EFFECT OF ORGANIC AND INORGANIC FERTILIZERS ON GROWTH, YIELD AND QUALITY OF AROMATIC RICE IN *BORO* SEASON

REFAT SULTANA

DEPARTMENT OF AGRICULTURAL BOTANY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

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BY

REFAT SULTANA

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Approved by:

....
Prof. Dr. Nasima Akhter
Supervisor
Department of Agricultural botany
SAU, Dhaka

....
Prof. Dr. Kamal Uddin Ahamed
Co-supervisor
Department of Agricultural Botany
SAU, Dhaka

....
Prof. Asim Kumar Bhadra
Chairman
Department of Agricultural botany
SAU, Dhaka

DEPARTMENT OF AGRICULTURAL BOTANY
Sher-e-Bangla Agricultural University (SAU)
Sher-e-Bangla Nagar, Dhaka-1207
Phone: 9134789

CERTIFICATE

This is to certify that thesis entitled ***"EFFECT OF ORGANIC AND INORGANIC FERTILIZERS ON GROWTH, YIELD AND QUALITY OF AROMATIC RICE IN BORO SEASON"*** *submitted to the* ***Faculty of Agriculture,*** *Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS) IN AGRICULTURAL BOTANY*** *embodies the result of a piece of bona fide research work carried out by* ***REFAT SULTANA, Registration no. 18-09276*** *under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

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

Dated: December, 2020
Place: Dhaka, Bangladesh

Prof. Dr. Nasima Akhter
Supervisor
Department of Agricultural Botany
SAU, Dhaka

DEDICATED

TO

MY BELOVED

PARENTS

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SAU, Dhaka

EFFECT OF ORGANIC AND INORGANIC FERTILIZERS ON GROWTH, YIELD AND QUALITY OF AROMATIC RICE IN *BORO* SEASON

REFAT SULTANA

ABSTRACT

The present investigation entitled "Effect of organic and inorganic fertilizers on growth, yield and quality of aromatic rice in *boro* season" was conducted from December 2018 to June 2019 at the Research Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The experiment was done mainly to show the performance of some selected aromatic rice varieties in *boro* season under organic and inorganic fertilizer. The experiment comprised of two factors; viz. Factors A: Two fertilization methods - Organic fertilizer (T_1) and Inorganic fertilizer (T_2) and Factor B: Six different aromatic rice varieties (Chiniatop 1, Katari2, Dulabhog (BR-5), Zirabhog, BRRI dhan34 and BRRI dhan50). The experiment was laid out in a Split Plot Design with three replications and 12 treatment combinations. Different treatment combinations expressed significant differences due to their interaction effect on morphological, physiological, yield contributing traits, yield and grain quality parameters. Considering the variety the tallest plant (149.4 cm), highest number of total tillers hill^{-1} (13.62), highest effective tillers hill^{-1}(13.49), highest number of leaves hill^{-1}(25.33), highest leaf area index (3.42), highest SPAD reading (47.52), highest Stomatal conductance (0.59 mmolCO_2m^{-2}s^{-1}), highest number of total dry matter (19.52 g), highest number of total spikelet panicle^{-1} (209.5), highest number of filled spikelet panicle^{-1} (189.0), maximum grain size (15.90 mg), highest grain yield (3.20 t ha^{-1}), highest straw yield (6.24 t ha^{-1}), highest biological yield (9.44 t ha^{-1}), highest harvest index (34.81%) were found in Chiniatop1 variety and maximum ineffective tillers hill^{-1} (1.52), maximum unfilled spikelet panicle^{-1} (40.10) and maximum grain sterility percentage (34.39%) were found in Zirabhog variety. Again considering the fertilizer application organic fertilizer was showed better performance than inorganic fertilizer. Considering both variety and fertilizer used, the tallest plant (149.5 cm), the highest number of total tillers hill^{-1} (14.55), highest effective tillers hill^{-1} (12.43), highest number of leaves hill^{-1} (26.87), highest total dry mater (22.37 g), highest leaf area index (3.44), highest SPAD reading (48.53), highest stomatal conductance (0.53 m mol CO_2 m^{-2} s^{-1}), highest total spikelet panicle^{-1} (231.6), highest filled spikelet panicle^{-1} (213.10), highest grain size (16.33 mg), highest grain yield (4.38 t ha^{-1}), highest straw yield (8.43 t ha^{-1}), highest biological yield (12.81 t ha^{-1}) and highest harvest index (38.67%) were recorded from the combined treatment of V_1T_1 (Chiniatop 1+Organic fertilizer) and highest ineffective tillers hill^{-1} (3.56), highest unfilled spikelet panicle^{-1} (43.43) and highest grain sterility (39.63%) were recorded from the combined treatment of V_4T_2 (Zirabhog+Inorganic fertilizer). Among the aromatic rice cultivars Chiniatop 1 showed better performance in case of grain qualities such as strong aroma, maximum length-breadth ratio (4.37), maximum elongation ratio (1.53) and minimum cooking duration under organic fertilizer than inorganic fertilizer. From the above discussion, Chiniatop1 was showed better performance under organic fertilizer in *boro* season.

LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	Full meaning
%	Percent
°C	Degree Celsius
AEZ	Agro-ecological Zone
AVOVA	Analysis of variance
AS	Aroma Scoring
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BRRI	Bangladesh Rice Research Institute
CD	Cooking Duration
cm	Centimeter
CV	Coefficient of variation
DAS	Days after sowing
DAT	Days after transplanting
d.f.	Degrees of freedom
et al.	And others
ER	Elongation ratio
FAO	Food and Agriculture Organization
G	Gram
ha	Hectare
J.	Journal
Kg	Kilogram
L/B	Length-breadth ratio
LSD	Least Significant Difference
Mg	Milligram
Ml	Milliliter
MP	Muriate of Potash
SAU	Sher-e-Bangla Agricultural University
SPAD	The Soil Plant Analysis Development Chlorophyll Meter
TSP	Triple Super Phosphate

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CHAPTER I

INTRODUCTION

Rice (*Oryza sativa* L.) crop is interwoven in the cultural, social and economic lives of millions of Bangladeshis and it holds the key for food and nutritional security of the country. It is consumed as the staple food in Bangladesh and has been given the highest priority in meeting the demands of its ever-increasing population. In recent years, aromatic rice has been introduced to the global market. Aromatic rice has great potential to attract rice consumer for its taste, deliciousness and high price to boost up the economic condition of the rice grower in the developing countries like Bangladesh (Sarkar *et al*. 2014). Aromatic rice is known for its fragrant characteristic when cooked. Bangladesh comprises an area of about 11.10 million hectares for rice production of which around 27% is occupied by fine rice varieties (BBS, 2003). Most of the consumers prefer aromatic rice varieties with good cooking quality that have aroma. Due to special flavor and taste, aromatic rice is highly favored. Bangladesh produces several fine aromatic rice varieties with excellent eating quality for regular consumption as steamed rice as well as for many purposes.

In Bangladesh, a number of fine rice cultivars are grown by the farmers. Some of them have special appeal for their aroma. Such common cultivars are Chinisagar, Badshabhog, Kataribhog, Kalizira, Tulsimala, Dulabhog, Basmati, Banglamoti (BRRI dhan50), BRRI dhan34, BRRI dhan37 and BRRI dhan38 (Sarkar *et al*. 2014). In Bangladesh, among the different aromatic rice varieties, Chinigura is the predominant one that covers more than 70% of rice farms in the northern districts of Naogaon and Dinajpur. Other important aromatic rice varieties are Kalijira (predominantly grown in Mymensingh) and Kataribhog (mainly cultivated in Dinajpur) (Baqui *et al*. 1997). Sharma and Haloi (2001) characterized some local aromatic rice on the basis of their physiological and assimilate partitioning behavior and suggested that the improvement of partitioning efficiency is one of the best criteria for improvement of aromatic rice. On the other hand, modern varieties possess short and stout culms with dark green, thick leaves and do not lodge. Dutta *et al*. (1997) pointed out some physiological limitations of modern *indica-japanica* type of rice and suggested improvement over IRRI scientists proposed new model for rice improvement. Traditional aromatic rice varieties possess an excellent aroma and quality but their level of productivity is quite low. Physiological indices of improved genotypes were greater than traditional genotypes. Generally traditional genotypes reach physiological maturity earlier than improved genotypes. Local and improved cultivars of rice have varied physiological characteristics (Peng and Senadhira 1998). Both types of rice organically grown could have different responses. And the yield of rice changes due to growing environment, such as different locations, seasonal fluctuations, different dates of planting etc. (Sarker 2002). Productivity of rice was increased after green revolution due to usage of large quantities of chemical fertilizers, chemical pesticides and herbicides (Hasanuzzaman *et al*. 2010 and Khan *et al*. 2007). The abundance use of chemical fertilizers and chemical pesticides caused excessive deterioration of soil properties (Hasanuzzaman *et al*. 2010), accelerated soil erosion, decreased land quality, contaminated underground water (Ikemura and Shukla 2009) and ultimately reduced the productivity of the land (Sanatl *et al*. 2011 and Ikemura and Shukla (2009). Salem (2006) reported that the continuous using of chemical fertilizers and chemical pesticides were emergence a serious environmental threat to plants, soil, water, animals and humans. Facing the threat of ecological damage, the emergence of today's farming culture that is an environmentally safe alternative, i.e. to organic farming (Aziez *et al*. 2018).

Bangladesh has a bright prospect for export of fine rice thereby earning foreign exchange. The yield of fine rice is lower than that of coarse and medium rice varieties. Although the geographical, climatic and edaphic conditions of Bangladesh are favorable for year-round rice cultivation. The reasons for low yield are mainly associated with selection of improved varieties and judicious fertilizer management especially of organic fertilizer like cowdung, poultry manure and/or their integration with inorganic fertilizers. In all the agricultural systems there is inevitably a loss of plant nutrients. Nutrient mining, depletion of soil organic matter and reduction in soil aggregates have been identified as reasons of yield stagnation or decline in the productivity of crops (Rahman and Yakupitiyage 2006). Use of fertilizer is an essential component of modern farming with about 50% of the world crop production (Prodhan 1992). Among the cultural technologies, integrated nutrient management like application of cowdung, poultry manure along with other inorganic fertilizers and selection of right variety are the important ones in augmenting the yield of crop. Therefore, the present study was undertaken to evaluate the effects of variety and nutrient (organic and inorganic fertilizer) management on the yield and quality of aromatic fine rice.

The primary objectives of this research are:

1. To clarify the influence of organic and inorganic fertilizers on the growth attributes and yield of aromatic rice in *boro* season.

2. To evaluate grain quality parameters of aromatic rice under organic and inorganic fertilizers in *boro* season.

CHAPTER II

REVIEW OF LITERATURE

Bangladesh is primarily an agriculture based country and rice is major crop. Most of the *Aman* fine coarse rice is aromatic rice. Farmers are showing interest regarding the cultivation of aromatic rice day by day due to their aroma, taste and high demand, there is a market of aromatic rice not only in Bangladesh but also throughout the world. So, the effect of organic and inorganic fertilizers on growth, yield and quality of aromatic rice in *boro* season is needed to be determined which are cultivated under organic and inorganic fertilizer. For this reason, some literatures are presented bellow in following sub-headings:

2.1. Effect of different cultivars on physiological characteristics of aromatic rice

N weight of leaf was multiplication of nitrogen (N) content of leaf by dry weight of leaf (Dobermann and Fairhurst, 2000). Tayefe *et al.* (2011) stated different N weight of leaf on different varieties. Peng *et al.* (1993) added N weight of leaf and were affected by plant genotype, stage of growth and leaf position.

Aziez *et al.* (2018) revealed that, there were interactions between cultivars and methods of cultivation to the N weight of leaf. N weight of leaf in cv. Cianjur under organic cultivation and the other varieties tend to be smaller too. This was due to nutrient levels (i.e. nitrogen) of organic cultivation that was smaller than those of inorganic cultivation. N weight of leaf influenced by fertilizer applied, the organic fertilizer in organic cultivations had nutrient levels lower than chemical fertilizer in inorganic cultivation thus causing N weight of leaves smaller than organic cultivation.

Aziez *et al.* (2018) also reported that there was no interaction between cultivars and the methods of cultivation on greenness of leaves but it was affected by methods of cultivations.

Greenness of leaves is a value representing the chlorophyll content of leaves and has linear correlation with the nitrogen concentration (Gholizadeh *et al.* 2011) and can be used to monitor the N status of rice (Varvel *et al.* 2007; Balasubramanlan *et al.* 1999; Peng *et al.* 1996 and Peng *et al.* 1995).

Yoshida (1981) reported that, the critical value of greenness of leaves with SPAD 502 in rice is 36 and below the critical value the plant has undergone a shortage of N in its growth. There was a strong linear relationship between SPAD values and leaves with total nitrogen concentration which than varies with cultivar (Turner and Jund, 1994 and Takebe and Yoneyama, 1989).

Stomatal conductance was a measure of the ability of the leaf or release water and absorb CO_2 through the stomata (Mohr and Schopfer, 1995). The amount of water released during transpiration determined by the conductance of stomata. The greater value of conductance, the greater water can be transpired by the leaves if other factors are in normal circumstances. Stomatal conductance and transpiration were closely correlated with leaf photosynthesis in rice (Kanemura *et al.* 2005; Mlah *et al.* 1997 and Kuroda and Kumora 1990).

Carbon dioxide (CO_2) is the main raw compound of plant photosynthesis. Sustainability of CO_2 fixation by photosynthesis process was highly dependent availability of CO_2 in the leaf cells (Sallsbury and Ross, 1992).

Rahman *et al.* (2016); Alamgir and Ali (2006) and Dabnath (2003) reported that, BRRI dhan34 produced the highest number of leaves at all growth duration except 30 DAT (155.03 at 45 DAT, 163.62 at 60 DAT, 145.18 at 75 DAT and 122.65 at 90 DAT). However, the lowest number of leaves was recorded in Binadhan-9 at 30 DAT (77.09), at 45 DAT (91.83) and in Binadhan-13 at 75 DAT (94.57), at 90 DAT (94.32).

Sarkar *et al.* (2014) showed that, variety influenced significantly crop characters, yield contributing characters and yield except harvest index. The tallest plant (142.7 cm), the highest number of effective tillers hill^{-1}(10.02), the highest number of grains panicle^{-1} (152.3), grain yield (3.71 t ha^{-1}), straw yield (5.11 t ha^{-1}) and biological yield (8.83 t ha^{-1}) were recorded in BRRI dhan34. BRRI dhan34 also gave the lowest number of non-effective tillers hill^{-1} (1.63), sterile spikelets panicle^{-1} (25.01) and 1000-grain weight (11.26 g). Similar results were found elsewhere (Tyeb *et al.* 2013 and Islam *et al.* 2012), who reported that variety exerted variable effect on yield and yield contributing characters of rice. The highest number of effective tillers hill^{-1} and the highest number of grains panicle^{-1} were mainly responsible for the highest grain yield.

Lasalita-Zapico *et al.* (2010) studied correlation coefficient of 10 quantitative traits for 32 upland rice varieties. In this distinguished significant positive correlation the majority of the morphological traits was recorded except flag leaf angle that had negative correlation with most of characters such as panicle length, leaf length, leaf width, ligule length, leaf area, and culm length. In our studies, grain yield positively correlated with panicle length. The findings indicate that plants with high panicles have high number of filled grains thereby increasing rice yield. Similar correlations were reported by Zafar *et al.* (2006).

The calculation of heritability and genetic advance are used to help the breeder to select traits that are highly heritable as compared to a trait which is less heritable (Johnson *et al.* 1955). Both high heritability and genetic advance value obtained in the study, flag leaf area, secondary branches per panicle, filled grains per panicle, grain length, grain breadth, length breadth ratio, and 1000-grain weight indicated reasonable variation for the traits. This suggests that selection can be easily practiced by using these traits to improve grain yield in aromatic rice genotypes (Islam *et al.* 2016). The results support the findings of Sedeek *et al.* (2009); Laxuman *et al.* (2010) and Pandey *et al.* (2009) who reported such type of heritability in rice.

Islam *et al.* (2013), who reported the variable effect of variety on the number of effective tillers hill^{-1}. The variation in plant height, number of effective tillers hill^{-1} and number of grains panicle^{-1} among the varieties were probably due to heredity or varietal characters.

The highest number of tillers hill^{-1} was found at 30 DAT (4.76), at 75 DAT (25.27) and at harvest (20.51) in case of Binadhan-9; at 45 DAT (10.13) and at 60 DAT (16.03) in case of BRRI dhan38 and at 45 DAT (10.03) in case of Binadhan-13. However, the lowest number of tillers hill^{-1} observed at 30 DAT (3.61) in BRRI dhan34; at 45 DAT (7.14), 60 DAT (12.59), 90 DAT (13.47) and harvest (12.02) in Kalijira; at 75 DAT (18.66) in Binadhan-13 (Rahman *et al.* 2016; Hasamuzzaman *et al.* 2009 and Islam *et al.* 2007).

Dutta *et al.* (1998) and Alam (2002) who recorded variable protein percentage among varieties. The highest aroma (1.81) was found in BRRI dhan38, which was similar to that of BRRI dhan37 (1.81). The lowest (1.76) aroma was observed in BRRI dhan34. Dutta *et al.* (1998) reported that aroma varied among the varieties. Varietal differences regarding grain protein content and aroma might be due to their difference in genetic make-up.

The higher dry mater production was attributed due to higher LAI where the variety Binasail resulted in higher leaf area consequently produced the greatest total dry matter content. The increase of TDM was dependent on the leaf area production as reported by Weng *et al.* (1982) and Tanaka, (1983). The significant variation in dry matter production among the cultivars was also reported by Arjuna *et al.* (1990). Generally, dry matter production was positively correlated with grain yield (Chen *et al.* 1991). Grain yield differences due to varieties were reported by Wu *et al.* (1998).

Generally, the plant height of modern cultivars was lower than aromatic fine grain. The differences of plant height are due to genetic make of these Ukunmadhu and longer plant height is not physiologically encouraging as there may be a possibility of lodging in different situation. This observation was reported by Mia and Shamsuddin, (2011) and supported by Awasthi and Sharma (1996).

Hossain and Alam (1991) observed that, variation in plant height due to varietal differences. It also generally noticed in aromatic fine cultivars that the number of tiller hill^{-1} ranged from 7 to 11, which are quite high as compared to high yielding modern cultivars.

Rahman *et al.* (2016) reported that, plant height of different varieties was measured at different growing period. The highest plant height was found in BRRI dhan38 at all growth duration except 90 DAT (97.98 cm at 30 DAT, 108.41 cm at 45 DAT, 110.51 cm at 60 DAT and 113.71 cm). However, highest plant height also observed in BRRI dhan34 at 75 DAT (112.33 cm) and at 90 DAT (119.05 cm); in Rajbhog at 30 DAT (97.98 cm). The plant height of BRRI dhan34 at 90 DAT and Rajbhog at 60, 75, and 90 DAT were statistically similar. This result was supported by Hossain and Sikdar (2009).

