MORPHO-PHYSIOLOGICAL ATTRIBUTES AND YIELD RESPONSE OF BORO RICE TO BORON AND ZINC

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CERTIFICATE

*This is to certify that the thesis entitled "MORPHO-PHYSIOLOGICAL ATTRIBUTES AND YIELD RESPONSE OF BORO RICE TO BORON AND ZINC" submitted to the Department of Agricultural Botany, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTERS OF SCIENCE (MS) in Agricultural Botany, embodies the result of a piece of bonafide research work carried out by **Zannat-E-Zerin**, Registration No. **14-05889** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that any help or source of information, received during the course of this investigation has been duly acknowledged

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DEDICATED TO

MY

BELOVED PARENTS

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MORPHO-PHYSIOLOGICAL ATTRIBUTES AND YIELD OF BORO RICE IN RESPONSE TO BORON AND ZINC

ABSTRACT

The present piece of work was carried out at the Research Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2019 to April 2020 in *Boro* season to investigate the morpho-physiological attributes and yield response of boro rice to boron and zinc. The experiment consisted of two factors, and followed Randomized Complete Block Design. Factor A: Boro rice varieties *viz* (3); V_1: BRRI dhan29, V_2: BRRI dhan50, V_3: BRRI dhan55, Factor B: Different level of boron and zinc fertilizers *viz* (4); F_0: Control, F_1: Boron @ 15 kg ha^{-1}, F_2: Zinc @ 20 kg ha^{-1} and F_3: Boron @ 15 kg ha^{-1} + Zinc@20 kg ha^{-1}. Data on different growths, yield contributing characters and yield were recorded to find out the response of boro rice varieties to different doses of zinc and boron fertilizers and different parameters of boro rice showed significant variations. Among the varieties, V_1 (BRRI dhan29) treatment perform the best and recorded the maximum number of effective tillers $hill^{-1}$ (16.09), panicle length (26.72 cm), filled grains $panicle^{-1}$ (148.45), number of total grains $panicle^{-1}$ (166.19), 1000 grains weight (26.24 g), grain yield (5.92 t ha^{-1}), straw yield (7.08 t ha^{-1}), biological yield (12.99 t ha^{-1}) and harvest index (45.36 %). In case of different doses of zinc and boron fertilizers applications, the maximum, number of effective tillers $hill^{-1}$ (17.72), panicle length (26.99 cm), filled grains $panicle^{-1}$ (150.75), total grains $panicle^{-1}$ (167.78), 1000 grains weight (28.39 g), grain yield (5.69 t ha^{-1}), straw yield (6.54 t ha^{-1}), biological yield (12.22 t ha^{-1}) and harvest index (46.38 %) were recorded in F_3 (Boron @ 15 kg/ha+ Zinc @ 20 kg/ha) treatment. In respect of treatment combinations V_1F_3 performed the best and recorded the highest grain yield (6.86 t ha^{-1}). Thus BRRI dhan29 along with application of Boron @ 15 kg ha^{-1} + Zinc @ 20 kg ha^{-1} considered as a suitable treatment combination for boro rice production.

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ABBREVIATIONS

Full word	Abbreviations	Full word	Abbreviations
Agriculture	Agric.	Milliliter	mL
Agro-Ecological Zone	AEZ	Milliequivalents	Meqs
And others	et al.	Triple super phosphate	TSP
Applied	App.	Milligram(s)	mg
Asian Journal of Biotechnology and Genetic Engineering	AJBGE	Millimeter	mm
Bangladesh Agricultural Research Institute	BARI	Mean sea level	MSL
Bangladesh Bureau of Statistics	BBS	Metric ton	MT
Biology	Biol.	North	N
Biotechnology	Biotechnol.	Nutrition	Nutr.
Botany	Bot.	Pakistan	Pak.
Centimeter	Cm	Negative logarithm of hydrogen ion concentration (-log[H+])	pH
Completely randomized design	CRD	Plant Genetic Resource Centre	PGRC
Cultivar	Cv.	Regulation	Regul.
Degree Celsius	°C	Research and Resource	Res.
Department	Dept.	Review	Rev.
Development	Dev.	Science	Sci.
Dry Flowables	DF	Society	Soc.
East	E	Soil plant analysis development	SPAD
Editors	Eds.	Soil Resource Development Institute	SRDI
Emulsifiable concentrate	EC	Technology	Technol.
Entomology	Entomol.	Tropical	Trop.
Environment	Environ.	Thailand	Thai.
Food and Agriculture Organization	FAO	United Kingdom	U.K.
Gram	g	University	Univ.
Horticulture	Hort.	United States of America	USA
International	Intl.	Wettable powder	WP
Journal	J.	Serial	Sl.
Kilogram	Kg	Percentage	%
Least Significant Difference	LSD	Number	No.
Liter	L	Microgram	µ

CHAPTER-I

INTRODUCTION

Rice (*Oryza sativa* L.) is the most important food crop and a primary food source for more than one-third of world's population (Sarkar *et al.,* 2017). Worldwide, rice provides 27% of dietary energy supply and 20% dietary protein (Kueneman, 2006). It constitutes 95% of the cereal consumed and supplies more than 80% of the calories and about 50% of the protein in the diet of the general people of Bangladesh (Yusuf, 1997). World's rice demand is projected to increase by 25% from 2001 to 2025 to keep pace with population growth (Maclean *et al.,* 2002), and therefore, meeting this ever increasing rice demand in a sustainable way with shrinking natural resources is a great challenge. In Bangladesh, majority of food grains comes from rice. Rice has tremendous influence on agrarian economy of the country. Annual production of rice in Bangladesh is about 36.28 million tons from 11.52 million ha of land (BBS, 2018). According to the USDA report in 2021, rice production for the 2020-21 marketing year is expected to rise to 36.3 million tonnes in Bangladesh as further cultivation of hybrid and high yield variety plantings increase. The country is expected to import 200,000 tonnes of rice in the 2020-21 marketing year to ease food security tensions brought on by the COVID-19 pandemic (USDA, 2021).

There are three distinct growing seasons of rice in Bangladesh, according to changes in seasonal conditions such as *Aus*, *Aman* and *Boro*. More than half of the total production (55.50 %) is obtained in *Boro* season occurring in December–May, second largest production in *Aman* season (37.90 %) occurring in July-November and little contribution from *Aus* season (6.60 %) occurring in April-June (APCAS, 2016).

Among three growing seasons (Aus, Aman and Boro) boro rice is the most important rice crops for Bangladesh with respect to its high yield and contribution to rice production. Boro cultivation area has declined to 4.75 million hectares in 2020, which was 4.9 million hectares in 2019. The country produced an all-time-high 20.03 million tonnes of *Boro rice* in 2019, The government expects to achieve 20.04 million tonnes of Boro production target, although acreage of this major crop fell to a three-year low in 2010 which was due to reason that many farmers, upset with low paddy and rice prices, switched to other crops like corn, vegetables and tobacco etc. (Express, 2021).

Recently, food security especially attaining self-sufficiency in rice production is a burning issue in Bangladesh. The average yield of rice is almost less than 50% of the world average rice grain yield. The national mean yield (2.60 t ha^{-1}) of rice in Bangladesh is lower than the potential national yield (5.40 t ha^{-1}) and world average yield (3.70 t ha^{-1}) (Pingali *et al.*, 1997). The lower yield of transplanted Boro Rice has been attributed to several reasons. In such condition, increasing rice production can play a vital role. Therefore, attempts must be made to increase the yield per unit area by adopting modern rice cultivars, applying improved technology and fertilizers management practices.

In Bangladesh, BINA, BRRI, IRRI and diverse seed organizations has been presented high yielding rice varieties and it acquires positive monumentaion in rice production for the particular three distinct growing seasons (Haque and Biswas, 2011). Improving and expanding the world's supply will likewise rely on the development and improvement of rice varieties with better yield potential, and to adopt different traditional and biotechnological approaches for the advancement of high yielding varieties that having resistance against various biotic and abiotic stresses (Khush, 2005).

Now-a-day’s different high yielding rice variety are available in Bangladesh which have more yield potential than different conventional varieties (Akbar, 2004). In 2020, the amount of land used for HYV varieties is 44.47 lakh (4.44 million) hectares, hybrid 2.40 lakh (0.24 million) hectares, local varieties 7.15 lakh (0.75 million) hectares (Magzter, 2021). Almost 78 per cent of the land is occupied by the HYV varieties supported by the Department of Agricultural Extension with fertilisers, pesticides and laboratory seeds, while only 12.5 per cent are local/traditional varieties cultivated by the farmers on their own initiatives in low lands. (BBS, 2017).

The growth process of rice plants under different agro-climatic condition differs due to the specific rice variety (Alam *et al*., 2012). Compared with conventional cultivars, the high yielding varieties have larger panicles resulting in an average increase of rice grain is 7.27% (Bhuiyan *et al*., 2014). These high yielding and hybrid rice variety however, needs further evaluation under different fertilizers managements, agro Ecological Zone (AEZ) to interact with different agro-climatic conditions.

Farmers of Bangladesh apply N, P, K and S fertilizers widely and application of micronutrients, such as, Zn, Cu, Mn and B is not a usual practice. Soils inadequate in their supply of micronutrients are alarmingly far reaching across the globe because of intensive cropping, loss of fertile topsoil and losses of nutrients through leaching (Somani, 2008). When micronutrients are in short supply, the growth and yield of crops are severely depressed (IPNI, 2014). Hence, application of nutrients particularly micronutrient are of critical importance for sustaining high productivity of rice in Bangladesh.

Boron and zinc are the essential plant micronutrients and their importance for crop productivity is similar to that of major nutrients (Rattan *et al.* 2009; Padbhushan and Kumar, 2014). Widespread and extensive occurrence of B and Zn deficiency has been reported in the soils of low- land rice cultivation of India, Bangladesh, Pakistan, Philippines, Myanmar, Indonesia, Japan, Korea, Taiwan and Thailand (IRRI, 1997).

Boron has been associated with one or more of the following processes: calcium utilization, cell division, flowering/reproductive phase, water relations, disease resistance, and nitrogen (N) metabolism (Sprague 1951; Goldbach *et al*. 2007; Ahmad *et al*. 2009). Boron deficiency in rice induces panicle sterility due to poor pollen and anther development and failed pollen germination and alters cell wall pectin in pollen tubes (Yang *et al*. 1999) which reduces the number of grains per panicle and, therefore, grain yield (Nieuwenhuis *et al*. 2000; Gowri, 2005). Moreover, B deficiency in rice not only reduces paddy yield but also damages grain quality (Rashid *et al.* 2004, 2007).

Rice soil conditions are usually not favorable for the availability of Zn and hence Zn deficiency has been reported countrywide in rice soils (Singh, 2001). It is therefore, imperative to apply Zn to such soils in addition to major nutrients for obtaining maximum yields. Application of Zn to soil is the most satisfactory way to cure Zn deficiency (Katyal and Agarwala, 1982). Zinc deficiency is the most common nutrient disorder constraining rice productivity worldwide and is effectively controlled by field application of zinc sulphate (Rashid and Fox, 1996).

Studies on B and Zn fertilizer proved that the application of B and Zn greatly influences growth, yield and quality of rice (Mahata *et al.* 2013; Raimani and Singh, 2015).

Keeping this in view, the present research was undertaken to investigate the response of boro rice to boron and zinc on morpho-physiological attributes and yield with the following objectives:

i. To know the effect of boron and zinc on growth and yield of *Boro* rice varieties.
ii. To identify the performance of different *Boro* rice varieties applying different doses of boron and zinc fertilizer.

CHAPTER II

REVIEW OF LITERATURE

An attempt was made in this section to collect and study relevant information available regarding to the morpho-physiological attributes and yield response of boro rice to boron and zinc, to gather knowledge helpful in conducting the present piece of work.

2.1 Effect of boro rice varieties

Plant height

Akter *et al.* (2018) reported that all the yield and yield contributing characters except number of sterile spikelet panicle^{-1} were significantly influenced by the variety. Performance of BRRI dhan74 was better compared to BRRI dhan29 in terms of all parameters. BRRI dhan74 produced the taller plant (89.00 cm) than the BRRI dhan29 (81.10 cm). The varietal differences might be due to heredity or varietal character.

Chamely *et al.* (2015) reported that plant height is a varietal character and it is the genetic constituent of the cultivar, therefore, plant height was different among the cultivars.

Rahman and Bulbul (2014) founded statistically significant effect of varieties was observed in plant height of boro rice. The tallest plant (107.00cm) was found in BRRI hybrid2 The shortest plant (101.95cm) was found in BRRI dhan29. Variation in plant height might be due to the differences in the genetic make–up of the varieties.

Tyeb *et al.* (2013) reported that the variation in plant height due varietal differences. Varietal differences in plant height might be due to the heredity or varietal character.

Shamsuddin *et al.* (1998) reported that a variable plant height existed among the varieties.

Number of tillers hill^{-1}

Akter *et al.* (2018) reported that higher (10.12) number of total tillers hill^{-1} obtained by BRRI dhan74 than (9.70) number of total tillers hill^{-1} reported by BRRI dhan29.

Chamely *et al*. (2015) reported that among different varieties, BRRI dhan29 produced the highest number of total tillers hil^{-1}. The results indicate that tillering pattern of different varieties differed due to genetic potentiality of the varieties.

Rahman and Bulbul (2014) reported that that all the yield and yield contributing characters were significantly influenced by the variety. The highest number of total tillers hill^{-1} (10.96) was found in BRRI hybrid2 and the lowest number of total tiller was found (10.63) in BRRI dhan29. The variation in number of total tillers hill-^{1} might be due to varietal characteristics.

Babikar (1986) reported the variation of tiller production due to cultivars.

Dry matter weight hill^{-1}

Chamely *et al*. (2015) showed that among the varieties the highest total dry matter (66.41 g m^{-2}) was observed in BRRI dhan45 and the lowest dry matter (61.24 g) was observed in BRRI dhan29.

Ullah *et al.* (2016) showed that among the varieties the maximum dry matter was found for Heera (41.5g/hill) whereas minimum from BRRI dhan29 (37.0 g/hill) at 105 DAT respectively.

Alam *et al.* (2009) found difference in total dry matter accumulation in different genotypes.

Sharma and Singh (1994) noticed a wide variability in photosynthetic rates exists in rice cultivars which may cause difference in dry matter accumulation.

Effective tillers hill^{-1}

Latif *et al.* (2020) showed that the highest number of effective tillers hill^{-1} (17.64) was produced by BRRI dhan29 whereas the lowest values of respective effective tillers were found in BR14. The reduction of number of effective tillers hill^{-1} in BR14 was due to tiller mortality in the vegetative stages. The probable reason of these results might be due to different genetic makeup of these varieties which are influence by heredity.

Akter *et al.* (2018) that all the yield and yield contributing characters except number of sterile spikelet panicle^{-1} were significantly influenced by the variety.

Chamely *et al*. (2015) reported that the highest number of effective tillers hill^{-1} (11.07) was recorded in the variety BRRI dhan29 and the lowest one was observed in BRRI dhan45. The reasons for differences in producing bearing tillers hill^{-1} might be due to the variation in genetic make-up of the variety that might be influenced by heredity.

Non effective tillers hill^{-1}

Rahman, and Bulbul (2014) revealed that all the yield and yield contributing characters were significantly influenced by the variety. The highest number of non-effective tillers (1.95) was found in BRRI dhan29 and the lowest number of non-effective tiller hill^{-1} (1.85) was found in BRRI hybrid2. These differences occurred due to variations of genetic make-up among the varieties.

Kamal *et al.* (2007) showed that there was significant difference on non effective tillers among the varieties. Among the different varieties BRRI dhan28 had the lowest number of effective tillers hill^{1} (6.44) and lowest number of grains panicle^{-1} (134.89) but the highest number of non-effective tillers hill^{-1} (6.67) which contributed to the worst performance of this variety.

Panicle length

Hossain *et al.* (2016) revealed that different rice varieties and nutrient levels along with their interaction have significant effect on growth and yield of rice. It was observed thatpanicle length of the crop influenced by variety. Binadhan-10 produced longer panicle (24.60 cm) compared to BRRI dhan28 (20.97 cm).

Chamely *et al.* (2015) reported that the longest panicle (23.19 cm) was found in the variety BRRI dhan29 and the smallest one was observed in BRRI dhan45. The variation as assessed might be due to genetic characters of the varieties primarily influenced by the heredity.

Diaz *et al.* (2000) also reported that panicle length varied among varieties.

Filled grain panicle^{-1}

Ullah *et al.* (2016) showed that among the varieties the maximum number of filled grain was for the Heera (98.8/panicle) whereas minimum for BRRI dhan58 (82.1/panicle) variety.

Unfilled grain panicle^{-1}

Afroz *et al.* (2019) showed that the highest number (81.20) of grains panicle^{-1} and the lowest number (17.43) of sterile spikelets panicle-^{1} were observed in BRRI dhan29 cultivar. On the other hand, the lowest number (76.82) of grains panicle^{-1} was recorded in BRRI dhan28 cultivar.

Akter *et al.* (2018) reported that numerically BRRI dhan29 gave the higher (6.32) number of sterile spikelet panicle-^{1} than BRRI dhan74 (6.01).

Ullah *et al.* (2016) showed that among the varieties the lowest number of unfilled grain was obtained from BRRI dhan29 (7.5/panicle) while highest BRRI dhan58 (13.7/panicle) variety.

Grains panicle^{-1}

Latif *et al.* (2020) indicated that among the varieties, BRRI dhan29 produced the highest number (111.0) of grains panicle^{-1} and the lowest one (93.0) was recorded in BR14. Number of grains panicle^{-1} differed significantly due to variety.

Akter *et al.* (2018) reported that higher (97.74) number of total grains panicle^{-1} obtained by BRRI dhan74 than (94.33) grains panicle^{-1} reported by BRRI dhan29.

Singh and Gangwar (1989) reported that variable numbers of grains panicle^{-1} were found among the varieties. Varietal differences regarding the number of grains panicle^{-1} might be due to differences in their genetic constituents.

1000 grains weight

Latif *et al.* (2020) reported that 1000 grains weight were significantly differ due to the varietal performance. The highest 1000-grain weight (26.33 g) was obtained in BR14 than BRRI dhan28 (22.60 g) and BRRI dhan29 (22.43 g).

Rahman *et al.* (2020) revealed that among the varieties the highest 1000-grain weight (26.65 g) was obtain in BRRI hybrid dhan3 while the lowest (21.43 g) was obtain in BRRI dhan28 rice variety.

