EVALUATION OF FOLIAGE APPLIED BORON ON GROWTH, YIELD ATTRIBUTES AND YIELD OF AROMATIC RICE

A THESIS
BY

MST. NISHAT TASLIM ETU
Student No. 1701360
Session: 2023-24
Thesis Semester: January-June, 2024

MASTER OF SCIENCE (M.S.)
IN
AGRONOMY

DEPARTMENT OF AGRONOMY
HAJEE MOHAMMAD DANESH SCIENCE AND TECHNOLOGY UNIVERSITY, DINAJPUR-5200

JUNE 2024

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JUNE 2024

DEDICATED

TO

MY BELOVED PARENTS

ACKNOWLEDGEMENTS

All praises are due to the Almighty Allah, the omniscient, omnipresent and omnipotent Authority of this Universe, who enabled me to pursue my education in Agriculture and to complete as well as to submit the thesis for the degree of Master of Science (MS) in Agronomy.

*It is a pleasure to me to express my heartiest gratitude and profound respect to my honorable teacher, research supervisor, **Professor Dr. Md. Mominur Rahman,**Department of Agronomy,Hajee Mohammad Danesh Science and Technology University, Dinajpur for his helpful advice, scholastic guidance during planning and execution of the research, valuable suggestions, continuous support and all kind of support and help throughout the period of research work and preparation of manuscript of the dissertation, otherwise it would be too tough to complete the thesis with the stipulated period.*

*I feel proud in expressing my respect and gratefulness to my honorable teacher and research co-supervisor, **Assistant Professor Md. Obaidullah Saddam,** Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur for his valuable suggestions, friendly support, sincere help and intellectual instruction during the period of experiment. I am also indebted to him for his encouragement and valuable appreciation in preparation of this thesis.*

I express my sincere appreciation, heartfelt gratitude and profound respect toall teachers of the Dept. of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur, for their kind co-operation, constant encouragement, useful suggestions, valuable instructions and immense help in successful completion of this thesis.

I extend my personal gratitude to all the staffs of Dept. of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur for their help and assistance during the period of the study.

*I want to say thanks to all of my classmates and friends, juniors for their active encouragement and inspiration. I also cannot but thank and appreciate to **Md. Shakil Islam Miajy** for supplying necessary support and sacrificing a lot of time during the research period.*

Finally, I would like to express my sense of gratitude, immense indebtedness to my beloved parents, friends and all the relatives for their everlasting love, patience, unlimited sacrifice, blessing, endless inspiration and co-operation to complete my MS degree.

The Authoress

June 2024

ABSTRACT

The field experiment was conducted at the research field of Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200, during the period from July 2023 to December 2023 in aman season to observe the growth and yield performance of aromatic rice in response to variety and level of Boron. The experiment comprised of two factors viz. factor A: Varieties; V_1 = katarivog, V_2 = Kalizira and V_3 = Tulsimala; factor B: Levels of Boron; T_1 = No application of boron, T_2 = 100 ppm, T_3 = 200 ppm, T_4 = 300 ppm. The experiment was laid out in a RCBD design with three replications. Different variety had significant influenced on growth, yield and yield contributing parameters. The highest plant height (59.92, 108.07, 137.98 and 152.77 cm at 30, 60, 90 DAT and at harvest respectively) was achieved from the variety V_2 (Kalizira). The highest number of tillers hill^{-1} (12.73, 22.75, 28.07 and 22.72 at 30, 60, 90 DAT and at harvest respectively) was obtained from the variety V_2 (Kalizira). The highest number of panicles hill^{-1} (29.98), panicles length (26.83cm), effective tiller (22.45), was found from V_2 (Kalizira). On the Other hand different rates of boron foliar application had also significant influenced on growth, yield and yield contributing parameters. The highest number of tillers hill^{-1} (14.84, 24.82, 29.78 and 22.55 at 30, 60, 90 DAT and at harvest respectively), panicle length (25.602 cm), number of effective tillers hill^{-1} (21.43), was obtained from T 3 treatment. Again the highest 1000-grains weight (11.87 g), grain yield (3.32 t ha^{-1}), straw yield (7.56 t ha^{-1}), biological yield (10.88 t ha^{-1}), harvest index (31.26%) was obtained from T_3 treatment. Interaction effect of variety and splitting different rates of boron as foliar application had also significant influenced on growth, yield and yield contributing characters of aromatic rice. The highest grain yield (3.430 t ha^{-1}) from V_2T_3 and the lowest yield (2.14 t ha^{-1}) obtained from V_3T_1 from the combined effect of varieties and Different levels of B doses. The results indicate that the best performing kalizira aromatic rice variety in Bangladesh would benefit by applying 200 ppm of boron.

Key words : Aromatic rice, Kalizira, Boron

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ABBREVIATIONS

AEZ= Agro Ecological Zone

ANOVA= Analysis of Variance

BBS = Bangladesh Bureau of Statistics

BRRI = Bangladesh Rice Research Institute

CV = Co-efficient of Variance

DAT = Days After Transplanting

DMRT = Duncan's Multiple Range Test

EC = Electrical Conductivity

FAO = Food and Agriculture Organization

FAOSTAT = The Food and Agriculture Organization Corporate Statistical Data

HSTU = Hajee Mohammad Danesh science and Technology University

IRRI = International Rice Research Institute

ISTA = International Seed Testing Association

LS = Level of Significance

LSD = Least Significant Difference

Meq = Milliequivalent

NS = Not Significant

ppm = Parts Per Million

RCBD = Randomized Complete Block Design

SRDI = Soil Research Development Institute

t/h = Ton per hectare

UNDP = United Nations Development Program

CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) is the staple food of more than half of the world's population. More than 3.5 billion people depend on rice for more than 20% of their daily calories. It provided 19% of global human per capita energy and 13% of per capita protein. Rice is a fundamental cereal crop that plays a vital role in sustaining food security for almost 50% of the world's population (Mohidem *et al.*, 2022). Aroma is the primary grain quality factor that significantly affects the price of rice in both domestic and global markets (Hui *et al.*, 2022). Rice stands the second in the world after wheat in area and population. It occupies an area of 153.76 m. ha with an annual production of 598.85 MT. with a productivity of 4895 kg ha^{-1} in the world (FAO, 2017).

Rice is the most important cereal crop in Bangladesh and it is our staple food.According to Bangladesh Bureau of Statistics (BBS, 2024), the total rice cultivated area was 28755000 acres and production was 39095000 metric ton per hectare in the fiscal year 2022-23. The 2nd largest part of the total production of rice comes of *Aman* rice after *Boro*. Agriculture in Bangladesh is characterized by intensive crop production with rice based cropping system. The average yield of rice in our country is around 4.57 t ha^{-1} which is less than the world average (7.48 t ha^{-1}) and frustratingly below the highest yield recorded (9.65 t ha^{-1}) in Australia (FAO, 2019).

In Bangladesh three distinct classes of rice, based on the season of cultivation namely Aus, *Aman* and *Boro* are cultivated during the period April to July, August to December and January to May, respectively. On average, *Aus, Aman* and *Boro* rice were recently reported to account for 7%, 38%, and 55%, respectively, of the total rice production in Bangladesh (Risingbd, 2014). Among three growing seasons *Aman* rice occupies the highest area coverage (34% of gross cropping area). There are 47 *Aman* rice varieties cultivated in Bangladesh including aromatic, non-aromatic, hybrid and HYV rice (BRRI, 2018).

Despite the challenges, there are significant opportunities for promoting GAPs adoption and enhancing the sustainability of aromatic rice production in Bangladesh (Hoque *et al.*, 2024). In addition, there are about 100 other volatile compounds, including 13 hydrocarbons, 14 acids, 13 alcohols, 16 aldehydes, 14 ketones, 8 esters, 5 phenols and some other compounds, which are associated with the aroma development in rice (Singh *et al.,* 1999). Most of the aromatic rice varieties in Bangladesh are traditional photoperiod sensitive types and are grown during *Aman* season. Demand for aromatic rice in recent years has increased largely for both internal consumption and export (Singh *et al.,* 2014). Aromatic rice varieties are rated best in quality and fetch a much higher price than non-aromatic rice.

In Northern districts of Bangladesh, 30% of the rice lands were covered by aromatic rice cultivars during Aman season (Islam *et al.,* 2012). Among the aromatic rice cultivars, Chinigura was the predominant one that covered more than 70% farms in the northern districts of Naogaon and Dinajpur (Baqui *et al.,* 1997). In Bangladesh, the practice of increased cropping and ongoing cultivation of high-yielding rice varieties has resulted in the gradual reduction of nitrogen (N), phosphorous (P), potassium (K) and other important macro and micro-nutrients from the soils (Urmi *et al.,* 2022). In respect of production of aromatic rice, Dinajpur, Naogaon, Chittagong and Sherpur had 1st, 2nd, 3rd and 4th position respectively in 2002-03 (Talukder *et al.,* 2004). Aromatic rice plays a vital role in international rice trading. Bangladesh has a bright prospect for export of fine rice thereby earning foreign exchange (Islam *et al.,* 2012). The demand of aromatic rice in this country is increasing due to its special appeal for aroma and acceptability although grain yield is low.

Mineral nutrition of plants is important for controlling physiological and biochemical processes of plants. Its deficiency may lead to changes in these processes and disturbed plant growth and yield. Boron is one of mineral nutrients that are required for normal plant growth. The essentiality of B for growth and development of higher plants has been earlier demonstrated (Marschner, 1995; Shelp, 1993).

Plant absorbs nutrients as well as other chemicals (e.g. herbicides) through their foliage. Foliar fertilization enables to correct deficiencies, strengthen weak or damage crop, speed growth and grow better plants, which is of course, the bottom line. Foliar fertilization increases chlorophyll production and synthesis in the cells of leaves most exposed to direct sunlight. This increase in cellular activity requires much more water by the leaf.

In general, farmers prefer rice varieties that are high yielding, have high market value and are of short duration (Bishwas *et al.,* 2023). Boron plays an important role for better pollination, seed setting and grain formation in different rice varieties (Rehman *et al.,* 2012). Boron is more important at the time of reproductive stage as contrast with vegetative stage of the crop and observed 90% of the boron in plants is localized in the cell walls (Loomis and Durst, 1992). A whitish discoloration and twisting of new leaves is the symptoms which begin in rice when boron deficiency (Yu and Bell, 1998). The severe deficiencies of boron symptom from rice include thinner stems, shorter and fewer tillers, shorter panicle length and failure to produce filled grains. Stems and leaves were found to be brittle while boron suffering leaves and stems are flaccid due to boron deficient. Decreasing productivity of rice in the rice growing countries is due to the deficiencies of micronutrient (Savithri *et al.,* 1999).

Boron deficiency is more important as it influences the flowering and plant reproductive process and therefore directly influences harvested yield (Bolanos *et al.,* 2004). In boron deficient plants, the amount of protein and soluble nitrogenous compounds are lower (Gupta, 1993).

Boric acid (H_3BO_3) is the most commonly used for B source and contain about 17% B. The most common methods of B application are broadcast banded or applied as a foliar spray or dust. Rate of B fertilizer application is dependent on plant species, soil cultural practices, rainfall, liming soil organic matter and other factors.

So, it is essentially required to elucidate the impact of different aromatic rice varieties with the application of different levels of Boron bio-fertilizer in Bangladesh condition. Under the above circumstances, the present experiment was undertaken with the following objectives.

Objective(s):

1. To compare the performance of different varieties of aromatic rice.
2. To evaluate the effect of foliar application of boron on the grain set and yield of aromatic rice.
3. To find out the optimum combination between variety and boron application on the growth and yield of aromatic rice.

CHAPTER II

REVIEW OF LITERATURE

Yield and yield contributing characters of rice considerably depend on basic ingredients of agriculture. The basic ingredients include variety, environment and agronomic practices (planting density, fertilizer, irrigation, seedling types etc.). Among the above factors B application are more responsible for the growth and yield of aromatic rice. The available relevant reviews of literature on the related works done in the recent past have been presented and discussed in this chapter.

2.1 Effects of variety on growth, yield attributes, yield and harvest index of aromatic rice

Khatun *et al.* (2020) conducted a field experiment with six rice cultivars to determine their growth and yield performance. The experiment was laid out in a randomized complete block design (RCBD) with four replications. All the growth and yield contributing attributes varied significantly among the six rice cultivars. The results revealed that in all rice cultivars maximum growth performance observed at 58-68 Days after transplanting and maximum dry matter production was observed at 68 days after transplanting. Maximum number of filled spikelet observed in Binadhan-17 (164.89 penicle^{-1}) and that was significantly different from other cultivars. Percent of sterile spikelet was highest in BRRI dhan39 (12.9%) and that was statistically similar with Binadhan-16 (11.96%) and BRRI dhan33 (12.36%). Maximum 1000-seed weight was observed in Binadhan-17 (27.25 g). Highest grain yield was obtained from Binadhan-17 (6.13 t ha^{-1}) that was significantly different from other cultivars. Lowest grain yield observed in BRRI dhan39 (4.49 t ha^{-1}) that was statistically similar to BRRI dhan33 (4.57 t ha^{-1}) and Binadhan-7 (4.86 t ha^{-1}).

Laila and Sarkar (2020) conducted an experiment to study the combined effect of vermicompost with inorganic fertilizers on the yield and yield contributing characters of aromatic fine rice cultivars. The experiment comprised three 5 cultivars viz. BRRI dhan34, Binadhan-13 and Kalizira and five nutrient managements viz. control (no application of manures and fertilizer), recommended dose of inorganic fertilizers (i.e. 150, 95, 70, 60, 12 kg ha^{-1} of Urea, TSP, MOP, Gypsum and Zinc Sulphate respectively), vermicompost @ 3 t ha^{-1}, 25% less than recommended dose of inorganic fertilizer + vermicompost @ 1.5 t ha^{-1}, 50 % less than recommended dose of inorganic fertilizer +

vermicompost @ 3 t ha^{-1}. The experiment was laid out in a randomized complete block design with three replications. Result showed that, yield and yield components of aromatic fine rice were significantly influenced by cultivar, nutrient management and interaction of cultivar and nutrient management. In case of cultivar, the highest and the lowest value of grain yield (3.89, 2.80 t ha^{-1}) and straw yield (5.29, 4.03 t ha^{-1}) were found in Binadhan-13 and Kalizira, respectively. In case of nutrient managements, the highest yield and yield component were obtained from 50% less than the recommended dose of inorganic fertilizers + vermicompost @ 3 t ha^{-1} treatment. The highest number of total tillers $hill^{-1}$, effective tillers $hill^{-1}$, number of grains $panicle^{-1}$, panicle length, grain yield (4.04 t ha^{-1}) and straw yield (6.20 t ha^{-1}) were obtained from the interaction of Binadhan-13 and 50% less than the recommended dose of inorganic fertilizers + vermicompost @ 3 t ha^{-1}. The lowest values related to yield were found in Kalizira with control condition. Binadhan-13 along with 50% less than the recommended dose of inorganic fertilizers + vermicompost @ 3 t ha^{-1} might be a promising practice for aromatic fine rice cultivation.