Panicle length was not significantly diverged among the varieties however number of primary and secondary branches of panicle was varied as well which was affected on grain yield. Yamagishi *et al.* (2003) reported that, high yielding variety possess relatively large number of primary rachis branches as compared with the secondary rachis branches. The most distinction of all cultivars is observed in respect of 1000-

grain weight where Ukunmadhu and Kataribhough showed lower values, whereas BRRI dhan32 showed very high values (Mia and Shamsuddin, 2011).

High yielding cultivars, the harvest index is around 43.48% that means the translocation of reserved assimilates from source to sink is poor and there is a possibility of improving this character by increasing the partitioning of assimilates towards grain (Cui-Jing *et al*. 2000 and Reddy *et al*. 1994).

The modern varieties possessed higher values throughout the whole growth period which led to the higher biomass production and yield than those of the traditional varieties (Chandra and Das, 2000 and Reddy *et al*. 1994).

Low yield is a common phenomenon of aromatic rice and consequently rice breeders are trying to develop the agronomic characters to gain a better grain yield. In this study, a total of 53 rice genotypes including 12 globally popular aromatic rice cultivars and 39 advanced breeding lines were evaluated for yield and yield contributing characters in Malaysian tropical environment. Two local varieties MRQ 50 and MRQ 72 were used as check varieties. Correlation analysis revealed that the number of fertile tillers (r= 0.69), grain/panicle (r= 0.86) and fertile grain per panicle (r= 0.65) have the positive contribution to grain yield. Highest grain yield was observed in E36, followed by KhauDau Mali, E26 and E13. E36 appeared with lowest plant height and it also produced highest number of fertile tillers. After evaluation of yield components four genotypes namely E36, KhauDau Mali, E26 and E13 were selected as outstanding genotypes, which can be used as potential breeding materials for Malaysian tropical environment (Golam *et al*. 2011; Kole and Hasib, 2008; Wang *et al*. 2007; Halil & Necmi, 2005; Golam *et al*. 2004; Tahir *et al*. 2002 and Prasad *et al*. 2001).

Hossain *et al*. (2008) reported that, plant heights at maturity of the tested varieties showed significant variation. Highest plant height (165.8cm) was observed in Chinigura and the lowest (137.1cm) in Chiniatap. Lodging of local aromatic rice varieties at maturity stage was observed due to higher plant height. These may be due to genetic characteristics of the varieties. Results showed that the total number of tillers hill^{-1} ranged from 8.8 to 12.5. Maximum number tillers hill^{-1} (12.5) was obtained from Chinigura and it was identically followed by Radhunipagal. The highest number of fertile tillers $hill^{-1}$ (10.5) was found in Badshabhog, which was statistically similar to Kataribhog (Philippines), Chinigura and Radhunipagal. The maximum panicle length (25.4cm) was obtained from Kataribhog (Deshi) that was statistically similar to Chiniatap. The minimum panicle length (20.7cm) was recorded from Kataribhog (Philippines). The maximum number of spikelets per panicle (154.5) was observed in Badshabhog and the minimum (93.3) was obtained from Madhumala. The highest number of grains $panicle^{-1}$ (136.8) was observed in Badshabhog and the lowest number of grains $panicle^{-1}$ (78.1) was counted from Kataribhog (Deshi). It was observed that short bold type (small) grains densely arranged higher number in a panicle. The highest 1000 grains weight (15.18g) was found in Kataribhog (Deshi) and the lowest (10.2g) in Zirabhog, and Chiniatap. Among, the ten aromatic rice varieties the highest grain yield (3.2 t ha^{-1}) was obtained from Kataribhog (Philippines) that was statistically similar to Badshabhog. Kataribhog (Philippines) gave higher yield due to higher numbers fertile tillers hill-1 and higher individual seed weight whereas Badshabhog due to higher number fertile tillers and grains per panicle. The lowest grain yield (1.68 t ha^{-1}) was obtained from Shakhorkora under Dinajpur conditions. The highest straw yield (8.5 t ha- 1) was obtained from Chinigura due to higher plant height and total tillers $hill^{-1}$. Similar result was recorded by ldris and Motin (1990).

2.2. Effect of different cultivars of aromatic rice on quality of aromatic rice

Sarkar *et al.* (2014) showed that, variety had significant effect on qualitative characters like grain protein content (%) and aroma. The highest grain protein content (8.18%) was found in BRRI dhan34 followed by BRRI dhan38 (7.98%) and the lowest one (7.75 %) was observed in BRRI dhan37.

Lestari *et al.* (2011) conducted a study with Bogor DS, Bogor WS, and Pusakanagara DS aromatic rice cultivars in Indonesia. The study conducted for Rice qualities tested include physical quality, cooking quality, and texture of cooked rice. The physical quality include length, shape, and chalkiness, as well as percentage of broken rice, husk, milled rice and head rice. Cooking quality composed of amylose content and gelatinization temperature. Rice texture was tested manually using a score. Thirty five lines as well as Ciherang and Sintanur varieties were planted at Bogor and Pusakanagara, West Java in the dry season (DS) 2009 and wet season (WS) 2009.

Three methods, i.e. leaf aroma tested with KOH, rice aroma tested in the test tube, and cooked rice aroma test, were used to evaluate the aroma of the lines. The results showed that line B11742-RS*2-3-MR-34-1-2-1 was aromatic identified using different methods. The line had long, slender, and small chalkiness grains, high percentage of head rice, high amylose, and hard texture. Lines IPB 140-F-6, B11249-9C-PN-3-3-2-2-MR-1, and B11955-MR-84-1-4 also had a high aroma score and grain yield. Testing leaf aroma with KOH can be used as early selection method in breeding program for aromatic lines. Lines derived from aromatic parents from highlands of South Sulawesi did not show consistent aroma under three testing methods. Those tested lines had good grain quality, both physical and cooked rice quality (Sarhadi *et al.* 2009; Oad *et al.* 2006; Hien *et al.* 2006; Sha and Linscombe, 2004; Imran 2003; Dong *et al.* 2001; Singh 2000; Weber *et al.* 2000 and Berner and Hoff, 1986.

Mousomin *et al.* (2017) reported that, all the grain quality parameters were significantly influenced by variety. Milling outturn ranged from 70.0-72.1% among the tested varieties. The highest milling outturn (72.1%) was recorded in Zirabhog. Zirabhog gave the highest head rice outturn (69.5%) and it was statistically similar to Badshabhog and Chiniatap. Head rice outturn was dependent on grain size and shape, moreover it is a varietals characteristic. Grains of short to medium length usually, but not always, break than long grains during milling. Highest grain length (5.2mm) and length breadth ratio (2.3) was obtained from Kataribhog (Philippines).The grain elongation of the tested varieties varied from 1.9-2.1. Maximum volume expansion ratio (4.1) was observed in Kataribhog (Philippines). Grain protein content ranged from 7.1 to 6.5% in brown rice among the tested varieties. Highest protein content (7.1 %) was obtained from Zirabhog that was identical to Badshabhog, Chiniatap and Chinigura. Amylose content of the tested varieties varied from 23.5-24.7%. All tested varieties were intermediate type. Intermediate amylose (20-25%) rice is the preferred type in most of the rice growing areas in the world. The cooking time of the tested varieties varied from 12.0-16.0 minutes. The highest cooking time (16.0 min.) was required for cooking of Kataribhog (Philippines). The cooking time of rice depends on coarseness and gelatinization temperature of the grain. Aroma intensity differed due to variety. The variety Kalizera, Badshabhog contained higher level of aroma among the tested varieties, while, rests of the varieties had moderate type aroma. The result agreed with the earlier findings of Mannan (2005); Ferdous *et al.* (2004); BRRI (2004); Tsuzuki *et al.* (1977).

Islam *et al.* (2013) reported that milling outrun is one of the key parameters of the rice grain quality as it increases the shell life and provides the consumer with more whiteness that they desire. Thirty five rice varieties showed the milling outrun more than 70%. In general milling outrun more than 50% is desirable as the more the value the less rough rice is discarded as bran. Head rice yield (HRY) is one of the important factors used to quantify rice grain and milling quality. It is calculated as the mass percentage of rough rice remaining after complete milling. In the present study, all the rice varieties with some exceptions of Begunbitchi (18.3%), Khazar (34.2%), and Basmati sufaid 106 (46.5%), showed high HRY, ranged from 59.9% to 97.8%. Short and medium type grains which are more round and bold than long grains produce high HRY. HRY less than 70% is undesirable and many factors like grain type, variety, chalkiness, culture practice and drying conditions are responsible for that. Rice moisture level should be at least 14% in order to get better HRY. From our results, it can be assumed that, Begunbitchi, Khazar, and Basmati sufaid had moisture content more than 14%. Rice grain quality largely depends on the physicochemical properties which are greatly influenced by the genotype. Rice varieties are categorized as long, medium, short and slender, round or bold according to their length and L/B ratio, respectively. Length (L), breadth (B) and the L/B ratio varied significantly and they ranged between 3.7 to 7.4 mm, 1.5 to 2.9 mm and 1.6 to 4.3 respectively. The cooking practices vary in different countries which in turn affect the cooking and eating qualities. There are many factors namely amylose content, protein content, gel consistency, gelatinization temperature, alkali spreading value influence the cooking and eating qualities of rice. Rice with increased L/B ratio was found to have good cooking quality (Danbaba *et al.*2011; Kishine *et al.* 2008; Adu-kwarteng *et al.* 2003; Dipti *et al.* 2003; Dipti *et al.* 2002; Oyegbayo *et al.* 2001; Sajwan *et al.* 1990 and Sood & Saddiq, 1986).

The ratio of the amylose and amylopectin in the rice grain influence the cooking and eating characteristics of rice (Williams, 1958).Rice varieties were classified into waxy (0-2%), very low (3-9%), low (10-19%), intermediate (20-25%) and high (>25%) on the basis of their amylose content (IRRI, 1972). This positive correlation between amylose content with the length, L/B ratio and cooking time were also reported by

(Danbaba *et al.* 2011). The protein content ranged between 5.7 % for Kalgochi to 11.3%for Khazar and Hatisail. The ranges obtained for the varieties fall within that for polished rice (5–14%) (Fofana *et al.* 2011 and Damardjati *et al.*1985). The variations observed maybe due to varietal and environmental influences. This may be due to the use of nitrogen fertilizer which decreased the amylose content with the subsequent increase of the protein content (Wang *et al.* 2005).

2.3. Effect of organic cultivation on quality and physiology of aromatic rice

Sarkar *et al.* (2014) reported that, influenced by nutrient management. The application of 75% of recommended dose of inorganic fertilizers + 50% cowdung showed superiority in terms of the highest plant height (139.5 cm), number of total tillers hill^{-1} (13.41), number of effective tillers hill^{-1}(11.59), panicle length (24.31 cm), number of grains panicle^{-1} (157.6), grain yield (3.97 t ha^{-1}), straw yield (5.49 t ha^{-1}) and biological yield (9.47 t ha^{-1}). Probably this treatment provided adequate nutrients to the plants and exhibited the best performance due to absorption of more nutrients, moisture.

Sikdar (2000) and Kabir *et al.* (2004) who found differences in yield and yield contributing characters due to different levels of nutrient management. Hossain (2008) also reported that Kataribhog and Badshabhog produced yield of 2.30 and 2.12 tons ha^{-1}, respectively. The treatment control (no manures and fertilizers) gave the lowest values for the same parameters due to lack of proper nutrient uptake. The lowest number of non-effective tillers hill^{-1} (1.15) was found from the treatment 75% of recommended dose of inorganic fertilizers + 50% cowdung. The highest grain protein content (9.15%) was found in the treatment of 75% of recommended dose of inorganic fertilizers + 50% poultry manure, which was similar (8.96 %) to that of recommended dose of inorganic fertilizers. This might be due to availability and uptake of adequate nitrogen from the soil. The highest aroma (2.46) was found in the treatment of 75% of recommended dose of inorganic fertilizers + 50% cowdung. The lowest (1.00) aroma was observed in the control treatment. These findings are in conformity with the findings of Dutta *et al*. (1998).

Carbon dioxide of leaf cells in organic fertilizer did not differ as compared to that of inorganic fertilizer. It was indicated that the different nutrient content between organic and inorganic fertilizer did not lead to different fixation of CO_2 from the air so that the CO_2 of leaf cell was also not different. Rice is a C_3 plant which was very responsive to CO_2 (Horle *et al.* 2000 and Imal, 1995).

Stomatal conductance between different varieties except for cv. Mentikwangi. Stomatal conductance was one of the things that affect CO_2 levels of leaf cells i.e. stomata opening, external CO_2 levels and CO_2 utilization by cells. Increased levels of external –internal CO_2 and becomes higher that will affect the process of diffusion of CO_2 into the leaf mesophyll faster. This resulted in leaf internal CO_2 levels and also increased in turn with the increasing CO_2 levels externally (Alam *et al.* 2008).

Photosynthesis was a process of the capturing light energy, converted into chemical energy and the product was stored as carbohydrates. Photosynthesis was effect by N content of leaf, greenness of leaves, CO_2 content of leaf cells and stomatal conductance. Photosynthesis rate of rice was strongly influenced by activity of rubisco enzyme, which was influenced by the ratio between CO_2 and O_2 in mesophyll (Sallsbury and Ross, 1992). Gardner *et al.* (1991) stated that, photosynthesis was affected by availability of water, temperature, age of leaves, translocation of carbohydrates and the availability of CO_2. Organic fertilizer tended to reduce the rate of photosynthesis. It was related to the greenness of leaves, stomatal conductance in organic fertilizer.

Yoshida, (1981) showed that, the net rate of photosynthesis of rice ranges from 400-500 mg CO_2 m^{-2} s^{-1} at full light, which was affected by the organic cultivation methods.

2.4. Effect of interaction of varieties and nutrient management of aromatic rice

Sarkar *et al.* (2014) revealed that, the interaction effect of variety and nutrient management was significant on yield and yield components of aromatic fine rice. The highest plant height (149.9 cm), number of total tillers $hill^{-1}$ (14.23), number of effective tillers $hill^{-1}$ (12.03), panicle length (25.60 cm), number of grains $panicle^{-1}$ (173), grain yield (4.18 t ha^{-1}), straw yield (5.88 t ha^{-1}) and biological yield (10.07 t ha^{-1}) were recorded in the interaction between BRRI dhan34 and 75% of recommended dose of inorganic fertilizers + 50% cowdung. The lowest values of these parameters were found in the interaction between BRRI dhan37 and control (no manures and fertilizers). But harvest index (44.06%) was found maximum in the interaction between BRRI dhan34 and 50% of recommended dose of inorganic fertilizers + 50% cowdung. Interaction of BRRI dhan34 with recommended dose of inorganic fertilizers produced the highest grain protein content (10.90%) which was as good as (10.87%) BRRI dhan38 with 75% of recommended dose of inorganic fertilizers + 50% poultry manure. The lowest grain protein content (6.28%) was observed in interaction of BRRI dhan37 × control, which was similar to that of BRRI dhan38 × control (6.34%), BRRI dhan37 × poultry manure at 5 t ha^{-1} (6.38%) and BRRI dhan34 × control (6.46%). The highest aroma (2.61) was found in BRRI dhan38 with 75% of recommended dose of inorganic fertilizers + 50% cowdung, which was similar to that of BRRI dhan38 × recommended dose of inorganic fertilizers. The lowest aroma was found in BRRI dhan34 × control (1.00) which was similar to aroma from the interactions of BRRI dhan37 × control (1.00), and BRRI dhan38 × control (1.00).

Mousomi *et al.* (2017) conducted a study in Bangladesh and found that, there was significant interaction between fertilizer doses and rice varieties on plant height the longest plant was found for applying recommended dose of fertilizer (F1) in soil and in all cases, the shortest plant was noticed where no fertilizer i.e. control treatment applied. In most of the cases, Maloti had the highest plant height and Kalizira produced the lowest. It was found that application of N-P-K (20:10:10) in lowland rice increases the heights of NERICA36 and NERICA42 rice varieties compared to the control (Herve *et al.* 2017). NERICA36 had a height of 60 cm at a dose of 200 kg while the control had a height of 15 cm, and NERICA42 had a height of 83cm at a dose of 180 kg while the control had only 30 cm. (Herve *et al.* 2017). Tallest plant was recorded (112.83 and 116.40 cm) in rice receiving N-200 kg ha^{-1} compared to four lower nitrogen doses (Pramanik and Bera, 2013). Different literatures show that plant height increased significantly with the increasing rates of fertilizers (Sudhaans Stalin, 2015; Panowan *et al.* 2013; Khan *et al.* 2007; Singh and Singh, 2002; Idris and Matin, 1990 and Singh *et al.* 1986). The shortest plant height might be due to no use of fertilizers that greatly reduced plant growth and development due to the shortage of nutrients resulting lowest height of plant(24.4 and 26.7) in hybrid rice receiving N-200 kg ha^{-1} while the rice receiving no nitrogen produced the lowest number of tillers $hill^{-1}$ (10.8 and 11.9) (Pramanik and Bera 2013). The growth characters of rice increased significantly with the application of increasing fertilizer doses (Chaturvedi and Lahori, 2007; Chandel *et al.* 2003; Sarfraz *et al.* 2002 and Mondal *et al.* 1987.

CHAPTER III

MATERIALS AND METHOD

The experiment was conducted to find out the effect of organic and inorganic fertilizers on growth, yield and quality of aromatic rice in *boro* season. The details of the materials and methods i.e. experimental period, location, soil and climatic condition of the experimental area, materials used, treatments and design of the experiment, growing of crops, data collection and data analysis procedure that followed in this experiment has been presented under the following headings:

3.1 Experimental period

The field experiment was conducted during the period of December, 2018 to June, 2019.

3.2 Description of the experimental site

3.2.1 Location of the experimental field

The experiment was carried out on the farm of Sher-e-Bangla Agricultural University, Dhaka. The location of the site is 23º74'N latitude and 90º35'E longitude with an elevation of 8.2 meter from sea level.

3.2 2 Characteristics of the soil

The experimental site belongs to the agro-ecological zone of Modhupur Tract (AEZ-28). Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and has organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land.

3.2.3 Climate

Subtropical in nature, characterized by three distinct seasons. The geographical location of the experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from December to February and the pre-monsoon period or hot season from March to April and monsoon period from May to October. Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e Bangla Nagar, presented in Appendix 2.

3.3 Plant material

In this research, six aromatic rice varieties namely Chiniatop 1, Katari 2, Dulabhog (BR 5), Zirabhog, BRRI dhan34 and BRRI dhan50 were used. The seeds were collected from the Bangladesh Rice Research Institution (BRRI), Joydeppur, Gajipur.

3.4 Experimental design

The experiment was followed a split plot design with three replications and it laid out following unit plot size of 4m x 2.5m.