Grain yield

Latif *et al.* (2020) reported that BRRI dhan29 produced the highest grain yield (4.56 t ha^{-1}) than BRRI dhan28 (4.01 t ha^{-1}) and BR14 (3.77 t ha^{-1}). The probable reason of the different grain yields due to the different yield parameters (tillers $hill^{-1}$, grains $panicle^{-1}$, 1000-grain weight etc.) influenced by the genetic make-up of the variety.

Afroz *et al.* (2019) showed that the highest grain yield (5.17 t ha^{-1}) was recorded in BRRI dhan29 cultivar. This might be due to the fact of producing highest number of total and effective tillers $hill^{-1}$, highest number of grains panicle-^{1}, lowest number of sterile spikelets $panicle^{-1}$ and heaviest 1000-grain weight of the cultivar BRRI dhan29. The lowest grain yield (3.89 t ha^{-1}) was found in BRRI dhan28 cultivar due to lowest number of total and effective tillers $hill^{-1}$, lowest number of grains $panicle^{-1}$, highest number sterile spikelets $panicle^{-1}$ and lightest 1000-grain weight.

Hossain *et al.* (2016) reported that due to difference in variety, the grain yield of rice varied significantly. The highest grain yield (6.38 t ha^{-1}) produced by the variety Binadhan-10 where BRRI dhan28 produced 4.69 t ha^{-1}.

Rahman, and Bulbul (2014) reported that among the varieties performance the highest grain yield (5.64 t/ha) was achieved from BRRI hybrid2. The lowest grain yield (4.93t/ha) was achieved from BRRI dhan 29. The highest yield occurred due to higher plant height, higher total tiller $hill^{-1}$ and lower number non-effective tiller $hill^{-1}$.

Straw yield

Chamely *et al*. (2015) showed that among the varieties the highest straw yield was observed in the variety BRRI dhan28. This was due to the higher total DM production in the cultivar BRRI dhan28.

Biological yield

Chowhan *et al.* (2019) revealed that Variety Shakti-2 (V_4) produced the highest biological yield (18.14 t/ha), whereas the lowest by BRRI dhan28 (V_1) (12.21 t/ha) and Binadhan-14 (V_2) (12.15 t/ha). It was observed that, varieties which had higher grain and straw yield ultimately obtained the highest biological yield.

Rahman, and Bulbul (2014) reported that among the varieties performance the highest biological yield (12.34tha^{-1}) was obtained from BRRI hybrid2 and the lowest one (10.76tha^{-1}) was obtained from BRRI dhan 29.

Harvest index

Chowhan *et al.* (2019) found significant differences of harvest index among different rice varieties. From their experiment, they observed that Varieties Shakti-2 (V_4), Heera-1 (V_3) and BRRI dhan28 (V_1) had an identical harvest index of 50.9%, 48.5% and 47.9 respectively. Only Binadhan-14 (V_2) produced the harvest index (40.0%). It appears that hybrid rice maintained higher harvest index.

Akter *et al.* (2018) reported that harvest index was higher in BRRI dhan29 (42.86%) than BRRI dhan74 (39.28%).

Kamal *et al.* (2007) showed that The highest harvest index (45.35%) was recorded from BRRI dhan28 and the lowest one (41.18%) was obtained form B1NADHAN-5.

2.2 Effect of boron and zinc fertilizer

Plant height

Arif *et al.* (2012) reveal that the plant height was significantly ($P<0.05$) affected by the micronutrient (Zn + B) supplement. Plant height varied from 92 to 121 cm in plant which received nutrient treatments. The plant treated with Zn + B at 6 + 3 kg/acre showed maximum response (121 cm) followed by Zn + B at 3 + 1.5 kg/acre (102 cm) and Zn 33% at 6 kg/acre (100 cm) which was 85 cm in the control. The other treatments like Zn 33% at 3 kg/acre, B 11.3% at 1.5 kg/acre, B 11.3% at 3 kg/acre and MT + Zn 6% + B + Fe + Mn + Cu 1% each at 500 ml/acre also had significant responses as compared to the control. Generally, nutrient supplementation in combination significantly enhanced plant height over the control and 29.75% plant height increased in Zn + B at 6 + 3 kg/acre treated plant. The plant height was also significantly ($P<0.05$) affected by the Zn, B and MT application.

Singh *et al.* (2012) Zinc have played a vital role in the vegetative growth especially under low temperature ambient and rhizosphere regime and adequate availability of zinc to young and developing plants resulting in sufficient growth and development.

Ali *et al.* (2011) reported that the increase in growth parameter, chlorophyll contents, biochemical profile and yield components were improved with micronutrient use and found to be dose dependent.

Patil *et al.* (2008) reported that the chlorophyll contents increased considerably in Zn and B treated group of plants. The photosynthesis enhanced in the presence of B indicates that it helps to activate the synthesis of tryptophan and precursor of indole acetic acid (IAA) which is responsible for stimulation of plant growth and accumulation of biomass. The micronutrient being a component of ferrodoxin and electron transport are also associated with chloroplast. The acceleration in photosynthesis is evident for better vegetative growth.

Phillips (2004) reported that the micronutrient acts as catalyst in the uptake and use of certain other macronutrients which helps in growth and development of the crops.

Bohnsack and Albert (1977) reported that boron application methods also improved plant height in rice, which is due to active involvement of B in meristematic growth of plant.

Number of tillers hill^{-1}

Reddy *et al.* (2020) revealed that maximum tillers was produced by treatment T_9 (RDF + 20 kg Zn/ha + 1kg B/ha) was 10.07 was significantly higher among all the treatments and statistically at par withT_5 (RDF + 10 kg Zn/ha + 0.5 B/ha), T_6(RDF + 10 kg Zn/ha + 1 kg B/ha), T_7 (RDF + 20 kg Zn/ha + 0 kg B/ha), T_8 RDF + 20 kg Zn/ha + 0.5 kg B/ha and minimum tillers in T_1 (control treatment).

Impa *et al.* (2013) observed that the increasing levels of zinc supply to rice increased the total zinc content per plant at different growth stages and have beneficial effect on tiller production.

Arif *et al.* (2012) reported that maximum number of tiller was observed in plant which was supplied with Zn and B in combination comparable to control one.

Goldbach *et al.* (2001) reported that improvement in tillering might be due to increase in the metabolic activities within the younger seedlings in the presence of B

Dry matter weight hill^{-1}

Reddy *et al.* (2020) reported that the treatment T9 (RDF+ 20 kg Zn/ha + 1kg B/ha) gave the highest dry matters weight (93.60g) was significantly higher among all the treatments and statistically at par with T6 (RDF + 10 kg Zn/ha + 1 kg B/ha), T8 RDF + 20 kg Zn/ha + 0.5 kg B/ha treatment comparable to control treatment (T_1).

Rani and Latha, (2017) reported that the highest DMP of 15.57 t ha^{-1} was recorded with the application of borax 10 kg ha^{-1} along with FYM 5t ha^{-1}, recommended NPK and lime 600 kg ha^{-1} in Kole lands of Kerala.

Kalala *et al.* (2016) reported that application of Zn @ 10 mg kg^{-1} soil enhanced the dry matter yield in rice.

Mousavi (2011) reported that foliar or soil application of Zn increases the biosynthesis of chlorophyll which are important for the photosynthetic process which helps physiological activities of the plant and increasing dry matter.

Pooniya and Shivay (2011) reported that continuous and balanced supply of nutrients right from the early stage of growth result in vigorous plant growth which eventually may have resulted in increased dry-matter accumulation.

Effective tillers hill^{-1}

Reddy *et al.* (2020) revealed that no. of effective tillers was also recorded highest in the treatment combination of T_9(RDF + 20 kg Zn/ha + 1 kg B/ha) was significantly higher among all the treatments and statistically at par with T_5(RDF + 10 kg Zn/ha + 0.5 B/ha, T_6(RDF + 10 kg Zn/ha + 1 kg B/ha), T_7(RDF + 20 kg Zn/ha + 0 kg B/ha),and T_8(RDF + 20 kg Zn/ha + 0.5 kg B/ha).This might be due to the application of zinc along with the recommended dose of NPK enhanced the yield attributing characters like productive tillers/hill grains per panicle and test grain weight.

Oahiduzzaman *et al*. (2016) opined that higher number of productive tillers hill^{-1} and filled grains panicle^{-1} were recorded with 4 kg Zn ha^{-1}.

Sohel *et al.* (2009) found that micronutrients had a positive influence on the increase of effective tillers hill^{-1} of rice.

Naik and Das (2007) reported that adequate supply of Zn produced higher number of panicle m^{-2}.

Fageria (2001) reported that Rice is deemed prone to Zn deficiency as Zn rates are not sufficient in soil limits tillering and therefore the number of panicles/region**.**

Panicle length

Shivay *et al.* (2015) reported that the application of Zinc enhanced the yield attributes like panicles/hill, panicle length and grains/ panicle in aromatic rice varieties when compared to control.

Arif *et al.* (2012) reported that the panicle length increased significantly and varied from 24 to 30.40 cm as a result of Zn, B and MT (Microtone) treatment. The plant treated with Zn + B at 3 + 1.5 kg/acre showed maximum response in panicle length of 30.40 cm as compared to the control (21.83 cm) followed by Zn + B at 6 + 3 kg/acre (29.70 cm) and B 11.3% at 1.5 kg/acre (29.67 cm).

Jena *et al.* (2006) reported that the higher value of panicle length might be due to increased transportation of photosynthates from source to sink due the application of zinc.

Brown *et al.* (2002) reported that boron deficiency reduces chlorophyll and soluble protein contents in the leaves, and the resultant loss in photosynthetic enzyme activity obstructs the Hill reaction and decreases net photosynthesis as a result its affects on growth and yield of plant.

Filled grains panicle^{-1}

Rani and Latha (2017) reported that higher number of spikelets panicle^{-1} (96.41) and filled grains panicle^{-1} (94.30) were recorded with application of borax 10 kg ha^{-1} along with FYM 5t ha^{-1}, recommended NPK and lime 600 kg ha^{-1} in Kole lands of Kerala which was 45% more than that of the control.

Islam (2015) showed significant variation in respect of combined effect of boron and zinc in case of filled grain panicle^{-1} of rice. Highest filled grain panicle^{-1} (143.60) was recorded from B_2Zn_2 followed B_2Zn_1 and where the lowest filed grain panicle^{-1} (67.46) were achieved by B_0Zn_0 followed by B_0Zn_1 and B_1Zn_0 and B_2Zn_0.

Unfilled grain panicle^{-1}

Islam (2015) reported that boron zinc and their combination had significant effect on unfilled grain production of rice. Among the different treatments result revealed the highest number of unfilled grain panicle^{-1} was recorded from control treatment where the lowest number of unfilled grain panicle^{-1} was achieved by boron and zinc treatment combination.

Grains panicle^{-1}

Kumar *et al.* (2017) carried out an study to know the effect of graded levels of zinc and boron on growth, yield and chemical properties of soils under paddy on Alfisols at Naganahalli village, Mysore district, Karnataka. The results showed that external application of zinc as $ZnSO_4$ @ 20 kg ha^{-1} and boron as borax @ 4 kg ha^{-1} significantly enhanced growth and yield of rice. Significantly highest number of grains per panicle (130.05 grains per panicle) and thousand grain weight (26.96 g) were recorded in T_{12} treatment which received RDF + ZnSO4 @ 20 kg ha^{-1} + Borax @ 4 kg ha^{-1} which was superior over all other treatments. The lowest number of grains per panicle (100.42 grains per panicle) was recorded in T_1 treatment which received RDF + FYM as compared to other treatments.

Qadir *et al.* (2013) reported that application of. Boron along with Zn and Fe resulted in the production of higher number of spikelets panicle^{-1} and grains with higher test grain weight.

Singh *et al.* (2012) reported that panicles m^{-2} and grains panicle^{-1} were significantly enhanced by the application of Zn @ 6 kg ha^{-1}.

Amin *et al.* (2004) reported that application of Zn and B fertilizers in addition to N and P showed significant increase in yield and yield contributing attributes.

Shivay *et al.* (2008). reported that Application of 3.5% zinc enriched urea significantly influenced the yield attributes of aromatic rice *viz.*, fertile tillers hill^{-1}, panicle length and grains panicle^{-1} in rice-wheat cropping system .

1000 grains weight

Kumar *et al.* (2017) reported significantly highest thousand grain weight (26.96 g) were recorded in T_{12} treatment which received RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 4 kg ha^{-1} which was superior over all other treatments.

Grain yield

Debnath *et al.* (2015) conducted a field experiment in Piedmont plain soil of East Siang of Arunachal, India to predict the responses of rice (Oryza sativa) to different levels of boron (B) andzinc (Zn) application. The result showed significance increase in grain and straw yield due to B fertilization. The highest yield response to the tune of 39.25 q/ha grain and 41.25 q/ha straw was recorded with 15 kg level of borax per hectare. Percent increase of grain and straw yield due to 15 kg borax alone over control was found to be 24.52 % and 17.78 % respectively. The soil also showed positive response to different levels of Zn fertilization but maximum response was observed upto 20 kg $ZnSO_4$/ha. Boron and Zn interacted synergistically to boost yield of rice crop resulting in additional yield of 7.1 q/ha of grain and 6.28 q/ha of straw. The increased percent of grain and straw yield of rice with Zn and interaction between B × Zn were 24.87 %, 17.67 % and 47.04, 35.72 %, respectively. The boron concentration and uptake in grain and straw of rice also significantly increases with increase in level of borax upto 15 kg/ha and $ZnSO_4$ 10 kg/ha.

Rani and Latha (2017) reported that application of borax @10 kg ha^{-1} along with recom-mended dose of NPK recorded the highest grain yield of 7.67 t ha^{-1}.

Arif *et al.* (2012) reported that the micronutrient required in minute quantity, and their deficiency leads to diminished growth and yield of crops.

Fageria *et al.* (2011) reported that Zinc fertilization had significant effect on the grain yield of rice and highest grain yield was recorded with the application of zinc.

Hatwar *et al. (*2003) observed that B enhances the growth attributes due to its favourable influence on metabolic pathways involved in cell division and elongation.

Straw yield

Qadir *et al*. (2013) reported that application of Zn and B @ 8 and 2 kg ha^{-1} along with recommended NPK recorded the highest grain and straw yield.

Arif *et al*. (2012) noticed that soil application of B and Zn @ 3 and 6 kg $acre^{-1}$ recorded the highest grain and straw yield (4.18 t ha^{-1}) and (13.84 t ha^{-1}) respectively.

Shivay *et al.* (2010) reported that application of Zn @ 7.5 kg ha^{-1} recorded the highest straw yield of 10.99 t ha^{-1} in aromatic rice.

Cihatak *et al.* (2005) observed that uptake of Zinc by plant when applied in the form of zinc sulphate to the soil increases the straw yield.

Biological yield

Podder (2017) conducted a field experiment at the Agronomy field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from November 2016 to May, 2017 to find out the response of boro rice to foliar spray of zinc and boron. Different spraying time and levels such as recommended fertilizers (RF) along with Foliar spray (FS) with water at tiller initiation (TI) and flower initiation stage FI) and (0.2, 0.5 and 0.8 %) and (0.5, 1.5 and 2 %) zinc and boron spray were considered as treatments. From the experiment result showed that there was Significant variation in terms of harvest index of rice influenced by different treatments. Results indicated that the highest biological yield (14.71 t ha^{-1}) was obtained from the treatment, T_{11} [B (1.5%) FS at TI + RF] followed by T_{14} [B (1.5%) FS at FI] where the lowest grain yield (11.43 t ha^{-1}) was found from the treatment, T_1 (Recommended Fertilizer (RF)) which was statistically identical with T2 (RF+ Foliar spray (FS) with water at tiller initiation (TI)) and T_3 (RF + Foliar spray (FS) with water at flowering initiation (FI).

Harvest index

Podder (2017) reported that the highest harvest index (48.26) was obtained from the treatment, T_{11} (B (1.5%) FS at TI + RF) followed by T_{13} [B (0.5%) FS at FI + RF] and T_{14} [B (1.5%) FS at FI] where the lowest harvest index (43.88) was found from the treatment, T_1 (Recommended Fertilizer (RF).

Hussain *et al*. (2012) reported that the Improvement in harvest index resulted from B application might be due to better starch utilization that results in higher seed setting and translocation of assimilates to developing grains, which increases the grain size and number of grains per panicle.

CHAPTER III

MATERIALS AND METHODS

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

3.1 Location of the experimental site

3.1.1 Geographical location

The experiment was conducted at the reasearch field of Sher-e-Bangla Agricultural University (SAU),Sher-e-Bangla Nagar Agargong, Dhaka, 1207. The experimental site is geographically situated at 23°77′ N latitude and 90°33′ E longitude at an altitude of 8.6 meter above sea level (Anon., 2004).

3.1.2 Agro-Ecological Zone

The experimental field belongs to the Agro-ecological zone (AEZ) of “The Modhupur Tract”, AEZ-28 (Anon., 1988 a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as ‘islands’ surrounded by floodplain (Anon., 1988 b). For better understanding about the experimental site has been shown in the Map of AEZ of Bangladesh in Appendix-I.

3.2 Experimental Duration

The experiment was conducted during the period from November 2019 to April 2020 in Transplanting *Boro* season.

3.3 Soil characteristics of the experimental field

Soil of the experimental site was silty clay loam in texture belonging to Tejgaon series (Anon., 1988 a). The area represents the Agro-Ecological Zone of Madhupur tract (AEZ No. 28) with pH 5.8–6.5, ECE-25–28 (Anon., 1988 b). Soil samples from 0- 15 cm depths were collected from the experimental field. The analytical data of the soil sample collected from the experimental area were analyzed in the Soil Resources

Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and have been presented in Appendix II.

3.4 Climate condition of the experimental field

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

3.5 Crop / planting material

BRRI dhan29, BRRI dhan50 and BRRI dhan55 were being used as test crops for this experiment.

3.6 Description of the planting material

Name of variety	Developed by	Year of Release	Growing season	Average yield (t ha^{-1})
BRRI dhan29	BRRI	1994	Boro	7.50
BRRI dhan50	BRRI	2008	Boro	6.00
BRRI dhan55	BRRI	2011	Boro	7.00

3.7 Seed collection and sprouting

BRRI dhan29, BRRI dhan50 and BRRI dhan55 rice variety seed was collected from BRRI (Bangladesh Rice Research Institute), Joydebpur, Gazipur. Healthy and disease free seeds were selected following standard technique. Seeds were immersed in water in a bucket for 24 hrs. These were then taken out of water and kept in gunny bags. The seeds started sprouting after 48 hrs which were suitable for sowing in 72 hrs.