Peter *et al.* (2019) reported that the aromatic group of Asian cultivated rice is a distinct population with considerable genetic diversity on the Indian subcontinent and includes the popular Basmati types characterized by pleasant fragrance. Genetic and phenotypic associations with other cultivated groups are ambiguous, obscuring the origin of the aromatic population. From analysis of genome-wide diversity among over 1,000 wild and cultivated rice accessions, we show that aromatic rice originated in the Indian subcontinent from 6 hybridization between a local wild population and examples of domesticated *japonica* that had spread to the region from their own center of origin in East Asia. Most present-day aromatic accessions have inherited their cytoplasm along with 29-47% of their nuclear genome from the local Indian rice. We infer that the admixture occurred 4,000-2,400 years ago, soon after japonica rice reached the region. We identify Aus as the original crop of the Indian subcontinent, *indica* and *japonica* as later arrivals, and aromatic a specific product of local agriculture. These results prompt a reappraisal of our understanding of the emergence and development of rice agriculture in the Indian subcontinent.

Kader *et al.* (2018) observed that BRRI dhan70 is a new aromatic, high yielding and extra-long slender grain containing transplanted *Aman* rice cultivar which is an improvement over existing premium quality rice BRRI dhan37. BRRI dhan70 has pleasingly passed in the proposed cultivar trial 7 conducted in the farmers' field. As a result National Seed Board (NSB) approved this cultivar for commercial cultivation in the wet season (T. *Aman*) of Bangladesh in 2015. The important feature of BRRI dhan70 is the straw colored extra-long slender, higher elongation ability and aroma of the cooked rice. The growth duration of BRRI dhan70 is 130 days which is 10-15 days earlier growth duration than BRRI dhan37. Thousand grain weight of the cultivar is 20 gm and it has colored grain tip and pointed awn. The rice has 21.7 % amylose content with 9.5% protein content. The special character of the cultivar is lodging tolerance. It has long, erect deep green flag leaf. BRRI dhan70 can produce 4.8-5.0 ha^{-1} yield with proper management which is approximately 1.0-1.35 t ha^{-1} higher yield than BRRI dhan37. The exportable aromatic rice BRRI dhan70 is an excellent cultivar for cultivating in the wet (T. *Aman*) season and farmers can be benefited by the cultivation of BRRI dhan70.

Halder *et al.* (2018) conducted an experiment at the Agronomy Field of Patuakhali Science and Technology University, Dumki, Patuakhali from June to December, 2013 to find out the effect of cultivar and planting density on the yield and yield attributing characters of local aromatic rice. The experiment was laid out in a factorial randomized complete block design with three replications, which consisted of three local aromatic rice cultivars (Chinigura, Shakhorkhora and Kalizira) and four planting densities were viz. S_1 (25 cm × 20 cm), S_2 (20 cm × 20 cm), S_3 (20 cm × 15 cm) and S_4 (20 cm × 10 cm). The results revealed that the local aromatic rice var. Shakhorkhora cultivar produced the highest number of grains per panicle (131) and 1000-grain weight (13.8 g), consequently higher grain (2.63 t ha^{-1}), followed by Kalizira (2.56 t ha^{-1}) and straw yield (4.21 t ha^{-1}). One the other hand, higher number of tillers per hill (14.8), number of grains per panicle (140 nos.) were found in 20 cm × 20 cm spacing with higher grain yield.

Murshida *et al.* (2017) conducted an experiment with three varieties (cv. BRRI dhan28, BRRI dhan29 and Binadhan-14) and four water management systems to examine the effect of variety and water management system on the growth and yield performance of *Boro* rice. At 100 DAT, the highest plant height, maximum number of tillers $hill^{-1}$, dry matter of shoot $hill^{-1}$ and dry matter of root $hill^{-1}$ were 4 obtained from BRRI dhan29 and the lowest values were found in Binadhan-14. Variety had significant effect on all the crop characters under study except 1000-grain weight. The highest grain yield was obtained from BRRI dhan29 and the lowest value was recorded from Binadhan-14.

Chowdhury *et al.* (2016) conducted an experiment with a view to finding out the effect of cultivar and level of nitrogen on the yield performance of fine aromatic rice. The experiment consisted of three cultivars viz. Kalizira, Binadhan-13 and BRRI dhan34. Cultivar significantly influenced the yield of aromatic rice. The highest grain yield (3.33 t ha^{-1}) was obtained from Binadhan-13 followed by BRRI dhan34 (3.16 t ha^{-1}) and the lowest grain yield was found in Kalizira (2.11 t ha^{-1}).

Bony *et al.* (2015) conducted an experiment to evaluate the performance of local aromatic rice cultivars viz. Kalijira, Khaskani, Kachra, Raniselute, 12 Morichsail and Badshabhog. The rice cultivars varied considerably in terms of crop growth characteristics as well as yield and yield contributing characters. The highest plant height (116.00 cm) was found in the cultivar Morichsail and the lowest in the cultivar Khaskani. Number of filled grains $panicle^{-1}$ was found highest (100) with the cultivar Khaskani and the lowest was recorded in the cultivar Raniselute. Raniselute produced the highest 1000-grain weight (32.09 g) and the lowest (13.32 g) was recorded from the cultivar Kalijira. The cultivar Morichsail produced the highest grain yield (2.53 t ha^{-1}) followed by Kachra (2.41 t ha^{-1}), Raniselute (2.13 t ha^{-1}) and Badshabhog (2.09 t ha^{-1}) and the lowest grain yield (1.80 t ha^{-1}) was obtained from Kalijira. The results of various characters studied in the experiments suggested that some good characters exist in local aromatic rice cultivars which can be exploited through breeding.

Hasan *et al.* (2014) carried out an experiment to study the performance of two *Aman* rice varieties (BRRI dhan31 and BRRI dhan41) under different planting methods (line sowing with sprouted seeds by drum seeder, haphazard transplanting and transplanting in line). The highest no. of total tillers m^{-2} (421.12), effective tillers m^{-2} (410.65) and grain yield (5.08 t ha^{-1}) were recorded due to effect of the interaction of line sowing method with sprouted seeds by drum seeder and the variety BRRI dhan41.

Sarkar *et al.* (2014) conducted an experiment to study the yield and quality of aromatic fine rice as affected by variety and nutrient management. The experiment comprised three aromatic fine rice varieties viz. BRRI dhan34, BRRI dhan37 and BRRI dhan38. The tallest plant (142.7 cm), the highest number of effective tillers $hill^{-1}$ (10.02), number of grains $panicle^{-1}$ (152.3), panicle length (22.71cm), 1000-grain weight (15.55g) and grain yield (3.71 t ha^{-1}) were recorded in BRRI dhan34.

2.2 Effects of boron bio-fertilizer on growth, yield attributes, yield and harvest index of aromatic rice

Rajput *et al.* (2024) conducted two field experiments were carried out in Kharif 2019 and 2020 at Meerut (Uttar Pradesh), India, to find the effect of iron and boron nutrition on rice with different planting densities. The main plot treatment consists of three planting densities, and the subplot treatment consists of five foliar applications of micronutrients. They were tested in a split-plot design (SPD) with three replications. The results revealed that the rice transplanted with one seedling hill^{-1} gave the highest iron and boron content in grains and/or the crop fortified with iron and boron at 0.1 and 0.04% applied at the maximum tillering (MT) and panicle initiation (PI) stages of rice, respectively. The higher values of yield-contributing characters such as effective tillers m^{-2}, panicle length (cm), grain weight panicle^{-1} (g), and test weight (g), as well as quality parameters such as nutrient content in grain (mg kg^{-1}), volume expansion ratio, protein content in grains (%), and amylose content (%) of rice were noticed in one seedling hill^{-1} except effective tillers m^{-2} during the first and second years. Application of Fe and B at the MT and PI stages of rice improved almost all the yield attributes and quality parameters. Planting density of two and three seedlings hill^{-1} was recorded at par values of grain yield, followed by one seedling hill^{-1}. Rice transplanted with three seedlings hill^{-1} obtained an average of 10.1 and 10.6% more grain yield than one seedling hill^{-1} during the first and second years, respectively. However, the application of Fe at 0.1% and B at 0.04% during both stages through foliar spray resulted in the highest seed yield and showed parity with the application of iron at 0.1% at the MT stage and boron at 0.04% at the PI stage. Economics revealed that the planting density of three seedlings hill^{-1} gave the maximum net returns of 61,585 and 66,752 tk. ha^{-1} with a benefit–cost ratio of 2.12 and 2.19 during 2019 and 2020, respectively. Furthermore, the highest net returns (62,188 and 67,938 tk. ha^{-1}) and benefit–cost ratio (2.15 and 2.23) were observed from the treatment of iron at 0.1% and boron at 0.04% at the MT and PI stages during the first and second years, respectively.

Paul *et al.* (2024) conducted an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh, to address this challenge; an investigation was conducted to find out the potential impact of micronutrients on enhancing the yield of Boro rice through foliar application. The study was structured using a randomized complete block design and replicated three times. Field trials were conducted with three micronutrients (Boron, Zinc and Copper) and involved seven treatments, namely control (NPK), NPK + Zinc, NPK + Boron, NPK + Zinc + Boron, NPK + Zinc + Copper, NPK + Boron + Copper, and NPK + Zinc + Boron + Copper. The addition of zinc, boron and copper led to a notable enhancement in the factors contributing to yield. The maximum number of total tillers hill^{-1} (11.29), effective tillers hill^{-1} (10.09), panicle length (24.69), grain panicle^{-1} (138.36), grain yield (5.43 t ha^{-1}) and straw yield (7.22 t ha^{-1}) was resulted when NPK + Zinc + Boron + Copper applied together. The least grain yield (3.64 t ha^{-1}) was produced in control (NPK) owing to lower number of effective tillers hill^{-1} (7.46), lower number of grain panicle^{-1} (118.46) and higher number of sterile spikelet panicle^{-1} (25.46). The findings suggested that the appliance of NPK combined with Zn, B and Cu yielded superior in BRRI dhan89.

Songsriin *et al.* (2023) examined the effect of B fertilizers applied by soil and foliar routes on the yield and total B uptake under glasshouse and field conditions. A high-yield rice variety, Sanpatong 1, was used in the experiments. In a pot experiment, soil B application produced a grain yield of 23.4 g pot^{-1}, similar to the control treatment, but foliar B decreased grain yield by 14.9%. The total uptake of B was the highest at 2.5 mg pot^{-1} when soil B was applied, 66.7% higher than the in the control and foliar B application treatments, but there was no significant effect on the numbers of filled or unfilled grains. Similar responses of grain yield and total B uptake were observed in both conditions. Soil B application produced a grain yield of 4.7 t ha^{-1}, similar to the control, but foliar B application decreased grain yield by 10.9%. The total uptake of B in the field was the highest at 4.7 mg m^{-2} when soil B was applied, being 42.4% higher than in the foliar B application and control treatments. This study indicates that the total uptake of B in rice plants can be successfully improved by applying soil B fertilizer, even though no effect was observed on productivity. The efficacy of B uptake in rice plants by soil B application is an interesting subject that should be further studied in greater detail to determine its utility in yield production, e.g., by splitting application times.

Deeksha *et al.* (2022) conducted an experiment during the rainy season (kharif) of 2019 at the Punjab Agricultural University, Ludhiana, to explore the role of boron (B) in improving seed filling, vascularisation and yield of rice (*Oryza sativa* L.). The field experiment comprising 14 treatments, viz. foliar application of boron (B) @ 24, 28, 32 and 40 mill molar (mM) at boot-leaf stage (BL) or at 1 week after boot-leaf stage (1 WABL) as well as at both the stages (BL+1 WABL) along with foliar application of water and control (unsprayed), were laid out in randomized complete-block design, with 3 replications. Plants sprayed with 24 mM B at different stages showed improved photosynthetic efficiency in terms of chlorophyll content, carotenoid content and hill-reaction activity of leaf chloroplasts. Also, the yield-attributing traits, viz. 1,000-grain weight, panicle weight and panicles m^{-2}, were significantly higher in plants treated with 24 mM B at BL + 1 WABL, followed by plants treated with 24 mM B at 1 WABL, which were similar to that treated with 24 mM B at BL or at 1 WABL. Increasing B concentration above 24 mM showed negative impact on the growth and yield of rice. Thus, foliar spray of 24 mM B at BL or 1 WABL may be used to improve the productivity of rice.

Islam *et al.* (2021) evaluated the performance of foliar-applied boron in mitigating that problem towards sustainable *Aman* rice production. A field experiment was laid out in a randomized complete block design where different levels of boron viz. 0, 50, 100, 150, 200, and 250 ppm were foliar-sprayed at 33 and 47 days after transplanting (DAT) to a popular aromatic rice cultivar Kataribhog grown in late monsoon. Data were collected on phenology, SPAD value at variable dates, pollen viability, boron concentration in leaves and grains, and yield traits and yield. The pollen viability increased by 81.6% for 200 ppm boron. Boron decreased flag leaf weight but increased panicle weight. Simultaneously, it decreased flag leaf SPAD value and subsequent increase in grain yield, which indicates profound flag leaf reserves translocation into the grain. Foliar-applied B at 200 ppm showed a 32.4 and 40.9% increase of B in leaf and grain, respectively, and improved yield attributes resulting in increased grain yield by 47.0%. The grain yield had strong positive relations with the B content in leaf and grain, and yield contributing characters. The results conclude that foliar-applied appropriate dose of B can reduce spikelet sterility, individual grain weight and eventually enhance grain formation towards increasing yield in late sown aromatic monsoon rice.