3.5 Treatments

The experiment was conducted to justify the effect of organic and inorganic fertilizers on growth, yield and quality of aromatic rice in boro season. It consisted of two factors as mentioned below:

Factor A: Fertilizer used (2) (Sob-plot treatment)

(i) Organic fertilizer (T_1): (Organic manure and compost were used)

(ii) Inorganic fertilizer (T_2): (N, P, K, S and Zn were used)

Factor B: Variety (6) (Main-plot treatment)

(i) Chiniatop 1 (V_1)

(ii) Katari 2 (V_2)

(iii) Dulabhog (BR 5) (V_3)

(iv) Zirabhog (V_4)

(v) BRRI dhan34 (V_5)

(vi) BRRI dhan50 (V_6)

Treatment Combinations (12):

1. V_1T_1: Chiniatop 1 + Organic fertilizer

2. V_1T_2: Chiniatop 1 + Inorganic fertilizer

3. V_2T_1: Katari 2 + Organic fertilizer

4. V_2T_2: Katari 2 + Inorganic fertilizer

5. V_3T_1: Dulabhog (BR 5) + Organic fertilizer

6. V_3T_2: Dulabhog (BR 5) + Inorganic fertilizer

7. V_4T_1: Zirabhog + Organic fertilizer

8. V_4T_2: Zirabhog + Inorganic fertilizer

9. V_5T_1: BRRI dhan34 + Organic fertilizer

10. V_5T_2: BRRI dhan34 + Inorganic fertilizer

11. V_6T_1: BRRI dhan50 + Organic fertilizer

12. V_6T_2: BRRI dhan50 + Inorganic fertilizer

3.6 Procedure of experiment

3.6.1 Raising seedling

3.6.1.1 Seed collection

Vigorous and healthy seeds of Chiniatop 1, Katari 2, Dulabhog, Zirabhog, BRRI dhan34 and BRRI dhan50 were collected from BRRI (Bangladesh Rice Research Institute), Gazipur, Bangladesh.

3.6.1.2 Seed sprouting

Healthy seeds were kept in water bucket for 24 hours and then it was kept tightly in gunny bags. The seeds started sprouting after 48 hours and were sown after 72 hours.

3.6.1.3 Preparation of nursery bed and seed sowing

As per BRRI recommendation seedbed was prepared with 1 m wide adding nutrients as per the requirements of soil. Seeds were sown in the seed bed on 10 December, 2018 in order to transplant the seedlings in the main field.

3.6.2 Preparation of the main field

The plot selected for the experiment was opened in the fourth week of December, 2018 with a power tiller and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross ploughed several times followed by laddering to obtain a good tilt. Weeds and stubble were removed and finally obtained a desirable tilt of soil for transplanting of seedlings.

3.6.3 Fertilizers and manure application

Organic and inorganic fertilizers were applied for the experiment. The amounts that were applied are discussed below:

3.6.3.1 Organic fertilizer

For organic fertilizer 10 ton of cow-dung and compost (4:1) were applied during final land preparation.

3.6.3.2 Inorganic fertilizer

The fertilizers N, P, K, S and Zn were applied in the form of Urea, TSP, MoP, Gypsum and Zinc Sulphate, respectively. All fertilizers except urea were applied as basal dose at the time of final land preparation. Urea was top-dressed into three equal splits each at 15, 30 and 45 days after transplanting (DAT). The dose and method of application are shown in Table 1.

Table 1. Dose and method of application of fertilizers in aromatic rice field

Fertilizers	Dose (kg/ha)	Application (%)			
		Basal	1st installment	2nd installment	3rd installment
Urea	90	0	30	30	30
TSP	60	60	-	-	-
MoP	45	45	-	-	-
Gypsum	8	8	-	-	-
Zinc Sulphate	3	3	-	-	-

3.6.4 Uprooting of seedlings

The nursery bed was made wet by application of water one day before uprooting the seedlings. The seedlings were uprooted without causing much mechanical injury to the roots.

3.6.5 Transplanting of seedlings in the field

Thirty (30) days old seedlings were transplanted in the experimental plots using three seedlings hill^{-1} on 10 January, 2019.

3.6.6 Intercultural operations

After establishment of seedlings, all intercultural operations were accomplished for better growth and development of the rice seed lings as and whenever necessary.

3.6.6.1 Irrigation and drainage

Flood irrigation was given to maintain a constant level of standing water up to 3 cm in the early stages to enhance tillering and 4-5 cm in the later stage to discourage late tillering. The field was finally dried out at 15 days before harvesting.

3.6.6.2 Gap filling

Gap filling was done for all of the plots at 10 days after transplanting (DAT) by planting same aged seedlings.

3.6.6.3 Weeding

The crop was infested with some common weeds, which were controlled by uprooting and remove them three times from the field during the period of experiment. Weeding was done after 15, 32 and 52 days of transplanting.

3.6.6.4 Top dressing

The urea fertilizer was top-dressed in 3 equal installments at 15, 30 and 45 days after transplanting (DAT).

3.6.6.5 Plant protection

There were some incidence of insects specially grasshopper, stem borer, rice ear cutting caterpillar, thrips and rice bug which was controlled by spraying some pesticides.

3.7 Harvesting, threshing and cleaning

Five hills were randomly selected at maturity (when 80% of the grains became golden yellow) and uprooted from each unit plot prior to harvest for recording data. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. The grains were threshed, cleaned and sun dried (adjusted to 12% moisture con-tent) to record grain yield plot^{-1}. Straws were also sun-dried to record its yield plot^{-1} and both grain and straw yields plot^{-1} were then converted to t ha^{-1}.

3.8 Data recording

The following data were collected during the study period:

Morphological parameters

1. Plant height (cm)

2. Leaves hill^{-1}

3. Total tillers hill^{-1}

4. Effective tillers hill^{-1}

5. Ineffective tillers hill^{-1}

Physiological parameters

1. Leaf area index

2. SPAD reading

3. Stomatal conductance (mmol CO_2 m^{-2} s^{-1})

4. Total dry matter distribution (g)

Yield contributing parameters

1. Total grains panicle^{-1}

2. Filled grains panicle^{-1}

3. Unfilled grains panicle^{-1}

4. Grain sterility (%)

Yield parameters

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

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

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

4. Harvest index (%)

5. Grain size (mg)

Grain quality parameters

1. Aroma scoring

2. Length- Breadth ratio (L/B) of cooked rice

3. Cooking duration (CD) (min.)

4. Elongation ratio (ER)

3.9 Procedure of recording data

3.9.1 Plant height (cm)

The height of plant was recorded in centimeter (cm) at the time of harvest. Data were recorded as the average of same 5 plants pre-selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the plant.

3.9.2 Leaves hill^{-1}

The total number of leaves hill^{-1} were counted from 5 selected hills at harvest and average value were recorded.

3.9.3 Total tillers hill^{-1}

Total tillers hill^{-1} were counted from the number of total tillers which had at least one visible leaf. It includes both productive and unproductive tillers.

3.9.4 Effective tillers hill^{-1}

The number of effective tillers which had at least one visible leaf were counted for the number of effective tillers hill^{-1}.

3.9.5 Ineffective tillers hill^{-1}

The number of ineffective tillers which had at least one visible leaf were counted for the number of ineffective tillers hill^{-1}.

3.9.6 Leaf area index (LAI)

Leaf area index was estimated by using the following formula-

LAI= Leaves area per hill / Ground area per hill

Here leaf area was estimated manually at the time of 55, 75 DAT and at harvest. Data were collected as the average of 5 plants selected. Final data were calculated multiplying by a correction factor 0.75.

Leaf area = Leaf length × leaf breadth × 0.75

And ground area means total surface area of the land.

3.9.7 SPAD reading

The greenness of the flag leaf of main stem was observed by SPAD meter (model-SPAD-502 Plus Chlorophyll Meter), which was starting from the day of anthesis to maturity at five days intervals. SPAD reading were taken in three locations: (a) 1/3 of the distance from the leaf base, (b) 1/2 of the distance from the leaf base, (c) 2/3 of the distance from the leaf base. In the meanwhile, mean the combination of the corresponding (a), (b) and (c) positions. Five randomly selected plants from each plot were measured in the field.

3.9.8 Stomatal Conductance (mmol$CO_2m^{-2}s^{-1}$)

The stomatal conductance of main stem flag leaf was measured by leaf porometer (G9-Leaf Porometer) from the day of anthesis to maturity at five days interval. Stomatal conductance was measured by Leaf porometer putting the conductance of a leaf in series with two known conductance elements and comparing the humidity measurements between them.

3.9.9 Total dry matter distribution (g)

Total dry matter hill-1 was measured in gram (g) at 25, 50, 75 DAT and at harvest from 5 randomly selected plants of each plot from inner rows leaving the boarder row. Collected plants were oven dried at 70°C for 72 hours, then transferred into a desecator and allowed to cool down at room temperature, then final weight was taken.

3.9.10 Relative performance

The relative performance was calculated as Asana and Williams (1965) by the following formula-

$$\text{Relative performance} = \frac{Variable\ measured\ under\ organic\ condition}{Variable\ measured\ under\ normal\ (inorganic)\ condition}$$

3.9.11 Total grains panicle^{-1}

The total number of grains were calculated by adding filled and unfilled grains from randomly selected five panicles per plot and then average number of grains panicle^{-1} were recorded.

3.9.12 Filled grains panicle^{-1}

The number of filled grains were collected from the randomly selected 5 panicles from each plot and then average number of filled grains panicle^{-1} were calculated.

3.9.13 Unfilled grains panicle^{-1}

The total number of unfilled grains were collected randomly from selected 5 plants of a plot and then average number of unfilled grains panicle^{-1} were recorded.

3.9.14 Grain sterility (%)

The grain sterility percentage was calculated by dividing number of unfilled grains with number of total grains and then multiply by 100.

Grain sterility percentage= (Number of unfilled grains / Number of total grains) x 100

3.9.15 Grain yield t ha^{-1}

Grains obtained from each unit plot were sun-dried and weighted carefully. The dry weight of grain of central 3 lines from each plot were harvested, threshed, dried, weighted and finally converted to t ha^{-1} basis.

3.9.16 Straw yield t ha^{-1}

Straw obtained from each unit plot were sun-dried and weighted carefully. The dry weight of straw of central 3 lines were harvested, threshed, dried and weighted and finally converted to t ha^{-1} basis.

3.9.17 Biological yield t ha^{-1}

The biological yield was calculated by adding total grain yield and total straw yield.

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

3.9.18 Harvest index

The harvest index was calculated with the following formula:

Harvest index = (Grain yield / Biological yield) x 100

3.9.19 Grain size (mg)

Thousand grains were measured randomly from the total cleaned harvested grains of each individual plot and then weighted in mg and finally recorded.

3.9.20 Aroma scoring (AS)

Aroma of rice was detected by olfactory test following the method developed by Lestari et al. (2011). A total of 200g of rice of each variety was cooked with 300 ml of water and then steamed for 30 minutes. Cooked rice aroma was tested by 5 panelists to determine the aroma level (using score). The sample were scored on 1-4 scale with 1, 2, 3, and 4 corresponding to absence of aroma, slight aroma, moderate aroma and strong aroma respectively.

3.9.21 Length-breadth ratio (L/B)

Length and breadth-wise arrangement of milled rice was done by slide calipers and their cumulative measurements (in mm) were taken. The value of L/B was determined by dividing length by breadth.

3.9.22 Cooking duration (min.) (CD)

Milled rice (5g) samples from each variety were taken in a graduated cylinder containing 5 ml of water and put it in a water bath. The cooking time was determined by removing a few kernels at different time intervals during cooking and pressing them between two glass plates until 90% of the cooked rice was gelatinized.

3.9.23 Elongation ratio (ER)

Cumulative length of 10 cooked rice kernels was divided by length of 10 uncooked raw kernels and the result was reported as elongation ratio.

3.24 Statistical Analysis

All the data collected on different parameters were statistically analyzed following the analysis of variance (ANOVA) technique using MSTAT-C computer package program and the mean difference were adjudged by least significant (LSD) test at 5% level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

The present investigation entitled "Effect of organic and inorganic fertilizers on growth, yield and quality of aromatic rice in *boro* season". The findings obtained from the study have been presented, discussed and compared in this chapter through different tables and figures. The analyses of variance (ANOVA) and other table on different parameters have been presented in Appendices. The results have been presented and discussed with the help of tables and graphs and possible interpretations have been given under the following sub-headings.

4.1 Morphological parameters

4.1.1 Plant height (cm) at harvesting stage

4.1.1.1 Effect of variety

Statistically significant variation was recorded among the aromatic rice varieties for plant height (cm) (Figure 1). Data revealed that, the tallest plant (149.4 cm) was observed from Chiniatop 1, which was statistically different from other varieties and followed by BRRI dhan34 (147.00 cm), Dulabhog (135.4 cm) and Katari 2 (124.9 cm).Whereas, the shortest plant (112.6 cm) was recorded from Zirabhog, which was significantly different from others and followed by BRRI dhan50 (114.5 cm). This confirms the report of Islam *et al.* (2013) that plant height differed from variety to variety. Plant height was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

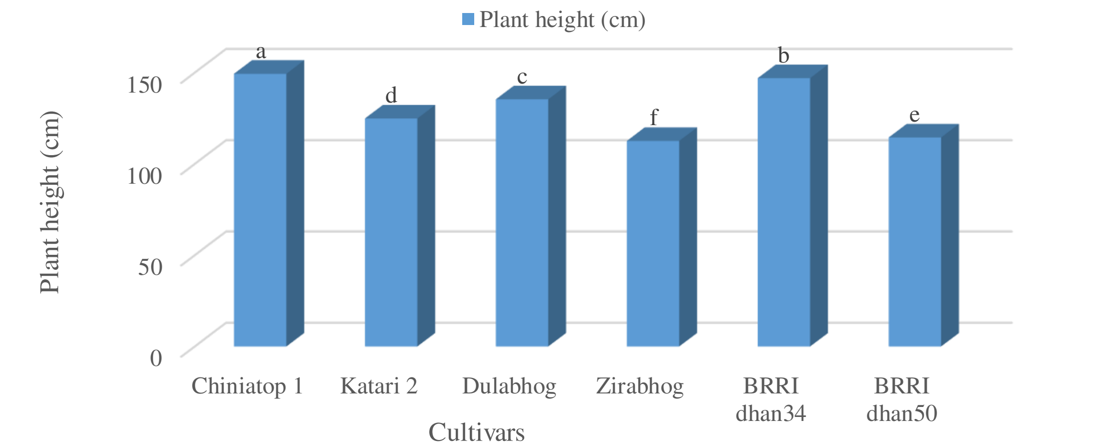

Figure 1: The effect of variety on plant height (cm) at harvest

4.1.1.2 Effect of organic and inorganic fertilizer

Significantly two different variations in plant height of rice was observed due to two different fertilizer that were used (Figure 2). The maximum plant height (132.7 cm) was observed from T_1 (organic fertilizer) which was significantly different from others. Whereas, minimum plant height (128.6 cm) was recorded from T_2 (inorganic fertilizer). It might be due to the fact that organic matter effect on the development of rice plant. Similar results were also reported by Sarkar *et al.* (2014).

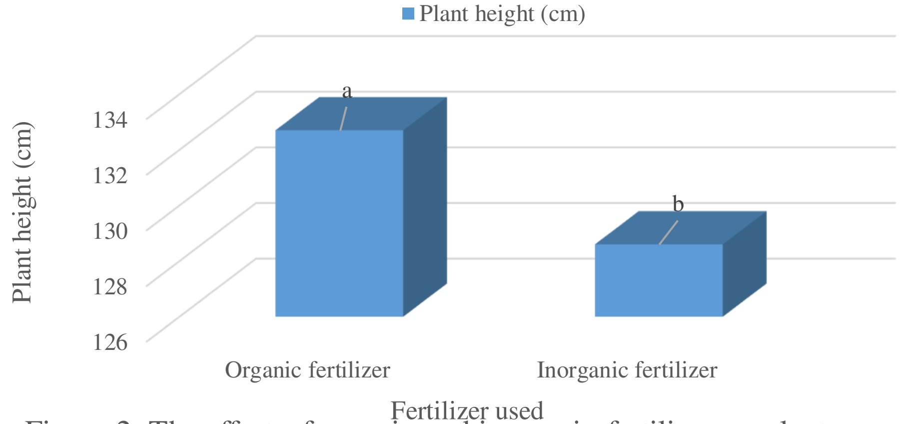

Figure 2: The effect of organic and inorganic fertilizer on plant height (cm) at harvest

4.1.1.3 Interaction effect of organic, inorganic fertilizer and variety

Different varieties and fertilizer used expressed significant differences due to their interaction effect on plant height of rice (Table 2). The maximum plant height (149.5 cm) was recorded from the V_1T_1 (Chiniatop 1 + Organic fertilizer) which was statistically similar to V_5T_1 (149.4 cm) and followed by V_1T_2 (148.5 cm), V_3T_1 (145.4 cm), V_5T_2 (137.4 cm), V_3T_2 (133.4 cm) and V_2T_1 (126.5 cm). The shortest plant (109.6 cm) was obtained from the V_4T_2 (Zirabhog + Inorganic fertilizer), which was statistically different from others and followed by V_4T_1 (110.4 cm), V_6T_2 (115.5 cm), V_2T_2 (118.7 cm) and V_6T_1 (123.3 cm).

Table 2: Interaction effect of organic, inorganic fertilizer and variety on plant height (cm) at harvesting stage

Fertilizers	Varieties	Plant height (cm)
Organic fertilizer (T_1)	V_1	149.5 a
	V_2	126.5 f
	V_3	145.4 c
	V_4	110.4 j
	V_5	149.4 a
	V_6	123.3 g
Inorganic fertilizer (T_2)	V_1	148.5 b
	V_2	118.7 h
	V_3	133.4 e
	V_4	109.6 k
	V_5	137.4 d
	V_6	115.5 i
CV (%)		0.25
LSD (0.05)		0.53

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, V_1= Chiniatop 1; V_2= Katari 2; V_3= Dulabhog; V_4= Zirabhog; V_5= BRRI dhan34 and V_6= BRRI dhan50

4.1.2 Tillers hill^{-1} at anthesis stage

4.1.2.1 Effect of variety

Statistically significant variation was recorded among the aromatic rice varieties for number of tillers hill^{-1}at grain filling stage (Table 3). Data revealed that, in case of total number of tillers hill^{-1}, the maximum number of total tillers hill^{-1} (13.62) was observed from Chiniatop 1, which was statistically different from other varieties and followed by BRRI dhan34 (12.77), Dulabhog (11.45) and Katari2 (10.00). Whereas, the minimum number of tillers hill-1 (8.2) was recorded from Zirabhog, which was significantly different from others and followed by BRRI dhan50 (8.51).

In case of number of effective tillers hill^{-1}, the maximum number of effective tillers hill^{-1} (13.49) was observed from Chiniatop 1, which was statistically different from other varieties and followed by BRRI dhan34 (12.34), Dulabhog (10.40) and Katari2 (8.80). Whereas, the minimum number of effective tillers hill^{-1} (6.68) was recorded from Zirabhog, which was significantly different from others and followed by BRRI dhan50 (7.09).

Again, in case of number of ineffective tillers hill^{-1}, the maximum number of ineffective tillers hill^{-1} (1.52) was observed from Zirabhog, which was significantly different from others and followed by BRRI dhan50 (1.42).Whereas, the minimum number of ineffective tillers hill^{-1} (0.13) was recorded from Chiniatop 1, which was statistically different from other variety and followed by BRRI dhan34 (0.43), Dulabhog (1.05) and Katari2 (1.20). This confirms the report of Islam *et al.* (2013) that number of tillers differed from variety to variety.