3.8 Raising of the Boro seedlings

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

3.9 Preparation of experimental field

The experimental field was first opened on 17 November, 2019 with the help of a power tiller, later the land was irrigated and prepared by three successive ploughings and cross-ploughings. Each ploughing was followed by laddering, to have a good puddled field. Various kind of weeds and developments of pest crop were disposed of from the field. Final land preparation and the field layout was made on 24 November 2019. Each plots were cleared in and finally leveled out with the help of wooden board.

3.10 Fertilizer management

The following doses of fertilizer were applied for cultivation of Boro rice (BARC, 2012).

Fertilizers	Quantity (kg/ha)
Urea	300
TSP	100
MP	120
Gypsum	60

Plant Macronutrients (*viz*. nitrogen, phosphorus, potash, sulfur) for rice were given through urea, triple super phosphate, muriate of potash, and gypsum, respectively. Plant micronutrients *viz*. Zinc and boron were as given through Zinc sulphate and boric acid according to the treatment requirements. All of the fertilizers except urea were applied as basal dose at the time of final land preparation. Urea (300 kg ha^{-1}) was applied in equal three splits. The first dose of urea was applied at 21 days after transplanting (DAT). The second dose of urea was added as top dressing at 45 days (active vegetative stage) after transplanting and third dose was applied at 60 days (panicle initiation stage) after transplanting recommended by BRRI.

3.11 Experimental design and layout

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

3.12 Experimental details

Seed bed preparation Date:

Seed Sowing Date: 1st November

Spacing: 15 cm × 20 cm

Fertilizer apply Date: All the fertilizers were applied at 24 November 2019 during final land preparation except total urea

Transplanting Date: 09/01/2020

Harvesting Date: 15/05/2020

3.13 Experimental treatments

The experiment consisted of two factors as mentioned below:

Factor A: Boro rice varieties (3) *viz:*

V_1: BRRI dhan29

V_2: BRRI dhan50

V_3: BRRI dhan55

Factor B: Different level of boron and zinc fertilizers (4) *viz*

F_0: Control

F_1: Boron@15 kg/ha

F_2: Zinc@20 kg/ha and

F_3: Boron@15 kg/ha+ Zinc@20 kg/ha

3.14 Experimental treatment combinations

There were 12 treatment combinations for this experiment. V_1F_0, V_1F_1, V_1F_2, V_1F_3, V_2F_0, V_2F_1 ,V_2F_2, V_2F_3, V_3F_0, V_3F_1, V_3F_2 and V_3F_3 were used as treatment combinations for this experiment.

3.15 Intercultural operations

3.15.1 Gap filling

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

3.15.2 Application of irrigation water

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

3.15.3 Method of water application

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

3.15.4 Weeding

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

3.15.5 Plant protection measures

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

3.15.6 General observations of the experimental field

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

3.15.7 Harvesting and post harvest operation

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

3.16 Data collection

The data were recorded on the following parameters

i). Crop growth characters

i. Plant height (cm) at 15 DAT interval start at 30 DAT
ii. Number of tillers $hill^{-1}$ at 15 DAT interval start at 30 DAT
iii. Above ground dry matter weight of plant at 15 DAT interval start at 30 DAT

ii). Yield contributing characters

iv. Number of effective tillers $hill^{-1}$
v. Number of non-effective tillers $hill^{-1}$
vi. Panicle length (cm)
vii. Number of filled grains $panicle^{-1}$
viii. Number of unfilled grains $panicle^{-1}$
ix. Number of total grains $panicle^{-1}$
x. Weight of 1000- grain (g)

iv). Yield

xi. Grain yield (t ha^{-1})
xii. Straw yield (t ha^{-1})
xiii. Biological yield (t ha^{-1})
xiv. Harvest index (%)

3.17 Procedure of recording data

i) Plant height (cm)

The height of the randomly selected 5 plant was determined by measuring the distance from the soil surface to the tip of the leaf at 15 DAT interval start at 30 DAT and harvest respectively. Mean plant height of rice plant were calculated and expressed in cm.

ii) Number of tillers hill^{-1}

Number of tillers hill^{-1} were counted at 15 DAT interval start at 30 DAT up to harvest from pre selected hills and finally averaged as their number hill^{-1}. Only those tillers having three or more leaves were considered for counting.

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

Total above ground dry matter weight hill^{-1} was recorded at 15 DAT interval start at 30 DAT and harvest respectively by drying plant sample. The sample plants were oven dried for 72 hours at 70°C and then data were recorded from plant samples hill^{-1} plot^{-1} selected at random from the outer rows of each plot leaving the border line and expressed in gram.

iv) Panicle length

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

v) Number of effective tillers hill^{-1}

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

vi) Number of non-effective tillers hill^{-1}

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

vii) Number of filled grains panicle^{-1}

The total number of filled grains was collected randomly from selected 5 plants of a plot and then average number of filled grains per panicle was recorded.

viii) Number of unfilled grains penicle^{-1}

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

ix) Number of total grains panicle^{-1}

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

x) Weight of 1000-grain

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

xi) Grain yield

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

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

xii) Straw yield

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

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

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

The summation of grain yield and above ground straw yield was the biological yield. Biological yield =Grain yield + straw yield.

xiv) Harvest index (%)

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

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

Here, Biological yield = Grain yield + straw yield

3.19 Data analysis technique

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

CHAPTER IV

RESULTS AND DISCUSSION

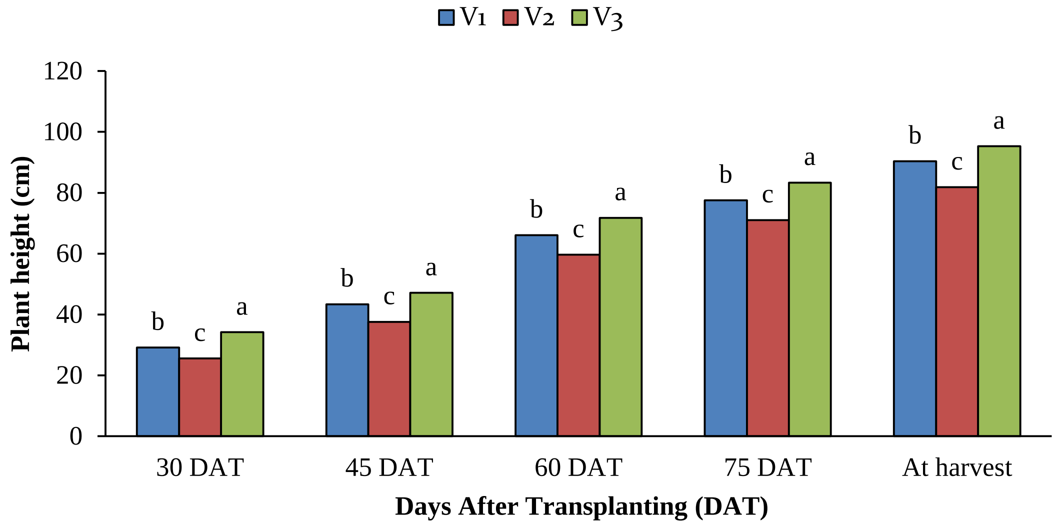
Results obtained from the present study have been presented and discussed in this chapter with a view to study the response of boro rice to boron and zinc on morpho-physiological attributes and yield. The data are given in different tables and figures. The results have been discussed, and possible interpretations are given under the following headings.

4.1 Plant growth parameters

4.1.1 Plant height (cm)

Effect of variety

Plant height is an important morphological character that acts as a potential indicator of availability of growth resources in its approach (Fig. 1). From the experiment, result revealed that, plant height showed significant variation at different days after transplanting due to effect of different rice variety. Experiment result showed that the maximum plant height (34.16, 47.12, 71.79, 83.35 and 95.27 cm) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in V_3 (BRRI dhan55) treatment. Whereas the minimum plant height (25.53, 37.60, 59.62, 71.07 and 81.85 cm) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in V_2 (BRRI dhan50) treatment. The variation of plant height is probably due to the genetic make-up of the variety. Similar result also observed by Akter *et al.* (2018) and Chamely *et al.* (2015). They reported that plant height is a varietal character and it is the genetic constituent of the cultivar, therefore, plant height was different among the cultivars. Shamsuddin *et al.* (1998) also reported that a variable plant height existed among the varieties.

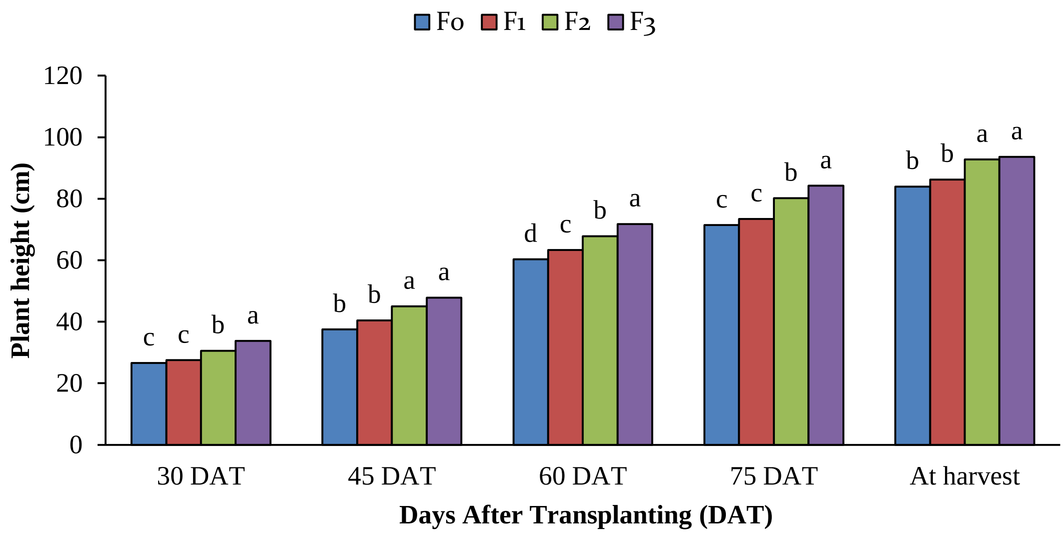


Here, V_1: BRRI dhan 29, V_2: BRRI dhan50 V_3: BRRI dhan55 and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 1. Effect of variety on plant height of boro rice at different DAT.

Effect of different levels of boron and zinc fertilizer

Different level of boron and zinc fertilizer significantly effect on plant height of boro rice at different days after transplanting (Fig. 2). Experiment result showed that the maximum plant height (33.74, 47.85, 71.81, 84.20 and 93.63 cm) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in F_3 (Boron @ 15 kg/ha+ Zinc @ 20 kg/ha) treatment, which was statistically similar with F_2 (Zinc @ 20 kg/ha) treatment recorded plant height (45.04 and 92.76 cm) at 45 DAT and at harvest respectively. Whereas the minimum plant height (26.63, 37.48, 60.30, 71.44 and 83.98 cm) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in F_0 (Control) treatment, which was statistically similar with F_1 (Boron @ 15 kg/ha) treatment recorded plant height (27.49, 40.47,73.44 and 86.27 cm) at 30, 45, 75 DAT and at harvest respectively. Boron is a micronutrient necessary for plant growth. Without adequate boron in the soil, plants may appear healthy but will not flower or fruit. Boron helps control the transport of sugars in plants. It is important to cell division and seed development. The function of zinc is to help the plant produce chlorophyll. Leaves discolor when the soil is deficient in zinc and plant growth is stunted. Zinc deficiency causes a type of leaf discoloration called chlorosis, which causes the tissue between the veins to turn yellow while the veins remain green. Chlorosis in zinc deficiency usually affects the base of the leaf near the stem causing less photosynthesis, which occur less dry matter production by plant and ultimate impact on growth and development of the plant. The result obtained from the present study was similar with the findings of Arif *et al.* (2012) and they reported that nutrient supplementation in combination significantly enhanced plant height over the control and 29.75% plant height increased in Zn + B at 6 + 3 kg/acre treated plant. Ali *et al.* (2011) also reported that the increase in growth parameter, chlorophyll contents, biochemical profile and yield components were improved with micronutrient use and found to be dose dependent. Phillips (2004) reported that the micronutrient acts as catalyst in the uptake and use of certain other macronutrients which helps in growth and development of the crops.



Here, F_0: Control, F_1: Boron @ 15 kg/ha, F_2: Zinc @ 20 kg/ha , F_3:Boron @ 15 kg/ha + Zinc @ 20 kg/ha and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 2. Effect of different levels of boron and zinc fertilizer on plant height of boro rice at different DAT.

Combined effect of variety and different levels of boron and zinc fertilizer

Different variety along with different level of boron and zinc fertilizer significantly effect on plant height of boro rice at different days after transplanting (Table 1). Experiment result revealed that, the maximum plant height (38.78, 52.03, 81.02, 92.68 and 104.53 cm) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in V_3F_3 treatment combination, which was statistically similar with V_3F_2 treatment combination recorded plant height (35.78, 50.57, 77.01, 90.11 and 102.23 cm) at 30, 45, 60, 75 DAT and at harvest respectively. Whereas the minimum plant height (23.10, 32.05, 54.73, 64.70 and 76.75 cm) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in V_2F_0 treatment combination, which was statistically similar with V_2F_1 (25.10 cm), V_2F_2 (25.25 cm), V_1F_0 (25.90 cm) and V_1F_1 (26.18 cm) treatment combination at 30 DAT; with V_2F_1 (34.07 cm) and V_1F_0 (36.95 cm) treatment combination at 45 DAT; and with V_2F_1 (56.93, 66.80 and 80.85 cm) treatment combination at 60, 75 DAT at harvest respectively.

Table 1. Combined effect of variety and different level of boron and zinc fertilizer on plant height of boro rice at different DAT

Treatment Combinations	Plant height (cm) at				
	30 DAT	45 DAT	60 DAT	75 DAT	At harvest
V_1F_0	25.90 ef	36.95 ef	63.02 c	74.20 bc	87.20 bc
V_1F_1	26.18 ef	44.91 b-d	67.14 bc	78.33 bc	91.66 b
V_1F_2	30.78 cd	43.63 cd	64.28 c	77.77 bc	91.44 b
V_1F_3	33.78 bc	48.14 a-c	69.82 b	79.70 b	91.17 b
V_2F_0	23.10 f	32.05 f	54.73 d	64.70 e	76.75 e
V_2F_1	25.10 f	34.07 f	56.93 d	66.80 de	80.85 de
V_2F_2	25.25 ef	40.91 de	62.23 c	72.55 cd	84.60 cd
V_2F_3	28.66 de	43.37 cd	64.60 c	80.21 b	85.20 cd
V_3F_0	30.90 cd	43.44 cd	63.15 c	75.41 bc	88.00 bc
V_3F_1	31.18 cd	42.44 c-e	65.99 bc	75.19 bc	86.31 c
V_3F_2	35.78 ab	50.57 ab	77.01 a	90.11 a	102.23 a
V_3F_3	38.78 a	52.03 a	81.02 a	92.68 a	104.53 a
$LSD_{(0.05)}$	3.53	5.81	4.95	6.40	4.61
CV(%)	7.05	8.04	4.44	4.89	3.05

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

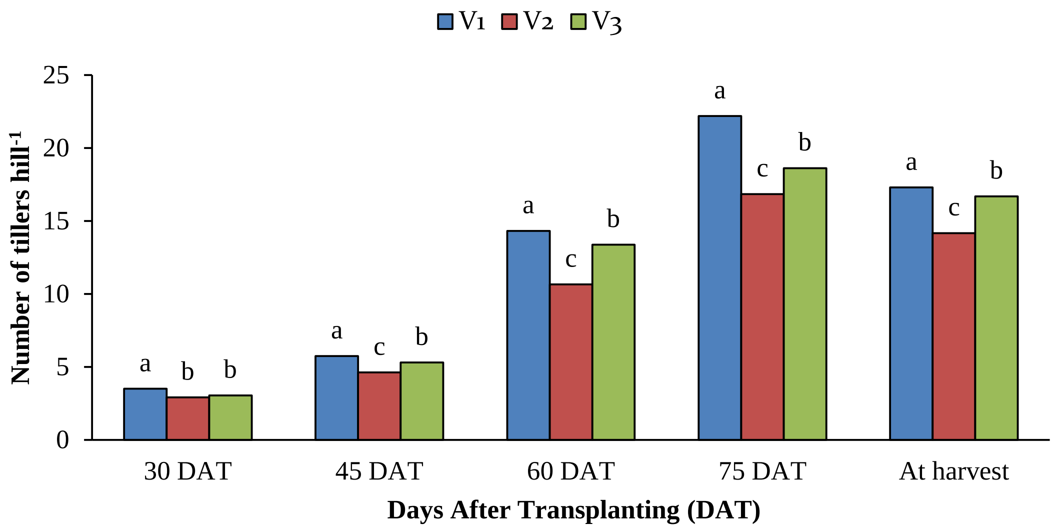
NS: Non Significant
V_1: BRRI dhan 29
V_2: BRRI dhan 50
V_3: BRRI dhan 55

F_0: Control
F_1: Boron @ 15 kg/ha
F_2: Zinc @ 20 kg/ha and
F_3: Boron @ 15 kg/ha + Zinc @ 20 kg/ha

4.1.2 Number of tillers hill^{-1}

Effect of variety

Rice variety significantly differ tiller number hill^{-1} at different days after transplanting of boro rice (Fig. 3). Experiment result revealed that, the maximum tiller number hill^{-1} (3.50, 5.75, 14.33, 22.20 and 17.30) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in V_1 (BRRI dhan29) treatment. Whereas the minimum tiller number hill^{-1} (2.92, 4.62, 10.66, 16.85 and 14.18) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in V_2 (BRRI dhan50) treatment which was statistically similar with V_3 (BRRI dhan55) recorded tiller number hill^{-1} (3.05) at 30 DAT. The variation of tiller number hill^{-1} is probably due to the genetic make-up of the cultivars. Similar result also observed by Akter *et al.* (2018) and they reported that higher (10.12) number of total tillers hill^{-1} obtained by BRRI dhan74 than (9.70) number of total tillers hill^{-1} reported by BRRI dhan29. Chamely *et al*. (2015) reported that tillering pattern of different varieties differed due to genetic potentiality of the varieties.

