yield attributes of three rice (*Oryza sativa* L.) varieties grown in rain-fed lowland ecosystem in Ghana. *Intl. J. Pl. Soil Sci.* **9**(3): 1-10.

Nayak, B.C., Dalei, B.B. and Chodhury, B.K. (2003). Response of hybrid rice to date of planting, spacing and seeding rate during wet season. *Indian J. Agron.* **48** (3): 172-174.

Oyange, W.A., Kamau, P.A. and Kanya, J.I. (2019). Effects of varied nitrogen levels and plant density on growth and yield of nerica-1 rice variety. *J. Agric. Vet. Sci.* **12**(3): 72-77.

Paez, A., Gonzalez, E., Yrausquín, X., Salazar, A. and Casanova, A. (1995).Water stress and clipping management effect on guinea Grass: I. Photosynthesis and water relations. *Agron. J.* **87**: 760-771.

Paul, N.C., Paul, S.C., Paul, S.K. and Salam, M.A. (2021). Response of nitrogen and potassium fertilization on the growth performance of aromatic *Boro* rice. *Arc. Agric. Environ. Sci.* **6**(3): 303-309.

Prakash, M., Anandan, A. and Kumar, B. S. (2011). Varietal variations in flag leaf area and yield in mutant lines of PY 5 rice. *Karnataka J. Agric. Sci.* **24**: 525-526.

Rajesh, V. and Thanunathan, K. (2003). Effect of seedling age, number and spacing on yield and nutrient uptake of traditional Kambachamba rice. *Madras Agric. J.* **90**(1-3): 47-49.

Ram, H., Singh, J.P.,Bohra, J.S., Singh, R.K. and Sutaliya, J.M. (2014). Effect of seedlings age and plant spacing on growth, yield, nutrient uptake and economics of rice (*Oryza sativa* L.) genotypes under system of rice intensification. *Indian J. Agron.* **59**(2): 256-260.

Ramesh, T., Sathiya, K., Padmanaban, P.K. and Martin, G.J. (2009). Optimization of nitrogen and suitable weed management practice for direct seeded rice. *Madras Agric. J*. **96**: 344-348.

Rasool, F., Habib, R. and Bhat, M.I. (2013). Agronomic evaluation of rice (*Oryza sativa* L.) for plant spacing and seedlings per hill under temperate conditions. *African J. Agric. Res.* **8**(37):4650-4653.

Rathiya, P.S., Singh, V.K. and Kumar, R. (2017). Growth and yield performance of aromatic rice (*Oryza sativa* L.) varieties as affected by various nutrient management practices. *J. Pharma. Phyto*. **1**: 866-868.

Ray, S., Mondal, W.A., Choudhury, M.A. (1983). Regulation of leaf senescence, grain filling and yield of rice by kinetin and abscisic acid. *Physiol. Pl.*. **59**: 343–346.

Ros, C,. Bell, R.W. and White, P.F. (2003). Seedling vigour and the early growth of transplanted rice (*Oryza sativa*). *Pl. Soil*. **252**: 325-337.

Roy, A., Sarkar, M.A.R. and Paul, S. K. (2018). Effect of age of seedlings at staggered transplanting and nutrient management on yield performance of aromatic fine rice (cv. BRRI dhan38). *SAARC J. Agric*. **16**(1): 49-59.

Safari, A.R., Roshan, N.M., Barimavandi, A.R. and Ariri, I. (2013). Effect of defoliation and late-season stress on yield, yield components and dry matter partitioning of grain in Kermanshah region, Iran. *Adv. Environ. Biol.* **7**(1): 47-55.

Sampath, O., Srinivas, A., Ramprakash T.and Avil Kumar, K. (2017). Nutrient uptake of rice varieties as influenced by combination of plant density and fertilizer levels under late sown conditions. *Inl. J. Curr. Microbiol. App. Sci*. **6**(6): 1337-1346.

Sarkar, M.A.R., Paul, S.K. and Hossain, M.A. (2011). Effect of row arrangement, age of tiller seedling and number of tiller seedlings per hill on performance of transplant aman rice. *The J. Agric. Sci.* **6**(2): 59-68.