Table 3: The effect of variety on number of tillers hill^{-1} at anthesis stage

Varieties	Total tillers hill^{-1}	Effective tillers hill^{-1}	Ineffective tillers hill^{-1}
Chiniatop 1	13.62 a	13.49 a	0.13 f
Katari 2	10.00 d	8.80 d	1.20 c
Dulabhog	11.45 c	10.40 c	1.05 d
Zirabhog	8.20 f	6.68 f	1.52 a
BRRI dhan34	12.77 b	12.34 b	0.43 e
BRRI dhan50	8.51 e	7.09 e	1.42 b
CV (%)	2.71	2.46	2.13
$LSD_{(0.05)}$	0.48	0.40	0.43

Values followed by same letter(s) did not differ significantly at 5% level of probability

4.1.2.2 Effect of organic and inorganic fertilizer

Significantly two variations in number of tillers hill^{-1} of aromatic rice were observed between two different fertilizers used at anthesis stage (Table 4). In case of number of total tillers hill^{-1}, the maximum number of tillers hill^{-1} (10.98) was observed from T_1 (organic fertilizer) which was significantly different from other. Whereas, minimum number of total tillers hill^{-1} (10.53) was recorded from T_2 (inorganic fertilizer).

In case of number of effective tillers hill^{-1}, between the two different fertilizer used, the maximum number of effective tillers hill^{-1} (10.20) was observed from T_1 (organic fertilizer) which was significantly different from other. Whereas, minimum number of effective tillers hill^{-1} (9.40) was recorded from T_2 (inorganic fertilizer).

Again, in case of number of ineffective tillers hill^{-1}, between two fertilizer used, the maximum number of ineffective tillers hill^{-1} (1.13) was observed from T_2 (inorganic fertilizer) which was significantly different from other. Whereas, minimum number of ineffective tillers hill^{-1} (0.78) was recorded fromT_1 (organic fertilizer). It might be due to the fact that organic matter effect on the development of rice plant. Similar results were also reported by Sarkar *et al.* (2014).

Table 4: The effect of organic and inorganic fertilizer on number of tillers hill^{-1} at anthesis stage

Fertilizers	Total tillers hill^{-1}	Effective tillers hill^{-1}	Ineffective tillers hill^{-1}
Organic fertilizer	10.98 a	10.20 a	0.78 b
Inorganic fertilizer	10.53 a	9.40 b	1.13 a
CV (%)	2.71	2.46	2.13
$LSD_{(0.05)}$	0.14	0.07	0.11

Values followed by same letter(s) did not differ significantly at 5% level of probability

4.1.2.3 Interaction effect of organic, inorganic fertilizer and variety

Different varieties and fertilization methods expressed significant differences due to their interaction effect on number of tillers hill^{-1} of aromatic rice at anthesis stage (Table 5). In case of total number of tillers hill^{-1}, the maximum number of total tillers hill^{-1} (14.55) was recorded from the V_1T_1 (Chiniatop 1+Organic fertilizer) which was statistically different from others and followed by V_5T_1 (13.50), V_1T_2 (12.68), V_3T_1 (12.04), V_5T_2 (11.51), V_3T_2 (11.39) and V_2T_1 (10.60). The minimum number of total tillers hill^{-1} (8.00) was obtained from the V_4T_2 (Zirabhog+Inorganic fertilizer), which was statistically similar to V_4T_1 (8.39) and V_6T_2 (8.48) and followed by V_2T_2 (8.54) and V_6T_1 (9.41) (Table 5).

In case of number of effective tillers hill^{-1}, the maximum number of effective tillers hill^{-1} (12.43) was recorded from the V_1T_1 (Chiniatop 1+Organic fertilizer) which was statistically similar to V_5T_1 (12.40), V_1T_2 (12.23), V_3T_1 (10.47), V_5T_2 (10.33), V_3T_2 (9.53) and V_2T_1 (9.30). The minimum number of effective tillers hill^{-1} (7.63) was obtained from the V_4T_2 (Zirabhog+Inorganic fertilizer), which was statistically similar to V_4T_1 (8.00) and followed by V_6T_2 (8.13), V_2T_2 (8.53) and V_6T_1 (8.60) (Table 5).

In case of number of ineffective tillers hill^{-1}, the maximum number of ineffective tillers hill^{-1} (3.56) was recorded from the V_4T_2 (Zirabhog+Inorganic fertilizer), which was statistically different from others and followed by V_4T_1 (3.21), V_6T_2 (2.97), V_2T_2 (2.88) and V_6T_1 (2.63). The minimum number of ineffective tillers hill^{-1} (0.37) was obtained from theV_1T_1 (Chiniatop 1+Organic cultivation) which was statistically similar to V_5T_1 (0.83) and followed by V_1T_2 (1.07), V_3T_1 (1.33), V_5T_2 (1.67), V_3T_2 (1.91) and V_2T_1 (2.47). (Table 5).

Table 5: Interaction effect of organic, inorganic fertilizer and variety on tillers hill^{-1} at anthesis stage

Fertilizers	Varieties	Total tillers hill^{-1}	Effective tillers hill^{-1}	Ineffective tillers hill^{-1}
Organic fertilizer (T_1)	V_1	14.55 a	12.43 a	0.37 h
	V_2	10.60 f	9.30 c	2.47 de
	V_3	12.04 d	10.47 b	1.33 f
	V_4	8.39 hi	8.00 ef	3.21 b
	V_5	13.50 b	12.40 a	0.83 h
	V_6	9.41 g	8.60 d	2.63 d
Inorganic fertilizer (T_2)	V_1	12.68 c	12.23 a	1.07 g
	V_2	8.54 h	8.53 d	2.88 c
	V_3	11.39 e	9.53 c	1.91 e
	V_4	8.00 i	7.63 f	3.56 a
	V_5	11.51 e	10.33 b	1.67 f
	V_6	8.48 hi	8.13 e	2.97 c
CV (%)		2.71	2.46	2.13
LSD (0.05)		0.48	0.40	0.43

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, V_1= Chiniatop 1; V_2= Katari2; V_3= Dulabhog; V_4= Zirabhog; V_5= BRRI dhan34 and V_6= BRRI dhan50

4.1.3 Leaves hill^{-1} at anthesis stage

4.1.3.1 Effect of variety

Statistically significant variation was recorded among the aromatic rice varieties for number of leaves hill^{-1}at anthesis stage (Figure 3). Data revealed that, the maximum number of leaves hill^{-1} (25.33) was observed from Chiniatop 1, which was statistically different from other varieties and followed by BRRI dhan34 (24.67), Dulabhog (24.13) and Katari2 (23.47). Whereas, the minimum number of leaves hill^{-1} (21.87) was recorded from Zirabhog, which was significantly different from others and followed by BRRI dhan50 (22.63).This confirms the report of Islam *et al.* (2013) that number of tillers differed from variety to variety.

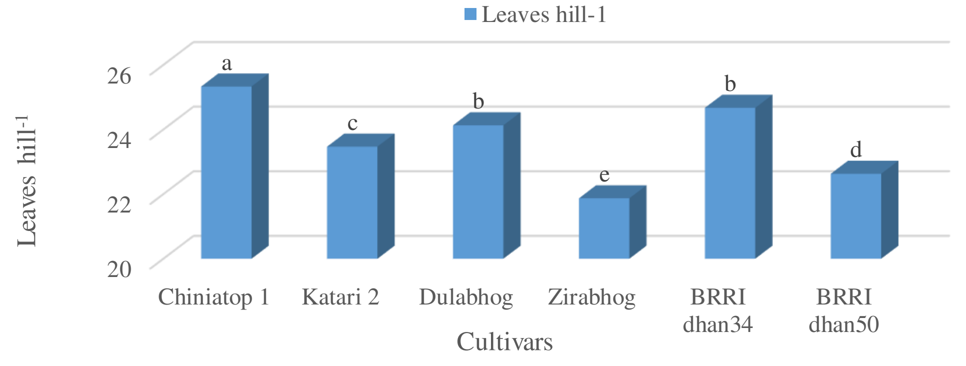

Figure 3: The effect of variety on leaves hill^{-1} at anthesis stage

4.1.3.2 Effect of organic and inorganic fertilizer

Significantly two different variations in number of leaves hill^{-1} of aromatic rice was observed between two fertilizer used at anthesis stage (Figure 4). Between the two fertilizer used, the maximum number of leaves hill^{-1} (20.17) was observed from T_1 (organic fertilizer) which was significantly different from other. Whereas, minimum number of leaves hill^{-1} (18.67) was recorded from T_2 (inorganic fertilizer).It might be due to the fact that organic matter effect on the development of rice plant. Similar results were also reported by Sarkar *et al*. (2014).

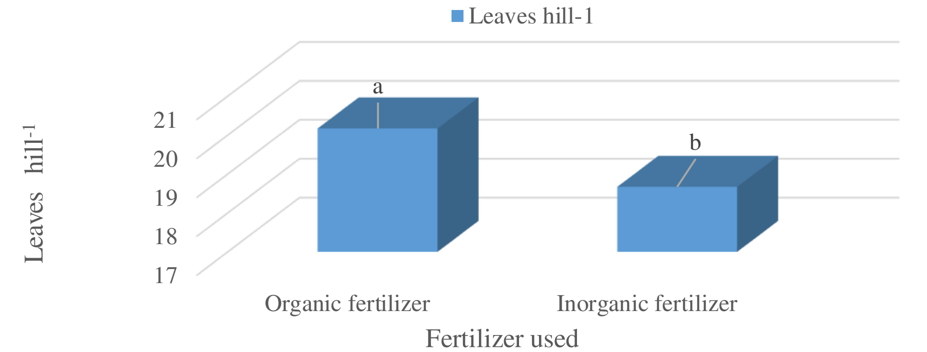

Figure 4: The effect of organic and inorganic fertilizer on leaves hill^{-1} at anthesis stage

4.1.3.3 Interaction effect of organic, inorganic fertilizer and variety

Different varieties and fertilizer used expressed significant differences due to their interaction effect on number of leaves hill^{-1} of aromatic rice at anthesis stage (Table 6). In case of number of leaves hill^{-1}, the maximum number of leaves hill^{-1} (26.87 leaves) was recorded from the V_1T_1 (Chiniatop 1+Organic fertilizer) which was statistically similar to V_5T_1 (26.16) and followed by V_1T_2 (25.56), V_3T_1 (25.13), V_5T_2 (25.09), V_3T_2 (24.78) and V_2T_1 (24.63). The minimum number of leaves hill^{-1} (21.16 leaves) was obtained from the V_4T_2 (Zirabhog+Inorganic fertilizer), which was statistically similar to V_4T_1 (22.47), V_6T_2 (23.53), V_2T_2 (24.17) and V_6T_1 (24.47 leaves).

Table 6: Interaction effect of organic, inorganic fertilizer and variety on leaves hill^{-1} at anthesis stage

Fertilizers	Varieties	Leaves hill^{-1}
Organic fertilizer (T_1)	V_1	26.87 a
	V_2	24.63 c
	V_3	25.13 b
	V_4	22.47 e
	V_5	26.16 a
	V_6	24.47c
Inorganic fertilizer (T_2)	V_1	25.56 b
	V_2	24.17c
	V_3	24.78 c
	V_4	21.16 f
	V_5	25.09 b
	V_6	23.53 d
CV (%)		0.39
LSD (0.05)		0.18

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, V_1= Chiniatop 1; V_2= Katari2; V_3= Dulabhog; V_4= Zirabhog; V_5= BRRI dhan34 and V_6= BRRI dhan50

4.2 Physiological parameters

4.2.1 Leaf area index at grain filling stage

4.2.1.1 Effect of variety

Statistically significant variation was recorded among the aromatic rice varieties for leaf area index (Figure 5). Data revealed that, the maximum leaf area index (3.42) was observed from Chiniatop 1, which was statistically different from other variety and followed by BRRI dhan34 (2.68), Dulabhog (2.46) and Katari2 (2.46).Whereas, the minimum leaf area index (1.73) was recorded from Zirabhog, which was significantly different from others and followed by BRRI dhan50 (1.91). This confirms the report of Islam *et al.* (2013) that leaf area index differed from variety to variety. The leaf area index was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

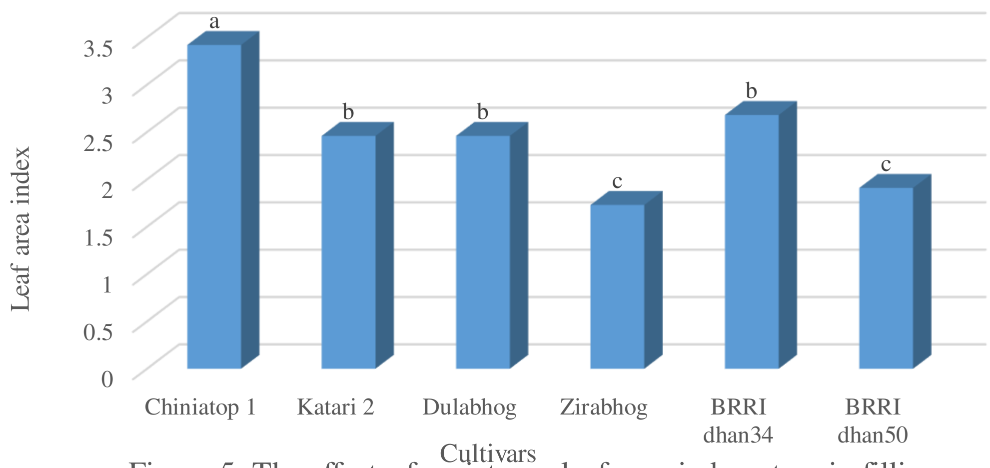

Figure 5: The effect of variety on leaf area index at grain filling stage

4.2.1.2 Effect of organic and inorganic fertilizer

Significantly two different variations in leaf area index of rice were observed in case of two different fertilizer used (Figure 6). Between the two different fertilizer used, the maximum leaf area index (2.51) was observed from T_1 (organic fertilizer) which was significantly different from other. Whereas, minimum leaf area index (2.36) was recorded from T_2 (inorganic fertilizer). It might be due to the fact that organic matter effect on the development of rice plant. Similar results were also reported by Sarkar *et al*. (2014).

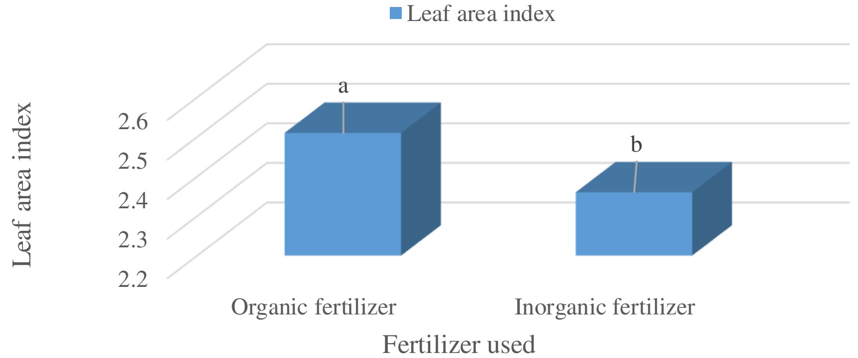

Figure 6: The effect of organic and inorganic fertilizer on leaf area index at grain filling stage

4.2.1.3 Interaction effect of organic, inorganic fertilizer and variety

significant differences were observed due to the interaction effect of variety and fertilizer used on leaf area index of aromatic rice (Table 7). The maximum leaf area index (3.44) was recorded from the V_1T_1 (Chiniatop 1+Organic fertilizer) which was statistically similar to V_5T_1 (3.40) and followed by V_1T_2 (2.76), V_3T_1 (2.61), V_5T_2 (5.60), V_3T_2 (2.52) and V_2T_1 (2.39). The minimum leaf area index (1.58) was obtained from the V_4T_2 (Zirabhog+Inorganic fertilizer), which was statistically similar to V_4T_1 (1.79), V_6T_2 (1.88), V_2T_2 (2.03) and V_6T_1 (2.21).

Table 7: Interaction effect of organic, inorganic fertilizer and variety on leaf area index at grain filling stage

Fertilizers	Varieties	Leaf area index
Organic fertilizer (T_1)	V_1	3.44 a
	V_2	2.39 bcd
	V_3	2.61 bc
	V_4	1.79 ef
	V_5	3.40 a
	V_6	2.21 cde
Inorganic fertilizer (T_2)	V_1	2.76 b
	V_2	2.03 de
	V_3	2.52 bc
	V_4	1.58 f
	V_5	2.60 bc
	V_6	1.88 ef
CV (%)		9.75
LSD (0.05)		0.39

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, V_1= Chiniatop 1; V_2= Katari2; V_3= Dulabhog; V_4= Zirabhog; V_5= BRRI dhan34 and V_6= BRRI dhan50

4.2.2 SPAD reading at grain filling stage

4.2.2.1 Effect of variety

Statistically significant variation was recorded among the aromatic rice varieties for SPAD reading at grain filling stage (Figure 7). Data revealed that, the maximum SPAD reading (47.52) was observed from Chiniatop 1, which was statistically different from other variety and followed by BRRI dhan34 (43.1), Dulabhog(29.92) and Katari 2 (29.92).Whereas, the minimum SPAD reading (28.78) was recorded from Zirabhog, which was significantly different from others and followed by BRRI dhan50 (32.47). This confirms the report of Islam *et al.* (2013) that SPAD reading of rice leaf differed from variety to variety. SPAD reading was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

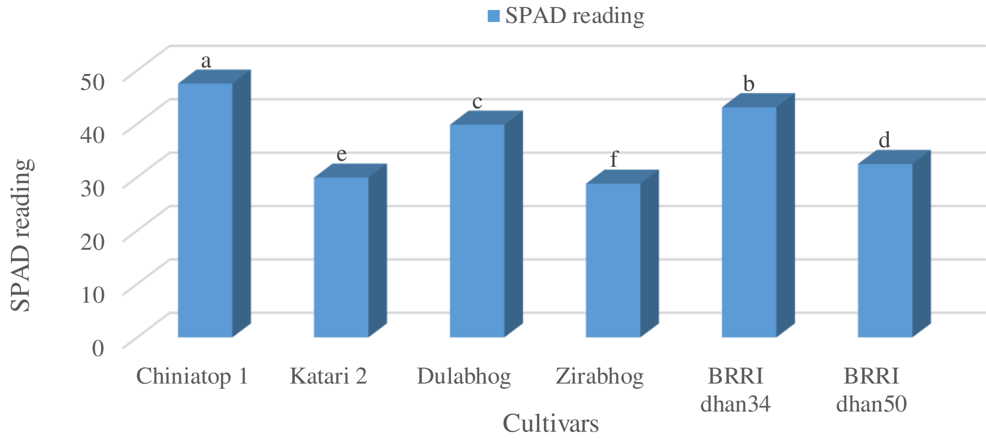

Figure 7: The effect of variety on SPAD reading at grain filling stage

4.2.2.2 Effect of organic and inorganic fertilizer

Significantly two different variations in SPAD reading of rice were observed in case of two fertilizer used at grain filling stage (Figure 8). Between the two different fertilizer used, the maximum SPAD reading (39.27) was observed from T_1 (organic fertilizer) which was significantly different from other. Whereas, minimum SPAD reading (34.6) was recorded from T_2 (inorganic fertilizer). It might be due to the fact that organic matter effect on the development of rice plant. Similar results were also reported by Sarkar *et al*. (2014).