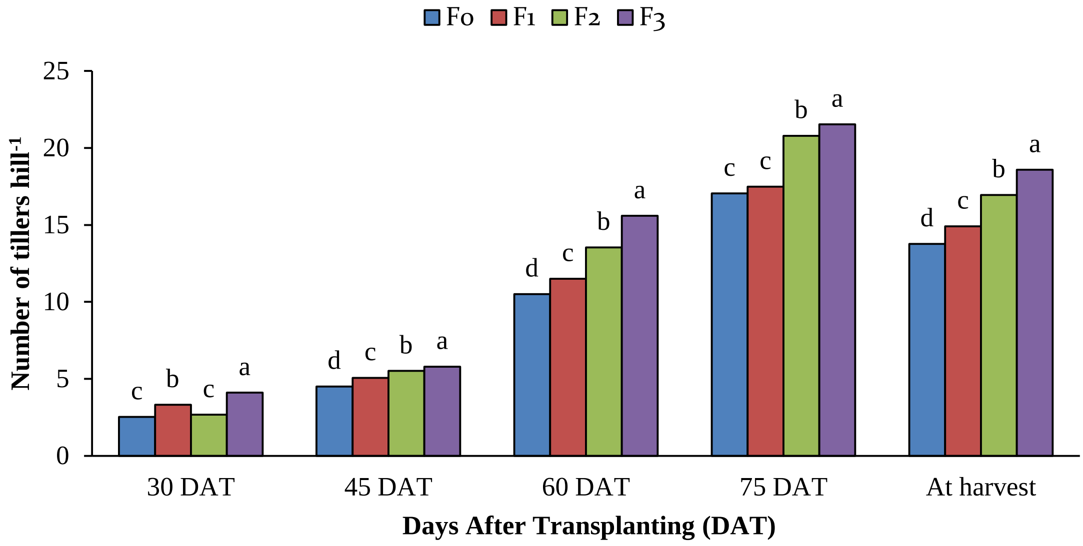


Here, V_1: BRRI dhan 29, V_2: BRRI dhan50 V_3: BRRI dhan55 and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 3. Effect of variety on number of tillers hill^{-1}of boro rice at different DAT.

Effect of different levels of boron and zinc fertilizer

Application of different levels of boron and zinc fertilizer significantly differ tiller number hill^{-1} at different days after transplanting of boro rice (Fig. 4). Experiment result showed that the maximum tiller number hill^{-1} (4.10, 5.80, 15.59, 21.54 and 18.59) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in F_3 (Boron @ 15 kg/ha + Zinc @ 20 kg/ha) treatment. Whereas the minimum tiller number hill^{-1} (2.53, 4.51, 10.51, 17.05 and 13.77) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in F_0 (Control) treatment, which was statistically similar with F_2 (Zinc @ 20 kg/ha) treatment recorded tiller number hill^{-1} (2.67) at 30 DAT and with F_1 (Boron @ 15 kg/ha) treatment recorded tiller number hill^{-1} (17.49) at 75 DAT. The improvement in tillers number hill^{-1} might be due to increase in the metabolic activities within the younger seedlings in the presence of boron and zinc. The result obtained from the present study was similar with the findings of Reddy *et al.* (2020) and they reported that maximum tillers was produced by treatment T_9 (RDF + 20 kg Zn/ha + 1kg B/ha) was 10.07 was significantly higher among all the treatments and statistically at par withT_5 (RDF + 10 kg Zn/ha + 0.5 B/ha), T_6(RDF + 10 kg Zn/ha + 1 kg B/ha), T_7 (RDF + 20 kg Zn/ha + 0 kg B/ha), T_8 RDF + 20 kg Zn/ha + 0.5 kg B/ha and minimum tillers in T_1 (control treatment). Impa *et al.* (2013) observed that the increasing levels of zinc supply to rice increased the total zinc content per plant at different growth stages and have beneficial effect on tiller production. Arif *et al.* (2012) also reported that maximum number of tiller was observed in plant which was supplied with Zn and B in combination comparable to control one.



Here, F_0: Control, F_1: Boron @ 15 kg/ha, F_2: Zinc @ 20 kg/ha , F_3:Boron @ 15 kg/ha + Zinc @ 20 kg/ha and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 4. Effect of different levels of boron and zinc fertilizeron number of tillers hill^{-1} of boro rice at different DAT.

Combined effect of variety and different levels of boron and zinc fertilizer

Different variety along with different level of boron and zinc fertilizer significantly effect on tillers number hill^{-1} of boro rice at different days after transplanting (Table 2). Experiment result revealed that, the maximum tillers number hill^{-1} (5.00, 6.20, 17.33, 23.97 and 20.10) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in V_1F_3 treatment combination, which was statistically similar with V_1F_2 (6.07) and V_3F_3 (6.00) treatment combination at 45 DAT; with V_3F_3 (6.00) treatment combination at 60 DAT; with V_1F_2 (6.07) treatment combination at 75 DAT respectively. Whereas the minimum tillers number hill^{-1} (2.00, 4.07, 9.20, 13.86 and 10.10) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in V_2F_0 treatment combination, which was statistically similar with V_1F_0 (2.00), V_2F_2 (2.00), and V_3F_2 (2.00) treatment combination at 30 DAT; with V_2F_1 (4.20) treatment combination at 45 DAT; with V_3F_0 (10.00) treatment combination at 60 DAT and with V_2F_1 (14.86) treatment combination at 75 DAT.

Table 2. Combined effect of variety and different level of boron and zinc fertilizers on number of tillers hill^{-1} of boro rice at different DAT

Treatment combinations	No. of tillers hill^{-1} at				
	30 DAT	45 DAT	60 DAT	75 DAT	At harvest
V_1F_0	2.00 f	5.00 e	12.33 d	20.10 bc	15.77 e
V_1F_1	3.00 e	5.73 bc	12.00 d	20.76 b	15.23 e
V_1F_2	4.00 b	6.07 a	15.67 b	23.97 a	18.10 bc
V_1F_3	5.00 a	6.20 a	17.33 a	23.97 a	20.10 a
V_2F_0	2.00 f	4.07 g	9.20 f	13.86 e	10.10 g
V_2F_1	3.66 c	4.20 fg	10.33 e	14.86 e	14.10 f
V_2F_2	2.00 f	5.00 e	10.42 e	19.33 c	15.53 e
V_2F_3	4.00 b	5.20 de	12.67 d	19.33 c	16.97 d
V_3F_0	3.60 c	4.47 f	10.00 ef	17.20 d	15.43 e
V_3F_1	3.30 d	5.27 de	12.20 d	16.87 d	15.43 e
V_3F_2	2.00 f	5.47 cd	14.53 c	19.10 c	17.23 cd
V_3F_3	3.30 d	6.00 ab	16.77 a	21.33 b	18.70 b
$LSD_{(0.05)}$	0.27	0.32	0.85	1.27	0.94
CV(%)	5.23	3.62	3.90	3.89	3.45

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

NS: Non Significant

V_1: BRRI dhan 29

V_2: BRRI dhan 50

V_3: BRRI dhan 55

F_0: Control

F_1: Boron @ 15 kg/ha

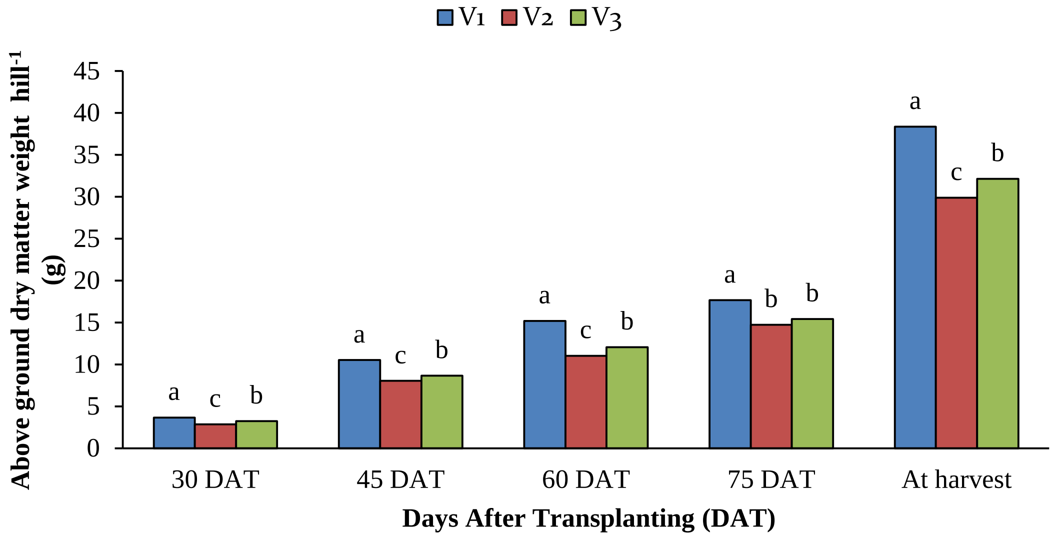
F_2: Zinc @ 20 kg/ha and

F_3: Boron @ 15 kg/ha + Zinc @ 20 kg/ha

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

Effect of variety

The above ground dry matter weight hill^{-1} (g) differ among different varieties due to reason that individual variety have individual leaf area, growth stage, and resources utilization its surrounded which influences the dry matter weight hill^{-1} (g). In this experiment result showed that different rice varieties significantly effect on dry matter weight hill^{-1} (g) of Boro rice at different DAT (Fig. 5). Experiment result revealed that, among different treatments the maximum above ground dry matter weight hill^{-1} (3.67, 10.51, 15.19, 17.66 and 38.38 g) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in V_1 (BRRI dhan29) treatment. Whereas the minimum above ground dry matter weight hill^{-1} (2.85, 8.03, 11.04, 14.74 and 29.90 g) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in V_2 (BRRI dhan50) treatment which was statistically similar with V_3 (BRRI dhan55) treatment recorded above ground dry matter weight hill^{-1} (15.43 g) at 75 DAT. Competition, weed suppression and resources utilization ability had greater in high yielding or hybrid varieties comparable to local one which influences the above ground dry matter weight hill^{-1} (g). The result obtained from the present study was similar with the findings of Chamely *et al*. (2015) and they reported that the highest total dry matter (g m^{-2}) differ among rice varieties. Alam *et al.* (2009) also found difference in total dry matter accumulation in different genotypes.

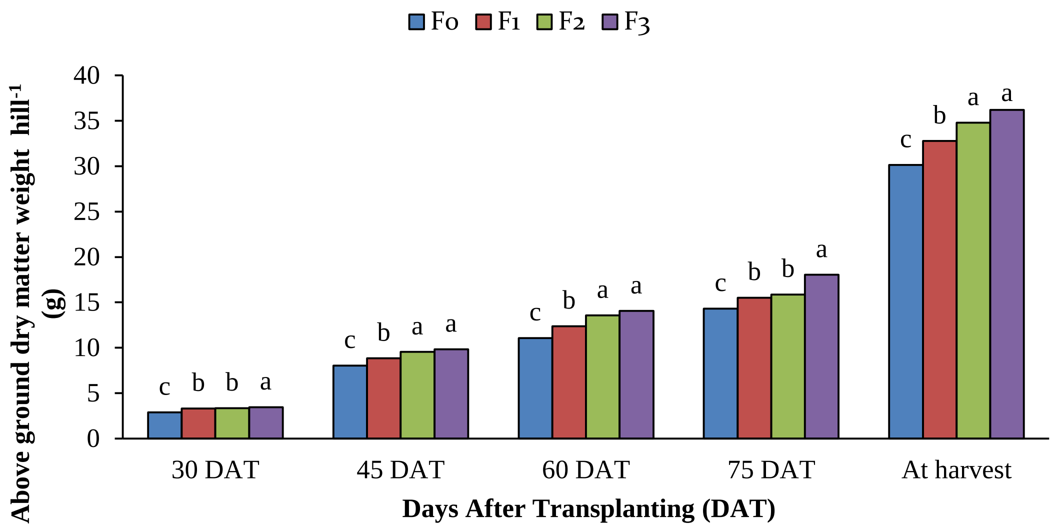


Here, V_1: BRRI dhan 29, V_2: BRRI dhan50 V_3: BRRI dhan55 and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 5. Effect of variety on above ground dry matter weight hill^{-1} (g) of boro rice at different DAT.

Effect of different levels of boron and zinc fertilizer

Application of different levels of boron and zinc fertilizer significantly differ above ground dry matter weight hill^{-1} (g) of boro rice at different days after transplanting (Fig. 6). Experiment result showed that the maximum above ground dry matter weight hill^{-1} (3.47, 9.84, 14.05, 18.05 and 36.19) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in F_3 (Boron @ 15 kg/ha + Zinc @ 20 kg/ha) treatment which was statistically similar with F_2 (Zinc @ 20 kg/ha) treatment recorded above ground dry matter weight hill^{-1} (9.54, 13.56 and 34.79 g) at 45, 60 DAT and at harvest respectively. Whereas the minimum above ground dry matter weight hill^{-1} (2.89, 8.04, 11.08, 14.32 and 30.15 g) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in F_0 (Control) treatment. Reddy *et al.* (2020) also found similar result which supported the present finding and reported that the treatment T_9 (RDF+ 20 kg Zn/ha + 1kg B/ha) gave the highest dry matters weight (93.60 g) was significantly higher among all the treatments. Rani and Latha, (2017) reported that the highest DMP of 15.57 t ha^{-1} was recorded with the application of borax 10 kg ha^{-1} along with FYM 5t ha^{-1}, recommended NPK and lime 600 kg ha^{-1} in Kole lands of Kerala. Kalala *et al.* (2016) reported that application of Zn @ 10 mg kg^{-1} soil enhanced the dry matter yield in rice. Pooniya and Shivay (2011) reported that continuous and balanced supply of nutrients right from the early stage of growth result in vigorous plant growth which eventually may have resulted in increased dry-matter accumulation.



Here, F_0: Control, F_1: Boron @ 15 kg/ha, F_2: Zinc @ 20 kg/ha , F_3:Boron @ 15 kg/ha + Zinc @ 20 kg/ha and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 6. Effect of different levels of boron and zinc fertilizer on above ground dry matter weight hill^{-1} (g) of boro rice at different DAT.

Combined effect of variety and different levels of boron and zinc fertilizer

Different variety along with different level of boron and zinc fertilizer significantly effect on above ground dry matter weight hill^{-1} (g) of boro rice at different days after transplanting (Table 3). Experiment result revealed that, the maximum above ground dry matter weight hill^{-1} (3.93, 11.64, 17.06, 21.24 and 42.12) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in V_1F_3 treatment combination, which was statistically similar with V_1F_2 (3.77 g) and V_1F_1 (3.77 g) treatment combination at 30 DAT; with V_1F_2 (11.12, 16.21 and 40.41 g) treatment combination at 45, 60, 75 DAT and at harvest respectively. Whereas the minimum above ground dry matter weight hill^{-1} (2.32, 7.56, 10.27 13.22 and 28.53 g) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in V_2F_0 treatment combination, which was statistically similar with V_3F_0 (7.82, 10.70, 14.25 and 29.40 g) treatment combination at 45, 60, 75

DAT and at harvest respectively; with V_2F_1 (7.82, 10.70, 14.25 and 29.40 g) treatment combination at 45, 60, 75 DAT and at harvest respectively and with V_2F_2 (30.23 g) treatment combination at harvest respectively.

Table 3. Combined effect of variety and different level of boron and zinc fertilizers on above ground dry matter weight hill^{-1} of boro rice at different DAT

Treatment combinations	Above ground dry matter weight hill^{-1} at				
	30 DAT	45 DAT	60 DAT	75 DAT	At harvest
V_1F_0	3.22 b	9.00 cd	12.68 c	15.51 b-d	33.36 cd
V_1F_1	3.77 a	10.28 b	14.81 b	16.95 b	37.62 b
V_1F_2	3.77 a	11.12 a	16.21 a	16.92 b	40.41 a
V_1F_3	3.93 a	11.64 a	17.06 a	21.24 a	42.12 a
V_2F_0	2.32 e	7.56 f	10.27 e	13.22 e	28.53 f
V_2F_1	2.89 d	7.82 ef	10.70 de	14.25 de	29.40 ef
V_2F_2	3.01 cd	8.37 e	11.62 d	15.17 cd	30.23 ef
V_2F_3	3.19 bc	8.37 e	11.56 d	16.30 bc	31.40 de
V_3F_0	3.14 bc	7.57 f	10.28 e	14.22 de	28.56 f
V_3F_1	3.27 b	8.39 de	11.64 d	15.36 cd	31.29 de
V_3F_2	3.27 b	9.12 c	12.86 c	15.51 b-d	33.72 cd
V_3F_3	3.29 b	9.51 c	13.52 c	16.62 bc	35.04 c
$LSD_{(0.05)}$	0.20	0.63	0.98	1.47	2.44
CV(%)	3.60	4.08	4.52	5.43	4.31

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

NS: Non Significant
V_1: BRRI dhan 29
V_2: BRRI dhan 50
V_3: BRRI dhan 55

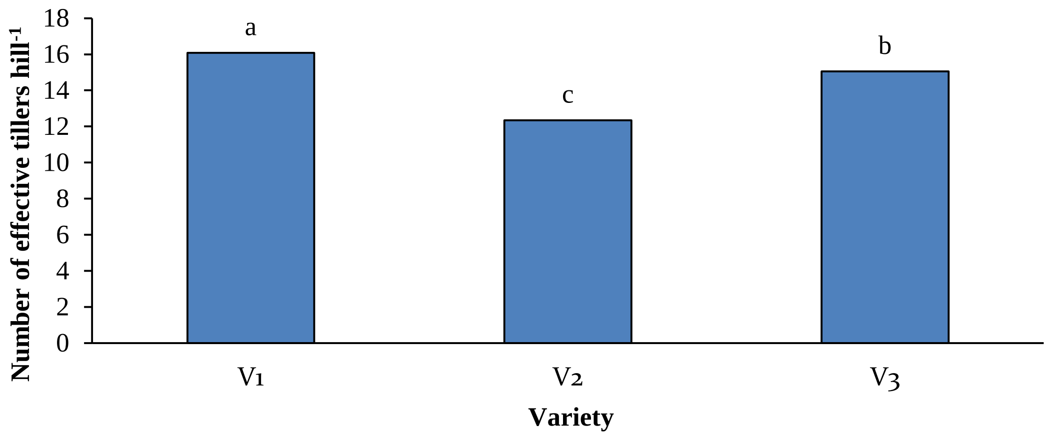
F_0: Control
F_1: Boron @ 15 kg/ha
F_2: Zinc @ 20 kg/ha and
F_3: Boron @ 15 kg/ha + Zinc @ 20 kg/ha

4.2 Yield contributing characters

4.2.1 Number of effective tillers hill^{-1}

Effect of variety

Rice variety significantly effect on number of effective tillers hill^{-1} of boro rice (Fig. 7). Experiment result revealed that the maximum, number of effective tillers hill^{-1} (16.09) was recorded in V_1 (BRRI dhan29) treatment. Whereas the minimum, number of effective tillers hill^{-1} (12.35) was recorded in V_2 (BRRI dhan50) treatment. The variation of effective tillers hill^{-1} is probably due to the genetic make-up of the variety. The result obtained from the present study was similar with the findings of Latif *et al.* (2020) and they reported that the highest number of effective tillers hill^{-1} (17.64) was produced by BRRI dhan29 whereas the lowest values of respective effective tillers were found in BR14. The reduction of number of effective tillers hill^{-1} in BR14 was due to tiller mortality in the vegetative stages. The probable reason of these results might be due to different genetic makeup of these varieties which are influence by heredity. Chamely *et al*. (2015) also reported that the reasons for differences in producing bearing tillers hill^{-1} might be due to the variation in genetic make-up of the variety that might be influenced by heredity.