Sharma, A., Dhaliwal, L.K., Sandhu, S.K. and Singh, S.P. (2011). Effect of plant spacing and transplanting time on phenology, tiller production and yield of rice (*Oryza sativa* L.*). Intl. J. Agric. Sci.* **7(**2): 249-253.

Shel, S.K., Paul, S.K., Uddin, F.M.J. and Rahman, M.M. (2019). Effect of row spacing on yield of short duration transplant aman rice varieties. *Acta Sci. Malaysia* **3**(2): 1-6.

Shivay, Y.S. and Singh, S. (2003). Effect of planting geometry and nitrogen level on growth, yield and nitrogen-use efficiency of scented hybrid rice. *Adiarz J. Agron.* **48**(1): 42-44.

Siddiqui, M.R.H., Lakpale, R. and Tripathi, R.S. (1999). Effect of spacing and fertilizer on medium duration rice varieties. *Indian J. Agron.* **44**(2): 310-312.

Singh, A.K., Gautam, U.S., Singh, J., Singh, A. and Shrivastava, P. (2016). Impact of nutrient management technologies in transplanted rice under irrigated domains of Central India. *African J. Agric. Res.* **10** (5): 345-350.

Singh, A.K., Singh, P.K., Nandan, R. and Rao, M. (2012). Grain quality and cooking properties of rice germplasm. *Ann. Pl. Soil Res.* **14**(1): 52-57.

Singh, B., Singh, S., Kumar, V. and Kumar, Y. (2013). Nitrogen and nipping schedule for higher productivity of sesame (*Sesamum indicum* L.) on aridisols of South-Western Haryana. *Haryana J. Agron.* **29**(1 & 2): 1-5.

Singh, G., Kumar, A., Shahi, U.P. and Kumar, K. (2003). Response of rice verities to nitrogen levels and false smut in mid-western plain zone of U.P. *J. Farming Sys. Res. Dev.* **14**(1): 138-139.

Sinha, T., Paul, S.K. and Sarkar, M.A.R. (2018). Effect of age of seedlings at staggered transplanting and weed management on growth and yield of aromatic Boro rice (cv. BRRI dhan50). *J. Bangladesh Agric. Uni*. **16**(1): 5-11.

Sridhara, C.J., Ramachandrappa, B.K., Kumarswamy, A.S. and Gurumurthy, K.T. (2011). Effect of genotypes, planting geometry and methods of establishment on root traits and yield of aerobic rice. *Karnataka J. Agric. Sci.* **24** (2): 129-132.

Sultana, M.R., Rahman, M.M. and Rahman, M.H. (2012). Effect of row and hill spacing on the yield performance of boro rice (BRRI dhan45) under aerobic system of cultivation. *J. Bangladesh Agric. Uni.* **10**: 39.

Thavapraprakash, N., Baskar, P., Siddeswaran, K. and Muthukrishnan, P. (2008). Effect of varied crop geometry levels under SRI on tillering behavior and yield of rice. *Third National Symposium on SRI at TNAU, Coimbatore*, 1-3 December. pp. 92-94.

Thawait, D., Patel, A.K., Kar, S., Sharma, M.K. and Meshram, M.R. (2009). Performance of transplanted scented rice (*Oryza sativa L.*) SRI based cultivation practices; a sustainable method for crop production. *The Intl. Quart. J. Life Sci.* **9**(2): 539-542.

Uddin, M.A., Ali, M.H., Biswas, P.K., Masum, S.M. and Mandal, M.S. (2013). Influence of nitrogen and plant spacing on the yield of boro rice. *Exp. Bio.* **4**(2):35-38.