Aamer *et al.* (2020) conducted a field experiment during kharif season of 2018-19 at Rice Research Station Bahawalnagar on the calcareous sandy loam soil to assess the effect of foliar application of boron on growth & yield components of rice varieties (Kissan & Punjab Basmati 2016).The foliar application of boron aqueous solution was used as treatments comprised of control, 0.5 kg ha^{-1}, 1.00 kg ha^{-1}, 1.5 kg ha^{-1} & 2.0 kg ha^{-1} Boron. Boric acid (11.17% B) was used as the source of boron (soluble in warm water). In this investigation a recommended dose of N at 133 kg, P_2O_5 at 85 kg ha^{-1}, 50 kg ha^{-1}

K_2O was applied to rice crop. The experiment was carried out in Randomized Complete Block Design (RCBD) with factorial arrangement having three replications and five treatments (T_1= control, T_2= 0.5 kg ha^{-1}, T_3= 1.00 kg ha^{-1}, T_4= 1.5 kg ha^{-1} & T_5= 2.0 kg ha^{-1} B). The data of growth and yield components (field data) was recorded according to the standard procedures. Fisher analysis of the variance was used for statistical analysis & treatments mean difference was compared using LSD at 5% probability level. Boron showed the significant effects on plant height (cm), number of tillers/plant, panicle length (cm), number of grains/panicle, 1000 grain weight & ultimately the paddy yield of rice over control.

A field experiment was conducted at Agricultural College Farm, Bapatla during Kharif season by Gowthami *et al.* (2018) to study the effect of foliar application of potassium, boron and zinc on quality p and seed yield in soybean. The experiment was carried out in clay loam soil in a randomized block design with eight treatments and three replications. Treatments consisted of T_1- Foliar applications of potassium nitrate @ 2% at 30 and 60 DAS, T_2- Foliar application of boric acid @ 50 ppm, T_3- Foliar application of zinc sulphate @ 1%, T_4- Foliar application of potassium nitrate @ 2% + boric acid @ 50 ppm, T_5- Foliar application of potassium nitrate @ 2% + zinc sulphate @ 1%, T_6- Foliar application of boric acid @ 50 ppm + zinc sulphate @ 1%, T_7- Foliar application of potassium nitrate @ 2% + boric acid @ 50 ppm + zinc sulphate @ 1% and T_8- Control (Water spray). The results revealed that foliar application of potassium nitrate @ 2% + boric acid @ 50 ppm + zinc sulphate @ 1% (T_7) at 30 and 60 DAS was found to be superior in increasing the quality parameters like SCMR (29.12% over control), total chlorophyll content (20.60% over control), protein (12.82% over control), oil content (26.24% over control) and yield (28.59% over control) followed by potassium nitrate @ 2% + boric acid @ 50 ppm at 30 and 60 DAS (T_4), boric acid @ 50 ppm + zinc sulphate 16 @ 1% at 30 and 60 DAS (T_6) and potassium nitrate @ 2% + zinc sulphate @ 1% at 30 and 60 DAS (T_5).

Patil *et al.* (2017) conducted a field experiment to examine the impact of soil application of boron on growth, yield and soil properties of lowland paddy. The doses of borax were (0, 2.5, 5.0, 7.5 and 10) kg ha^{-1} respectively. The soil available B (hot water soluble) was ranges between 0.292 to 0.412 ppm. The pooled analysis reported that treatment T_5 (Soil application of borax @10 kg ha^{-1}) produced significantly higher grain (43.45 q ha^{-1}) and straw yield (51.91 q ha^{-1}), however it was at par with treatment T_3 (Soil application of borax @ 5 kg ha^{-1}) and T_4 (Soil application of borax @ 7.5 kg ha^{-1}). It was recommended to apply 5 kg borax ha^{-1} in boron deficient soils at the time of transplanting to get higher yield and returns of paddy.

Ali *et al.* (2016) carried out an experiment to assess the effect of foliar application of B on yield and yield contributing characters of rice in calcareous soils with six B foliar application rates (0, 5, 10, 15, 20 and 25 mg L^{-1}). Boron (B) is an important micro nutrient 12 and its deficiency caused a reduction in final crop harvest and quality of the yield. The outcome delineated a noteworthy impact of B as foliar application on grains number $panicle^{-1}$, number of filled grains and finally grain yield. The most noteworthy grain yield (352 g m^{-2}) was observed in 20 mg L^{-1} foliar application of B. On the other hand, an increase in B as foliar application to 25 mg L^{-1} reduces the grain yield significantly (313 g m^{-2}). Adverse impacts of the most noteworthy B application on yield contributing characters were also found. The decrease in the quantity and quality rice yield came about by increasing B application may be because of the harmful impact of higher concentration of B application.

Rahman *et al.* (2016) conducted a field experiment to evaluate the effect of foliar application of boron (B) on the grain set and yield of wheat (cv. Shatabdi). The different level of B treatments were (i) B as control, (ii) soil application of B, (iii) seed priming into boric acid solution, (iv) foliar application of B at primordial stage of crop, (v) foliar application of B at booting stage and (vi) foliar application of B at primordial and booting stages. The amount of B for soil application was 1.5 kg B ha^{-1} from boric acid (17% B) and the amount for each foliar application was 0.4% boric acid solution. The treatment getting foliar application of B at both primordial and booting stages of the crop resulted the highest yield (3.63 t ha^{-1}) which was statistically similar with the yield observed with foliar application of B at primordial or booting stage of crop and with soil application of B before crop (wheat) was sown; all the yields were significantly higher over the yield noted with seed priming or control treatment. The control treatment (no B application) had the least grain yield (2.60 t ha^{-1}).

CHAPTER III

MATERIALS AND METHODS

This chapter deals with a brief description on experimental design, layout and duration, geographical location of the experimental site, soil characteristics, climatic condition, planting materials, treatments, land preparation, intercultural operations, data collection and data analysis which are described below:

3.1 Duration

The experiment was conducted at the Agronomy Research Field of Hajee Mohammad Danesh Science and Technology University, Dinajpur during the period from July 2023 to December, 2023.

3.2 Description of the Experimental site

3.2.1 Location

The experimental field was located at 25.38° N latitude and 88. 41°E longitude at an altitude of 37.5 m above from the mean sea level. The land belongs to the Agro-ecological Zone of the Old Himalayan Piedmont Plain (AEZ-1) (UNDP and FAO, 1988).

3.2.2 Soil

The soil of the experimental field belongs to the Old Himalayan Piedmont Plain (Agro ecological Zone-1). The general soil type of the experimental field was non-calcareous dark gray floodplain. Top soil was sandy loam in texture. Organic matter content was 1.48 % and soil pH varies from 5.41 (Appendix II). The land is above flood level and well drained.

3.2.3 Climate

The climate of experimental site is subtropical, characterized by three distinct seasons, the monsoon from November to February and pre-monsoon period or hot season from March to April and monsoon period from May to October. The weather data including temperature and rainfall during the period of experimental recorded from the Bangladesh Meteorological Department. The climate in Dinajpur during the period of experimentation has been presented in Appendix III.

3.3 Planting materials

Three variety of fine rice (Kataribhog, Kalizira and Tulsimala) was used as planting materials of the experiment.

Katarivog: Katarivog variety is grown in *Aman* season. It is aromatic transplanted local *Aman* rice. Katarivog rice was GI production in Dinajpur region. The grain is short and thick.

Kalizira: Kalizira variety is grown in *Aman* season. Grains are medium small that has distinct aroma and taste.

Tulsimala: Tulsimala is an indigenous variety of aromatic or scented rice. Grains are small, fine and black in color. However, this rice genotype is characterized by its sensory properties like aroma, size and taste.

3.4 Treatments

Two factors were included in the experiment namely, Boron doses and Variety. The treatments were designated as follows:

Factor A: Variety

V_1= Kataribhog

V_2= Kalizara

V_3= Tulsimala

Factor B: Foliar application of Boron

T_1= No foliar application of B

T_2= 100 ppm B

T_3= 200 ppm B

T_4= 300 ppm B

3.5 Experimental design

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. There were 12 treatment combinations, each treatment replicated three times. The treatments were randomly distributed to the plots within a block. Thus, the number of plots was 3 × 12 = 36. All the treatments were randomly allocated in the experiment plots. The plot size was 4 m × 2.5 m. The spaces between line to line and plant to plant were 20 cm and 15 cm, respectively.

3.6 Layout of the experiment:

R_1	R_2	R_3
V_1T_3	V_1T_1	V_2T_3
V_1T_4	V_2T_1	V_2T_2
V_3T_2	V_1T_4	V_3T_4
V_2T_3	V_2T_2	V_1T_1
V_2T_2	V_2T_3	V_2T_1
V_3T_3	V_2T_4	V_1T_3
V_2T_1	V_3T_4	V_3T_2
V_3T_4	V_3T_2	V_1T_4
V_1T_1	V_1T_3	V_3T_1
V_3T_1	V_3T_3	V_1T_2
V_2T_4	V_1T_2	V_2T_4
V_1T_2	V_3T_1	V_3T_3

Replication:

R_1,R_2,R_3

Unit plot size:

Plot size = 4 m × 2.5 m

Block to Block distance = 100 cm

Plot to Plot distance = 50 cm

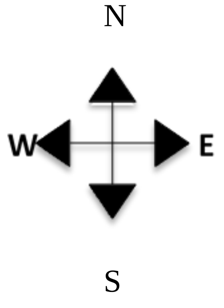

Fig. 1. Layout of the experimental design

3.7 Conduction of experiment

3.7.1 Collection of seed

Seeds were collected from the Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur.

3.7.2 Raising of seedling

Seedlings were raised in well prepared seedbed at the Agronomy research field, Hajee Mohammad Danesh Science and Technology University, Dinajpur. Before sowing in the nursery, seeds were soaked in water for 24 hours and then kept in gunny bags in dark condition. After sprouting, the seeds were sown in the wet seedbed on 23th June, 2023; Proper operations were done as per necessary.

3.7.3 Land preparation

The land was first opened in 22th June 2023. Firstly, two ploughs were given with a tractor mounted disc plough. After a few days the land was further ploughed and cross ploughed with the country plough followed by laddering to get a good puddle condition. Weeds and stubbles were removed from the field prior to transplanting of seedlings. The bounds around individual plot were made firm enough to control water movement between plots. The layout of the experiment in the field was done according to the experimental design adopted.

3.7.4 Fertilizer application

The whole amount of triple super phosphate (60 kg P_2O_5 ha^{-1}) muriate of potash (40 kg K_2O ha^{-1}), gypsum (15 kg ha^{-1}) two types of compost were applied at final land preparation time for properly mixed with soil of the field. The nitrogen was applied in the form of urea as experimental specification. One third of urea was applied during the final land preparation and the rest urea as were applied in two equal installments at 35 and 55 DAT, respectively.

3.7.5 Uprooting of seedling

The seedbeds were made wet by applications of water both in the morning and in the evening on the previous days of uprooting the seedlings. Seedlings were uprooted carefully without causing an injury to the roots and were kept in shade.

3.7.6 Preparation of experimental plots

The experiment was laid out on 22 July 2023 according to the experimental design.

3.7.7 Transplanting

Thirty-five days old seedlings of three aromatic rice varieties were transplanted with 3 seedlings hill on 26 July 2023.

3.7.8 Intercultural operations

The experimental field was frequently visited the experimental field to observed to the growth performance of rice plants as well as insects and diseases infestation in the field. The experimental field was weeded twice at 32 and 61 DAT to keep the crop-weed competition at a minimum level Top dressing of urea was done on the days previously mentioned. The crop was irrigated during growth period when necessary. Pesticide application was applied when pest infestation during the growth and development period of the crop.

3.7.9 Harvesting

Maturity of crops was determined when 80% of the seeds became golden yellow in color. The crop was harvested at full maturity on 3 December 2023 and it was done plot wise and was tagged for proper identification for threshing, cleaning and drying. The yields of both grain and straw were recorded after thoroughly drying in sun.

3.7.10 Processing

After harvest, grains were threshed, cleaned and sun dried to record the grain yield plot. The grain was adjusted to 14 % moisture content. The straw was also sun dried to record the straw yield plot. Grain and straw yield plot were converted to t ha^{-1}

3.8 Collection of data before harvest

The data of the crop were collected as follows:

3.8.1 Plant sampling

Five hills (excluding border hills) from each plot were selected randomly and tagged just after transplanting for measuring counting tillers at 20 days intervals from 35 DAT to 75 DAT.

3.8.2 Tiller counting

Tillers were counted from the selected hills at 20 days interval beginning 35 DAT to 75 DAT and final harvesting time.

3.9 Collection of data at harvest

3.9.1 Data were recorded on the following crop characteristics

i. Plant height (cm)
ii. Number of total tillers hill^{-1}
iii. Number of effective tillers hill^{-1}
iv. Number of non-effective tillers hill^{-1}
v. Length of panicle (cm)
vi. Number of grains panicle^{-1}
vii. 1000-grain weight (g)
viii. Grain yield (t ha^{-1})
ix. Straw yield (t ha^{-1})
x. Biological yield (t ha^{-1})
xi. Harvest index (%)

Data on individual plant parameters (i-vii) were recorded from selected hills of each plot, those on grain yield, straw yield, biological yield and harvest index were recorded from the whole plot at harvest, and qualitative characters were recorded from selected grain.

3.10 Procedure of recording data

A brief outline of the data recording procedure is given below:

3.10.1 Plant height (cm)

The height of plant was recorded in centimeter (cm) at 35, 55, 75 DAT and at harvest stage. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the panicle.

3.10.2 Number of total tillers hill^{-1}

Number of the tillers hill^{-1} was recorded at 35, 55, 75 DAT and at harvest stage as the average of randomly selected 5 plants from the inner rows of each plot.

3.10.3 Number of effective tillers hill^{-1}

The panicles that had at least one grain were considered as effective tillers.

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

The panicles, which had no grain, were regarded as non- Effective tillers.

3.10.5 Panicle length (cm)

The length of panicle was measured with a meter scale from 5 selected plants and the average value was recorded as per plant. Panicle length was recorded from the basal node of the rachis to the apex of each panicle.

3.10.6 Number of grains panicle

Presence of any food material in the spikelet was considered as grain and total numbers of grains present on each panicle are counted.

3.10.7 1000- Grain weight (g)

One thousand clean dried grains were counted from the seed stock obtained from five sample plants of each plot and weighted by using an electrical balance.

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

Grains obtained from each unit plot were suns dried and weighed carefully. The dry weight of grains of selected plants was added to respective unit plot to record the final grain yield plot. The grain yield was finally converted to t ha^{-1}.

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

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

Straw obtained from each unit plot including the straw of sample plants of respective unit plot was dried in sun and weighed to record that final straw yield plot and finally converted to t ha^{-1}

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

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

Grain yield and straw yield were altogether regarded as biological yield. The biological yield was calculated with the following formula:

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

3.10.11 Harvest index (%)

It denotes the ratio of economic yield to biological yield and was calculated with the following formula (Gardner *et al.*, 1985)

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

3.11 Statistical Analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference of different treatments on growth, yield and quality parameters of aromatic rice. The mean values of all the characters were statistically analyzed by following the analysis of variance (ANOVA) technique and mean differences were adjusted by Duncan's Multiple Range Test (DMRT) using the Statistic 10 computer package program. The mean differences among the treatments were compared by least significant difference (LSD) test at 5% level of significance.

CAHPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to find out the growth and yield performance of aromatic rice in response to variety and levels of boron. The results obtained from the study have been presented, discussed and compared in this chapter through table(s) and figures. The analysis of variance of data in respect of all the parameters has been shown in Appendix IV to IX. The results have been presented and discussed with the help of table and graphs and possible interpretations given under the following headings. The analytical results have been presented in Table 1 to Table 8 and Figure 1 to Figure 12.

4.1 Growth parameters

4.1.1 Plant height

4.1.1.1 Effect of variety

Significant influenced was observed on plant height by different variety of rice at different growth stages (Figure 1 and Appendix IV). The highest plant height (59.917, 108.07, 137.98 and 152.77 cm at 30, 60, 90 DAT and at harvest respectively) was achieved from the variety V_2 (Kalizira) where the lowest plant height (48.167, 99.00, 124.58 and 135.33 cm at 30, 60, 90 DAT and at harvest respectively) was observed from the variety V_1 (Katarivog). Similar results on plant height were also obtained by Murshida *et al.* (2017) who revealed that plant height of rice significantly influenced by varietal differences.

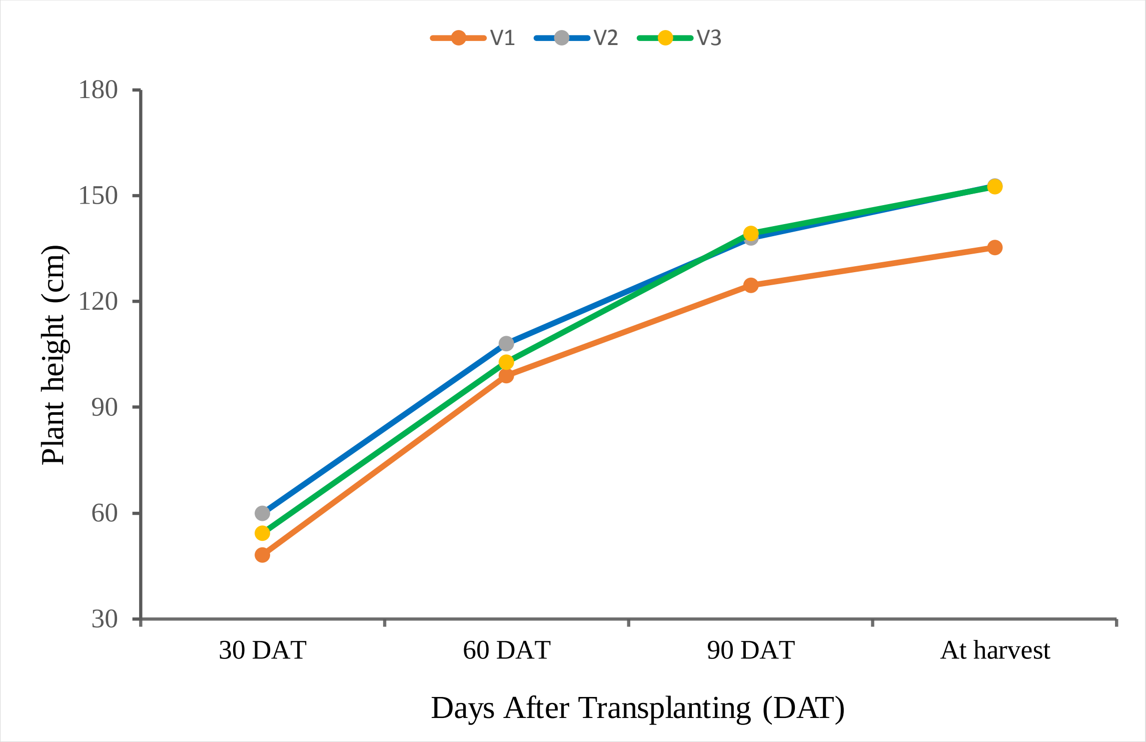

Figure 1: Effect of variety on the plant height of aromatic rice at different days after transplanting ($LSD_{0.05}$ =4.1416, 2.8645, 6.9386, 4.6095 at 30, 60, 90 DAT and at harvest, respectively)

4.1.1.2 Effect of levels of boron

Plant height at different growth stages was significantly influenced by splitting different rates of boron in the study (Table 1 and Appendix IV). It was observed that the highest plant height (61.889, 111.27, 144.49, 158.33 cm at 30, 60, 90 DAT and at harvest respectively) was obtained from T_3 treatment where the lowest plant height (45.556, 94.53, 126.27 and 135.91 cm at 30, 60, 90 DAT and at harvest respectively) was found from T_4 treatment.

Ali *et al.* (2016) revealed that splitting boron as foliar application significantly enhanced plant height of rice. Because boron is essential in increasing carbohydrate metabolism, sugar transport, cell wall structure, protein metabolism, root growth and stimulating other physiological processes of plant that helped to trigger the plant height. Crop up taken more nutrients and improved the crop vigor in splitting boron application treatment, healthy and vigorous plants will ultimately have great impact on crop growth. Similar trend of results on plant height were also achieved by Saleem *et al.* (2010) and Shafiq and Maqsood (2010).

Table-1: Effect of different levels of boron foliar application on the plant height of aromatic rice at different days after transplanting

Treatment	Plant height			
	30 DAT	**60 DAT**	**90 DAT**	**At harvest**
T_1	51.56b	100.49c	128.38b	143.82c
T_2	57.44a	106.87b	136.62a	149.51b
T_3	61.89a	111.27a	144.49a	158.33a
T_4	45.56c	94.53d	126.27b	135.91d
$LSD_{(0.05)}$	4.7823	3.3076	8.0120	5.3226
CV%	9.04	3.28	6.12	3.71
LS	NS	NS	NS	NS

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

T_1 = Control, T_2 = 100 ppm Boron foliar application, T_3 = 200 ppm Boron foliar application,

T_4 = 300 ppm Boron foliar application.

NS = Not significant.

4.1.1.3 Interaction effect of variety and boron levels

Significant difference on plant height of rice at different growth stages was observed in the study. Interaction effect of variety and splitting different rates of boron showed significant differences (Table 2 and Appendix IV). Results observed that the highest plant height (67.667, 115.13, 153.53 and 169.47 cm at 30, 60, 90 DAT and at harvest respectively) was found from the treatment combination of V_2T_3 which were statistically similar with V_2T_2, V_3T_2 and V_3T_1. The lowest plant height 47.00 at 30 DAT was obtained from the treatment combination of V_3T_4, 89.13, 116.07 and 122.53 at (60, 90 DAT and at harvest respectively) was obtained from the treatment combination of V_1T_4.

Table-2: Interaction effect of variety and different levels of boron foliar application on the plant height of aromatic rice at different days after transplanting

Combination	Plant height			
	30 DAT	60 DAT	90 DAT	At harvest
$V_1 T_1$	48.00d	95.13f	118.33de	132.00f
$V_1 T_2$	48.00d	102.67de	128.73cde	139.93ef
$V_1 T_3$	57.00bc	109.07bc	135.20bc	146.87cde
$V_1 T_4$	39.67e	89.13g	116.07e	122.53g
V_2T_1	55.00bcd	104.87cde	137.33bc	148.53cde
V_2T_2	67.00a	110.67ab	138.93bc	153.13bcd
V_2T_3	67.67a	115.13a	153.53a	169.47a
V_2T_4	50.00cd	101.60de	130.93bcd	139.93ef
V_3T_1	51.67cd	101.47e	129.47cde	150.93bcd
V_3T_2	57.33bc	107.27bcd	142.20abc	155.47bc
V_3T_3	61.00ab	109.60abc	144.73ab	158.67b
V_3T_4	47.00de	92.87fg	131.80bcd	145.27de
$LSD_{(0.05)}$	8.2833	5.7289	13.877	9.2191
CV%	9.04	3.28	6.12	3.71
LS	**	**	**	**

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

V_1 = Katarivog, V_2 = Kalizira, V_3=Tulsimala; T_1 = Control, T_2 = 100 ppm Boron foliar application, T_3 = 200 ppm Boron foliar application, T_4 = 300 ppm Boron foliar application.

** = Significant at 1% level of significance.

4.1.2 Number of tillers hill^{-1}

4.1.2.1 Effect of variety

Significant variation was found on number of tillers hill^{-1} at different growth stages due to cause of different variety of rice (Table 3 and Appendix V). But result revealed that the highest number of tillers hill^{-1} (12.736, 22.716, 28.072 and 22.718 at 30, 60, 90 DAT and at harvest respectively) was obtained from the variety V_2 (Kalizira) where the lowest number of tillers hill^{-1} (10.244, 20.225, 25.932 and 21.320 at 30, 60, 90 DAT and at harvest respectively) was observed from the variety V_1 (Katarivog). The result achieved from the present study was similar with the findings of Murshida *et al.* (2017) and Chamely *et al.* (2015).

Table-3: Effect of variety on the number of tillers hill^{-1} of aromatic rice at different days after transplanting

Variety	Number of tillers hill^{-1}			
	30 DAT	**60 DAT**	**90 DAT**	**At harvest**
V_1	10.24c	20.23c	25.93c	21.32b
V_2	12.74a	22.72a	28.07a	22.72a
V_3	11.94b	21.92b	26.32 b	21.58b
LSD	0.3672	0.3672	0.3090	0.6106
CV%	3.73	2.01	1.36	3.30
LS	**	**	**	**

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

V_1 = Katarivog, V_2 = Kalizira, V_3=Tulsimala
** = Significant at 1% level of significance.

4.1.2.2 Effect of boron

Number of tillers hill^{-1} at different growth stages of rice was significantly affected by splitting different rate of boron (Figure 2 and Appendix V). Results showed that the highest number of tillers hill^{-1} (14.842, 24.822, 29.780 and 22.555 at 30, 60, 90 DAT and at harvest respectively) was achieved from T_3 treatment where the lowest number of tillers hill^{-1} (9.109, 19.089, 24.22 and 21.321 at 30, 60, 90 DAT and at harvest respectively) was achieved from T_4 treatment. The findings were also similar with the findings of Shafiq and Maqsood (2010).

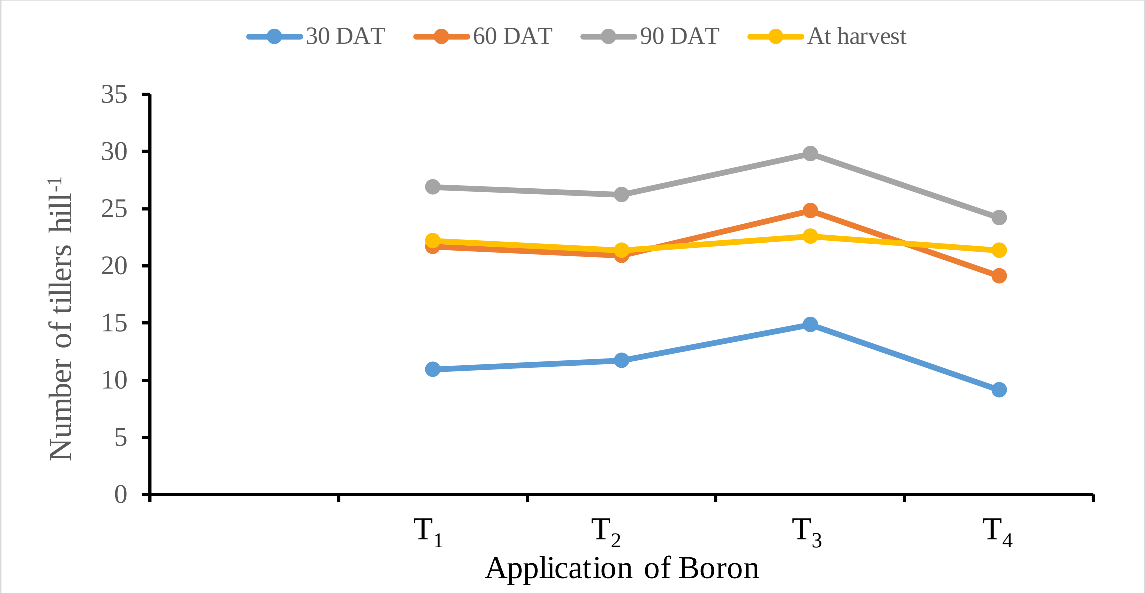

Figure 2: Effect of different levels of boron foliar application on the number of tillers hill^{-1} of aromatic rice at different days after transplanting ($LSD_{0.05}$ =0.4240, 0.4240, 0.3568 and 0.7050 at 30, 60, 90 DAT and at harvest, respectively)

4.1.2.3 Interaction effect of variety and boron

Statistically significant difference was exerted for number of tillers hill^{-1} at different growth stages of rice due to interaction effect of variety and splitting different rate of boron (Table 4 and Appendix V). Results showed that the highest number of tillers hill^{-1} (16.06, 26.046, 31.204 and 23.551 at 30, 60, 90 DAT and at harvest respectively) was achieved from the treatment combination of V_2T_3. The lowest number of tillers hill^{-1} (6.421, 16.401, 25.195 and 20.211 at 30, 60, 90 DAT and at harvest respectively) was revealed from the treatment combination of V_1 T_4.

Table-4: Interaction effect of variety and different levels of boron foliar application on the number of tillers hill^{-1} of aromatic rice at different days after transplanting

Combination	Number of tillers hill^{-1}			
	30 DAT	**60 DAT**	**90 DAT**	**At harvest**
V_1 T_1	10.49e	20.47e	25.89e	21.92bc
V_1 T_2	10.12e	20.10e	29.65b	20.50de
V_1 T_3	13.95b	23.92b	28.49c	22.64abc
V_1 T_4	6.42f	16.40f	25.20f	20.21e
V_2T_1	12.78c	22.76c	27.48d	22.88ab
V_2T_2	11.95d	21.94d	27.28d	22.08bc
V_2T_3	16.06a	26.05a	31.20a	23.55a
V_2T_4	10.15e	20.13e	25.43ef	22.36abc
V_3T_1	11.80d	21.78d	25.28ef	21.74bc
V_3T_2	10.69e	20.67e	28.18c	21.67bcd
V_3T_3	14.51b	24.49b	24.07g	21.47cd
V_3T_4	10.76e	20.74e	23.17h	21.44cd
$LSD_{(0.05)}$	0.7344	0.7344	0.6179	1.2211
CV%	3.73	2.01	1.36	3.30
LS	**	**	**	*

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

V_1 = Katarivog, V_2 = Kalizira, V_3=Tulsimala; T_1 = Control, T_2 = 100 ppm Boron foliar application, T_3 = 200 ppm Boron foliar application, T_4 = 300 ppm Boron foliar application

** = Significant at 1% level of significance.

* = Significant at 5% level of significance.