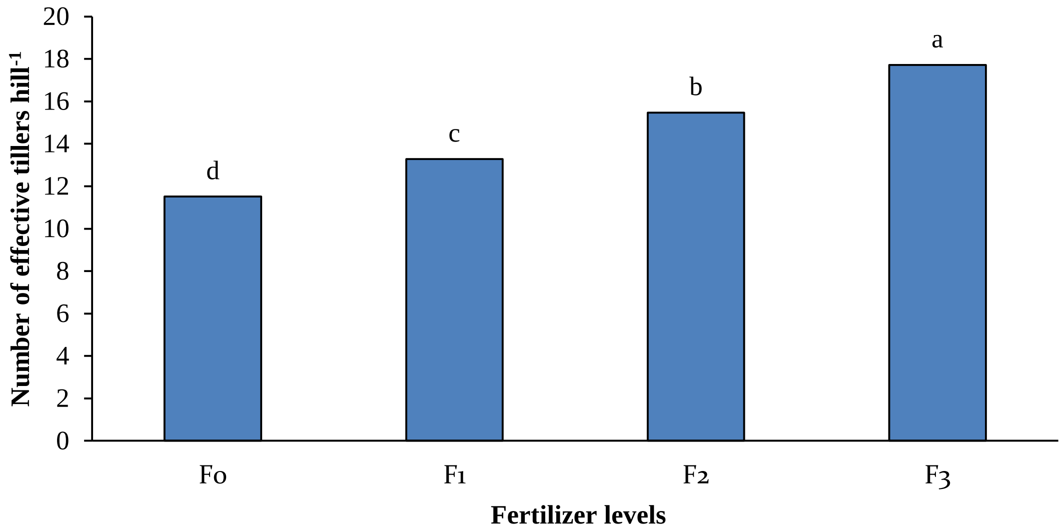


Here, V_1: BRRI dhan 29, V_2: BRRI dhan50 V_3: BRRI dhan55 and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 7. Effect of variety on number of effective tillers hill^{-1}of boro rice.

Effect of different levels of boron and zinc fertilizer

Number of effective tillers hill^{-1} of boro rice was significantly differ due to the effect of different levels of boron and zinc fertilizer (Fig. 8). Experiment result showed that the maximum, number of effective tillers hill^{-1} (17.72) was recorded in F_3 (Boron @ 15 kg/ha+ Zinc @ 20 kg/ha) treatment. Whereas the minimum , number of effective tillers hill^{-1} (11.51) was recorded in F_0 (Control) treatment. This might be due to the application of zinc and boron along with the recommended dose of NPK enhanced the yield attributing characters like productive effective tillers hill^{-1}. Similar result also observed by Sohel *et al.* (2009) and found that micronutrients had a positive influence on the increase of effective tillers hill^{-1} of rice.



Here, F_0: Control, F_1: Boron @ 15 kg/ha, F_2: Zinc @ 20 kg/ha , F_3:Boron @ 15 kg/ha + Zinc @ 20 kg/ha and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 8. Effect of different levels of boron and zinc fertilizer on number of effective tillers hill^{-1}of boro rice.

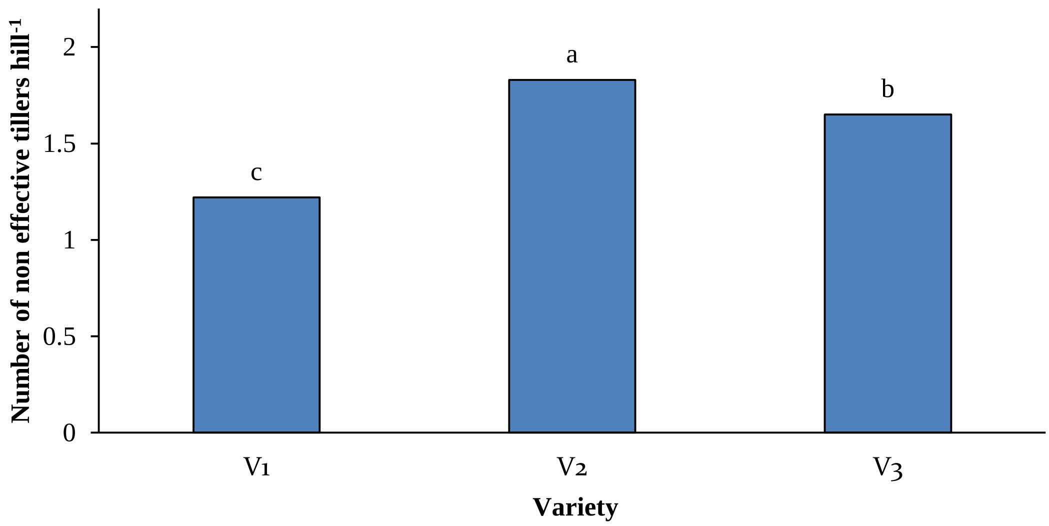
Combined effect of variety and different levels of boron and zinc fertilizer

Combined effect of variety and different levels of boron and zinc fertilizer significantly effect on number of effective tillers hill^{-1} of boro rice (Table 4). Experiment result showed that, the maximum number of effective tillers hill^{-1} (19.60) was recorded in V_1F_3 treatment combination. Whereas the minimum number of effective tillers hill^{-1} (7.33) was recorded in V_2F_0 treatment combination.

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

Effect of variety

Rice variety significantly effect on number of non effective tillers hill^{-1} of boro rice (Fig. 9). Experiment result revealed that the maximum, number of non effective tillers hill^{-1} (1.83) was recorded in V_2 (BRRI dhan50) treatment. Whereas the minimum, number of non effective tillers hill^{-1} (1.22) was recorded in V_1 (BRRI dhan29) treatment. The differences of non effective tillers hill^{-1} is the genetic makeup of the variety. Rahman, and Bulbul (2014) also found similar result which supported the present finding and reported that all the yield and yield contributing characters were significantly influenced by the variety. The highest number of non-effective tillers (1.95) was found in BRRI dhan29 and the lowest number of non-effective tiller hill^{-1} (1.85) was found in BRRI hybrid2. These differences occurred due to variations of genetic make-up among the varieties.

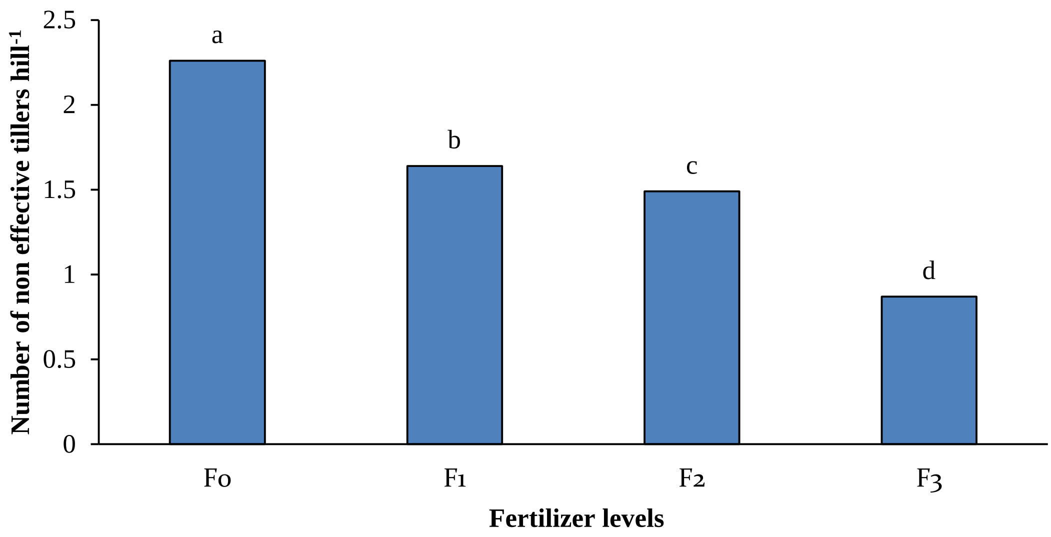


Here, V_1: BRRI dhan 29, V_2: BRRI dhan50 V_3: BRRI dhan55 and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 9. Effect of variety on number of non effective tillers hill^{-1}of boro rice.

Effect of different levels of boron and zinc fertilizer

Number of non effective tillers hill^{-1} of boro rice was significantly differ due to the effect of different levels of boron and zinc fertilizer (Fig. 10). Experiment result showed that the maximum, number of non effective tillers hill^{-1} (2.26) was recorded in F_0 (Control) treatment. Whereas the minimum, number of non effective tillers hill^{-1} (0.87) was recorded in F_3 (Boron @ 15 kg/ha+ Zinc @ 20) treatment. Micronutrients are essential elements needed for crop growth that are required in relatively small quantities. Even though demands for micronutrients are small in quantity, these nutrients directly affect crop growth and development.



Here, F_0: Control, F_1: Boron @ 15 kg/ha, F_2: Zinc @ 20 kg/ha , F_3:Boron @ 15 kg/ha + Zinc @ 20 kg/ha and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 10. Effect of different levels of boron and zinc fertilizer on number of non effective tillers hill^{-1} of boro rice.

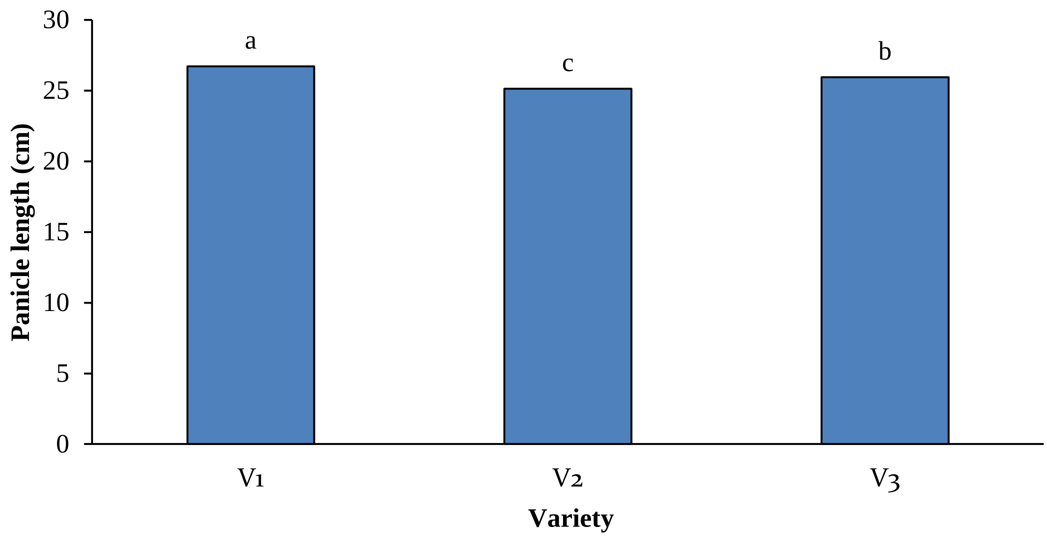
Combined effect of variety and different levels of boron and zinc fertilizer

Combined effect of variety and different levels of boron and zinc fertilizer significantly effect on number of non effective tillers hill^{-1} of boro rice (Table 4). Experiment result showed that, the maximum number of non effective tillers hill^{-1} (2.77) was recorded in V_2F_0 treatment combination. Whereas the minimum number of non effective tillers hill^{-1} (0.50) was recorded in V_1F_3 treatment combination.

4.2.3 Panicle length (cm)

Effect of variety

Panicle length is one aspect of panicle architecture and is usually measured as a yield-related trait. Panicle length, together with spikelet number and density, seed setting rate and grain plumpness, determines the grain number per panicle; hence, yield increases in rice. Experiment result revealed that different rice variety significantly influenced panicle length of boro rice (Fig. 11). From the experiment result it was clear that the maximum panicle length (26.72 cm) was recorded in V_1 (BRRI dhan29) treatment, whereas the minimum panicle length (25.13 cm) was recorded in V_2 (BRRI dhan50) treatment. Different rice varieties have different panicle length due to the genetic makeup of the variety and higher panicle length is obtained from high yielding varieties comparable to low yielding rice varieties. Hossain *et al.* (2016); Chamely *et al.* (2015) and Diaz *et al.* (2000) were found similar result which supported the present study and reported that panicle length varied among varieties.

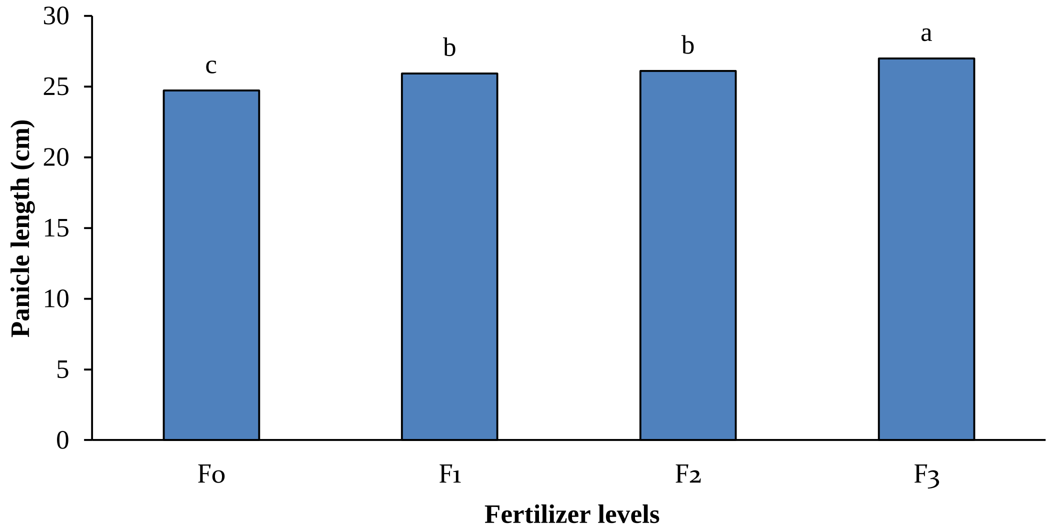


Here, V_1: BRRI dhan 29, V_2: BRRI dhan50 V_3: BRRI dhan55 and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 11. Effect of variety on panicle length of boro rice.

Effect of different levels of boron and zinc fertilizer

Panicle is an important yield contributing character as its bear grains and it was significantly influenced due to effect of different levels of boron and zinc fertilizer (Fig. 12). Result revealed that, the maximum panicle length (26.99 cm) was recorded in F_3 (Boron @ 15 kg/ha+ Zinc @ 20 kg/ha) treatment, whereas the minimum panicle length (24.71 cm) was recorded in F_0 (Control) treatment. Arif *et al.* (2012) also found similar result which supported the present finding and reported that the panicle length increased significantly and varied from 24 to 30.40 cm as a result of Zn, B and MT (Microtone) treatment. The plant treated with Zn + B at 3 + 1.5 kg/acre showed maximum response in panicle length of 30.40 cm as compared to the control (21.83 cm). Jena *et al.* (2006) reported that the higher value of panicle length might be due to increased transportation of photosynthates from source to sink due the application of zinc. Brown *et al.* (2002) reported that boron deficiency reduces chlorophyll and soluble protein contents in the leaves, and the resultant loss in photosynthetic enzyme activity obstructs the Hill reaction and decreases net photosynthesis as a result its affects on growth and yield of plant.



Here, F_0: Control, F_1: Boron @ 15 kg/ha, F_2: Zinc @ 20 kg/ha , F_3:Boron @ 15 kg/ha + Zinc @ 20 kg/ha and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 12. Effect of different levels of boron and zinc fertilizer on panicle length of boro rice.

Combined effect of variety and different levels of boron and zinc fertilizer

Different variety along with different level of boron and zinc fertilizer significantly effect on panicle length of boro rice (Table 4). Experiment result showed that, the maximum panicle length (28.67cm) was recorded in V_1F_3 treatment combination. Whereas the minimum panicle length (23.07 cm) was recorded in V_2F_0 treatment combination.

Table 4. Combined effect of variety and different level of boron and zinc fertilizers on effective, non-effective tillers hills^{-1} and panicle length of boro rice.

Treatment combinations	Effective tillers hill^{-1} (No.)	Non-effective tillers hill^{-1} (No.)	Panicle length (cm)
V_1F_0	13.67 e	2.10 b	25.33 c
V_1F_1	14.30 e	0.93 e	26.26 bc
V_1F_2	16.77 bc	1.33 d	26.60 b
V_1F_3	19.60 a	0.50 f	28.67 a
V_2F_0	7.33 g	2.77 a	23.07 d
V_2F_1	12.00 f	2.10 b	25.73 bc
V_2F_2	14.20 e	1.33 d	25.63 bc
V_2F_3	15.87 cd	1.10 e	26.10 bc
V_3F_0	13.53 e	1.90 c	25.73 bc
V_3F_1	13.53 e	1.90 c	25.80 bc
V_3F_2	15.43 d	1.80 c	26.03 bc
V_3F_3	17.70 b	1.00 e	26.20 bc
$LSD_{(0.05)}$	1.00	0.19	1.24
CV(%)	4.11	7.10	2.83

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

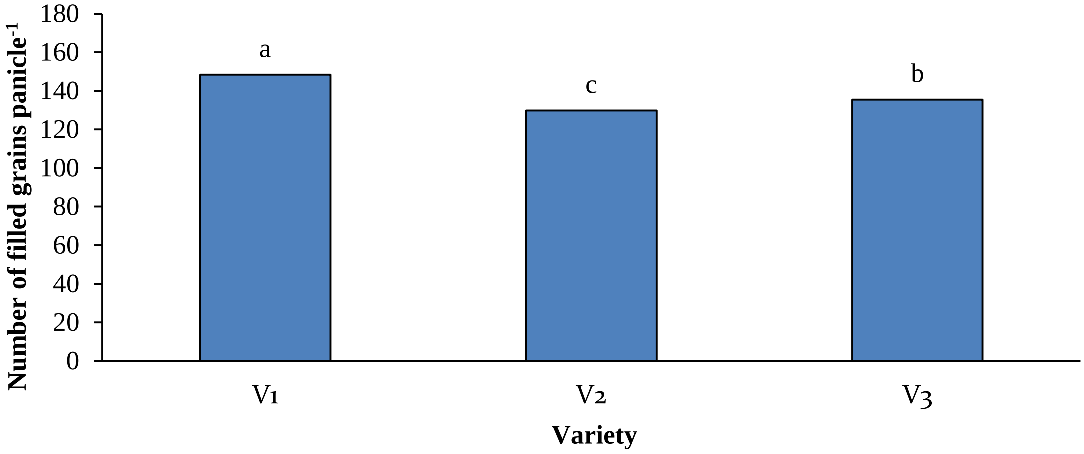
NS: Non Significant
V_1: BRRI dhan 29
V_2: BRRI dhan 50
V_3: BRRI dhan 55

F_0: Control
F_1: Boron @ 15 kg/ha
F_2: Zinc @ 20 kg/ha and
F_3: Boron @ 15 kg/ha + Zinc @ 20 kg/ha

4.2.4 Number of filled grains panicle^{-1}

Effect of variety

It is clear from the experiment data that different rice variety significantly influenced number of filled grains panicle^{-1} of boro rice (Fig. 13). Experiment result revealed that, the maximum, number of filled grains panicle^{-1} (148.45) was recorded in V_1 (BRRI dhan29) treatment. Whereas the minimum, number of filled grains panicle^{-1} (129.85) was recorded in V_2 (BRRI dhan50) treatment. Variation in grain filling may have occurred due to genetic, environmental or cultural management practices adopted. Ullah *et al.* (2016) also reported that the variation in filled grains panicle^{-1} was due to genotypic differences of varieties.