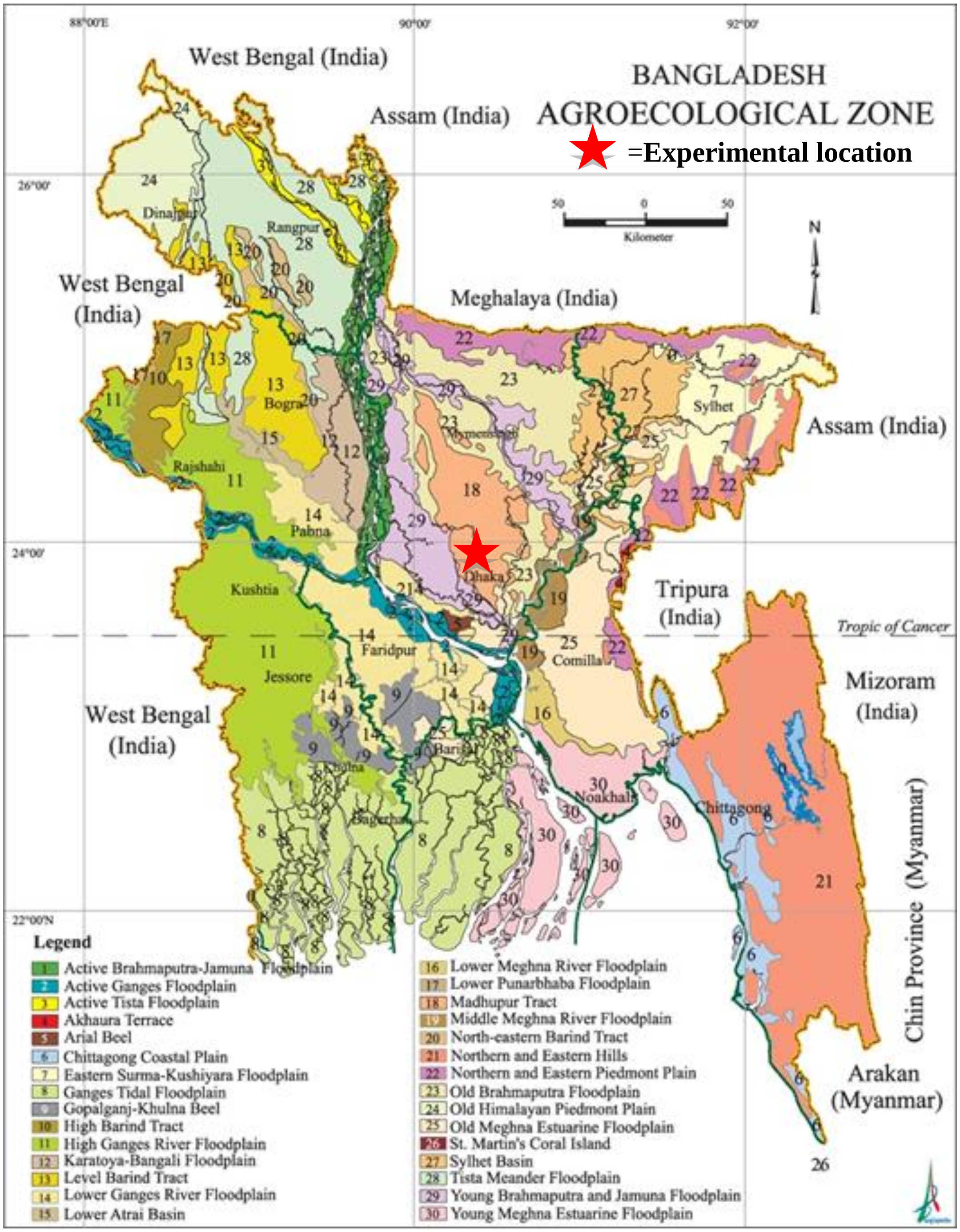
Usman, K., Khan, E.A., Khan, Q., Wakil, A. and Khan, M.U. (2007). Effect of detopping on forage and grain yield of rice under agro-climatic conditions of D. I. Khan. *Sarhad J. Agric*. **23**(1): 1–4.

Yoshida, S. (1981). Fundamentals of rice crop science. International Rice Research Institute, Manila, Philippines. Los Baños, Laguna. p. 269.

Yue, B., Xue, W.Y., Luo, L.J. and Xing, Y.Z. (2006). QTL analysis for flag leaf characteristics and their relationships with yield and yield traits in rice. *Acta. Genetica. Scizica*. **2**: 824-832.