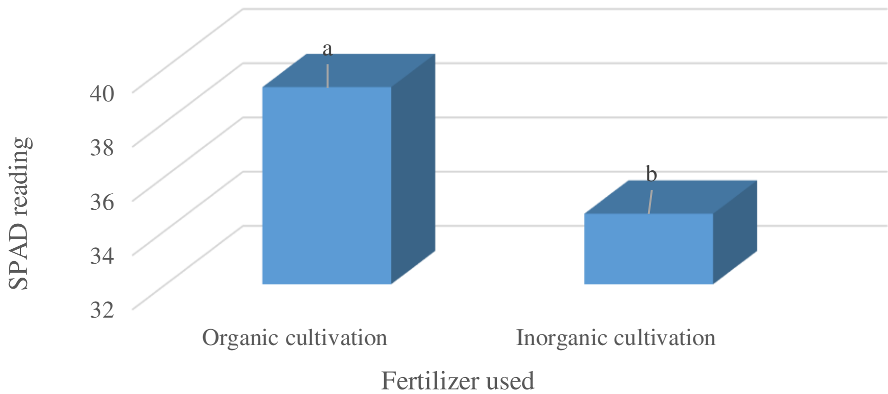

Figure 8: The effect of organic and inorganic fertilizer on SPAD reading at grain filling stage

4.2.2.3 Interaction effect of organic, inorganic fertilizer and variety

Different varieties and fertilizer applying methods expressed significant differences due to their interaction effect on SPAD reading of aromatic rice at grain filling stage (Table 8). The maximum SPAD reading (48.53) was recorded from the V_1T_1 (Chiniatop 1+Organic fertilizer) which was statistically different from others and followed by V_5T_1 (46.50), V_1T_2 (44.60), V_3T_1 (41.60), V_5T_2 (41.33), V_3T_2 (38.30) and V_2T_1 (36.53). The minimum SPAD reading (24.37) was obtained from the V_4T_2 (Zirabhog+Inorganic fertilizer), which was statistically different from others and followed by V_4T_1 (26.40), V_6T_2 (28.40), V_2T_2 (33.20) and V_6T_1 (33.43).

Table 8: Interaction effect of organic, inorganic fertilizer and variety on SPAD reading at grain filling stage

Fertilizers	Varieties	SPAD reading
Organic fertilizer (T_1)	V_1	48.53 a
	V_2	36.53 f
	V_3	41.60 d
	V_4	26.40 i
	V_5	46.50 b
	V_6	33.43 g
Inorganic fertilizer (T_2)	V_1	44.60 c
	V_2	33.20 g
	V_3	38.30 e
	V_4	24.37 j
	V_5	41.33 d
	V_6	28.40 h
CV (%)		0.68
LSD (0.05)		0.42

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, V_1= Chiniatop 1; V_2= Katari2; V_3= Dulabhog; V_4= Zirabhog; V_5= BRRI dhan34 and V_6= BRRI dhan50

4.2.3 Stomatal conductance (mmol$CO_2m^{-2}s^{-1}$) at grain filling stage

4.2.3.1 Effect of variety

Statistically significant variation was recorded among the aromatic rice varieties for stomatal conductance (mmol$CO_2m^{-2}s^{-1}$) at grain filling stage (Figure 9). Data revealed that, the maximum stomatal conductance (0.59 mmol CO_2 m^{-2} s^{-1}) was observed from Chiniatop 1, which was statistically different from other variety and followed by BRRI dhan34 (0.54 mmol CO_2 m^{-2} s^{-1}), Dulabhog (0.51 mmol CO_2 m^{-2} s^{-1}) and Katari2 (0.47 mmol CO_2 m^{-2} s^{-1}).Whereas, the minimum stomatal conductance (0.44

mmol CO_2 m^{-2} s^{-1}) was recorded from Zirabhog, which was significantly different from others and followed by BRRI dhan50 (0.46 mmol CO_2 m^{-2} s^{-1}). This confirms the report of Islam *et al.* (2013) that stomatal conductance of rice leaf differed from variety to variety. Stomatal conductance was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

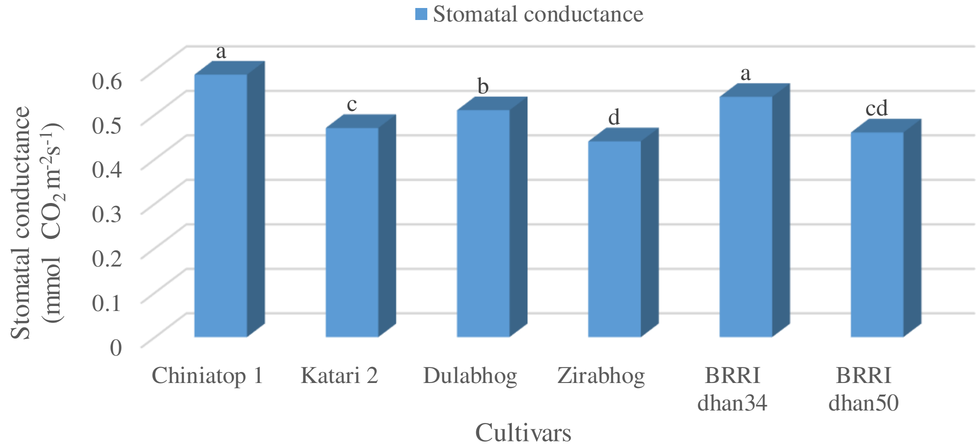

Figure 9: The effect of variety on stomatal conductance (mmol CO_2 m^{-2} s^{-1}) at grain filling stage

4.2.3.2 Effect of organic and inorganic fertilizer

Significantly two different variations in stomatal conductance of rice were observed in case of different fertilizer used at grain filling stage (Figure 10). Between the two fertilizer applying method, the maximum stomatal conductance (0.48 mmol CO_2 m^{-2} s^{-1}) was observed from T_1 (organic fertilizer) which was significantly different from other. Whereas, minimum stomatal conductance (0.46 mmol CO_2 m^{-2} s^{-1}) was recorded from T_2 (inorganic fertilizer). It might be due to the fact that organic matter effect on the development of rice plant. Similar results were also reported by Sarkar *et al*. (2014).

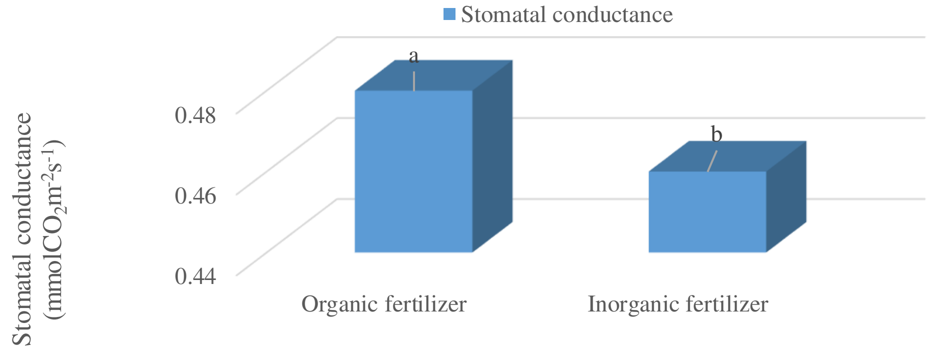

Figure 10: The effect of organic and inorganic fertilizer on stomatal conductance (mmol $CO_2m^{-2}s^{-1}$) at grain filling stage

4.2.3.3 Interaction effect of organic, inorganic fertilizer and variety

Different varieties and fertilizer applying method expressed significant differences due to their interaction effect on stomatal conductance of aromatic rice at grain filling stage (Table 9). The maximum stomatal conductance (0.53 mmol CO_2 m^{-2} s^{-1}) was recorded from the V_1T_1 (Chiniatop 1+Organic fertilizer) which was statistically different from others and followed by V_5T_1 (0.51 mmol CO_2 m^{-2} s^{-1}), V_1T_2 (0.49 mmol CO_2 m^{-2} s^{-1}), V_3T_1 (0.48 mmol CO_2 m^{-2} s^{-1}), V_5T_2 (0.46 mmol CO_2 m^{-2} s^{-1}), V_3T_2 (0.45 mmol CO_2 m^{-2} s^{-1}) and V_2T_1 (0.44 mmol CO_2 m^{-2} s^{-1}). The minimum stomatal conductance (0.41 mmol CO_2 m^{-2} s^{-1}) was obtained from the V_4T_2 (Zirabhog+Inorganic fertilizer), which was statistically different from others and followed by V_4T_1 (0.42 mmol CO_2 m^{-2} s^{-1}), V_6T_2 (0.42 mmol CO_2 m^{-2} s^{-1}), V_2T_2 (0.43 mmol CO_2 m^{-2} s^{-1}) and V_6T_1 (0.43 mmol CO_2 m^{-2} s^{-1}). The higher stomatal conductance in Chiniatop 1 under organic fertilizer used higher might be due to higher SPAD value in this variety.

Table 9: Interaction effect of organic, inorganic fertilizer and variety on stomatal conductance (mmol$CO_2m^{-2}s^{-1}$) at grain filling stage

Fertilizers	Varieties	Stomatal conductance (mmol CO_2 m^{-2} s^{-1})
Organic fertilizer (T_1)	V_1	0.53 a
	V_2	0.44 bcd
	V_3	0.48 ab
	V_4	0.42 cde
	V_5	0.51 a
	V_6	0.43 bcd
Inorganic fertilizer (T_2)	V_1	0.49 ab
	V_2	0.43 bcd
	V_3	0.45 bc
	V_4	0.41 de
	V_5	0.46 bc
	V_6	0.42 cde
CV (%)		1.17
LSD (0.05)		0.05

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, V_1= Chiniatop 1; V_2= Katari2; V_3= Dulabhog; V_4= Zirabhog; V_5= BRRI dhan34 and V_6= BRRI dhan50

4.2.4 Total dry matter distribution at harvesting stage

4.2.4.1 Effect of variety

Statistically significant variation was recorded among the aromatic rice varieties for total dry mater distribution (g) at harvesting stage (Table 10). Data revealed that, the maximum total dry mater (g) (19.52 g) was observed from Chiniatop 1, which was statistically different from other variety and followed by BRRI dhan34 (16.48 g), Dulabhog (15.37 g) and Katari2 (12.45 g).Whereas, the minimum total dry mater (g) (10.45 g) was recorded from Zirabhog, which was significantly similar to BRRI dhan50 (10.98 g) (Table 10).

In case of total grain dry weight (g), the maximum weight (15.33 g) was observed from Chiniatop 1, which was statistically different from other varieties and followed by BRRI dhan34 (12.61 g), Dulabhog (11.91 g) and Katari2 (9.28 g).Whereas, the minimum weight (8.04 g) was recorded from Zirabhog, which was significantly similar to BRRI dhan50 (8.35 g) (Table 10).

In case of dry straw weight (g), the maximum weight (4.19 g) was observed from Chiniatop 1, which was statistically similar to BRRI dhan34 (3.87 g) and followed by Dulabhog (3.46 g) and Katari2 (3.17 g).Whereas, the minimum weight (2.41 g) was recorded from Zirabhog, which was significantly similar to BRRI dhan50 (2.63 g) (Table 10).

Table 10: The effect of variety on total dry matter distribution (g) at harvest

Varieties	Total dry matter distribution		
	Total dry matter (g)	Total grain dry weight (g)	Total dry straw weight (g)
Chiniatop 1	19.52 a	15.33a	4.19 a
Katari 2	12.45 d	9.28 d	3.17 b
Dulabhog	15.37 c	11.91 c	3.46 b
Zirabhog	10.45 e	8.04 e	2.41 c
BRRI dhan 34	16.48 b	12.61 b	3.87 ab
BRRI dhan 50	10.98 e	8.35 e	2.63 c
CV (%)	1.79	1.13	0.46
$LSD_{(0.05)}$	0.42	0.21	0.28

Values followed by same letters did not differ significantly at 5% level of probability

4.2.4.2 Effect of organic and inorganic fertilizer

Significantly two different variations in total dry mater (g) of aromatic rice was observed in case of two different fertilizer applying methods at harvesting stage (Table 11). Between the two different fertilizer used, the maximum total dry mater (16.58 g) was observed from T_1 (organic fertilizer) which was significantly different from other. Whereas, minimum total dry mater (11.84 g) was recorded from T_2 (inorganic fertilizer) (Table 11).

In case of total grain dry weight (g), between the two fertilizer applying methods, the maximum weight (13.22 g) was observed from T_1 (organic fertilizer) which was significantly different from other. Whereas, minimum weight (8.97 g) was recorded from T_2 (inorganic fertilizer) (Table 11).

In case of dry straw weight (g), between the two different fertilizer applying methods, the maximum weight (3.36 g) was observed from T_1 (organic fertilizer) which was significantly different from other. Whereas, minimum weight (2.87 g) was recorded from T_2 (inorganic fertilizer) (Table 11).

Table 11: The effect of organic and inorganic fertilizer on total dry matter distribution (g) at harvesting stage

Fertilizers	Total dry matter distribution		
	Total dry matter (g)	Total grain dry weight (g)	Total dry straw weight (g)
Organic fertilizer	16.58 a	13.22 a	3.36 a
Inorganic fertilizer	11.84 b	8.97 b	2.87 b
CV (%)	1.79	1.13	1.41
$LSD_{(0.05)}$	0.11	0.23	0.18

Values followed by same letters did not differ significantly at 5% level of probability

4.2.4.3 Interaction effect of organic, inorganic fertilizer and variety

Different varieties and fertilizer applying methods expressed significant differences due to their interaction effect on total dry mater (g) of rice (Table 12). The maximum total dry mater (22.37 g) was recorded from the V_1T_1 (Chiniatop 1+Organic fertilizer) which was statistically different from others and followed by V_5T_1 (19.57 g), V_1T_2 (18.40), V_3T_1(16.67), V_5T_2 (14.37), V_3T_2 (13.40) and V_2T_1 (12.53 g). The minimum total dry mater (8.67 g) was obtained from the V_4T_2 (Zirabhog+Inorganic fertilizer), which was statistically different from others and followed by V_4T_1 (9.43 g), V_6T_2 (10.53), V_2T_2 (12.23) and V_6T_1 (12.33 g) (Table 12).

In case of total grain dry weight (g), among the interaction treatments, the maximum weight (17.24 g) was recorded from the V_1T_1 (Chiniatop 1+Organic fertilizer) which was statistically different from others and followed by V_5T_1 (14.79 g), V_1T_2 (13.87), V_3T_1 (12.54), V_5T_2 (10.51), V_3T_2 (9.77) and V_2T_1 (9.26 g). The minimum weight (6.34 g) was obtained from the V_4T_2 (Zirabhog+Inorganic fertilizer), which was statistically similar to V_4T_1 (6.97 g), V_6T_2 (7.81), V_6T_1 (9.14) and V_2T_2 (9.20 g) (Table 12).

In case of dry straw weight (g), among the interaction treatments, the maximum weight (5.13 g) was recorded from the V_1T_1 (Chiniatop 1+Organic fertilizer) which was statistically different from others and followed by V_5T_1 (4.78 g), V_1T_2 (4.53), V_3T_1 (4.13), V_5T_2 (3.86), V_3T_2 (3.63) and V_2T_1 (3.27 g). The minimum weight (2.33 g) was obtained from the V_4T_2 (Zirabhog+Inorganic fertilizer), which was statistically similar to V_4T_1 (2.46 g), V_6T_2 (2.72), V_2T_2 (3.03) and V_6T_1 (3.19 g) (Table 12). Higher SPAD reading and higher stomatal conductance might be contributed to higher dry matter.

Table 12: Interaction effect of organic, inorganic fertilizer and variety on total dry matter distribution (g) at harvesting stage

Fertilizers	Varieties	Total dry matter distribution		
		Total dry matter (g)	Total grain dry weight (g)	Total dry straw weight (g)
Organic fertilizer (T_1)	V_1	22.37 a	17.24 a (77.07%)	5.13 a (22.93%)
	V_2	12.53 g	9.26 f (73.90%)	3.27 c (26.10%)
	V_3	16.67 d	12.54 d (75.23%)	4.13 bc (24.77%)
	V_4	9.43 i	6.97 h (73.91%)	2.46 d (26.09%)
	V_5	19.57 b	14.79 b (75.57%)	4.78 b (24.43%)
	V_6	12.33 g	9.14 f (74.13%)	3.19 c (25.87%)
Inorganic fertilizer (T_2)	V_1	18.40 c	13.87 c (75.38%)	4.53 b(24.62 %)
	V_2	12.23 g	9.20 f (75.23%)	3.03 cd (24.77%)
	V_3	13.40 f	9.77 f (72.91%)	3.63 c (27.09%)
	V_4	8.67 j	6.34 h (73.13%)	2.33 d (26.87%)
	V_5	14.37 e	10.51e (73.14%)	3.86 c (26.86%)
	V_6	10.53 h	7.81g (74.17%)	2.72 d (25.83%)
CV (%)		1.79	1.13	0.46
LSD (0.05)		0.42	0.21	0.28

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, V_1= Chiniatop 1; V_2= Katari2; V_3= Dulabhog; V_4= Zirabhog; V_5= BRRI dhan34 and V_6= BRRI dhan50Values inside the parenthesis indicate the value relative to total dry matter

4.3. Yield contributing parameters

4.3.1 Effect of variety

4.3.1.1 Total spikelet panicle^{-1}

Statistically significant variation was recorded among the aromatic rice varieties for number of total spikelet panicle^{-1}at harvesting stage (Table 13). Data revealed that, the maximum number of total spikelet panicle^{-1} (209.5) was observed from Chiniatop 1, which was statistically different from other varieties and followed by BRRI dhan34 (188.1), Dulabhog (159.9) and Katari2 (132.4).Whereas, the minimum number of total spikelet panicle^{-1} (116.6) was recorded from Zirabhog, which was significantly different from others and followed by BRRI dhan50 (117.9). This confirms the report of Islam *et al.* (2013) that the total spikelet panicle^{-1} differed from variety to variety. Total spikelet panicle^{-1} was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

4.3.1.2 Filled spikelet panicle^{-1}

Statistically significant variation was recorded among the aromatic rice varieties for number of filled spikelet panicle^{-1}at harvesting stage (Table 13). Data revealed that, the maximum number of filled spikeletpanicle^{-1} (189.0) was observed from Chiniatop 1, which was statistically different from other variety and followed by BRRI dhan34 (165.55), Dulabhog (132.90) and Katari2 (97.73).Whereas, the minimum number of filled spikelet panicle^{-1} (76.50) was recorded from Zirabhog, which was significantly different from others and followed by BRRI dhan50 (77.48). This confirms the report of Islam *et al.* (2013) that filled spikelet panicle^{-1} differed from variety to variety. Filled spikelet panicle^{-1} was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

4.3.1.3 Unfilled spikelet panicle^{-1}

Statistically significant variation was recorded among the aromatic rice varieties for number of unfilled spikelet panicle^{-1}at harvesting stage (Table 13). Data revealed that, the maximum number of unfilled spikelet panicle^{-1} (40.10) was observed from Zirabhog, which was significantly different from others and followed by BRRI dhan50 (39.42).Whereas, the minimum number of unfilled spikelet panicle^{-1} (20.50) was recorded from Chiniatop 1, which was statistically different from other variety and followed by BRRI dhan34 (22.55), Dulabhog (27.00) and Katari2 (34.67).