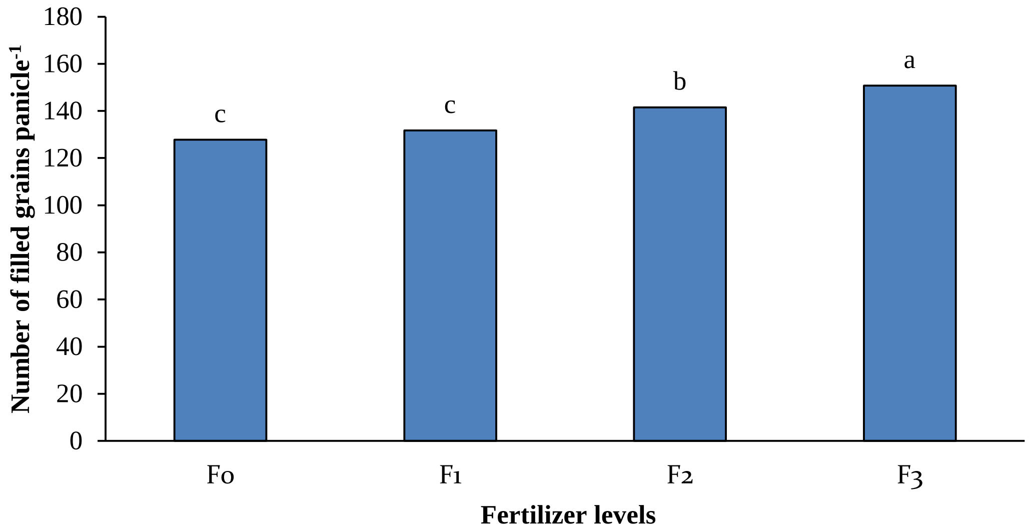


Here, V_1: BRRI dhan 29, V_2: BRRI dhan50 V_3: BRRI dhan55 and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 13. Effect of variety on number of filled grains panicle^{-1} of boro rice.

Effect of different levels of boron and zinc fertilizer

Different levels of boron and zinc fertilizer application alone with recommended NPK had significantly influenced number of filled grains panicle^{-1} of boro rice (Fig. 14). Experiment result showed that the maximum number of filled grains panicle^{-1} (150.75) was recorded in F_3 (Boron @ 15 kg/ha+ Zinc @ 20 kg/ha) treatment, whereas the minimum number of filled grains panicle^{-1} (127.80) was recorded in F_0 (Control) treatment which was statistically similar with F_1 (Boron @ 15 kg/ha) treatment recorded number of filled grains panicle^{-1} (131.69). The result obtained from the present study was similar with the findings of Islam (2015) and showed significant variation in respect of combined effect of boron and zinc in case of filled grain panicle^{-1} of rice. Highest filled grain panicle^{-1} (143.60) was recorded from B_2Zn_2 followed B_2Zn_1 and where the lowest filed grain panicle^{-1} (67.46) were achieved by B_0Zn_0 followed by B_0Zn_1 and B_1Zn_0 and B_2Zn_0.



Here, F_0: Control, F_1: Boron @ 15 kg/ha, F_2: Zinc @ 20 kg/ha , F_3:Boron @ 15 kg/ha + Zinc @ 20 kg/ha and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 14. Effect of different levels of boron and zinc fertilizer on number of filled grains panicle^{-1} of boro rice.

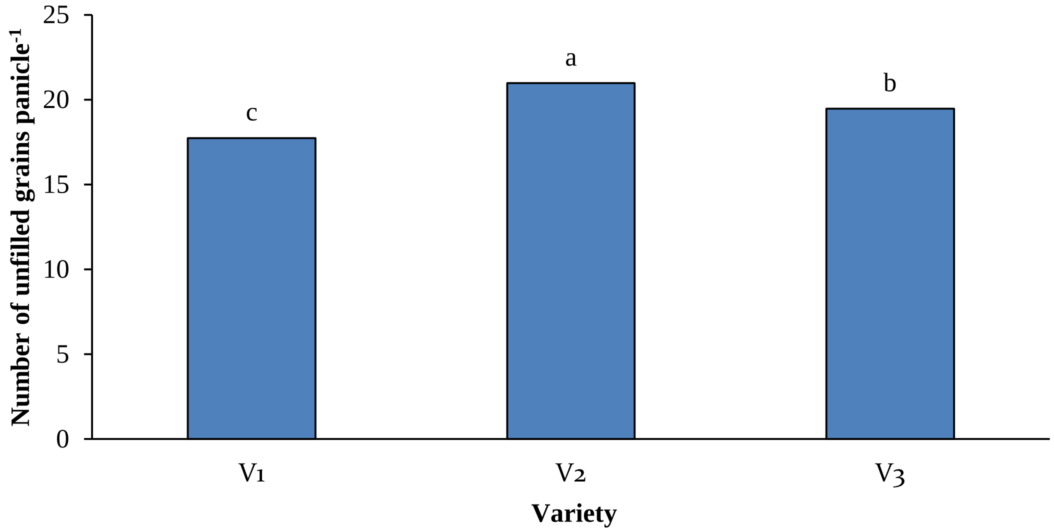
Combined effect of variety and different levels of boron and zinc fertilizer

Different variety along with different level of boron and zinc fertilizer significantly effect on number of filled grains panicle^{-1} boro rice (Table 5). Experiment result showed that, the maximum number of filled grains panicle^{-1} (159.63) was recorded in V_1F_3 treatment combination which was statistically similar with V_1F_2 (154.43) treatment combination. Whereas the minimum number of filled grains panicle^{-1} (115.90) was recorded in V_2F_0 treatment combination.

4.2.5 Number of unfilled grains panicle^{-1}

Effect of variety

Different rice variety showed significant effect on number of unfilled grains panicle^{-1} of boro rice (Fig. 15). Experiment result revealed that, the maximum, number of unfilled grains panicle^{-1} (20.97) was recorded in V_2 (BRRI dhan50) treatment. Whereas the minimum, number of unfilled grains panicle^{-1} (17.74) was recorded in V_1 (BRRI dhan29) treatment. Variation in number of unfilled grains panicle^{-1} might be due to genetic characteristics of the varieties. Afroz *et al.* (2019) also found similar result which supported the present finding and reported that different variety had different genetic characteristics which influences the unfilled grains panicle^{-1} and among different rice varieties the highest number (81.20) of grains panicle^{-1} and the lowest number (17.43) of sterile spikelets panicle^{-1} were observed in BRRI dhan29 cultivar. On the other hand, the lowest number (76.82) of grains panicle^{-1} was recorded in BRRI dhan28 cultivar.

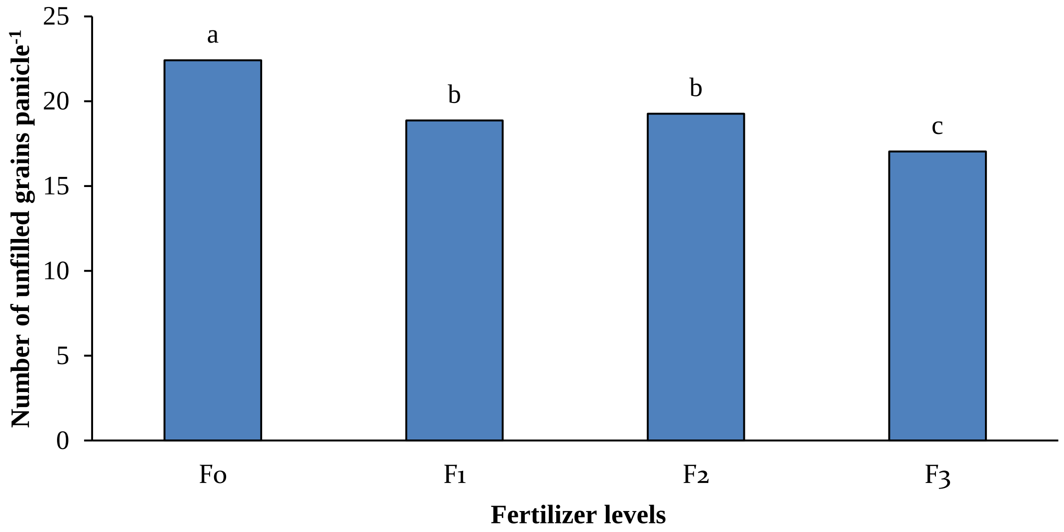


Here, V_1: BRRI dhan 29, V_2: BRRI dhan50 V_3: BRRI dhan55 and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 15. Effect of variety on number of unfilled grains panicle^{-1} of boro rice.

Effect of different levels of boron and zinc fertilizer

Among the undesirable traits, number of unfilled grains panicle^{-1} was important one and played a vital role in yield reduction. Different levels of boron and zinc fertilizer application alone with recommended NPK had significantly effect on number of unfilled grains panicle^{-1} of boro rice (Fig. 16). Experiment result showed that the maximum number of unfilled grains panicle^{-1} (22.41) was recorded in F_0 (Control) treatment, whereas the minimum number of filled grains panicle^{-1} (17.03) was recorded in F_3 (Boron @ 15 kg ha^{-1}+ Zinc @ 20 kg ha^{-1}) treatment. Islam (2015) also found similar result which supported the present finding and reported that boron, zinc and their combination had significant effect on unfilled grain production of rice. Among the different treatments result revealed the highest number of unfilled grain panicle^{-1} was recorded from control treatment where the lowest number of unfilled grain panicle^{-1} was achieved by boron and zinc treatment combination.



Here, F_0: Control, F_1: Boron @ 15 kg/ha, F_2: Zinc @ 20 kg/ha , F_3:Boron @ 15 kg/ha + Zinc @ 20 kg/ha and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 16. Effect of different levels of boron and zinc fertilizer on number of unfilled grains panicle^{-1} of boro rice.

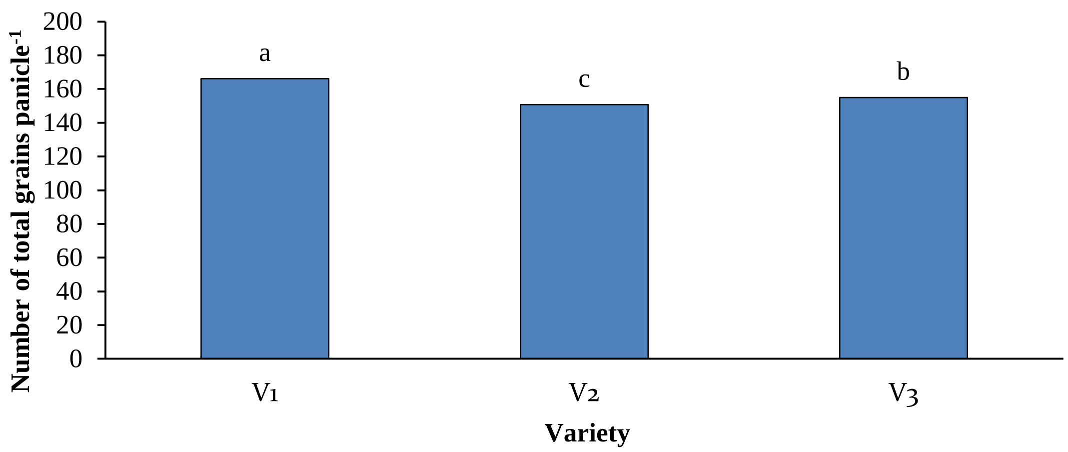
Combined effect of variety and different levels of boron and zinc fertilizer

Combined effect of variety and different levels of boron and zinc fertilizer significantly effect on number of unfilled grains panicle^{-1} boro rice (Table 5). Experiment result showed that, the maximum number of unfilled grains panicle^{-1} (25.50) was recorded in V_2F_0 treatment combination. Whereas the minimum number of unfilled grains panicle^{-1} length (15.20 g) was recorded in V_1F_3 treatment combination.

4.2.6 Number of total grains panicle^{-1}

Effect of variety

Number of total grains panicle^{-1} significantly influenced by different rice varieties (Fig. 17). Experiment result revealed that, the maximum, number of total grains panicle^{-1} (166.19) was recorded in V_1 (BRRI dhan29) treatment. Whereas the minimum, number of total grains panicle^{-1} (150.82) was recorded in V_2 (BRRI dhan50) treatment. Latif *et al.* (2020) reported that among the varieties, BRRI dhan29 produced the highest number (111.0) of grains panicle^{-1} and the lowest one (93.0) was recorded in BR14. Number of grains panicle^{-1} differed significantly due to variety. Singh and Gangwar (1989) also reported that variable numbers of grains panicle^{-1} were found among the varieties. Varietal differences regarding the number of grains panicle^{-1} might be due to differences in their genetic constituents.

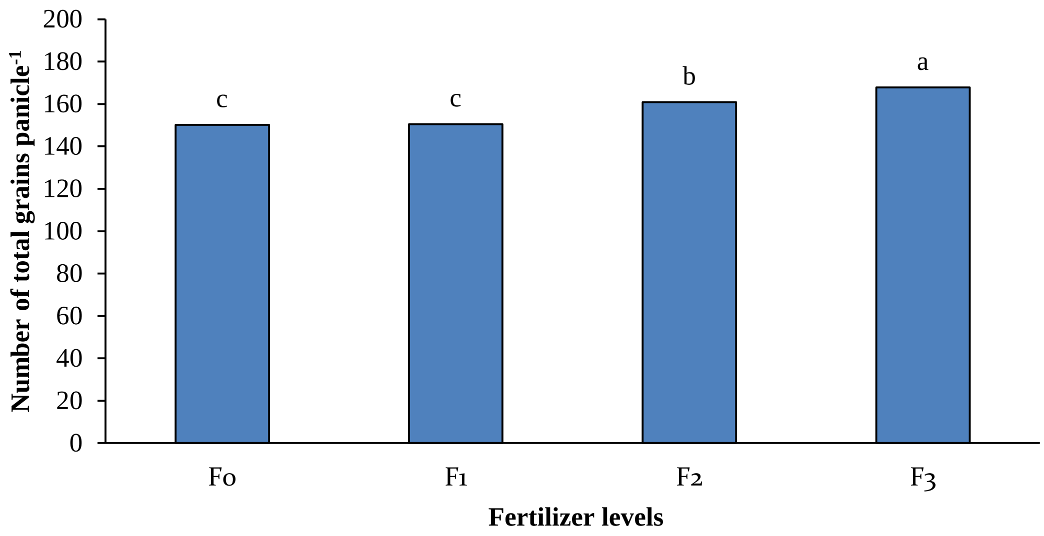


Here, V_1: BRRI dhan 29, V_2: BRRI dhan50 V_3: BRRI dhan55 and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 17. Effect of variety on number of total grains panicle^{-1}of boro rice.

Effect of different levels of boron and zinc fertilizer

Different levels of boron and zinc fertilizer application alone with recommended NPK had significantly influenced number of total grains panicle^{-1} of boro rice (Fig. 18). Experiment result showed that the maximum number of total grains panicle^{-1} (167.78) was recorded in F_3 (Boron @ 15 kg/ha+ Zinc @ 20 kg/ha) treatment, whereas the minimum number of total grains panicle^{-1} (150.21) was recorded in F_0 (Control) treatment which was statistically similar with F_1 (Boron @ 15 kg/ha) treatment recorded number of total grains panicle^{-1} (150.54). Qadir *et al.* (2013) also found similar result which supported the present finding and reported that application of. Boron along with Zn and Fe resulted in the production of higher number of spikelets panicle^{-1} and grains with higher test grain weight. Singh *et al.* (2012) reported that panicles m^{-2} and grains panicle^{-1} were significantly enhanced by the application of Zn @ 6 kg ha^{-1}. Amin *et al.* (2004) reported that application of Zn and B fertilizers in addition to N and P showed significant increase in yield and yield contributing attributes.



Here, F_0: Control, F_1: Boron @ 15 kg/ha, F_2: Zinc @ 20 kg/ha , F_3:Boron @ 15 kg/ha + Zinc @ 20 kg/ha and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 18. Effect of different levels of boron and zinc fertilizer on number total grains panicle^{-1} of boro rice.

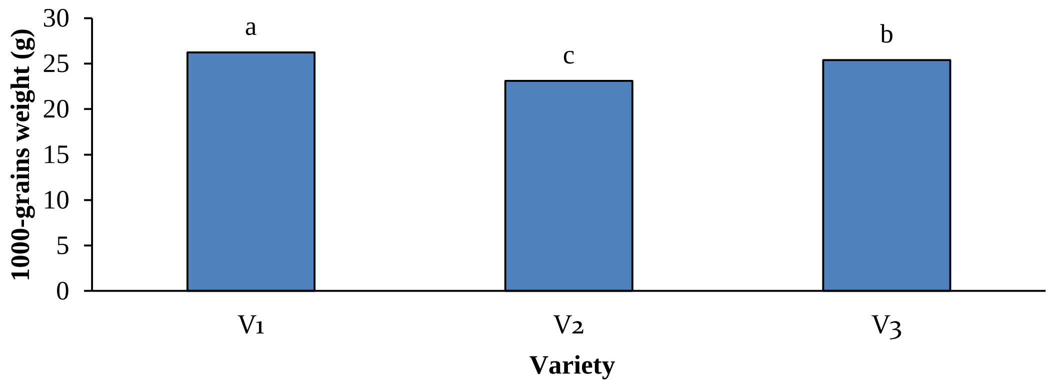
Combined effect of variety and different levels of boron and zinc fertilizer

Different variety along with different level of boron and zinc fertilizer significantly effect on number of total grains panicle^{-1} boro rice (Table 5). Experiment result showed that, the maximum number of total grains panicle^{-1} (174.83) was recorded in V_1F_3 treatment combination which was statistically similar with V_1F_2 (172.36) treatment combination. Whereas the minimum number of total grains panicle^{-1} (141.40) was recorded in V_2F_0 treatment combination which was statistically similar with V_2F_1 (144.64) treatment combination.