4.2 Yield contributing parameters

4.2.1 Panicle number

4.2.1.1 Effect of variety

Number of panicles hill^{-1} of aromatic rice showed statistically significant differences due to different rice variety (Table 5 and Appendix VI). The highest number of panicles hill^{-1} (21.74) was found from V_2 (Kalizira), while the lowest panicles number (19.85) was recorded from V_1 (Katarivog).

Table-5: Effect of variety on panicle number, panicle length, effective, non-effective tillers hills^{-1} of Aromatic rice

Variety	Panicle Number	Panicle Length	Effective tillers hills^{-1}	Non-effective tillers hills^{-1}
V_1	19.85c	22.51b	19.32b	1.99a
V_2	21.74a	23.75a	20.95a	1.77b
V_3	20.65b	21.73c	19.64b	1.94a
LSD	0.6253	0.2575	0.5923	0.0869
CV%	3.56	1.34	3.50	5.40
LS	**	**	**	**

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

V_1 = Katarivog, V_2 = Kalizira, V_3=Tulsimala
** = Significant at 1% level of significance.

4.2.1.2 Effect of levels of boron

Number of panicles hill^{-1} of aromatic rice was significantly influenced by the application of different levels of boron (Table 6 and Appendix VI). The highest number of panicles hill^{-1} (28.65) was recorded from T_3 treatment. On the other hand, the lowest number of panicles hill^{-1} (17.20) was observed in T_2 treatment.

4.2.1.3 Interaction effect of variety and boron levels

Interaction effect of variety and boron was found significant on number of panicles hill^{-1} of aromatic rice (Table 7 and Appendix VI). The highest number of panicles hill^{-1} (29.98) was found from the combination of V_2T_3. On the other hand, the lowest number of panicles hill^{-1} (13.397) was found in V_3T_4 treatment combination.

4.2.2 Panicle length

4.2.2.1 Effect of variety

The panicle length varied significantly due to variety shown in Figure 3 and Appendix VI. It was observed that V_2 (Kalizira) produced significantly the longest (23.751 cm) panicle. The second highest panicle length (22.512 cm) was measured from V_1 (Katarivog) and the shortest panicle length (21.732 cm) was measured from V_3 (Tulsimala).

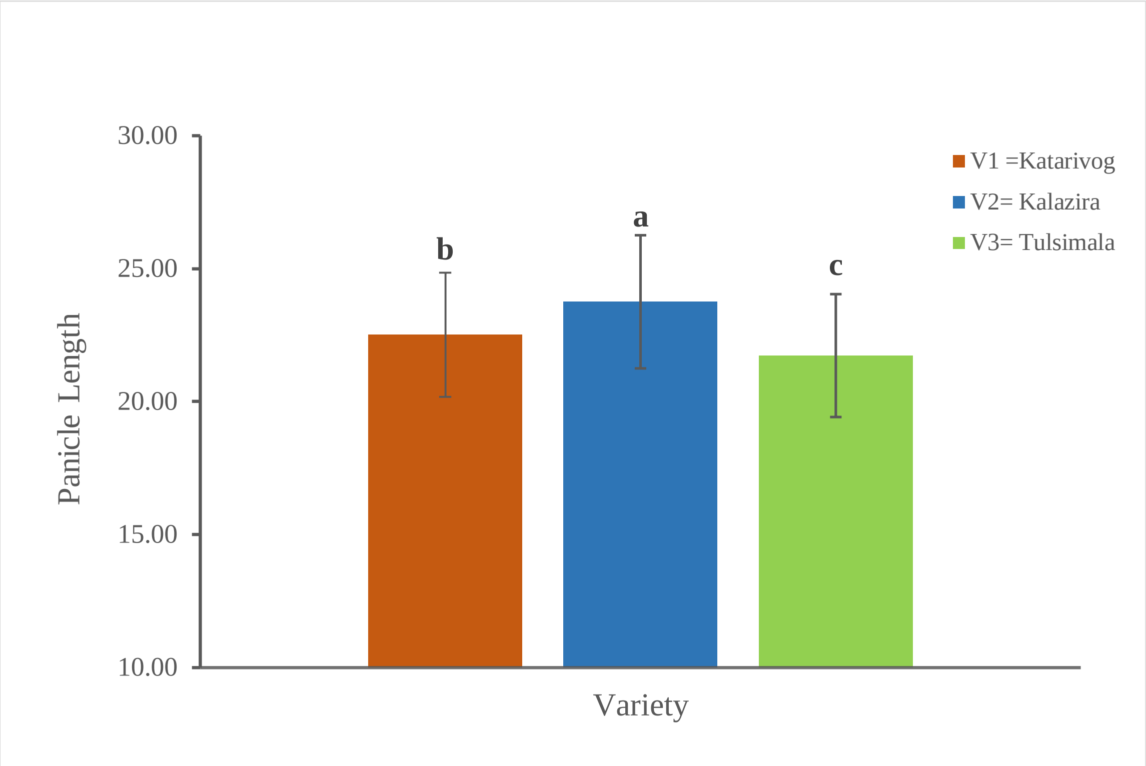

Figure 3: Effect of variety on the panicle length of aromatic rice at different days after transplanting ($LSD_{0.05}$ = 0.6253, 0.2575, 0.5923, 0.0869 at 30, 60, 90 DAT and at harvest, respectively)

4.2.2.2 Effect of levels of Boron

Panicle length was statistically significant by different levels of boron (Table 6 and Appendix VI). The longest panicle length (25.602 cm) was produced due to application of 200 ppm boron (T_3) and shortest (20.230 cm) was produced in T_4 (300 ppm boron) treatment.

4.2.2.3 Interaction effect of variety and boron levels

Interaction of different variety and boron levels significantly influenced the panicle length of aromatic rice (Table 7 and Appendix VI). The longest panicle length (26.830 cm) was recorded from V_2T_3 treatment combination. On the other hand, the shortest panicle length (19.433 cm) was observed in V_3T_4 treatment combination.

4.2.3 Number of effective tillers hill^{-1}

4.2.3.1 Effect of variety

Number of effective tiller hill^{-1} of different aromatic rice varieties showed significant difference presented in the Table 5 and Appendix VI. Among the varieties, the highest (20.954) number of effective tiller found in the variety, V_2 (Kalizira) which was significantly different from the rest of the varieties. On the other hand the lowest number of effective tiller (19.322) found in the variety V_1 (Katarivog). Similar results were also reported by Yang *et al.* (2007).

4.2.3.2 Effect of levels of boron

Number of effective tillers hill^{-1} of rice was significantly affected by splitting different rate of boron (Figure 6 and Appendix VI). Results exposed that the highest number of effective tillers hill^{-1} (21.433) was observed from T_3 treatment. On the other hand, the lowest number of effective tillers hill^{-1} (18.633) was obtained from T_4 treatment followed by T_2 (19.311).

Saleem *et al.* (2011) reported that, the positive effect on plant effective tillers may be due to the proper development and differentiation of tissue as B 11.35, 11.4, 11.45, 11.5, 11.55, 11.6, 11.65, V_1, V_2 Number of effective tillers hill^{-1} Variety 45 affects the deposition of cell wall material by altering membrane properties. Costa *et al.* (2006) observed that appropriate boron availability in soils favors root growth and a sufficient supply of this micronutrient is very important for adequate rice plant development. So, appropriate foliar application of B resulting maximum production of effective tillers hill^{-1}. The result was consistent with the findings of Khan *et al.* (2007) who reported that B application significantly affected the plant growth.

Table-6: Effect of different levels of boron foliar application on panicle number, panicle length, effective, non-effective tillers hills^{-1} of Aromatic rice

Treatment	Panicle Number (no.)	Panicle Length (cm)	Effective tillers hills^{-1} (no.)	Non-effective tillers hills^{-1} (no.)
T_1	22.33b	21.34c	20.51b	1.67c
T_2	17.20c	23.48b	19.31c	2.01b
T_3	28.65a	25.60a	21.43a	1.12d
T_4	14.80d	20.23d	18.63c	2.80a
LSD	0.7220	0.2974	0.6839	0.1003
CV%	3.56	1.34	3.50	5.40
LS	**	**	**	**

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

T_1 = Control, T_2 = 100 ppm Boron foliar application, T_3 = 200 ppm Boron foliar application,

T_4 = 300 ppm Boron foliar application.

** = Significant at 1% level of significance.

4.2.3.3 Interaction effect of variety and boron levels

Significant difference was observed for number of effective tillers hill^{-1} of rice influenced by interaction effect of variety and splitting different rate of boron (Table 7 and Appendix VI). It was remarked that the highest number of effective tillers hill^{-1} (22.453) was obtained from the treatment combination of V_2T_3 which was statistically similar with V_2T_1 treatment combination. On the other hand, the lowest number of effective tillers hill^{-1} (17.570) was obtained from the treatment combination of V_1 T_4

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

4.2.4.1 Effect of variety

Number of ineffective tiller hill^{-1} of different aromatic rice varieties showed non significant difference presented in the Table 5 and Appendix VI. Among the varieties, the highest (1.996) number of ineffective tiller found in the variety, V_1 (Katarivog) On the other hand, the lowest (1.765) number of ineffective tiller was found in the variety V_2 (Kalizira). Similar results were observed by Siddique *et al.* (2002).

4.2.4.2 Effect of levels of boron

Significant difference was found in terms of number of non-effective tillers hill^{-1} of rice influenced by splitting different rates of boron (Table 6 and Appendix VI). The highest number of non-effective tillers hill^{-1} (2.800) was obtained from T_4 treatment followed by T_2 (2.010) where the lowest number of non-effective tillers hill^{-1} (1.1222) was obtained from T_3 treatment.

4.2.4.3 Interaction effect of variety and boron levels

Interaction effect of variety and splitting different rates of boron showed significant variation on number of non-effective tillers hill^{-1} (Table 7 and Appendix VI). It was found that the highest number of non-effective tillers hill^{-1} (2.933) was observed from the treatment combination of V_1T_4 followed by V_3T_4 where the lowest number of non-effective tillers hill^{-1} (1.1767) was obtained from the treatment combination of V_1T_3 which was statistically identical with V_3T_3.

Table-7: Interaction effect of variety and different levels of boron foliar application on panicle number, panicle length, effective, non-effective tillers hills^{-1} of Aromatic rice

Combination	Panicle Number (no.)	Panicle Length (cm)	Effective tillers hills^{-1} (no.)	Non-effective tillers hills^{-1} (no.)
V_1 T_1	21.03d	21.37f	20.16d	1.763d
V_1 T_2	16.30fg	23.19d	18.10fg	2.113c
V_1 T_3	26.63b	25.43b	21.47abc	1.18f
V_1 T_4	15.43g	20.06g	17.57g	2.93a
V_2T_1	23.38c	22.35e	21.54ab	1.377e
V_2T_2	18.02 e	24.62c	20.29cd	1.80d
V_2T_3	29.98a	26.83a	22.45a	1.10f
V_2T_4	15.57g	21.20f	19.57de	2.79ab
V_3T_1	22.58c	20.30g	19.87de	1.87d
V_3T_2	17.29ef	22.66e	19.55de	2.12c
V_3T_3	29.34a	24.55c	20.38bcd	1.09f
V_3T_4	13.40h	19.43h	18.76ef	2.68b
$LSD_{(0.05)}$	1.2506	0.5151	1.1845	0.1737
CV%	3.56	1.34	3.50	5.40
LS	**	NS	*	**

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

V_1 = Katarivog, V_2 = Kalizira, V_3=Tulsimala; T_1 = Control, T_2 = 100 ppm Boron foliar application, T_3 = 200 ppm Boron foliar application, T_4 = 300 ppm Boron foliar application

** = Significant at 1% level of significance.

NS = Not Significant.

4.2.5 Number of filled grains panicle^{-1}

4.2.5.1 Effect of variety

Significant difference was observed on number of filled grains panicle^{-1} due to different variety of rice (Table 8 and Appendix VII). Results stated that the highest number of filled grains panicle^{-1} (184.55) was obtained the variety V_1 (Katarivog). the lowest number of filled grains panicle^{-1} (133.72) was achieved from the variety V_3 (Tulsimala). Paul *et al.* (2014) and Sarkar *et al.* (2013) also found similar results with the present study.

Table-8: Effect of variety on no. of filled grains panicle^{-1}, no. of unfilled grains panicle^{-1}, no. of total filled grains panicle^{-1}, 1000-grains weight of aromatic rice

Variety	No. of filled Grains panicle^{-1}	No. of unfilled Grains panicle^{-1}	No. of total filled Grains panicle^{-1}	1000-Grains weight
V_1	184.55a	14.73a	199.28a	10.192c
V_2	169.16b	11.31b	180.47b	11.218a
V_3	133.72c	6.86c	140.57c	10.714b
LSD	8.8526	0.8469	8.4211	0.2114
CV%	6.44	9.12	5.73	2.33
LS	**	**	**	**

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

V_1 = Katarivog, V_2 = Kalizira, V_3=Tulsimala
** = Significant at 1% level of significance.

4.2.5.2 Effect of levels of boron

Number of filled grains panicle^{-1} of rice was significantly influenced by splitting different rate of boron (Table 9 and Appendix VII). It was found that the highest number of filled grains panicle^{-1} (229.33) was achieved from T_3 treatment. The lowest number of filled grains panicle^{-1} (95.64) was observed from T_4 treatment. More number of grains per panicle and higher grain weight by B application might be due to involvement of B in reproductive growth as B improves the panicle fertility in rice (Farooq *et al.,* 2012). Rashid *et al.* (2004) observed that there was a substantial increase in grain yield of rice varieties due to reduced panicle sterility after B application. Maximum number of grains per panicle against control plots might be due to the reduction in pollen sterility of rice and proper grain filling (Rashid *et al.,* 2004). Ali *et al.* (2016), Saleem *et al.* (2010) and Shafiq and Maqsood (2010) also found similar trend of results with the present study.

4.2.5.3 Interaction effect of variety and boron levels

Significant difference was exerted for number of filled grains panicle^{-1} of rice due to interaction effect of variety and splitting different rate of boron (Table 10 and Appendix VII). Results showed that the highest number of filled grains panicle^{-1} (250.29) was obtained from the treatment combination of V_1T_3 followed by V_2T_3. The lowest number of filled grains panicle^{-1} (72.87) was revealed from the treatment combination of V_3T_4.