4.3.1.4 Grain sterility (%)

Statistically significant variation was recorded among the aromatic rice varieties for percent grain sterility at harvesting stage (Table 13). Data revealed that, the maximum percent grain sterility (34.39%) was observed from Zirabhog, which was significantly different from others and followed by BRRI dhan50 (33.44%). Whereas, the minimum percent grain sterility (9.79%) was recorded from Chiniatop 1, which was statistically different from other variety and followed by BRRI dhan34 (11.99%), Dulabhog (16.89%) and Katari2 (26.19%).

Table 13: The effect of variety on yield contributing characters at harvest

Varieties	Total spikelet panicle^{-1}	Filled spikelet panicle^{-1}	Unfilled spikelet panicle^{-1}	Grain sterility (%)
Chiniatop 1	209.5 a	189.00 a	20.50 f	9.79 f
Katari 2	132.4 d	97.73 d	34.67 c	26.19 c
Dulabhog	159.9 c	132.90 c	27.00 d	16.89 d
Zirabhog	116.6 f	76.50 f	40.10 a	34.39 a
BRRI dhan34	188.1 b	165.55 b	22.55 e	11.99 e
BRRI dhan50	117.9 e	77.48 e	39.42 b	33.44 b
CV (%)	0.14	0.18	0.76	0.83
$LSD_{(0.05)}$	0.15	0.42	0.40	0.31

Values followed by same letter(s) did not differ significantly at 5% level of probability

4.3.2 Effect of organic and inorganic fertilizers

4.3.2.1 Total spikelet panicle^{-1}

Significantly two variations in total number of spikelet panicle^{-1} of rice were observed in case of two different fertilizer used at harvesting stage (Table 14). Between the two fertilizer applying methods, the maximum total number of spikelet panicle^{-1} (169.9) was observed from T_1 (organic fertilizer) which was significantly different from other. Whereas, minimum total number of spikelet panicle^{-1} (138.2) was recorded from T_2 (inorganic fertilizer). It might be due to the fact that organic matter effect on the development of rice plant. Similar results were also reported by Sarkar *et al.* (2014).

4.3.2.2 Filled spikelet panicle^{-1}

Significantly two variations in number of filled spikelet panicle^{-1} of aromatic rice were observed in case of two different fertilizer used at harvesting (Table 14). Between the two different fertilizer applying methods, the maximum number of filled spikelet panicle^{-1} (142.57) was observed from T_1 (organic fertilizer) which was significantly different from other. Whereas, minimum number of filled spikelet panicle^{-1}at harvesting stage (104.22) was recorded from T_2 (inorganic fertilizer). It might be due to the fact that organic matter effect on the development of rice plant. Similar results were also reported by Sarkar *et al.* (2014).

4.3.2.3 Unfilled spikelet panicle^{-1}

Significantly two different variations in number of unfilled spikelet panicle^{-1} of aromatic rice were observed in case of two different fertilizer used at harvesting stage

(Table 14). Between the two different fertilizer applying methods, the maximum unfilled spikelet panicle^{-1} (33.98) was observed fromT_2 (inorganic fertilizer) which was significantly different from other. Whereas, minimum number of unfilled spikelet panicle^{-1} (27.43) was recorded fromT_1 (organic fertilizer). It might be due to the fact that organic matter effect on the development of rice plant. Similar results were also reported by Sarkar *et al.* (2014).

4.3.2.4 Grain sterility (%)

Significantly two different variations in percent grain sterility of rice were observed in case of two different fertilizer applying at harvesting stage (Table 14). Between the two different fertilizer applying methods, the maximum percent grain sterility (24.59%) was observed fromT_2 (inorganic fertilizer) which was significantly different from other treatment. Whereas, minimum percent grain sterility (16.15%) was recorded from T_1 (organic fertilizer). It might be due to the fact that organic matter effect on the development of rice plant. Similar results were also reported by Sarkar *et al.* (2014).

Table 14: The effect of organic and inorganic fertilizer on yield contributing characters at harvest

Fertilizers	Total spikelet panicle^{-1}	Filled spikelet panicle^{-1}	Unfilled spikelet panicle^{-1}	Grain sterility (%)
Organic fertilizer	169.9 a	142.57 a	27.43 b	16.15 b
Inorganic fertilizer	138.2 b	104.22 b	33.98 a	24.59 a
CV (%)	0.14	0.18	0.76	0.83
$LSD_{(0.05)}$	0.15	0.42	0.40	0.31

Values followed by same letter(s) did not differ significantly at 5% level of probability

4.3.3 Interaction effect of organic, inorganic fertilizer and variety

4.3.3.1 Total spikelet panicle^{-1}

Different varieties and fertilizer used were expressed significant differences due to their interaction effect on total number of spikelet panicle^{-1}at harvesting stage (Table 15). The maximum number of total spikelet panicle^{-1} (231.6) was recorded from the V_1T_1 (Chiniatop 1+Organic fertilizer) which was statistically different from others and followed by V_5T_1 (212.6), V_1T_2 (187.4), V_3T_1 (183.3), V_5T_2 (163.6), V_3T_2 (143.3) and V_2T_1 (136.5). The minimum total number of spikelet panicle^{-1} (109.6) was obtained from the V_4T_2 (Zirabhog+Inorganic fertilizer), which was statistically different from others and followed by V_4T_1 (110.4), V_6T_2 (121.5), V_2T_2 (123.5) and V_6T_1 (125.4) (Table 15).

4.3.3.2 Filled spikelet panicle^{-1}

Different varieties and fertilizer used were expressed significant differences due to their interaction effect on filled spikelet panicle^{-1} of rice at harvesting stage (Table 15). The maximum filled spikelet panicle^{-1} (213.10) was recorded from the V_1T_1 (Chiniatop 1+Organic fertilizer) which was statistically different from others and followed by V_5T_1 (193.13), V_1T_2 (164.90), V_3T_1 (159.63), V_5T_2 (137.97), V_3T_2 (113.60) and V_2T_1 (106.17). The minimum filled spikelet panicle^{-1} (66.17) was obtained from the V_4T_2 (Zirabhog+Inorganic fertilizer), which was statistically different from others and followed by V_4T_1 (73.93), V_6T_1 (83.03),V_2T_2 (83.87) and V_6T_2 (84.73) (Table 15).

4.3.3.3 Unfilled spikelet panicle^{-1}

Different varieties and fertilizer used were expressed significant differences due to their interaction effect on number of unfilled spikelet panicle^{-1}at harvesting stage (Table 15). The maximum number of unfilled spikelet panicle^{-1} (43.43) was recorded from the V_4T_2 (Zirabhog+Inorganic fertilizer), which was statistically different from others and followed by V_4T_1 (36.47), V_6T_2 (36.77), V_2T_2 (39.63) and V_6T_1 (42.37).The minimum number of unfilled spikelet panicle^{-1}(18.50) was obtained from the V_1T_1 (Chiniatop 1+Organic fertilizer) which was statistically different from others and followed by V_5T_1 (19.47), V_1T_2 (22.50), V_3T_1 (23.67), V_5T_2 (25.63), V_3T_2 (29.70) and V_2T_1 (30.33).

4.3.3.4 Grain sterility (%)

Different varieties and fertilizer used were expressed significant differences due to their interaction effect on percent grain sterility at harvesting stage (Figure 11). The maximum percent grain sterility (39.63%) was recorded from the V_4T_2 (Zirabhog+Inorganic fertilizer), which was statistically different and followed by others.The minimum percent grain sterility (7.99%) was obtained from the

V_1T_1(Chiniatop 1+Organic fertilizer) which was statistically different and followed by others.

Table 15: Interaction effect of organic, inorganic fertilizer and variety on yield contributing characters at harvest

Fertilizers	Varieties	Total spikelet panicle^{-1}	Filled spikelet panicle^{-1}	Unfilled spikelet panicle^{-1}
Organic fertilizer (T_1)	V_1	231.6 a	213.10 a	18.50 k
	V_2	136.5 g	106.17 g	30.33 e
	V_3	183.3 d	159.63 d	23.67 h
	V_4	110.4 k	73.93 j	36.47 d
	V_5	212.6 b	193.13 b	19.47 j
	V_6	125.4 h	83.03 i	42.37 b
Inorganic fertilizer (T_2)	V_1	187.4 c	164.90 c	22.50 i
	V_2	123.5 i	83.87 i	39.63 c
	V_3	143.3 f	113.60 f	29.70 f
	V_4	109.6 l	66.17 k	43.43 a
	V_5	163.6 e	137.97 e	25.63 g
	V_6	121.5 j	84.73 h	36.77 d
CV (%)		0.14	0.18	0.76
LSD (0.05)		0.15	0.42	0.40

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, V_1= Chiniatop 1; V_2= Katari2; V_3= Dulabhog; V_4= Zirabhog; V_5= BRRI dhan34 and V_6= BRRI dhan50

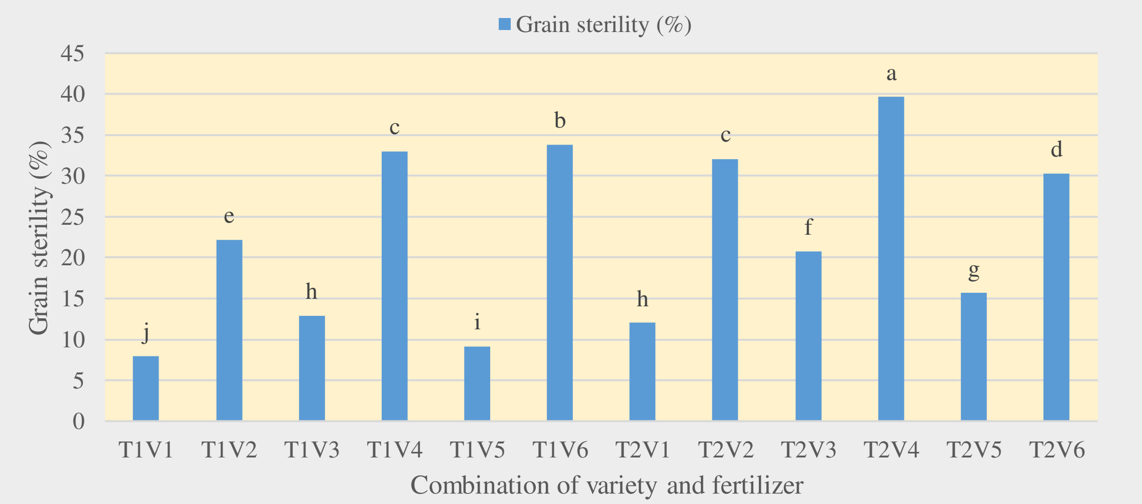

Figure 11: Interaction effect of variety and fertilizer used on grain sterility (%) at harvesting stage

4.4. Yield parameters

4.4.1 Effect of variety

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

Statistically significant variation was recorded among the aromatic rice varieties for grain yield (t ha^{-1}) at harvesting stage (Table 16). Data revealed that, the maximum yield (3.92 t ha^{-1}) was observed from Chiniatop 1, which was statistically different from other variety and followed by BRRI dhan34 (3.37 t ha^{-1}), Dulabhog (3.35 t ha^{-1}) and Katari2 (3.25 t ha^{-1}).Whereas, the minimum yield (2.18 t ha^{-1}) was recorded from Zirabhog, which was significantly different from others and followed by BRRI dhan50 (2.55 t ha^{-1}). This confirms the report of Islam *et al.* (2013) that grain yield of aromatic rice differed from variety to variety. A significant increase in effective tillers, leaf area, SPAD value, stomatal conductance, filled spikelet panicle^{-1} and decrease in unfilled spikelet panicle^{-1} were the main cause of better yield in Chiniatop 1 under organic fertilizer.

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

Statistically significant variation was recorded among the aromatic rice varieties for yield of straw (t ha^{-1}) at harvesting stage (Table 16). Data revealed that, the maximum yield (7.93 t ha^{-1}) was observed from Chiniatop 1, which was statistically different from other variety and followed by BRRI dhan34 (7.57 t ha^{-1}), Dulabhog (6.05 t ha^{-1}) and Katari2 (6.02 t ha^{-1}).Whereas, the minimum yield (3.85 t ha^{-1}) was recorded from Zirabhog, which was significantly different from others and followed by BRRI dhan50 (4.47 t ha^{-1}). This confirms the report of Islam *et al.* (2013) that straw yield of rice differed from variety to variety.

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

Statistically significant variation was recorded among the aromatic rice varieties for biological yield (t ha^{-1}) at harvesting stage (Table 16). Data revealed that, the maximum yield (11.85 t ha^{-1}) was observed from Chiniatop 1, which was statistically different from other variety and followed by BRRI dhan34 (10.94 t ha^{-1}), Dulabhog (9.40 t ha^{-1}) and Katari2 (9.27 t ha^{-1}).Whereas, the minimum yield (6.03 t ha^{-1}) was recorded from Zirabhog, which was significantly different from others and followed by BRRI dhan50 (7.02 t ha^{-1}). This confirms the report of Islam *et al.* (2013) that biological yield of rice differed from variety to variety.

4.4.1.4 Harvest index (%)

Statistically significant variation was recorded among the aromatic rice varieties for harvest index (%) at harvesting stage (Table 16). Data revealed that, the maximum harvest index (36.32%) was observed from Chiniatop 1, which was statistically similar to BRRI dhan34 (35.91%), Dulabhog (35.69%) and Katari2 (35.15%).Whereas, the minimum harvest index (30.77%) was recorded from Zirabhog, which was significantly similar to BRRI dhan50 (32.95%). This confirms the report of Islam *et al.* (2013) that harvest index of rice differed from variety to variety.

Table 16: The effect of variety on yield at harvesting stage

Varieties	**Grain yield (t ha^{-1})**	**Straw yield (t ha^{-1})**	**Biological yield (t ha^{-1})**	**Harvest index (%)**
Chiniatop 1	3.92 a	7.93 a	11.85 a	36.32 a
Katari 2	3.25 b	6.02 b	9.27 c	35.15 a
Dulabhog	3.35 b	6.05 b	9.40 c	35.69 a
Zirabhog	2.18 c	3.85 d	6.03 e	30.77 b
BRRI dhan34	3.37 b	7.57 a	10.94 b	35.91 a
BRRI dhan50	2.55 c	4.47 c	7.02 d	32.95 ab
CV (%)	8.68	4.37	3.66	6.77
$LSD_{(0.05)}$	0.45	0.43	0.36	3.87

Values followed by same letter(s) did not differ significantly at 5% level of probability

4.4.2 Effect of organic and inorganic fertilizer

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

Significantly two different variations in yield of grain of aromatic rice were observed in case of two different fertilizer used at harvesting stage (Table 17). Between the two different fertilizer applying methods, the maximum yield (3.20 t ha^{-1}) was observed from T_1 (organic fertilizer) which was significantly different from other. Whereas, minimum yield (3.01 t ha^{-1}) was recorded from T_2 (inorganic fertilizer). It might be due to the fact that organic matter effect on the development of rice plant. Similar results were also reported by Sarkar *et al.* (2014). A significant increase in effective tillers, leaf area, SPAD value, stomatal conductance, filled spikelet panicle^{-1} and decrease in unfilled spikelet panicle^{-1} were the main cause of better yield in Chiniatop 1 under organic cultivation.

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

Significantly two different variations in yield of straw of rice were observed in case of two different fertilizer used at harvesting stage (Table 17). Between the two different treatments, the maximum yield (6.24 t ha^{-1}) was observed from T_1 (organic fertilizer) which was significantly different from other. Whereas, minimum yield (5.72 t ha^{-1}) was recorded from T_2 (inorganic fertilizer). It might be due to the fact that organic matter effect on the development of rice plant. Similar results were also reported by Sarkar *et al*. (2014).

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

Significantly two different variations in biological yield of aromatic rice were observed in case of two different fertilizer used at harvesting stage (Table 17). Between the two different fertilizer application, the maximum yield (9.44 t ha^{-1}) was observed from T_1 (organic fertilizer) which was significantly different from other treatment. Whereas, minimum yield (8.73 t ha^{-1}) was recorded from T_2 (inorganic fertilizer). It might be due to the fact that organic matter effect on the development of rice plant. Similar results were also reported by Sarkar *et al.* (2014).

4.4.2.4 Harvest index (%)

Significantly two different variations in harvest index of aromatic rice were observed in case of two different fertilizer used at harvesting stage (Table 17). Between the two different fertilization method, the maximum harvest index (34.81%) was observed from T_1 (organic fertilizer) which was significantly different from other treatment. Whereas, minimum harvest index (34.12%) was recorded from T_2 (inorganic fertilizer). It might be due to the fact that organic matter effect on the development of rice plant. Similar results were also reported by Sarkar *et al.* (2014).

Table 17: The effect of organic and inorganic fertilizer on yield at harvesting stage

Fertilizers	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Organic fertilizer	3.20 a	6.24 a	9.44 a	34.81 a
Inorganicfertilizer	3.01 a	5.72 b	8.73 b	34.12 a
CV (%)	8.68	4.37	3.66	2.73
$LSD_{(0.05)}$	0.37	0.47	0.31	2.73

Values followed by same letter(s) did not differ significantly at 5% level of probability

4.4.3 Interaction effect of organic, inorganic fertilizer and variety

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

Different varieties and fertilizer used were expressed significant differences due to their interaction effect on yield of grain of aromatic rice at harvesting stage (Table 18). The maximum yield (4.38 t ha^{-1}) was recorded from the V_1T_1 (Chiniatop 1+Organic fertilizer) which was statistically different from others and followed by V_5T_1 (3.47 t ha^{-1}), V_1T_2 (3.43 t ha^{-1}), V_3T_1 (3.40 t ha^{-1}), V_5T_2 (3.37 t ha^{-1}), V_3T_2 (3.33 t ha^{-1}) and V_2T_1 (3.27 t ha^{-1}). The minimum yield (1.97 t ha^{-1}) was obtained from the V_4T_2 (Zirabhog+Inorganic fertilizer), which was statistically similar to V_4T_1 (2.37 t ha^{-1}) and V_6T_2 (2.40 t ha^{-1}) and followed by V_2T_2 (2.73 t ha^{-1}) and V_6T_1 (3.13 t ha^{-1}). A significant increase in effective tillers, leaf area, SPAD value, stomatal conductance, filled spikelet panicle^{-1} and decrease in unfilled spikelet panicle^{-1} were the main cause of better yield in Chiniatop 1 under organic fertilizer.