4.2.7 1000-grains weight (g)

Effect of variety

Different rice variety significantly effect on 1000 grains weight of boro rice (Fig. 19). Experiment result revealed that the maximum 1000 grains weight (26.24 g) was recorded in V_1 (BRRI dhan29) treatment whereas the minimum 1000 grains weight (23.10 g) was recorded in V_2 (BRRI dhan50) treatment. The differences of the 1000 grains weight among different rice varieties may be attributes to the varietal performance and genetic makeup of the varieties. The result obtained from the present study was similar with the findings of Latif *et al.* (2020) and they reported that 1000 grains weight were significantly differ due to the varietal performance. The highest 1000-grain weight (26.33 g) was obtained in BR14 than BRRI dhan28 (22.60 g) and BRRI dhan29 (22.43 g).

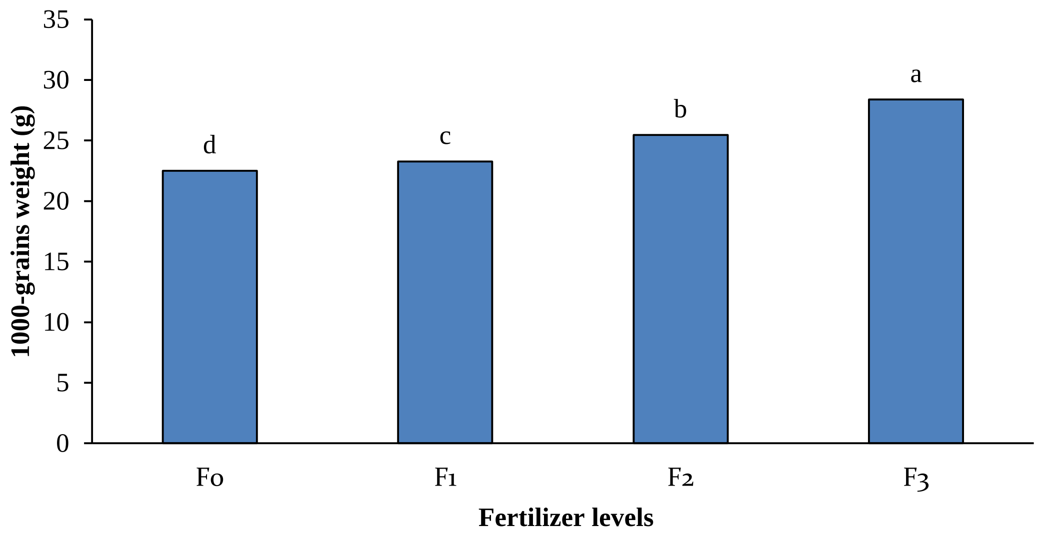


Here, V_1: BRRI dhan 29, V_2: BRRI dhan50 V_3: BRRI dhan55 and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 19. Effect of variety on 1000 grains weight of boro rice.

Effect of different levels of boron and zinc fertilizer

It is obvious from the experiment result that the 1000 grains weight of boro rice significantly varied due to effect of different levels of boron and zinc fertilizer (Fig. 20). Experiment result showed that, the maximum 1000 grains weight (28.39 g) was recorded in F_3 (Boron @ 15 kg/ha+ Zinc @ 20 kg/ha) treatment whereas the minimum 1000 grains weight (22.51 g) was recorded in F_0 (Control) treatment. Kumar *et al.* (2017) also found similar result which supported the present finding and showed that external application of zinc as $ZnSO_4$ @ 20 kg ha^{-1} and boron as borax @ 4 kg ha^{-1} significantly enhanced growth and yield of rice. Significantly highest thousand grain weight (26.96 g) were recorded in T_{12} treatment which received RDF + $ZnSO_4$ @ 20 kg ha^{-1} + Borax @ 4 kg ha^{-1} which was superior over all other treatments.



Here, F_0: Control, F_1: Boron @ 15 kg/ha, F_2: Zinc @ 20 kg/ha , F_3:Boron @ 15 kg/ha + Zinc @ 20 kg/ha and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 20. Effect of different levels of boron and zinc fertilizer on 1000 grains weight of boro rice.

Combined effect of variety and different levels of boron and zinc fertilizer

Combined effect of variety and different levels of boron and zinc fertilizer significantly effect on 1000 grains weight of boro rice (Table 5). Experiment result showed that, the maximum 1000 grains weight (30.20 g) was recorded in V_1F_3

treatment combination. Whereas the minimum 1000 grains weight (20.33 g) was recorded in V_2F_0 treatment combination.

Table 5. Combined effect of variety and different level of boron and zinc fertilizers on filled, unfilled, total grains panicle^{-1} and 1000-grains weight of boro rice

Treatment combinations	Number of filled grains panicle^{-1} (No.)	Number of unfilled grains panicle^{-1} (No.)	Number of total grains panicle^{-1} (No.)	1000-grains Weight (g)
V_1F_0	142.40 cd	19.43 c-f	161.83 b	23.67 e
V_1F_1	137.33 de	18.40 d-f	155.73 c	24.30 e
V_1F_2	154.43 ab	17.93 ef	172.36 a	26.77 c
V_1F_3	159.63 a	15.20 g	174.83 a	30.20 a
V_2F_0	115.90 g	25.50 a	141.40 f	20.33 g
V_2F_1	124.27 f	20.37 c	144.64 ef	22.00 f
V_2F_2	134.21 e	19.67 c-e	153.88 c	24.20 e
V_2F_3	145.04 c	18.33 d-f	163.37 b	25.87 cd
V_3F_0	125.10 f	22.30 b	147.40 de	23.53 e
V_3F_1	133.46 e	17.80 ef	151.26 cd	23.53 e
V_3F_2	136.10 de	20.17 cd	156.27 c	25.43 d
V_3F_3	147.57 bc	17.57 f	165.14 b	29.10 b
$LSD_{(0.05)}$	6.99	1.89	5.40	1.01
CV(%)	2.99	5.75	2.03	2.39

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

NS: Non Significant
V_1: BRRI dhan 29
V_2: BRRI dhan 50
V_3: BRRI dhan 55

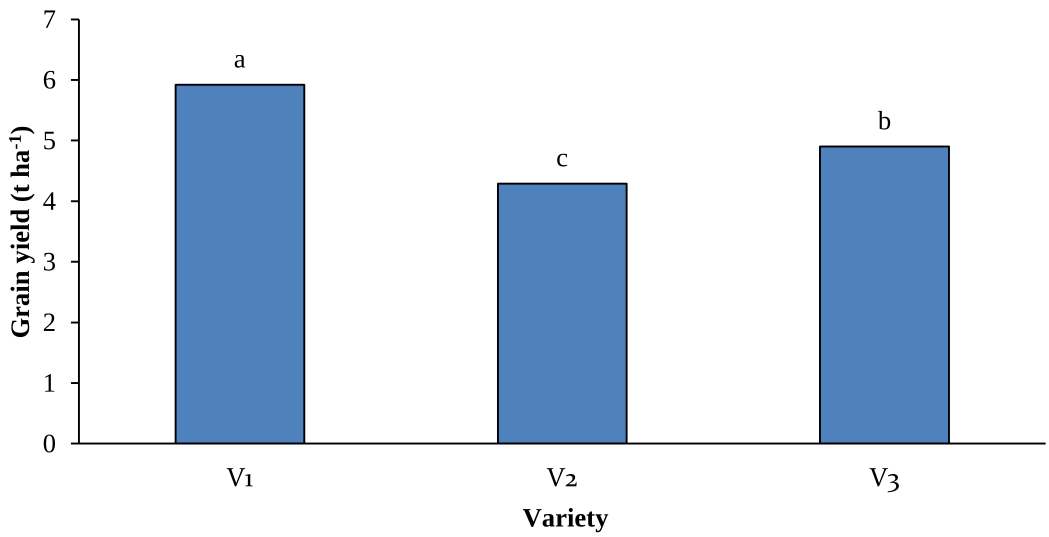
F_0: Control
F_1: Boron @ 15 kg/ha
F_2: Zinc @ 20 kg/ha and
F_3: Boron @ 15 kg/ha + Zinc @ 20 kg/ha

4.3 Yield characters

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

Effect of variety

Different rice varieties significantly influenced grain yield (t ha^{-1}) of boro rice (Fig. 21). Experiment result showed the maximum grain yield (5.92 t ha^{-1}) was recorded in V_1 (BRRI dhan29) treatment due to reason that filled grains per panicle along with maximum 1000-seed weight collectively contributed to higher grain yield whereas the minimum grain yield (4.29 t ha^{-1}) was recorded in V_2 (BRRI dhan50) treatment. Different rice variety have individual genetic makeup which influenced the growth and yield among different varieties. The result obtained from the present study was similar with the findings of Latif *et al.* (2020) and reported that BRRI dhan29 produced the highest grain yield (4.56 t ha^{-1}) than BRRI dhan28 (4.01 t ha^{-1}) and BR14 (3.77 t ha^{-1}). The probable reason of the different grain yields due to the different yield parameters (tillers hill^{-1}, grains panicle^{-1}, 1000-grain weight etc.) influenced by the genetic make-up of the variety. Hossain *et al.* (2016) reported that due to difference in variety, the grain yield of rice varied significantly.

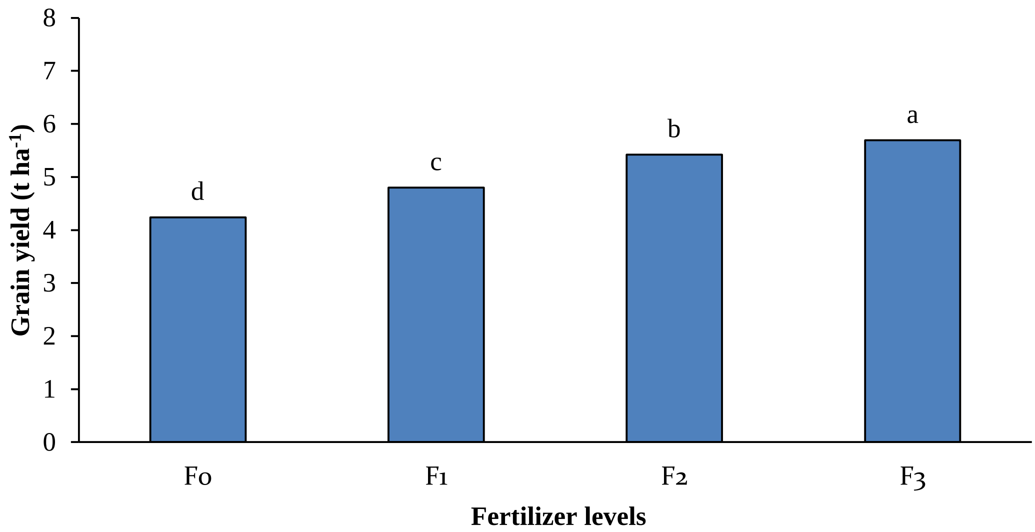


Here, V_1: BRRI dhan 29, V_2: BRRI dhan50 V_3: BRRI dhan55 and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 21. Effect of variety on grain yield of boro rice.

Effect of different levels of boron and zinc fertilizer

Grain yield of rice was significantly influenced due to effect of different levels of boron and zinc fertilizer. It is clear from the result that different levels of boron and zinc fertilizer caused marked variations in grain yield of boro rice (Fig. 22). Experiment result showed that, the maximum grain yield (5.69 t ha^{-1}) was recorded in F_3 (Boron @ 15 kg/ha+ Zinc @ 20 kg/ha) whereas the minimum grain yield (4.24 t ha^{-1}) was recorded in F_0 (Control) treatment. Debnath *et al.* (2015) reported that boron and Zn interacted synergistically to boost yield of rice crop. Arif *et al.* (2012) reported that the micronutrient required in minute quantity, and their deficiency leads to diminished growth and yield of crops. Fageria *et al.* (2011) reported that Zinc fertilization had significant effect on the grain yield of rice and highest grain yield was recorded with the application of zinc. Hatwar *et al. (*2003) observed that B enhances the growth attributes due to its favourable influence on metabolic pathways involved in cell division and elongation.



Here, F_0: Control, F_1: Boron @ 15 kg/ha, F_2: Zinc @ 20 kg/ha , F_3:Boron @ 15 kg/ha + Zinc @ 20 kg/ha and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 22. Effect of different levels of boron and zinc fertilizer on grain yield of boro rice.

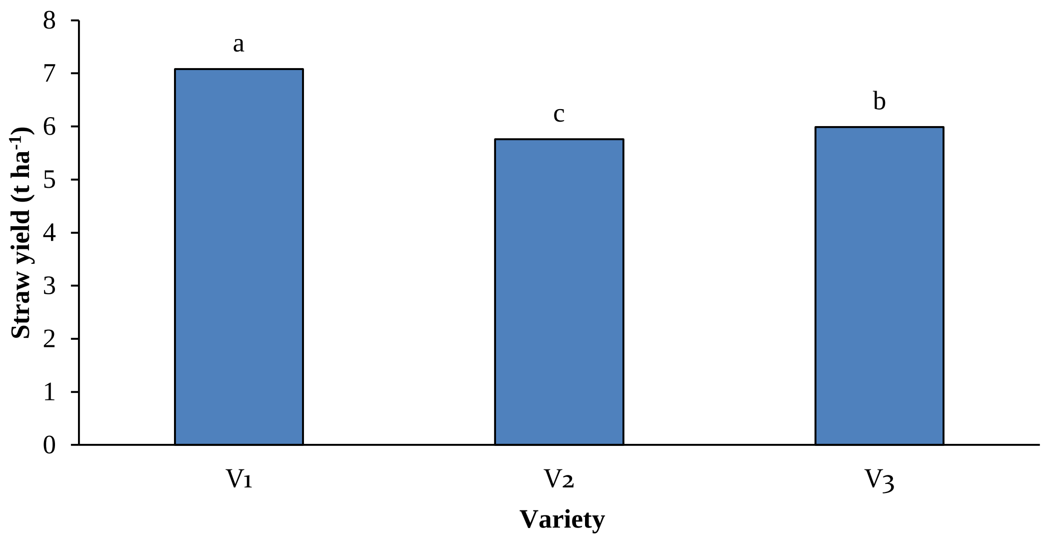
Combined effect of variety and different levels of boron and zinc fertilizer

Different variety along with different level of boron and zinc fertilizer significantly effect on grain yield boro rice (Table 6). Experiment result showed that, the maximum grain yield (6.86 t ha^{-1}) was recorded in V_1F_3 treatment combination. Whereas the minimum grain yield (3.80 t ha^{-1}) was recorded in V_2F_0 treatment combination which was statistically similar with V_2F_1 (4.02 t ha^{-1}) treatment combination.

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

Effect of variety

It is evident from the data that different rice variety caused significant variation in respect of straw yield of boro rice (Fig. 23). Experiment result showed that the maximum straw yield (7.08 t ha^{-1}) was recorded in V_1 (BRRI dhan29) treatment whereas the minimum straw yield (5.76 t ha^{-1}) was recorded in V_2 (BRRI dhan50) treatment. The differences of straw yield may be attributed to the genetic makeup and variation of the different rice varieties. Chamely *et al*. (2015) also found similar result with the present study and reported that straw yield varied among rice varieties.

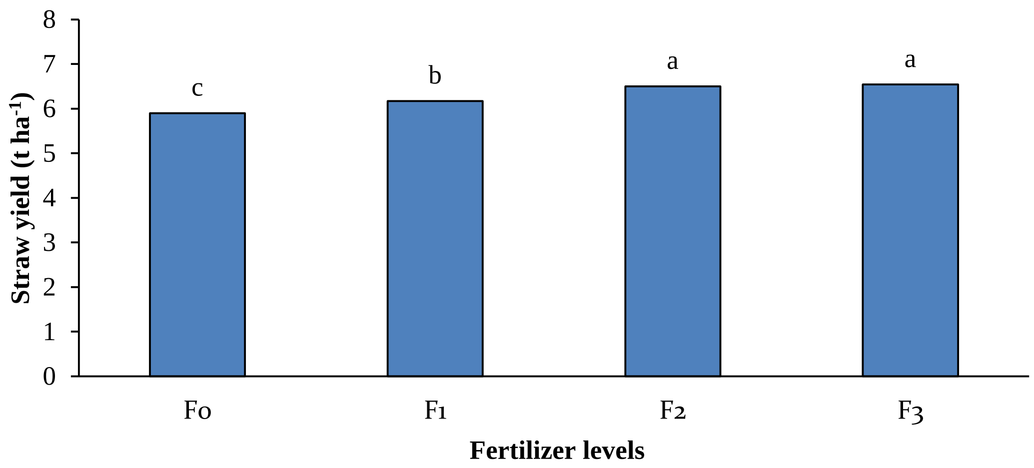


Here, V_1: BRRI dhan 29, V_2: BRRI dhan50 V_3: BRRI dhan55 and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 23. Effect of variety on straw yield of boro rice.

Effect of different levels of boron and zinc fertilizer

Different levels of boron and zinc fertilizer application alone with recommended NPK had significant effect on straw yield of boro rice (Fig. 24). Experiment result showed that the maximum straw yield (6.54 t ha^{-1}) was recorded in F_3 (Boron @ 15 kg/ha+ Zinc @ 20 kg/ha) treatment, which was statistically similar with F_2 (Zinc @ 20 kg/ha) treatment recorded straw yield (6.50 t ha^{-1}) whereas the minimum straw yield (5.90 t ha^{-1}) was recorded in F_0 (Control) treatment. The result obtained from the present study was similar with the findings of Qadir *et al*. (2013) and they reported that application of Zn and B @ 8 and 2 kg ha^{-1} along with recommended NPK recorded the highest grain and straw yield. Arif *et al*. (2012) also noticed that soil application of B and Zn @ 3 and 6 kg $acre^{-1}$ recorded the highest straw yield (13.84 t ha^{-1}) respectively.