APPENDICES

Appendix I. Map showing the experimental location under study



Appendix II. Soil characteristics of the experimental field

A. Morphological features of the experimental field

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

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

Physical characteristics	
Constituents	**Percent**
Clay	29 %
Sand	26 %
Silt	45 %
Textural class	Silty clay
Chemical characteristics	
Soil characteristics	**Value**
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10
Organic carbon (%)	0.45
Organic matter (%)	0.78
pH	5.6
Total nitrogen (%)	0.03

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

Appendix III. Monthly meteorological information during the period from June to November, 2021.

Year	**Month**	**Air temperature (^{0}C)**		**Relative humidity (%)**	**Average rainfall (mm)**
		Maximum	**Minimum**		
2021	June	34	27.3	76	134
	July	32.6	26.8	81	114
	August	32.6	25.5	80	106
	September	32.4	25.7	80	86
	October	31.2	23.9	76	52
	November	29.6	19.8	53	00

Source: Bangladesh Metrological Départment, Agargaon, Dhaka (Climate Division)

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

Source	**DF**	Plant height at		
		30 DAT	**60 DAT**	**At harvest**
Replication (R)	2	3.528	13.194	18.750
Clipping (C)	2	439.548**	177.831**	54.802**
Spacing (S)	3	237.635**	362.571**	573.316**
C×S	6	26.020**	6.197*	1.988*
Error	22	2.982	8.649	9.659

** : Significant at 1% level of probability
*: Significant at 5% level of probability

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

Source	**DF**	Number of tillers hill^{-1} at		
		30 DAT	**60 DAT**	**At harvest**
Replication (R)	2	0.8611	0.8325	1.0833
Clipping (C)	2	22.5444**	63.9032**	10.1397**
Spacing (S)	3	56.4645**	76.2541**	18.4553**
C×S	6	3.4009**	2.5304*	1.6089*
Error	22	0.4975	0.7507	0.8106

** : Significant at 1% level of probability
*: Significant at 5% level of probability

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

Source	DF	Number of effective tillers hill^{-1}	Number of non-effective tillers hill^{-1}
Replication (R)	2	0.7078	0.00908
Clipping (C)	2	13.4400**	1.30503**
Spacing (S)	3	31.5267**	3.26489**
C×S	6	2.2870**	0.25809**
Error	22	0.5260	0.00744

** : Significant at 1% level of probability
*: Significant at 5% level of probability

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

Source	DF	Above ground dry matter weight hill^{-1} at at		
		30 DAT	**60 DAT**	**At harvest**
Replication (R)	2	0.3333	1.141	0.778
Clipping (C)	2	10.2718**	86.639**	48.009**
Spacing (S)	3	46.7386**	162.993**	399.544**
C×S	6	1.0024*	4.124*	0.693*
Error	22	0.3333	1.359	2.414

** : Significant at 1% level of probability
*: Significant at 5% level of probability

Appendix VIII. Analysis of variance of the data of on panicle length, filled, unfilled and 1000 grains weight of aromatic rice

Source	DF	Panicle length	Filled grains panicle^{-1}	Unfilled grains panicle^{-1}	1000 grains weight
Replication (R)	2	12.8694	593.32	4.3150	13.4216
Clipping (C)	2	10.3826**	906.02**	43.9578**	10.6489**
Spacing (S)	3	10.8016**	1042.78**	44.9295**	12.9255**
C×S	6	0.7234*	36.23*	4.6439**	0.4494*
Error	22	0.7136	35.70	0.4614	0.7628

** : Significant at 1% level of probability
*: Significant at 5% level of probability

Appendix IX. Analysis of variance of the data of on grain yield, straw yield, biological yield and harvest index

Source	**DF**	Grain yield	Straw yield	Biological yield	Harvest index
Replication (R)	2	0.08333	0.02778	0.19444	1.420E-28
Clipping (C)	2	2.15267**	0.90470**	5.83174**	21.4329**
Spacing (S)	3	1.35829**	0.77344**	4.18056**	9.63636**
C×S	6	0.10284*	0.11680*	0.40626*	1.09286*
Error	22	0.08333	0.04414	0.39263	0.72727

** : Significant at 1% level of probability
*: Significant at 5% level of probability