4.2.6 Number of unfilled grains panicle^{-1}

4.2.6.1 Effect of variety

Significantly influenced by different variety of rice on number of unfilled grains panicle^{-1} was observed under the study (Table 8 and Appendix VII). It was revealed that the lowest number of unfilled grains panicle^{-1} (6.855) was found from the variety V_3 (Tulsimala) where the highest number of unfilled grains panicle^{-1} (14.729) was achieved from the variety V_1 (Katarivog).

4.2.6.2 Effect of boron

Significant difference was found in terms of number of unfilled grains panicle^{-1} of rice influenced by splitting different rates of boron (Table 9 and Appendix VII). Results showed that the lowest number of unfilled grains panicle^{-1} (7.519) was exhibited from the T_3 treatment the highest number of unfilled grains panicle^{-1} (14.414) was found from the treatment T_4. This might be due to the supplemental foliar application of B which helped to reduce panicle sterility during panicle formation stage ultimately reduce the number of unfilled grain per panicle, on the other hand the control plot did not receive supplementary B during panicle formation stage, which may cause increasing the number of unfilled grain per panicle. This finding was in line with the findings of Ali *et al.* (2016) and Saleem *et al.* (2010) who revealed that the supplemental application of B during panicle formation stage increase the number of filled grain per panicle but lack of boron during this stage could increase the number of unfilled grain.

Table-9: Effect of different levels of boron foliar application on no. of filled grains panicle^{-1}, no. of unfilled grains panicle^{-1}, no. of total filled grains panicle^{-1}, 1000-grains weight of aromatic rice

Treatment	No. of filled Grains panicle^{-1}	No. of unfilled Grains panicle^{-1}	No. of total filled Grains panicle^{-1}	1000-Grains weight
T_1	140.18c	12.11b	152.29c	10.17c
T_2	184.75b	9.81c	194.56b	10.76b
T_3	229.33a	7.52d	236.85a	11.87a
T_4	95.64d	14.41a	110.05d	10.03d
LSD	10.222	0.9779	9.7239	0.2442
CV%	6.44	9.12	5.73	2.33
LS	**	**	**	**

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

T_1 = Control, T_2 = 100 ppm Boron foliar application, T_3 = 200 ppm Boron foliar application,

T_4 = 300 ppm Boron foliar application.

** = Significant at 1% level of significance.

4.2.6.3 Interaction effect of variety and boron

Significant difference on number of unfilled grains panicle^{-1} was observed by interaction effect of variety and splitting different rates of boron (Table 10 and Appendix VII). It was revealed that the lowest number of unfilled grains panicle^{-1} (5.290) was observed from thetreatment combination of V_3T_3 which was statistically similar with V_3T_2, V_2T_3. The highest number of unfilled grains panicle^{-1} (20.827) was achieved from the treatment combination of V_1T_4.

4.2.7 Number of total grains panicle^{-1}

4.2.7.1 Effect of variety

There was marked variation observed on number of total grains panicle^{-1} due to different variety of rice (Table 8 and Appendix VII). Results exhibit that the highest number of total grains panicle^{-1} (199.28) was obtained the variety V_1 (Katarivog) where the lowest number of total grains panicle^{-1} (140.57) was observed from the variety V_3 (Tulsimala). Paul *et al.* (2014) and Sarkar *et al.* (2013) also found similar results with the present study.

4.2.7.2 Effect of boron

Number of total grains panicle^{-1} of rice was significantly affected by splitting different rate of boron (Table 9 and Appendix VII). It was observed that the highest number of total grains panicle^{-1} (236.85) was obtained from T_3 treatment. The lowest number of total grains panicle^{-1} (110.05) was obtained from T_4 treatment. Total number of grains per panicle and higher grain weight by B application might be due to involvement of B in reproductive growth as B improves the panicle fertility in rice (Farooq *et al.*, 2012). Rashid *et al.* (2004) observed that there was a substantial increase in grain yield of rice varieties due to reduced panicle sterility after B application. Maximum number of grains per panicle against control plots might be due to the reduction in pollen sterility of rice and proper grain filling (Saleem *et al.* (2010), Shafiq and Maqsood (2010) and Ali *et al.* (2016) also found similar trend of results with the present study.

4.2.7.3 Interaction effect of variety and boron

There was remarked variation was exerted for number of total grains panicle^{-1} of rice due to Interaction effect of variety and splitting different rate of boron (Table 10 and Appendix VII). Among the different treatment combinations, the highest number of total grains panicle^{-1} (259.78) was achieved from the treatment combination of V_1T_3 which was statistically similar with V_2T_3. The lowest number of total grains panicle^{-1} (80.49) was obtained from the treatment combination of V_3T_4.

4.2.8 Weight of 1000-grains

4.2.8.1 Effect of variety

Weight of 1000-grains was remarkably influenced by different variety of rice (Table 8 and Appendix VII). It was remarked that the highest 1000-grains weight (11.218 g) was obtained from the variety V_2 (Kalizira) where the lowest 1000-grains weight (10.192g) was achieved from the variety V_1 (Katarivog). Similar trend of result with the present study was also observed by Murshida *et al.* (2017), Paul *et al.* (2014).

4.2.8.2 Effect of boron

There was marked difference found in terms of 1000-grain weight of rice affected by splitting different rates of boron (Figure 4 and Appendix VII). It was noted that the highest 1000-grains weight (11.870 g) was achieved from T_4 treatment. The lowest 1000 grain weight (10.031 g) was observed from T_4 treatment. It might be in case of more efficient participation of B in various metabolic processes which enhanced accumulation of assimilates in the grains and resulted in heavier grains weight. It is well established fact that B supply is imperative for obtaining high yields and good quality because of its fundamental part in the biochemical processes (Gupta, 1993). These results are supported by the findings of Saleem *et al.* (2010), Shafiq and Maqsood (2010). They concluded that 1000-grain weight of rice increased with the increasing level of B fertilizer.

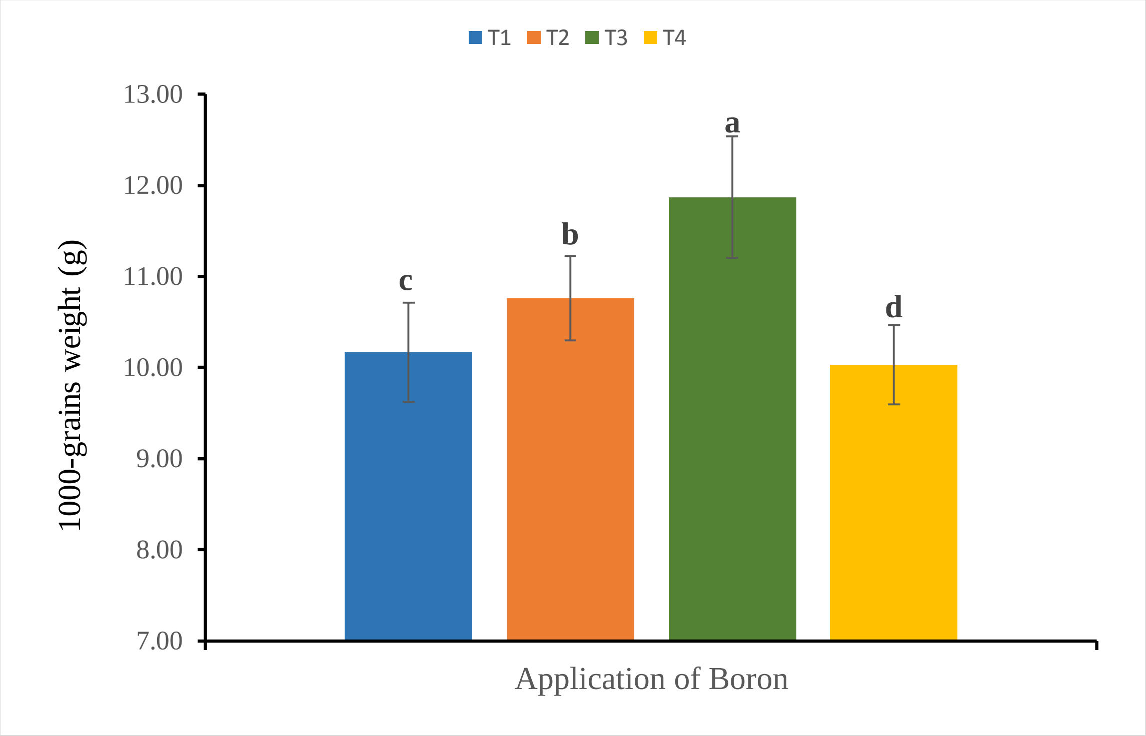

Figure 4: **Effect of different levels of boron foliar application on the 1000-grains weight (g) of aromatic rice (LSD$_{0.05}$ = 0.2442)**

4.2.8.3 Interaction effect of variety and boron

Significant variation on 1000-grains weight was influenced by Interaction effect of variety and splitting different rates of boron (Table 10 and Appendix VII). Among the different treatment combinations, the highest 1000-grains weight (12.427 g) was obtained from the treatment combination of V_2T_3 which was statistically similar with V_3T_3. The lowest 1000 grain weight (9.580 g) was achieved from the treatment combination of V_1T_1.

Table-10: Interaction effect of variety and different levels of boron foliar application on no. of filled grains panicle^{-1}, no. of unfilled grains panicle^{-1}, no. of total filled grains panicle^{-1}, 1000-grains weight of aromatic rice

Combination	No. of filled grains panicle^{-1} (no.)	No. of unfilled grains panicle^{-1} (no.)	No. of total filled grains panicle^{-1} (no.)	1000-grains weight (g)
V_1 T_1	151.72d	17.68b	169.41d	9.58he
V_1 T_2	221.41b	10.92de	232.33b	10.39c
V_1 T_3	250.29a	9.48ef	259.78a	11.13b
V_1 T_4	114.77ef	20.83a	135.59fg	9.67e
V_2T_1	146.30d	12.42d	158.73de	10.65c
V_2T_2	191.80c	10.22e	202.03c	11.28ab
V_2T_3	239.25a	7.78gh	247.04ab	12.43a
V_2T_4	99.28f	14.80c	114.08h	10.52c
V_3T_1	122.51e	6.23hi	128.74gh	10.29cd
V_3T_2	141.04d	8.28fg	149.32ef	10.61c
V_3T_3	198.44c	5.29i	203.73c	12.05a
V_3T_4	72.87g	7.62gh	80.49i	9.91de
$LSD_{(0.05)}$	17.705	1.6938	16.842	0.4229
CV%	6.44	9.12	5.73	2.33
LS	*	**	*	NS

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

V_1 = Katarivog, V_2 = Kalizira, V_3=Tulsimala; T_1 = Control, T_2 = 100 ppm Boron foliar application, T_3 = 200 ppm Boron foliar application, T_4 = 300 ppm Boron foliar application

** = Significant at 1% level of significance.

* = Significant at 5% level of significance.

NS = Not Significant.

4.3 Yield parameters

4.3.1 Grain yield

4.3.1.1 Effect of variety

Grain yield was significantly affected by different variety of rice (Figure 5 and Appendix VIII). It was observed that the highest grain yield (2.990 t ha^{-1}) was obtained from the variety V_2 (Kalizira) where the lowest grain yield (2.604 t ha^{-1}) was found from the variety V_3 (Tulsimala).

Varietal execution on grain yield might be a genetical attribute which influenced the grain yield of rice. The results on grain yield agreement with the findings of Murshida *et al.* (2017), and Chamely *et al.* (2015) who reported that grain yield varied due to varietal differences.

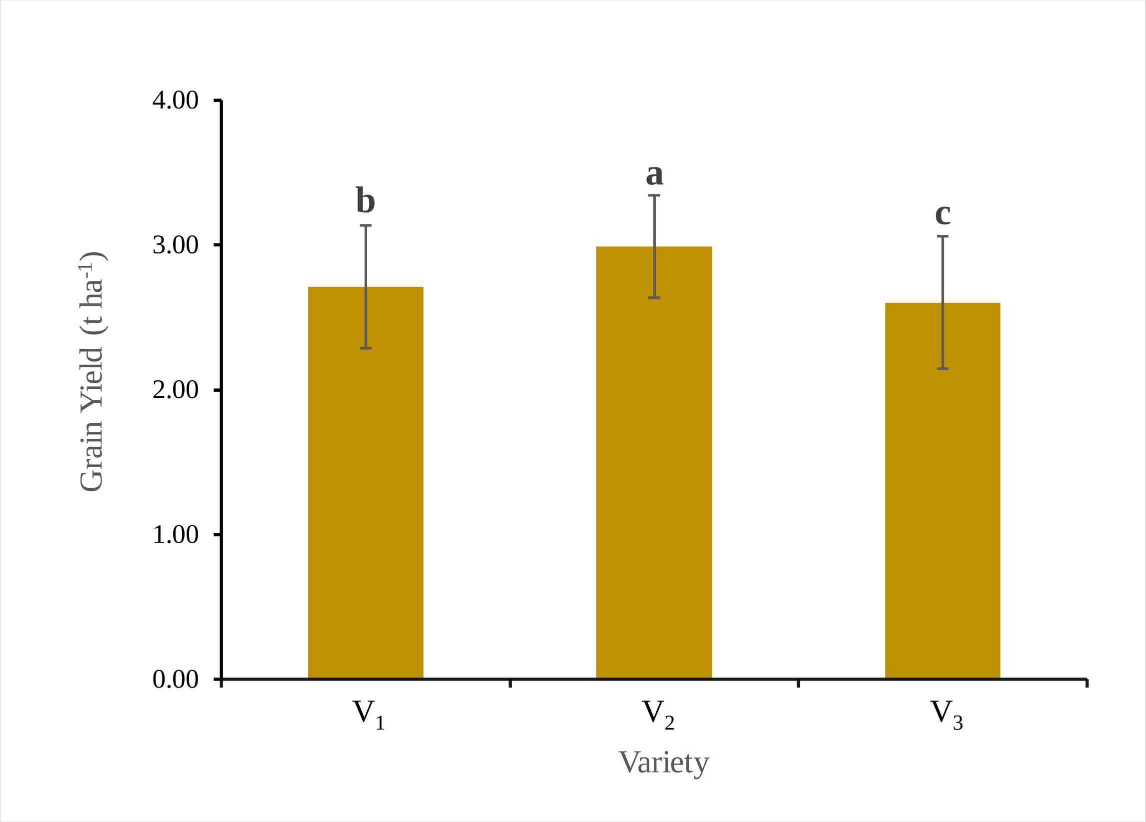

Figure 5: Effect of variety on the grain yield (t ha^{-1}) of aromatic rice ($LSD_{0.05}$ = 0.0589)