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

Different varieties and fertilizer used were expressed significant differences due to their interaction effect on yield of straw of aromatic rice at harvesting stage (Table 18). The maximum yield (8.43 t ha^{-1}) was recorded from the V_1T_1 (Chiniatop+Organic fertilizer) which was statistically different from others and followed by V_5T_1 (7.60 t ha^{-1}), V_1T_2 (7.53 t ha^{-1}), V_3T_1 (7.43 t ha^{-1}), V_5T_2 (6.47 t ha^{-1}), V_3T_2 (6.40 t ha^{-1}) and V_2T_1 (5.70 t ha^{-1}). The minimum yield (3.73 t ha^{-1}) was obtained from the V_4T_2 (Zirabhog+Inorganic fertilizer), which was statistically similar to V_4T_1 (3.97 t ha^{-1}) and followed by V_6T_2 (4.33 t ha^{-1}), V_2T_2 (4.60 t ha^{-1}) and V_6T_1 (5.57 t ha^{-1}).

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

Different varieties and fertilizer used were expressed significant differences due to their interaction effect on biological yield of aromatic rice at harvesting stage (Table 18). The maximum yield (12.81 t ha^{-1}) was recorded from the V_1T_1 (Chiniatop 1+Organic fertilizer) which was statistically different from others and followed by V_5T_1 (11.07 t ha^{-1}), V_1T_2 (10.96 t ha^{-1}), V_3T_1 (10.83 t ha^{-1}), V_5T_2 (9.84 t ha^{-1}), V_3T_2 (9.73 t ha^{-1}) and V_2T_1 (8.97 t ha^{-1}). The minimum yield (5.70 t ha^{-1}) was obtained from the V_4T_2 (Zirabhog+Inorganic fertilizer), which was statistically different from others and followed by V_4T_1 (6.34 t ha^{-1}), V_6T_2 (6.73 t ha^{-1}), V_2T_2 (7.33 t ha^{-1}) and V_6T_1 (8.70 t ha^{-1}).

4.4.3.4 Harvest index (%)

Different varieties and fertilizer used were expressed significant differences due to their interaction effect on harvest index of aromatic rice at harvesting index (Figure 12). The maximum harvest index (38.67%) was recorded from the V_1T_1 (Chiniatop 1+Organic fertilizer) which was statistically similar to V_5T_1 (37.70%), V_1T_2 (37.59%) and V_3T_1 (36.05%) and followed by V_5T_2 (34.24%), V_3T_2 (34.15%) and V_2T_1 (34.11%). The minimum harvest index (30.66%) was obtained from the V_4T_2 (Zirabhog+Inorganic fertilizer), which was statistically similar to V_4T_1 (30.89%), V_6T_2 (31.75%), V_2T_2 (33.78%) and V_6T_1 (33.97%).

Table 18: Interaction effect of organic, inorganic fertilizer and variety on yield at harvesting stage

Fertilizers	Varieties	Yield of grain (t ha^{-1})	Yield of straw (t ha^{-1})	Biological yield (t ha $^{-1}$)
Organic fertilizer (T_1)	V_1	4.38 a (128%)	8.43 a (120%)	12.81 a
	V_2	3.27 b (120%)	5.70 d (124%)	8.97 e
	V_3	3.40 b (102%)	7.43 b (161%)	10.83 c
	V_4	2.37 de (120%)	3.97 fg (106%)	6.34 g
	V_5	3.47 b (103%)	7.60 b (117%)	11.07 b
	V_6	3.13 bc (42%)	5.57 d (129%)	8.70 e
Inorganic fertilizer (T_2)	V_1	3.43 b	7.53 b	10.96 c
	V_2	2.73 cd	4.60 e	7.33 f
	V_3	3.33 b	6.40 c	9.73 d
	V_4	1.97 e	3.73 g	5.70 h
	V_5	3.37 b	6.47 c	9.84 d
	V_6	2.40 de	4.33 ef	6.73 g
CV (%)		8.68	4.37	3.66
LSD (0.05)		0.37	0.47	0.31

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, V_1= Chiniatop1; V_2= Katari2; V_3= Dulabhog; V_4= Zirabhog; V_5= BRRI dhan34 and V_6= BRRI dhan50

Values inside the parenthesis indicate the value relative to inorganic cultivation

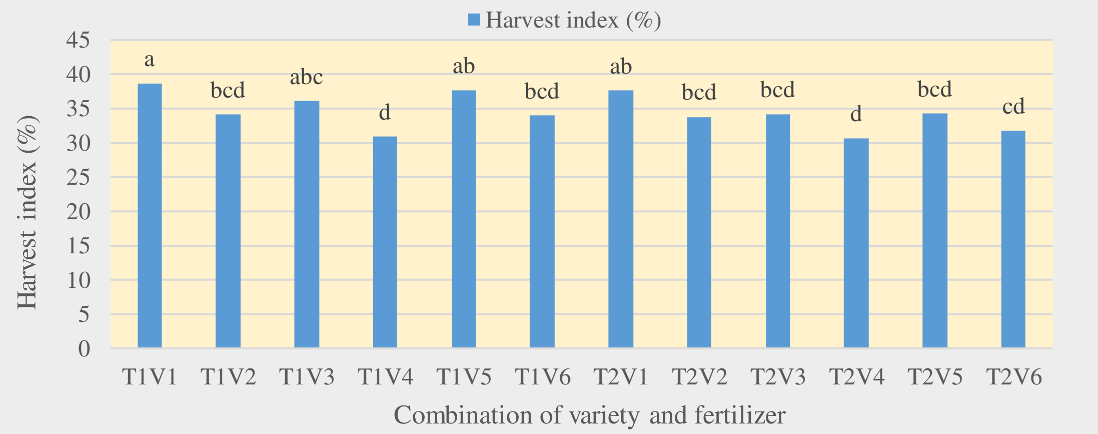

Figure 12: Interaction effect of variety and fertilizer used on harvest index (%) at harvesting stage

4.4.4. Grain size (mg)

4.4.4.1 Effect of variety

Statistically significant variation was recorded among the aromatic rice varieties for grain size (mg) at harvesting stage (Figure 13). Data revealed that, the maximum grain size (15.90 mg) was observed from Chiniatop 1, which was statistically different from other variety and followed by BRRI dhan34 (15.18 mg), Dulabhog (14.45 mg) and Katari2 (13.53 mg).Whereas, the minimum grain size (11.13 mg) was recorded from Zirabhog, which was significantly different from others and followed by BRRI dhan50 (11.83 mg). This confirms the report of Islam *et al.* (2013) that grain size of rice differed from variety to variety. Grain size was greatly influenced by different varieties possibly due to the reason that the height of the plant is a varietal trait which is primarily influenced by genetic makeup.

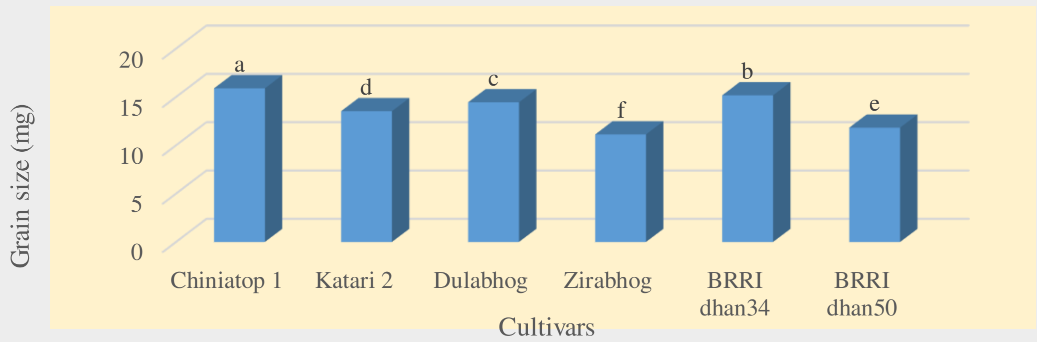

Figure 13: The effect of variety on grain size (mg) at harvesting stage

4.4.4.2 Effect of organic and inorganic fertilizer

Significantly two different variations in grain size (mg) of rice were observed in case of two different fertilizer used at harvesting stage (Figure 14). Between the two different fertilization methods, the maximum grain size (14.31 mg) was observed from T_1 (organic fertilizer) which was significantly different from other. Whereas, minimum grain size (13.04 mg) was recorded from T_2 (inorganic fertilizer). It might be due to the fact that organic matter effect on the development of rice plant. Similar results were also reported by Sarkar *et al.* (2014).

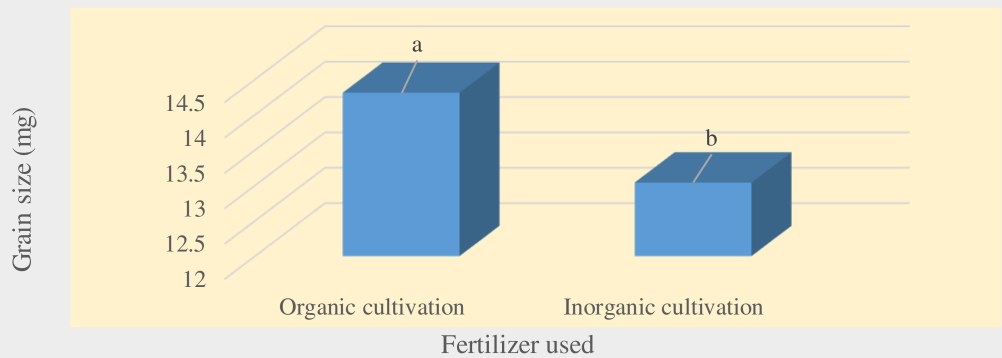

Figure 14: The effect of organic and inorganic fertilizer on grain size (mg) at harvesting stage

4.4.4.3 Interaction effect of organic, inorganic fertilizer and variety

Different varieties and fertilizer used were expressed significant differences due to their interaction effect on grain size (mg) of aromatic rice at harvesting stage (Table 19). The maximum grain size (16.33 mg) was recorded from the V_1T_1 (Chiniatop 1+Organic fertilizer) which was statistically different from others and followed by V_5T_1 (15.67 mg), V_1T_2 (15.47), V_3T_1 (15.33), V_5T_2 (14.70), V_3T_2 (14.47) and V_2T_1 (13.57) mg. The minimum grain size (10.50 mg) was obtained from the V_4T_2 (Zirabhog+Inorganic fertilizer), which was statistically different from others and followed by V_4T_1 (11.40 mg), V_6T_2 (11.77), V_2T_2 (12.27) and V_6T_1 (12.60) mg.

Table 19: Interaction effect of organic, inorganic fertilizer and variety on grain size (mg) at harvesting stage

Fertilizers	Varieties	Grain size (mg)
Organic fertilizer (T_1)	V_1	16.33 a
	V_2	13.57 d
	V_3	15.33 b
	V_4	11.40 f
	V_5	15.67 b
	V_6	12.60 e
Inorganic fertilizer (T_2)	V_1	15.47 b
	V_2	12.27 e
	V_3	14.47 c
	V_4	10.50 g
	V_5	14.70 c
	V_6	11.77 f
CV (%)		1.99
LSD (0.05)		0.45

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, V_1= Chiniatop 1; V_2= Katari2; V_3= Dulabhog; V_4= Zirabhog; V_5= BRRI dhan34 and V_6= BRRI dhan50

4.5. Grain quality characters

4.5.1. Effect of variety

4.5.1.1 Aroma scoring (AS)

Statistically significant variations were recorded among the aromatic rice varieties for aroma testing (Table 20). Data revealed that, the strong aroma was observed from Chiniatop 1, which was statistically different from other variety. Whereas, the moderate aroma was recorded from Katari2, Dulabhog and BRRI dhan34. And slight aroma was found from BRRI dhan50 and Zirabhog was found absence of aroma which was significantly different from other varieties.

4.5.1.2 Length-breadth ratio (L/B)

Statistically significant variations were recorded among the aromatic rice varieties for Length-breadth ratio (Table 20). Data revealed that, the maximum L/B ratio (4.30) was observed from Chiniatop 1, which was statistically different from other variety and followed by others. Whereas, the minimum L/B (1.88) was recorded from Zirabhog, which was significantly different from others.

4.5.1.3 Cooking duration (CD) (min)

Statistically significant variations were recorded among the aromatic rice varieties for aroma testing as cooking duration(Table 20). Data revealed that, the minimum cooking duration (13.18 min) was observed from Chiniatop 1, which was statistically different from other variety and followed by others. Whereas, the maximum cooking duration (115.30 min) was recorded from Zirabhog, which was significantly different from others.

4.5.1.4 Elongation ratio (ER)

Statistically significant variations were recorded among the aromatic rice varieties for aroma testing as elongation ratio (Table 20). Data revealed that, the maximum elongation ratio (1.48) was observed from Chiniatop 1, which was statistically different from other variety and followed by others. Whereas, the minimum elongation ratio (1.17) was recorded from Zirabhog, which was significantly different from others.

Table 20: The effect of variety on grain quality characters of aromatic rice

Varieties	AS	L/B ratio	CD(min)	ER
Chiniatop 1	4	4.30 a	13.18 c	1.48 a
Katari 2	3	2.22 b	13.25 c	1.35 ab
Dulabhog	3	2.30 b	13.32 c	1.37 ab
Zirabhog	1	1.88 c	15.30 a	1.17 c
BRRI dhan34	3	2.45 b	13.72 b	1.38 ab
BRRI dhan50	2	2.20 b	13.23 c	1.27 bc
CV (%)	13.19	6.00	0.83	6.65
$LSD_{(0.05)}$	0.42	0.26	0.19	0.15

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, 1= Absence of Aroma; 2= Slight Aroma; 3= Moderate Aroma and 4= strong Aroma; AS= Aroma scoring, L/B ratio= length-breadth ratio, CD= Cooking duration, ER= Elongation ratio

4.5.2 Effect of organic and inorganic fertilizer

4.5.2.1 Aroma Scoring (AS)

Significantly different variations in aroma characteristics of aromatic rice were observed in case of two different fertilizers used (Table 21). Between the two different fertilization methods, the strong aroma was observed from T_1 (organic fertilizer) which was significantly different from other. Whereas, the slight aroma was recorded from T_2 (inorganic fertilizer).

4.5.2.2 Length-breadth ratio (L/B)

Significantly two different variations in aroma characteristics of aromatic rice were observed in case of two different fertilizer used (Table 21). Between the two different fertilization methods, the maximum length-breadth ratio (2.59) was observed from T_1 (organic fertilizer) which was significantly different from other. Whereas, the minimum length-breadth ratio (2.53) was recorded from T_2 (inorganic fertilizer).

4.5.2.3 Cooking duration (CD) (min)

Significantly two different variations in aroma characteristics of aromatic rice were observed in case of two different fertilizer used (Table 21). Between the two different fertilization methods, the minimum cooking duration (13.48 min) was observed from T_1 (organic fertilizer) which was significantly different from other. Whereas, maximum cooking duration (13.85 min) was recorded from T_2 (inorganic fertilizer).

4.5.2.4 Elongation ratio (ER)

Significantly two different variations in aroma characteristics of aromatic rice were observed in case of two different fertilizer used (Table 21). The maximum ER (1.38) was observed from T_1 (organic fertilizer) which was significantly different from other. Whereas, the minimum ER (1.29) was recorded from T_2 (inorganic fertilizer).

Table 21: The effect of organic and inorganic fertilizer on grain quality characters of aromatic rice

Fertilizers	AS	L/B ratio	CD (min)	ER
Organic fertilizer	4	2.59 a	13.48 b	1.38 a
Inorganicfertilizer	2	2.53 a	13.85 a	1.29 a
CV (%)	13.19	6.00	0.83	6.65
$LSD_{(0.05)}$	0.19	0.40	0.21	0.25

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, 1= Absence of Aroma; 2= Slight Aroma; 3= Moderate Aroma and 4= strong Aroma; AS=Aroma scoring, L/B ratio= length-breadth ratio, CD= Cooking duration, ER= Elongation ratio

4.5.3. Interaction effect of organic, inorganic fertilizer and variety

4.5.3.1. Aroma Scoring (AS)

Different varieties and fertilizer used were expressed significant differences due to their interaction effect on aroma of aromatic rice (Table 22). The strong aroma was recorded from the V_1T_1 (Chiniatop 1+Organic fertilizer) and which was statistically similar to V_5T_1. Moderate aroma was found from V_1T_2 (Chiniatop 1+inorganic fertilizer) and followed by V_3T_1, V_5T_2,V_2T_1. The slight aroma was obtained from V_6T_1 (BRRI dhan50 + organic fertilizer), which was statistically similar to V_6T_2,V_2T_2 and V_3T_2. Absence of aroma was found from V_4T_1 (Zirabhog+organic fertilizer) and which was statistically similar to V_4T_2.

4.5.3.2. Length-breadth ratio (L/B)

Different varieties and fertilizer used were expressed significant differences due to their interaction effect on length-breadth ratio of aromatic rice (Table 22). The maximum length-breadth ratio (4.37) was recorded from the V_1T_1 (Chiniatop 1+Organic fertilizer) which was statistically similar to V_5T_1 (4.23) and followed by V_1T_2 (2.53), V_3T_1 (2.37), V_5T_2 (2.37), V_3T_2 (2.33) and V_2T_1 (2.27). The minimum length-breadth ratio (1.67) was obtained from the V_4T_2 (Zirabhog+Inorganic fertilizer), which was statistically different from others and followed by V_4T_1 (2.03), V_6T_2 (2.10), V_2T_2 (2.17) and V_6T_1 (2.27).

4.5.3.3. Cooking Duration (CD) (min)

Different varieties and fertilizer used were expressed significant differences due to their interaction effect on cooking time of aromatic rice (Table 22). The minimum cooking duration (13.03 min) was recorded from the V_1T_1 (Chiniatop 1+Organic fertilizer) which was statistically different from others. The maximum cooking duration (15.50 min) was obtained from the V_4T_2 (Zirabhog+Inorganic fertilizer), which was statistically different from others.

4.5.3.4. Elongation ratio (ER)

Different varieties and fertilizer used were expressed significant differences due to their interaction effect on ER ratio of aromatic rice (Table 22). The maximum ER ratio (1.53) was recorded from the V_1T_1 (Chiniatop 1+Organic fertilizer) which was statistically different from others. The minimum ER ratio (1.17) was obtained from the V_4T_2 (Zirabhog+Inorganic fertilizer), which was statistically different from others.

Table 22: Interaction effect of organic, inorganic fertilizer and variety on grain quality characters of aromatic rice

Fertilizers	Varieties	AS	L/B ratio	CD (min)	ER
Organic fertilizer (T_1)	V_1	4	4.37 a	13.03 f	1.53 a
	V_2	3	2.27 bcd	13.37 de	1.30 bcd
	V_3	3	2.37 bc	13.47 d	1.43 ab
	V_4	1	2.03 d	14.07 c	1.27 d
	V_5	4	4.23 a	15.10 b	1.53 a
	V_6	2	2.27 bcd	13.33 de	1.27 bcd
Inorganic fertilizer (T_2)	V_1	3	2.53 b	13.10 f	1.43 ab
	V_2	2	2.17 cd	13.17 ef	1.27 bcd
	V_3	2	2.33 bc	13.37 de	1.33 bcd
	V_4	1	1.67 e	15.50 a	1.17 d
	V_5	3	2.37 bc	13.37 de	1.37 bc
	V_6	2	2.10 cd	13.13 f	1.23 cd
CV (%)		13.19	6.00	0.83	6.65
LSD (0.05)		0.19	0.40	0.21	0.25

Values followed by same letter(s) did not differ significantly at 5% level of probability. Here, 1= Absence of Aroma; 2= Slight Aroma; 3= Moderate Aroma and 4= strong Aroma. AS= Aroma scoring, L/B ratio= length-breadth ratio, CD= Cooking duration, ER= Elongation ratio.