4.3.1.2 Effect of boron

Statistically marked difference was found in terms of grain yield affected by splitting different rates of boron (Table 11 and Appendix VIII). Results showed that the highest grain yield (3.320 t ha^{-1}) was obtained from T_3 treatment. The lowest grain yield (2.404 t ha^{-1}) was found from T_4 treatment. The yield increase was because of the role of B in plant physiological functions very remarkably during plant reproductive stage so its growth attributes such as tillers number, panicle length, number of filled grains panicle^{-1} and 1000-grains weight improved which attributed the higher grain yield. Boron is basically embroils in several biochemical processes such as carbohydrate metabolism, sugar transport, lignification, nucleotide synthesis, respiration and pollen viability therefore its deficiency directly influences panicle production and hence the rice yield (Dobermann and Fairhurst, 2000). Hussain *et al.* (2012) revealed that, maximum grain yield by foliage application of B at the flowering stage might be the direct impact ofhigher number of grains panicle^{-1} and 1000-grain weight. Many reports concluded that B applied at the heading or flowering phase in rice resulted in increased rice grain yield and grains number panicle^{-1} (Ramanthan *et al.*, 2002). Along this, by supplying plants with micronutrients especially B, either through soil application, foliar application, or seed treatment, increases yield and quality as well as macronutrient use efficiency (Imtiaz *et al.,* 2006). B has remarkably identified as one of the important elements for the grain crop production in the world. Rashid *et al.* (2006) reported that, B application enhanced rice yield due to reduced panicle sterility appreciably. On the other hand, the reason for the lowest grain yield in boron deficient plots might be the higher pollen infertility and lower grain filling as it plays very essential role in both processes Rashid *et al.,* 2004. Again, Cheng and Rerkasem (1993) opined that, B deficiency reduces pollen germination and the fertilization process. Farooq *et al.* (2012) also revealed that, decrease in panicle sterility and increases in grain size are the principal reasons of increase in grain yield by B as foliage application. The trend of on grain yield from the present study was similar with the findings of Patil *et al.* (2017), Rahman *et al.* (2016). Micronutrient malnutrition is a major human health problem in the developing world (Farooq *et al.,* 2012). So, considering the human sound health, biofortification of B offers an attractive and economical solution of this important issue (Mao *et al.,* 2014).

Table-11: Effect of different levels of boron foliar application on grain yield, straw yield, biological yield, harvest index of aromatic rice

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
T_1	2.56c	5.62c	8.18c	31.26b
T_2	2.79b	6.41b	9.20b	30.35b
T_3	3.32a	7.56a	10.88a	30.56b
T_4	2.40d	4.82d	7.23d	33.27a
LSD	0.0681	0.2185	0.2330	0.9682
CV%	2.51	3.66	2.69	3.16
LS	**	**	**	**

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

T_1 = Control, T_2 = 100 ppm Boron foliar application, T_3 = 200 ppm Boron foliar application,

T_4 = 300 ppm Boron foliar application.

** = Significant at 1% level of significance.

4.3.1.3 Interaction effect of variety and boron

There was marked variation on grain yield of rice was observed by interaction effect of variety and splitting different rates of boron (Table 12 and Appendix VIII). It was noted that the highest grain yield (3.430 t ha^{-1}) was obtained from the treatment combination of V_2T_3 which was statistically dissimilar with the other treatment combination where the lowest grain yield (2.1367 t ha^{-1}) was obtained from the treatment combination of V_3T_4 which was statistically identical with V_1 T_1, V_3T_1.

4.3.2 Straw yield

4.3.2.1 Effect of variety

Significant influence on straw yield was found because of different variety of rice (Table 8 and Appendix VIII). Considering varietal variation, the highest straw yield (6.405 t ha^{-1}) was observed from the variety V_2 (Kalizira). The lowest straw yield (5.855 t ha^{-1}) was obtained from thevariety V_3 (Tulsimala).

4.3.2.2 Effect of boron

Significant impact was observed in terms of straw yield influenced by splitting different rates of boron under the study (Figure 6 and Appendix VIII). Among the different boron treatment, the highest straw yield (7.558 t ha^{-1}) was noted from T_3 treatment. The lowest straw yield (4.82 t ha^{-1}) was observed from T_4 treatment.

Application of B increased rice straw yield because boron improved the membranes function which directly affect the transport of all metabolites that required for the normal growth and development, as well as the activities of membrane bound enzymes which attributed to higher straw yield of rice (Gupta, 1993). Saleem *et al.* (2011) reported that, the highest straw yield was recorded at 3 kg B ha^{-1} over control. This result was in agreement with the findings of Rashid *et al.* (2007).

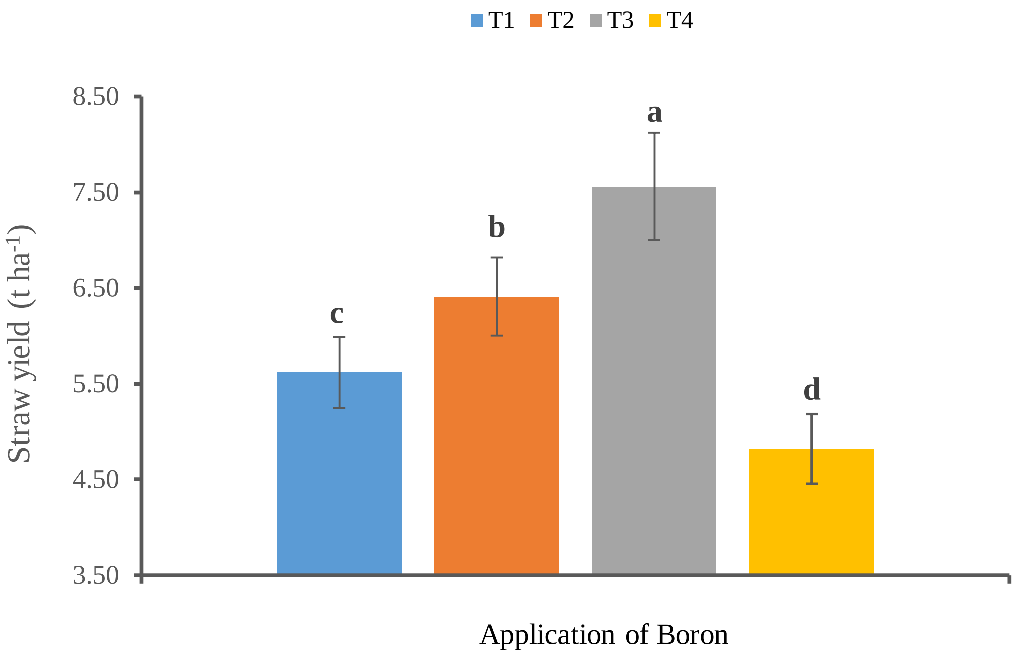

Figure 6: **Effect of different levels of boron foliar application on the Straw yield (t ha^{-1}) of aromatic rice (LSD$_{0.05}$ = 0.2185)**

4.3.2.3 Interaction effect of variety and boron

There was marked variation was observed on straw yield of rice by interaction effect of variety and splitting different rates of boron (Table 7 and Appendix VIII). Among the different treatment combinations, the highest straw yield (7.903 t ha^{-1}) was found from the treatment combination of V_2T_3 which was statistically similar with V_1 T_3 and V_3T_3. On theother hand, the lowest straw yield (2.136 t ha^{-1}) was achieved from the treatment combination of V_3T_4 which was statistically similar with V_1 T_1, V_3T_1.

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

4.3.3.1 Effect of variety

Significant difference was observed on biological yield because of different variety of rice(Table 10 and Appendix VIII). It was found that the highest biological yield (9.395 t ha^{-1}) was obtained from the variety V_2 (Kalizira) where the lowest biological yield (8.460 t ha^{-1}) was observed from the variety V_3 (Tulsimala).

4.3.3.2 Effect of boron

Biological yield of rice was significantly influenced by splitting different rate of boron (Table 11 and Appendix XI). Results showed that the highest biological yield (10.88 t ha^{-1})

was achieved from T_3 treatment where the lowest biological yield (7.226 t ha^{-1}) was observed from T_4 treatment.

4.3.3.3 Interaction effect of variety and boron

Significant difference was notable for biological yield of rice because of Interaction effect of variety and splitting different rates of boron (Table 12 and Appendix VIII). It was remarked that the highest biological yield (11.337 t ha^{-1}) was achieved from the treatment combination of V_2T_3 which was statistically dissimilar with other treatment combinations. On the other hand, the lowest biological yield (6.537 t ha^{-1}) was achieved from the treatment combination of V_3T_4 which was statistically similar with V_3T_1, V_1 T_1.

4.3.4 Harvest index (%)

4.3.4.1 Effect of variety

Harvest index was significantly affected by different variety of rice (Table 10 and Appendix VIII). It was expressed that the highest harvest index (32.031%) was obtained from the variety V_2 (Kalizira) where the lowest harvest index (30.998%) was achieved the variety V_1 (Katarivog).

4.3.4.2 Effect of boron

Marked variation was exerted in terms of harvest index of rice influenced by splitting different rates of boron (Table 11 and Appendix VIII). Results showed that the highest harvest index (33.268%) was achieved from T_4 treatment followed by T_1 (31.256%) where the lowest harvest index (30.350%) was obtained from T_2 treatment followed by T_3 (30.562%). Boron nutrition is more crucial during the reproductive phase as compared to the vegetative phase of the crop in cereals (Rerkasem and Jamjod, 2004). Harvest index improved in case of B application might be because of better starch utilization that results in more seed setting and translocation of assimilates to developing grains, that increases the grain size and grains number per panicle (Hussain *et al.*, 2012).

4.3.4.3 Interaction effect of variety and boron

Interaction effect of variety and splitting different rates of boron showed remarkable impact on harvest index of boro rice (Table 12 and Appendix VIII). It was indicated that the highest harvest index (33.710%) was obtained from the treatment combination of V_2T_4 followed by V_1T_4. The lowest harvest index (29.017%) was achieved from the treatment combination of V_1T_2 which was statistically similar with V_1T_1, V_3T_3.

Table-12: Interaction effect of variety and different levels of boron foliar application on grain yield, straw yield, biological yield, harvest index of aromatic rice

Combination	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
V_1 T_1	2.36 h	5.75 c	8.11 f	29.10 f
V_1 T_2	2.67 e	6.54 b	9.20 d	29.02 f
V_1 T_3	3.32 ab	6.91 b	10.23 b	32.45 a-d
V_1 T_4	2.50 fg	4.99 d	7.49 g	33.42 a
V_2T_1	2.89 d	5.91 c	8.80 e	32.93 ab
V_2T_2	3.06 c	6.74 b	9.80 c	31.22 c-e
V_2T_3	3.43 a	7.90 a	11.34 a	30.26 ef
V_2T_4	2.58 ef	5.07 d	7.65 g	33.71 a
V_3T_1	2.42 gh	5.20 d	7.62 g	31.73 b-e
V_3T_2	2.65 e	5.95 c	8.60 e	30.81 de
V_3T_3	3.21 b	7.86 a	11.08 a	28.98 f
V_3T_4	2.14 i	4.40 e	6.54 h	32.67 a-c
$LSD_{(0.05)}$	0.1179	0.3784	0.4035	1.6770
CV%	2.51	3.66	2.69	3.16
LS	**	**	**	**

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

V_1 = Katarivog, V_2 = Kalizira, V_3=Tulsimala; T_1 = Control, T_2 = 100 ppm Boron foliar application, T_3 = 200 ppm Boron foliar application, T_4 = 300 ppm Boron foliar application

** = Significant at 1% level of significance.

CHAPTER V
SUMMARY AND CONCLUSION

The field experiment was conducted at the research field of Department of Agronomy, Hajee Mohammad Danesh Science and Technology University, Dinajpur-5200 of during the period from July 2023 to December 2023 to find out the effect of foliar application of boron at different varieties for increasing aromatic rice production. Two factors were used in the experiment, *viz*. three rice varieties - V_1 (katarivog), V_2 (Kalizira) and V_3 (Tusimala) and four levels of boron application – T_1 = No application of boron, T_2 = 100 ppm of Boron, T_3 = 200 ppm of Boron, T_4= 300 ppm of Boron. The experiment was laid out in a RCBD design with three replications. Data on different growth yield and yield contributing parameters were recorded.

Different variety had significant influenced on growth, yield and yield contributing parameters. Considering the growth parameters, the highest plant height (59.917, 108.07, 137.98 and 152.77 cm at 30, 60, 90 DAT and at harvest, respectively) were achieved from the variety V_2 (Kalizira). The highest number of tillers hill^{-1} (12.736, 22.716, 28.072 and 22.718 at 30, 60, 90 DAT and at harvest, respectively) were obtained from the variety V_2 (Kalizira). Again, the lowest plant height (48.167, 99.00, 124.58 and 135.33 cm at 30, 60, 90 DAT and at harvest, respectively) were observed from the variety V_1 (Katarivog). On the other hand, the lowest number of tillers hill^{-1} (10.244, 20.225, 25.932 and 21.320 at 30, 60, 90 DAT and at harvest, respectively) were observed from the variety V_1 (Katarivog). In case of yield and yield contributing parameters, the highest number of panicles hill^{-1} (21.738), panicles length (23.751 cm), effective tiller (20.954), were found from V_2 (Kalizira). Again the highest number of ineffective tiller (1.996), filled grains panicle^{-1} (184.55), unfilled grains panicle^{-1} (14.729), total grains panicle^{-1} (199.28), found in the variety, V_1 (Katarivog). On the Other hand the highest 1000-grains weight (11.218 g), grain yield (2.990 t ha^{-1}), straw yield (6.405 t ha^{-1}), biological yield (9.395 t ha^{-1}), harvest index (32.031 %) were obtained from the variety V_2 (Kalizira). The lowest number of plant height (48.167, 99.00, 124.58 and 135.33 cm at 30, 60, 90 DAT and at harvest, respectively), number of tillers hill^{-1} (10.244, 20.225, 25.932 and 21.320 at 30, 60, 90 DAT and at harvest, respectively) number of panicles (21.738), panicle length (19.850 cm), number of effective tiller (19.322), 1000-grains weight (10.192 g), harvest index (30.998 %) were observed from the variety V_1 (Katarivog), the lowest number of effective tiller (1.765), straw yield (5.855 t ha^{-1}) were found in the variety V_2 (Kalizira), and the lowest number of filled grains panicle^{-1} (133.72), unfilled grains panicle^{-1} (6.855), grains panicle^{-1} (140.57), grain yield (2.604 t ha^{-1}), biological yield (8.460 t ha^{-1}) were achieved from the variety V_3 (Tulsimala).