Again, V_1= Chiniatop 1; V_2= Katari2; V_3= Dulabhog; V_4= Zirabhog; V_5= BRRI dhan34 and V_6= BRRI dhan50

Before cooking (rice grain)	**After cooking (rice grain)**

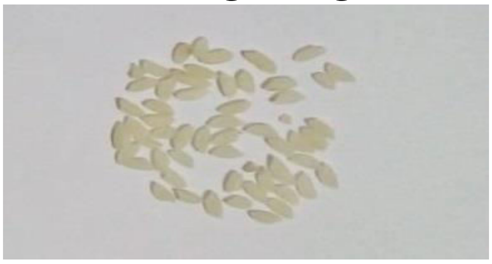

Plate 1: Chiniatop 1

Plate 2: Chiniatop 1

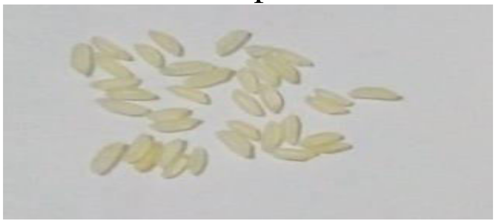

Plate 3: Katari 2

Plate 4: Katari 2

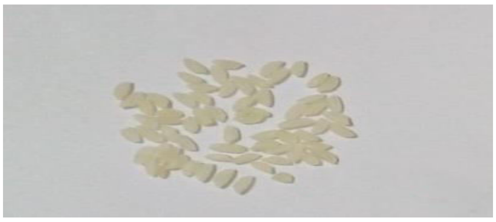

Plate 5: Dulabhog

Plate 6: Dulabhog

Plate 7: Zirabhog

Plate 8: Zirabhog

Plate 9: BRRI dhan34

Plate 10: BRRI dhan34

Plate 11: BRRI dhan50

Plate 12: BRRI dhan50

CHAPTER V

SUMMARY AND CONCLUSION

The present investigation entitled "Effect of organic and inorganic fertilizers on growth, yield and quality of aromatic rice in *boro* season" was conducted during the period from December, 2018 to June, 2019 at the Agricultural research field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh. The experiment comprised of two factors; viz. Factor A: fertilizer used (organic fertilizer and inorganic fertilizer) and Factor B: rice varieties (Chiniatop 1, Katari2, Dulabhog, Ziabhog, BRRI dhan34 and BRRI dhan50). The experiment was laid out in a split-plot design and 2 factors with three replications. There were 12 treatment combinations and total numbers of unit plots were 36. The size of unit plot was 10 m^2 (4 m × 2.5 m). The field was fertilized with 10 ton cowdung and compost (4:1) for organic fertilizer and nitrogen, phosphate, potash, sulphur and zinc at the rate of 90, 60, 45, 8 and 3 kg/ha, respectively in the form of urea, triple super phosphate, muriate of potash, gypsum and zinc-sulphate. Results revealed that variety, fertilizers applying and their interaction effect had significant effect on morphological, physiological, yield and grain quality behavior of aromatic rice production under organic fertilization method in boro season.

Among the different varieties the tallest plant (149.4 cm at harvest), maximum tillers $hill^{-1}$ (13.62), effective tillers $hill^{-1}$ (12.42), maximum number of leaves $hill^{-1}$ (25.33), maximum total dry mater (19.52 g), maximum leaf area index (3.42), maximum SPAD reading (47.52), maximum stomatal conductance (0.59 mmol CO_2 m^{-2} s^{-1}), maximum total spikelet $panicle^{-1}$ (209.5), maximum filled spikelet $panicle^{-1}$ (189), maximum grain size (15.90 mg), maximum grain yield (3.92 t ha^{-1}), maximum straw yield (7.93 t ha^{-1}), maximum biological yield (11.85 t/ha) and maximum harvest index (36.32%) were found from Chiniatop1 variety. Whereas, the maximum number of ineffective tillers $hill^{-1}$(1.52), unfilled spikelet $panicle^{-1}$ (40.10) and grain sterility (%) (34.39%) were found from Zirabhog variety.

Among the two different fertilizers that were applied, the tallest plant (132.7 cm), maximum tillers $hill^{-1}$ (10.98), maximum effective tillers $hill^{-1}$ (10.20), maximum number of leaves $hill^{-1}$ (20.17), maximum total dry mater (16.58 g), maximum leaf area index (2.51), maximum SPAD reading (39.27), maximum stomatal conductance

(0.48 mmol CO_2 m^{-2} s^{-1}), maximum total spikelet $panicle^{-1}$ (169.9), maximum filled spikelet $panicle^{-1}$(142.57), maximum grain size (14.31mg), maximum grain yield (3.20 t ha^{-1}), maximum straw yield (6.24 t ha^{-1}), maximum biological yield (9.44t/ha) and maximum harvest index (34.81%) were recorded from T_1 (organic fertilizer). Whereas, maximum ineffective tillers $hill^{-1}$ (1.13), unfilled spikelet $panicle^{-1}$ (33.98) and grain sterility (24.59%) were recorded from T_2 (inorganic fertilizer).

In case of different treatment combinations, the tallest plant (149.5 cm), the maximum number of total tillers $hill^{-1}$ (14.55), maximum effective tillers $hill^{-1}$ (12.43), maximum number of leaves $hill^{-1}$ (26.87), maximum total dry mater (22.37 g), maximum leaf area index (3.44), maximum SPAD reading (48.53), maximum stomatal conductance (0.53 mmol CO_2 m^{-2} s^{-1}), maximum total spikelet $panicle^{-1}$ (231.6), maximum filled spikelet $panicle^{-1}$(213.10), maximum grain size (16.33 mg), maximum grain yield (4.38 t ha^{-1}), maximum straw yield (8.43 t ha^{-1}) maximum biological yield (12.81) and maximum harvest index (38.67%) were recorded from the combined treatment of V_1T_1 (Chiniatop 1+Organic fertilizer). Whereas, maximum ineffective tillers $hill^{-1}$(3.56), maximum unfilled spikelet $panicle^{-1}$ (43.43) and maximum grain sterility (39.63%) were recorded from the combined treatment of V_4T_2 (Zirabhog+Inorganic fertilizer).

In case of grain qualities such as, strong aroma, maximum length-breadth ratio, minimum cooking duration and maximum elongation ratio were observed in Chiniatop 1 variety. Between the two fertilization methods, organic fertilizer was showed better grain qualities such as strong aroma, maximum length-breadth ratio, minimum cooking duration and maximum elongation ratio. Again, among the different interactions of variety and fertilization methods (Chiniatop 1 + Organic fertilizer) was showed better grain qualities such as strong aroma, maximum length-breadth ratio, minimum cooking duration and maximum elongation ratio.

Conclusion

From this experiment following conclusions were figured out and they were given bellow:

1. Organic fertilizer had a great effect on growth and yield performance of aromatic rice varieties. Among the different varieties, better plant growth and grain yield were observed in Chiniatop 1, which was due to highest plant height, increased number of effective tillers hill^{-1}, increased number of leaves hill^{-2}, increased number of leaf area index, highest SPAD reading, highest stomatal conductance (mmolCO_2m^{-2}s^{-1}) and increased total dry matter distribution (g) and increased number of filled grains panicle^{-1}under organic fertilizer compared to inorganic fertilizer.
2. Organic fertilizer also had a great influence on grain quality of different aromatic rice varieties. Better grain quality was observed in Chiniatop 1 under organic fertilizer, which was due to increased length-breadth ratio, increased elongation ratio, minimum coocking duration and strong aroma of rice grain after cooking.

CHAPTER V

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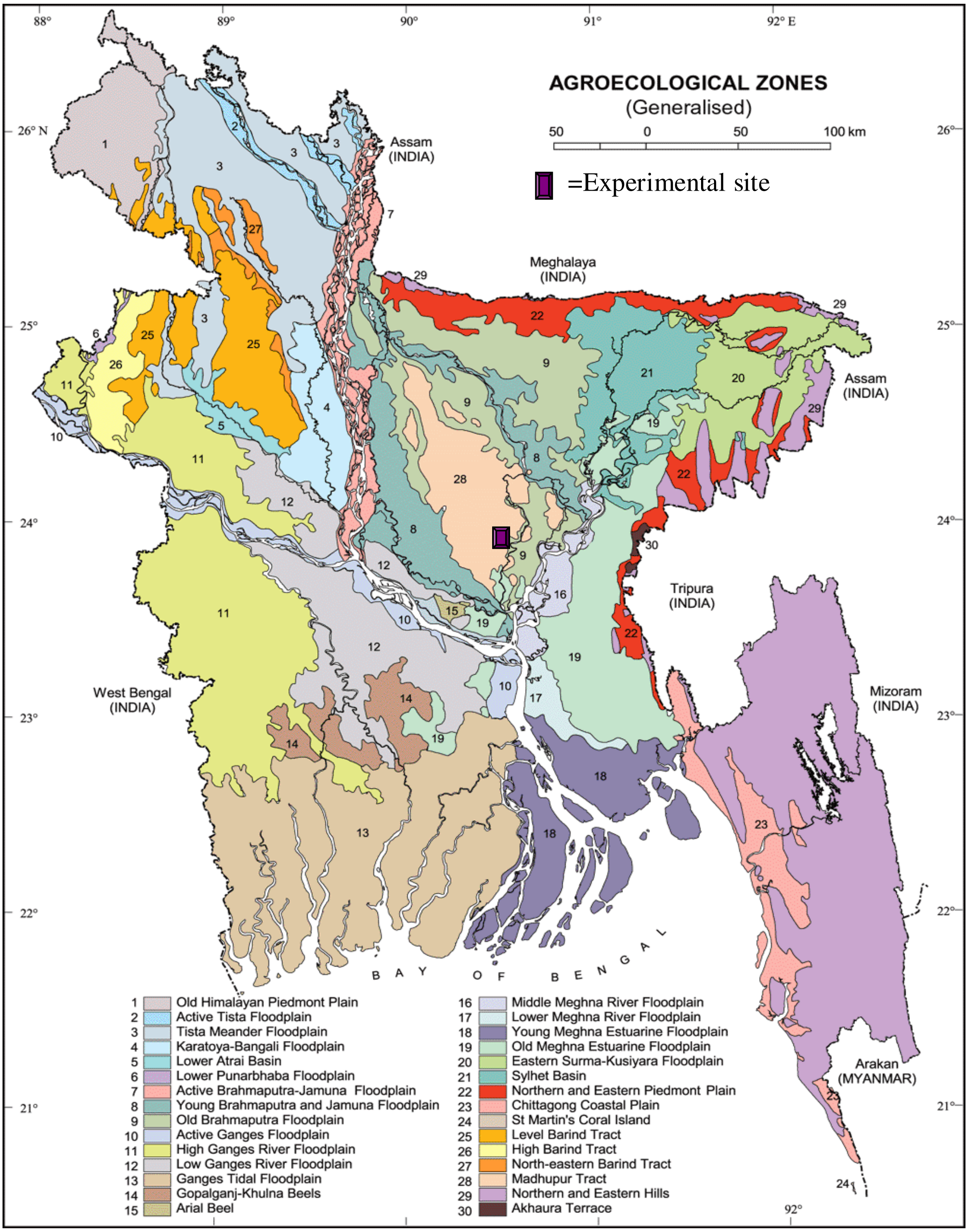
CHAPTER VI

APPENDIXES

Appendix I. Experimental location on the map of Agro-ecological Zones of Bangladesh



Appendix II. The physical and chemical characteristics of soil of the experimental site as observed prior to experimentation (0-15 cm depth)

Constituents	**Percent**
Sand	26
Silt	45
Clay	29
Textural class	Silty clay

Chemical composition:

Soil characters	**Value**
Organic carbon (%)	0.45
Organic matter (%)	0.54
Total nitrogen (%)	0.027
Phosphorus	6.3 µg/g soil
Sulphur	8.42 µg/g soil
Magnesium	1.17 meq/100 g soil
Boron	0.88 µg/g soil
Copper	1.64 µg/g soil
Zinc	1.54 µg/g soil
Potassium	0.10 meg/100g soil

Source: Soil Resources Development Institute (SRDI), Khamarbari, Dhaka

Appendix III: Analysis of variance of the data on plant height of rice as influenced by varieties and cultivation method

Source of variance	Degrees of freedom	Mean square
Replication	2	0.079 NS
Factor A	1	149.247*
Error	2	0.017
Factor B	5	1514.354
A×B	5	12.044*
Error	20	0.102

Here, NS= Non-significant; *= Significant at 1% level; **= Significant at 5% level; ***= Significant at 10% level

Appendix IV: Analysis of variance of the data on tillers hill^{-1} of rice as influenced by varieties and cultivation method

Source of variance	Degrees of freedom	Mean square
Replication	2	0.245 NS
Factor A	1	1.863***
Error	2	0.007
Factor B	5	29.875*
A×B	5	1.803
Error	20	0.085

Here, NS= Non-significant; *= Significant at 1% level; **= Significant at 5% level; ***= Significant at 10% level

Appendix V: Analysis of variance of the data on leaf area of rice as influenced by varieties and cultivation method

Source of variance	Degrees of freedom	Mean square
Replication	2	0.018NS
Factor A	1	0.213
Error	2	0.007
Factor B	5	2.159*
A×B	5	0.063
Error	20	0.056

Here, NS= Non-significant; *= Significant at 1% level; **= Significant at 5% level; ***= Significant at 10% level

Appendix VI: Analysis of variance of the data on effective tillers hill^{-1} of rice as influenced by varieties and cultivation method

Source of variance	Degrees of freedom	Mean square
Replication	2	0.001NS
Factor A	1	0.90
Error	2	0.002
Factor B	5	19.129*
A×B	5	1.506
Error	20	0.058

Here, NS= Non-significant; *= Significant at 1% level; **= Significant at 5% level; ***= Significant at 10% level

Appendix VII: Analysis of variance of the data on total dry matter of rice as influenced by varieties and cultivation method

Source of variance	Degrees of freedom	Mean square
Replication	2	0.10NS
Factor A	1	202.114*
Error	2	0.004
Factor B	5	74.776*
A×B	5	2.882
Error	20	0.065

Here, NS= Non-significant; *= Significant at 1% level; **= Significant at 5% level; ***= Significant at 10% level

Appendix VIII: Analysis of variance of the data on total spikelet panicle^{-1} of rice as influenced by varieties and cultivation method

Source of variance	Degrees of freedom	Mean square
Replication	2	0.066NS
Factor A	1	2737.034***
Error	2	0.087
Factor B	5	2688.717*
A×B	5	60.421*
Error	20	0.064

Here, NS= Non-significant; *= Significant at 1% level; **= Significant at 5% level; ***= Significant at 10% level

Appendix IX: Analysis of variance of the data on unfilled spikelet panicle^{-1} of rice as influenced by varieties and cultivation method

Source of variance	Degrees of freedom	Mean square
Replication	2	0.03NS
Factor A	1	386.778*
Error	2	0.059
Factor B	5	437.072*
A×B	5	5.564*
Error	20	0.054

Here, NS= Non-significant; *= Significant at 1% level; **= Significant at 5% level; ***= Significant at 10% level

Appendix X: Analysis of variance of the data on percent sterility of rice as influenced by varieties and cultivation method

Source of variance	Degrees of freedom	Mean square
Replication	2	0.001NS
Factor A	1	647.278*
Error	2	0.025
Factor B	5	689.218*
A×B	5	11.599*
Error	20	0.035

Here, NS= Non-significant; *= Significant at 1% level; **= Significant at 5% level; ***= Significant at 10% level

Appendix XI: Analysis of variance of the data on grain size of rice as influenced by varieties and cultivation method

Source of variance	Degrees of freedom	Mean square
Replication	2	0.134***
Factor A	1	14.44**
Error	2	0.143
Factor B	5	21.238*
A×B	5	0.306*
Error	20	0.074

Here, NS= Non-significant; *= Significant at 1% level; **= Significant at 5% level; ***= Significant at 10% level

Appendix XII: Analysis of variance of the data on grain yield of rice as influenced by varieties and cultivation method

Source of variance	Degrees of freedom	Mean square
Replication	2	0.206***
Factor A	1	0.308
Error	2	0.051
Factor B	5	2.369*
A×B	5	0.309*
Error	20	0.073

Here, NS= Non-significant; *= Significant at 1% level; **= Significant at 5% level; ***= Significant at 10% level

Appendix XIII: Analysis of variance of the data on straw yield of rice as influenced by varieties and cultivation method

Source of variance	Degrees of freedom	Mean square
Replication	2	0.104***
Factor A	1	2.507***
Error	2	0.079
Factor B	5	15.80*
A×B	5	0.228*
Error	20	0.068

Here, NS= Non-significant; *= Significant at 1% level; **= Significant at 5% level; ***= Significant at 10% level

Appendix XIV: Analysis of variance of the data on harvest index of rice as influenced by varieties and cultivation method

Source of variance	Degrees of freedom	Mean square
Replication	2	23.344
Factor A	1	4.23***
Error	2	2.714
Factor B	5	28.092*
A×B	5	16.737*
Error	20	5.45

Here, NS= Non-significant; *= Significant at 1% level; **= Significant at 5% level; ***= Significant at 10% level

Appendix XV: Analysis of variance of the data on length-breadth ratio of rice as influenced by varieties and cultivation method

Source of variance	Degrees of freedom	Mean square
Replication	2	0.013 NS
Factor A	1	0.034
Error	2	0.058
Factor B	5	4.575*
A×B	5	0.101*
Error	20	0.024

Here, NS= Non-significant; *= Significant at 1% level; **= Significant at 5% level; ***= Significant at 10% level

Appendix XVI: Analysis of variance of the data on cooking duration of rice as influenced by varieties and cultivation method

Source of variance	Degrees of freedom	Mean square
Replication	2	0.016 NS
Factor A	1	1.21***
Error	2	0.016
Factor B	5	4.065*
A×B	5	0.045NS
Error	20	0.013

Here, NS= Non-significant; *= Significant at 1% level; **= Significant at 5% level; ***= Significant at 10% level

Appendix XVII: Analysis of variance of the data on ER of rice as influenced by varieties and cultivation method

Source of variance	Degrees of freedom	Mean square
Replication	2	0.004NS
Factor A	1	0.063*
Error	2	0.023
Factor B	5	0.07
A×B	5	0.023NS
Error	20	0.008

Here, NS= Non-significant; *= Significant at 1% level; **= Significant at 5% level; ***= Significant at 10% level

Appendix XVIII: Analysis of variance of the data on SPAD value of rice as influenced by varieties and cultivation method

Source of variance	Degrees of freedom	Mean square
Replication	2	0.123NS
Factor A	1	196.00*
Error	2	0.016
Factor B	5	352.747*
A×B	5	25.595*
Error	20	0.063

Here, NS= Non-significant; *= Significant at 1% level; **= Significant at 5% level; ***= Significant at 10% level