Different rates of boron foliar application had also significant influenced on growth, yield and yield contributing parameters. Considering growth parameters, the highest plant height (61.889, 111.27, 144.49, 158.33 cm at 30, 60, 90 DAT and at harvest, respectively), number of tillers hill^{-1} (14.842, 24.822, 29.780 and 22.555 at 30, 60, 90 DAT and at harvest, respectively), panicles hill^{-1} (28.651), panicle length (25.602 cm), number of effective tillers hill^{-1} (21.433), non-effective tillers hill^{-1} (1.1222), number of filled grains panicle^{-1} (229.33), total grains panicle^{-1} (236.85), grain yield (3.320 t ha^{-1}), straw yield (7.558 t ha^{-1}), biological yield (10.88 t ha^{-1}), were obtained from T_3 treatment, Again the highest number of non-effective tillers hill^{-1} (2.800), unfilled grains panicle^{-1} (14.414), 1000-grains weight (11.870 g), harvest index (33.268%) were obtained from T_4 treatment.

Interaction effect of variety and splitting different rates of boron as foliar application had also significant influenced on growth, yield and yield contributing characters of aromatic rice. Considering growth parameters, the highest plant height plant height (67.667, 115.13, 153.53 and 169.47 cm at 30, 60, 90 DAT and at harvest, respectively), number of tillers hill^{-1} (16.06, 26.046, 31.204 and 23.551 at 30, 60, 90 DAT and at harvest, respectively), number of panicles hill^{-1} (29.98), panicle length (26.830 cm), number of effective tillers hill^{-1} (22.453), filled grains panicle^{-1} (250.29), total grains panicle^{-1} (259.78), 1000-grains weight (12.427 g), grain yield (3.430 t ha^{-1}), straw yield (7.903 t ha^{-1}), biological yield (11.337 t ha^{-1}) were found from the treatment combination of V_2T_3. Again the highest harvest index (33.710%) were obtained from the treatment combination of V_2T_3 and the highest number of non-effective tillers hill^{-1} (2.933), unfilled grains panicle^{-1} (20.827) were observed from the treatment combination of V_1T_4.

The lowest plant height 47.00 cm at 30 DAT were obtained from the treatment combination of V_3T_4, 89.13, 116.07 and 122.53 cm at (60, 90 DAT and at harvest, respectively), 6.421, 16.401, 25.195 and 20.211 at 30, 60, 90 DAT and at harvest, respectively), number of effective tillers hill^{-1} (17.570), were obtained from the treatment combination of V_1T_4. Agian the lowest number of non-effective tillers hill^{-1} (1.1767) were obtained from the treatment combination of V_1T_3. Again the lowest number of unfilled grains panicle^{-1} (5.290) were observed from the treatment combination of V_3T_3

and the lowest 1000 grain weight (9.580 g), harvest index (29.017%) were achieved from the treatment combination of V_1T_1 another the lowest number of panicles hill^{-1} (13.397), panicle length (19.433 cm), filled grains panicle^{-1} (72.87), total grains panicle^{-1} (80.49), grain yield (2.1367 t ha^{-1}), straw yield (2.136 t ha^{-1}), lowest biological yield (6.537 t ha^{-1}) were found in V_3T_4 treatment combination.

CONCLUSION

The study found that the variety Kalizira (V_2) exhibited superior performance in terms of growth and yield, with the highest plant height, tiller count, and grain yield across various growth stages. In contrast, Katarivog (V_1) showed the lowest values in these parameters.

The application of boron, particularly in the 200 ppm (T_3) treatment, significantly enhanced plant growth, resulting in higher plant height, tiller count and grain yield. The interaction between variety and boron application also yielded significant results with the V_2T_3 combination achieving the best overall growth and yield outcomes.

In summary, the variety Kalizira and the T_3 boron treatment either alone or in combination, produced the highest growth and yield metrics, suggesting their effectiveness in optimizing aromatic rice production.

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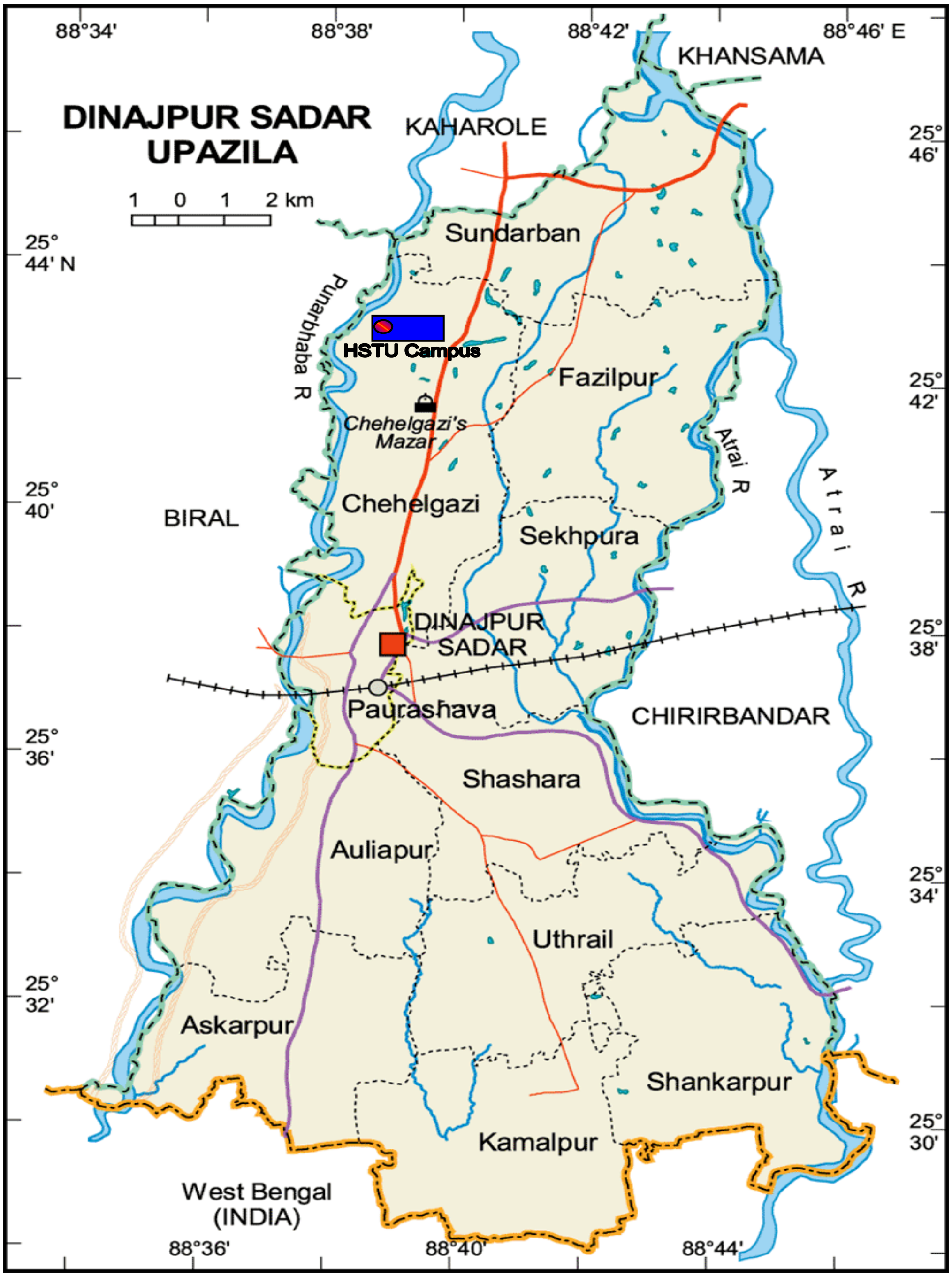
APPENDICES

Appendix I. Location of the experimental site (map of Dinajpur Sadar Upazila showing the research plot).



Appendix II: Morphological, physical and chemical characteristics of soil of experimental field (Agronomic research field, HSTU)

A. Morphological characteristics of soil

Morphological parameters	Characteristics
Location	Agronomy research field, HSTU, Dinajpur
Agro-ecological Zone (AEZ-1)	Old Himalayan Piedmont Plain
Geographical position	$25^0$38N latitude and $88^0$41E longitude
General soil types	Non-calcareous dark gray floodplain soil
Parent materials	Old Brahmaputra river borne deposit
Land type	Medium high land
Elevation	37 meter above the mean sea level
Drainage	Well drained
Cropping pattern	Rice crop grown year round
Topography	Fairly leveled

Source: Bangladesh Meteorological Department (Weather Research Station) Rajbati, Dinajpur

B. Physical characteristics of soil

Characteristics	Value (%)
Sand	58
Silt	28
Clay	14
Soil textural class	Sandy loam

Source: Bangladesh Meteorological Department (Weather Research Station) Rajbati, Dinajpur

C. Chemical properties of soil

Characteristics	Value (%)
pH (soil: water= 1: 1.25)	5.41
Organic matter	1.48
Organic carbon	0.72
Total N	0.08
Available P (ppm)	11.20
Exchangeable P (meq)	0.10
Exchangeable Ca (meq)	2.48
Exchangeable Mg (meq)	2.29
Available S (ppm)	17.29
Available B (ppm)	0.13
Available Zn (ppm)	0.90
Available Fe (ppm)	51.90
Available Mn (ppm)	12.13

Source: Bangladesh Meteorological Department (Weather Research Station) Rajbati, Dinajpur

Appendix III. Monthly average temperature and total rainfall of the experimental site during the period of July 2023 to December 2023

Month	Air temperature (^oC)		Total rainfall (mm)
	Maximum	Minimum	
July	34.1	26.4	356
August	33.4	26.5	458
September	33.4	25.6	533
October	31.7	22.6	213
November	30.8	16.8	0
December	26.5	12.5	15

Source: Bangladesh Meteorological Department

Appendix IV. Mean square values of plant height of different rice varieties through foliar boron application

Source of variance	Degree of freedom	Mean Squares of plant height			
		30 DAT	60 DAT	90 DAT	Atharvest
Variety	2	414.361**	248.764**	792.551**	1203.03**
Treatment	3	454.000**	482.836**	624.875**	803.30**
Interaction	6	21.694^{NS}	9.822^{NS}	38.590^{NS}	44.52^{NS}
Error	22	23.929	11.447	67.163	29.64
CV (%)		9.04	3.28	6.12	3.71

* = Significant at 5% level of significance
** = Significant at 1% level of significance
NS = Not significant

Appendix V. Analysis of variance (mean square) of data of the data for total tillers hill^{-1} of aromatic rice

Source of variance	Degree of freedom	Mean Squares of number of tillers hill^{-1}			
		30 DAT	60 DAT	90 DAT	Atharvest
Variety	2	38.870**	19.4351**	15.5871**	6.6374**
Treatment	3	154.617**	51.5390**	47.7257**	3.1749**
Interaction	6	14.635**	2.4391**	1.5222**	1.0801*
Error	22	2.4391	0.1881	0.1332	0.5200
CV (%)		3.73	2.01	1.36	3.30

* = Significant at 5% level of significance
** = Significant at 1% level of significance
NS=Notsignificant

Appendix VI. Mean square values of yield contributing parameters of different rice varieties through foliar boron application

Source of variance	Degree of freedom	Mean Squares			
		Panicle Number	Panicle Length	Effective tillers hills^{-1}	Non-effective tillers hills^{-1}
Variety	2	10.79**	12.43**	8.99**	0.18**
Treatment	3	338.77**	50.97**	13.97**	4.44**
Interaction	6	3.21**	0.08^{NS}	1.10*	0.06**
Error	22	0.55	0.09	0.49	0.01
CV (%)		3.56	1.34	3.50	5.40

* = Significant at 5% level of significance
** = Significant at 1% level of significance
NS = Not significant

Appendix VII. Analysis of variance (mean square) of data for yield contributing parameters of aromatic rice varieties through foliar boron application

Source of variance	Degree of freedom	Mean Squares yield contributing parameters			
		No. offilled Grains panicle^{-1}	No. of unfilled Grains panicle^{-1}	No. of total filled Grains panicle^{-1}	1000-Grains weight
Variety	2	8153.6**	187.067**	10783.7**	3.15221**
Treatment	3	29789.5**	79.266**	26796.1**	6.29813**
Interaction	6	370.2*	20.535**	248.7*	0.09499^{NS}
Error	22	109.3	1.001	98.9	0.06237
CV (%)		6.44	9.12	5.73	2.33

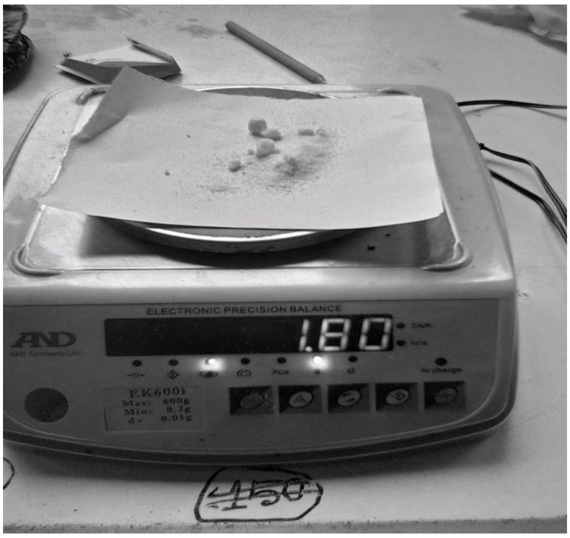
* = Significant at 5% level of significance
** = Significant at 1% level of significance
NS = Not significant

Appendix VIII. Analysis of variance (mean square) of data for yield parameters of different aromatic rice varieties through foliar boron application

Source of variance	Degree of freedom	Mean Squares yield parameters			
		Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Variety	2	0.47522**	0.9378**	2.7413**	4.0713*
Treatment	3	1.44513**	12.2786**	22.0149**	15.9212**
Interaction	6	0.04772**	0.4420**	0.4890**	7.2325**
Error	22	0.00485	0.0499	0.0568	0.9809
CV (%)		2.51	3.66	2.69	3.16

* = Significant at 5% level of significance
** = Significant at 1% level of significance
NS = Not significant

Appendix IX. Some photographs of my research works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