Here, F_0: Control, F_1: Boron @ 15 kg/ha, F_2: Zinc @ 20 kg/ha , F_3:Boron @ 15 kg/ha + Zinc @ 20 kg/ha and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 24. Effect of different levels of boron and zinc fertilizer on straw yield of boro rice.

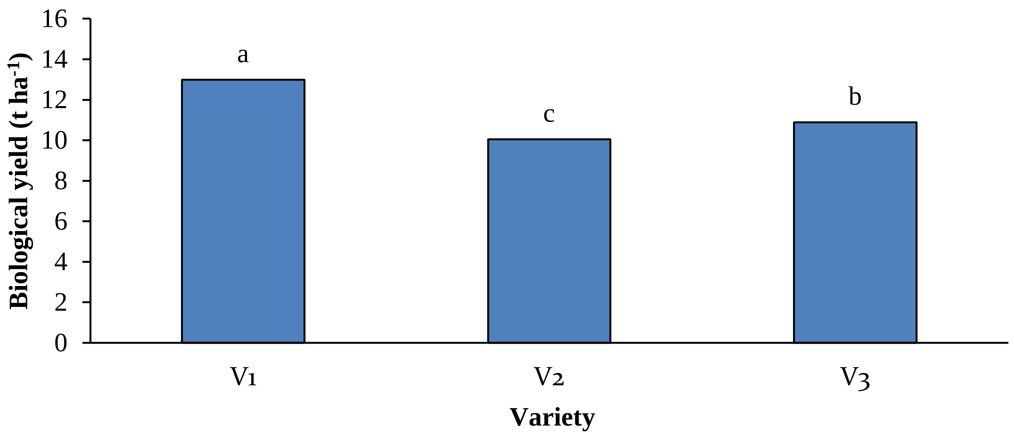
Combined effect of variety and different levels of boron and zinc fertilizer

Different variety along with different level of boron and zinc fertilizer significantly effect on straw yield of boro rice (Table 6). Experiment result showed that, the maximum straw yield (7.56 t ha^{-1}) was recorded in V_1F_3 treatment combination which was statistically similar with V_1F_2 (7.39 t ha^{-1}) treatment combination. Whereas the minimum straw yield (5.62 t ha^{-1}) was recorded in V_2F_0 treatment combination which was statistically similar with V_3F_0 (5.72 t ha^{-1}), V_3F_1 (5.75 t ha^{-1}), V_2F_1 (5.78 t ha^{-1}), V_2F_2 (5.79 t ha^{-1}) and V_2F_3 (5.85 t ha^{-1}) treatment combination.

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

Effect of variety

Different rice variety caused significant variation in respect of biological yield of boro rice (Fig. 25). Experiment result showed that the maximum biological yield (12.99 t ha^{-1}) was recorded in V_1 (BRRI dhan29) treatment whereas the minimum biological yield (10.05 t ha^{-1}) was recorded in V_2 (BRRI dhan50) treatment. The differences of straw yield may be attributed to the genetic makeup and variation of the different rice varieties. Chowhan *et al.* (2019) found similar results with the present study and reported that, varieties which had higher grain and straw yield ultimately obtained the highest biological yield.

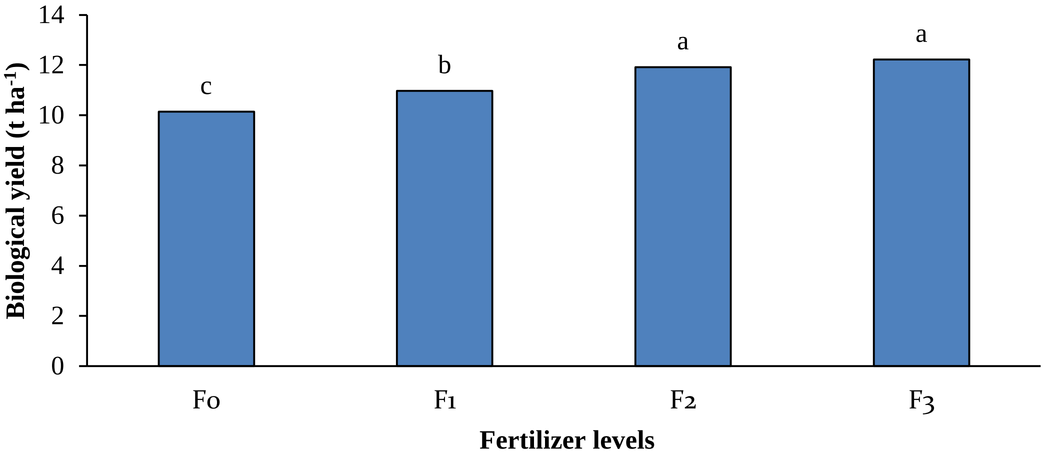


Here, V_1: BRRI dhan 29, V_2: BRRI dhan50 V_3: BRRI dhan55 and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 25. Effect of variety on biological yield of boro rice.

Effect of different levels of boron and zinc fertilizer

Different levels of boron and zinc fertilizer application had significant effect on biological yield of boro rice (Fig. 26). Experiment result showed that the maximum biological yield (12.22 t ha^{-1}) was recorded in F_3 (Boron @ 15 kg/ha+ Zinc @ 20 kg/ha) treatment, which was statistically similar with F_2 (Zinc @ 20 kg/ha) treatment recorded biological yield (11.92 t ha^{-1}) whereas the minimum biological yield (10.14 t ha^{-1}) was recorded in F_0 (Control) treatment. Zinc used in the formation of chlorophyll and some carbohydrates, conversion of starches to sugars and its presence in plant tissue helps the plant to withstand cold temperatures. Zinc is essential in the formation of auxins, which help with growth regulation and stem elongation. Boron plays an important role in regulating plants' hormone levels and promoting proper growth. Boron increases flower production and retention, pollen tube elongation and germination, and seed and fruit development. Application of Boron and zinc improved yield attributes of rice resulted in increase in grain, straw and biological yield of rice.



Here, F_0: Control, F_1: Boron @ 15 kg/ha, F_2: Zinc @ 20 kg/ha , F_3:Boron @ 15 kg/ha + Zinc @ 20 kg/ha and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 26. Effect of different levels of boron and zinc fertilizer on biological yield of boro rice.

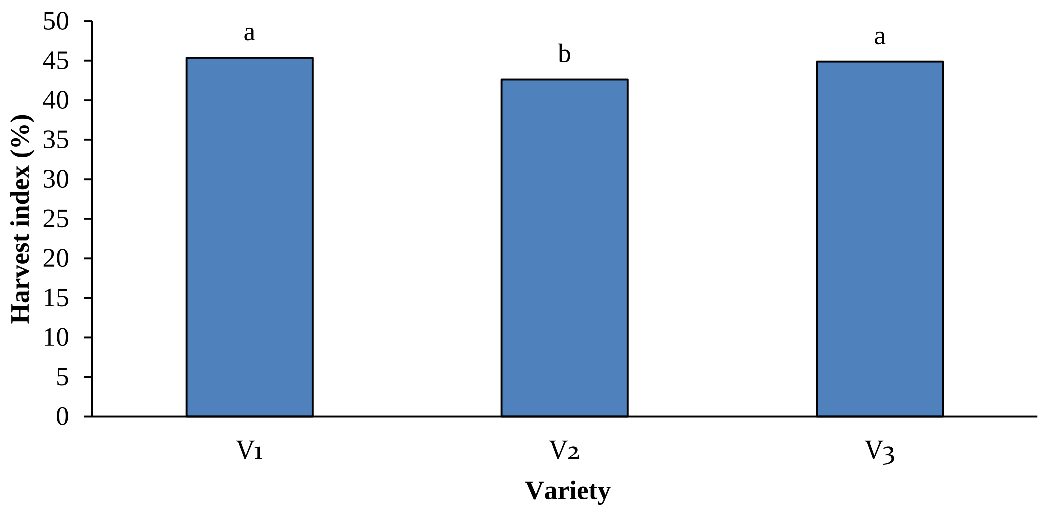
Combined effect of variety and different levels of boron and zinc fertilizer

Different variety along with different level of boron and zinc fertilizer significantly effect on biological yield of boro rice (Table 6). Experiment result showed that, the maximum biological yield (14.42 t ha^{-1}) was recorded in V_1F_3 treatment combination. Whereas the minimum biological yield (9.42 t ha^{-1}) was recorded in V_2F_0 treatment combination which was statistically similar with V_2F_1 (9.80 t ha^{-1}) and V_3F_0 (9.89 t ha^{-1}) treatment combination.

4.3.4 Harvest index (%)

Effect of variety

It is evident from the data that different rice variety caused significant variation in respect of harvest index of boro rice (Fig. 27). Experiment result revealed that, the maximum harvest index (45.36 %) was recorded in V_1 (BRRI dhan29) treatment which was statistically similar with V_3 (BRRI dhan55) treatment recorded harvest index (44.87 %) whereas the minimum harvest index (42.60 %) was recorded in V_2 (BRRI dhan50) treatment. Harvest index differed significantly among the varieties due to its genetic variability. Chowhan *et al.* (2019) also found similar result which supported the present finding and reported that high yielding rice maintained higher harvest index. Akter *et al.* (2018) also reported that harvest index was higher in BRRI dhan29 (42.86%) than BRRI dhan74 (39.28%).

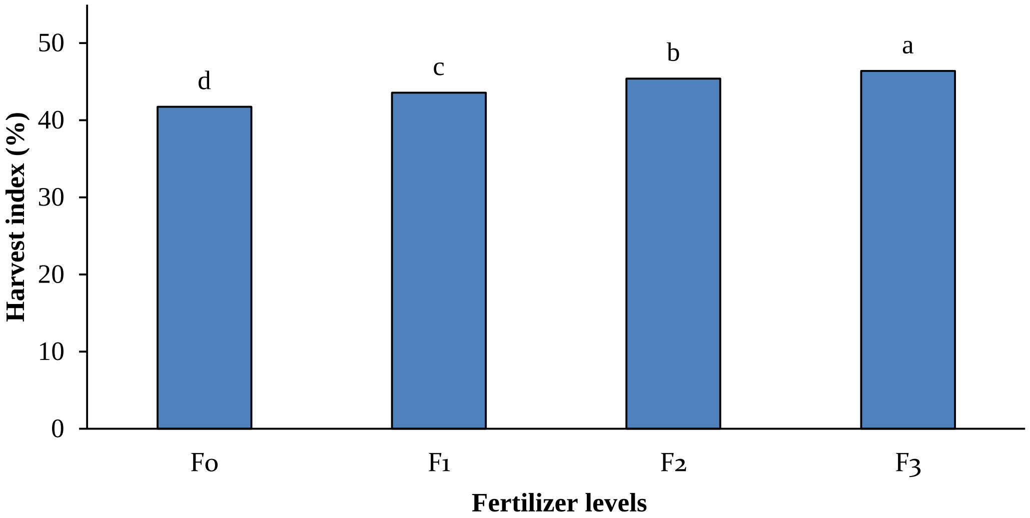


Here, V_1: BRRI dhan 29, V_2: BRRI dhan50 V_3: BRRI dhan55 and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 27. Effect of variety on harvest index of boro rice.

Effect of different levels of boron and zinc fertilizer

Different levels of boron and zinc fertilizer application had significant effect on harvest index of boro rice (Fig. 28). Experiment result showed that the maximum harvest index (46.38 %) was recorded in F_3 (Boron @ 15 kg/ha+ Zinc @ 20 kg/ha) treatment, whereas the minimum harvest index (41.74 %) was recorded in F_0 (Control) treatment. Zinc is an important micronutrient needed by the rice plant and its deficiency especially during the grain filling stage reduces the grain yield and efficiency of plants which ultimately impact on harvest index. Hussain *et al*. (2012) reported that the improvement in harvest index resulted from B application might be due to better starch utilization that results in higher seed setting and translocation of assimilates to developing grains, which increases the grain size and number of grains per panicle.



Here, F_0: Control, F_1: Boron @ 15 kg/ha, F_2: Zinc @ 20 kg/ha , F_3:Boron @ 15 kg/ha + Zinc @ 20 kg/ha and in bars having similar letter(s) are statistically similar and those having dissimilar letter(s) differ significantly at 0.05 level of probability.

Fig. 28. Effect of different levels of boron and zinc fertilizer on harvest index of boro rice.

Combined effect of variety and different levels of boron and zinc fertilizer

Combined effect of variety and different levels of boron and zinc fertilizer significantly effect on harvest index of boro rice (Table 6). Experiment result showed that, the maximum harvest index (47.57 %) was recorded in V_1F_3 treatment combination which was statistically similar with V_3F_3 (46.92 %). Whereas the minimum harvest index (40.34 %) was recorded in V_2F_0 treatment combination which was statistically similar with V_2F_1 (41.02 %) treatment combination.

Table 6. Combined effect of variety and different level of boron and zinc fertilizers on grain, straw, biological yield and harvest index of boro rice

Treatment combinations	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
V_1F_0	4.75 e	6.37 c	11.12 de	42.72 f
V_1F_1	5.69 c	6.98 b	12.67 c	44.83 de
V_1F_2	6.38 b	7.39 a	13.77 b	46.33 bc
V_1F_3	6.86 a	7.56 a	14.42 a	47.57 a
V_2F_0	3.80 g	5.62 e	9.42 h	40.34 g
V_2F_1	4.02 fg	5.78 e	9.80 h	41.02 g
V_2F_2	4.62 e	5.79 e	10.41 fg	44.38 e
V_2F_3	4.72 e	5.85 de	10.57 ef	44.65 de
V_3F_0	4.17 f	5.72 e	9.89 gh	42.16 f
V_3F_1	4.68 e	5.75 e	10.43 fg	44.87 de
V_3F_2	5.26 d	6.31 c	11.57 d	45.52 cd
V_3F_3	5.48 cd	6.20 cd	11.68 d	46.92 ab
$LSD_{(0.05)}$	0.32	0.38	0.61	1.08
CV(%)	3.75	3.63	3.18	1.45

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

NS: Non Significant

V_1: BRRI dhan 29

V_2: BRRI dhan 50

V_3: BRRI dhan 55

F_0: Control

F_1: Boron @ 15 kg/ha

F_2: Zinc @ 20 kg/ha and

F_3: Boron @ 15 kg/ha + Zinc @ 20 kg/ha

CHAPTER V

SUMMARY AND CONCLUSION

The present piece of work was carried out at the Research Farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2019 to April 2020 in Transplanting *Boro* season to investigate the morpho-physiological attributes and yield response of boro rice to boron and zinc. The experimental field belongs to the Agro-ecological zone (AEZ) of "The Modhupur Tract", AEZ-28. The soil of the experimental field belongs to the General soil type, Deep Red Brown Terrace Soils under Tejgaon soil series. The experiment consisted of two factors, and followed Randomized Complete Block Design. Factor A: Boro rice varieties *viz* (3); V_1: BRRI dhan29, V_2: BRRI dhan50, V_3: BRRI dhan55, Factor B: Different level of boron and zinc fertilizers *viz* (4); F_0: Control, F_1: Boron @ 15 kg/ha, F_2: Zinc @ 20 kg/ha and F_3: Boron @ 15 kg/ha + Zinc@20 kg/ha. The total numbers of unit plots were 36. The size of unit plot was 5.76 m^2 (2.4 m × 2.4 m). Data on different growths, yield contributing characters and yield were recorded to find out the response of boro rice varieties to different doses of zinc and boron fertilizers.

Different rice varieties and different doses of zinc and boron fertilizers, either individually or combined showed significant variations in respect of various parameters of boro rice.

In respect of different rice varieties, the maximum plant height (34.16, 47.12, 71.79, 83.35 and 95.27 cm) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in V_3 (BRRI dhan55) treatment. The maximum tiller number $hill^{-1}$ (3.50, 5.75, 14.33, 22.20 and 17.30) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in V_1 (BRRI dhan29) treatment. The maximum above ground dry matter weight $hill^{-1}$ (3.67, 10.51, 15.19, 17.66 and 38.38 g) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in V_1 (BRRI dhan29) treatment. The maximum, number of effective tillers $hill^{-1}$ (16.09) was recorded in V_1 (BRRI dhan29) treatment. The maximum, number of non effective tillers $hill^{-1}$ (1.83) was recorded in V_2 (BRRI dhan50) treatment. The maximum panicle length (26.72 cm), filled grains $panicle^{-1}$ (148.45), were recorded in V_1 (BRRI dhan29) treatment. The maximum, number of unfilled grains panicle^{-1} (20.97) was recorded in V_2 (BRRI dhan50) treatment. The maximum, number of total grains panicle^{-1} (166.19), 1000 grains weight (26.24 g), grain yield (5.92 t ha^{-1}), straw yield (7.08 t ha^{-1}), biological yield (12.99 t ha^{-1}) and harvest index (45.36 %) were recorded in V_1 (BRRI dhan29) treatment. Whereas the minimum plant height (25.53, 37.60, 59.62, 71.07 and 81.85 cm) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in V_2 (BRRI dhan50) treatment. The minimum tiller number hill^{-1} (2.92, 4.62, 10.66, 16.85 and 14.18) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in V_2 (BRRI dhan50) treatment. The minimum above ground dry matter weight hill^{-1} (2.85, 8.03, 11.04, 14.74 and 29.90 g) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in V_2 (BRRI dhan50) treatment. The minimum, number of effective tillers hill^{-1} (12.35) was recorded in V_2 (BRRI dhan50) treatment. The minimum, number of non effective tillers hill^{-1} (1.22) was recorded in V_1 (BRRI dhan29) treatment. The minimum panicle length (25.13 cm), number of filled grains panicle^{-1} (129.85) were recorded in V_2 (BRRI dhan50) treatment. The minimum, number of unfilled grains panicle^{-1} (17.74) was recorded in V_1 (BRRI dhan29) treatment. The minimum, number of total grains panicle^{-1} (150.82), 1000 grains weight (23.10 g), grain yield (4.29 t ha^{-1}), straw yield (5.76 t ha^{-1}), biological yield (10.05 t ha^{-1}) and harvest index (42.60 %) were recorded in V_2 (BRRI dhan50) treatment.

In respect of different doses of zinc and boron fertilizers applications, the maximum plant height (33.74, 47.85, 71.81, 84.20 and 93.63 cm) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in F_3 (Boron @ 15 kg/ha+ Zinc @ 20 kg/ha) treatment. The maximum tiller number hill^{-1} (4.10, 5.80, 15.59, 21.54 and 18.59) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in F_3 (Boron @ 15 kg/ha + Zinc @ 20 kg/ha) treatment. The maximum above ground dry matter weight hill^{-1} (3.47, 9.84, 14.05, 18.05 and 36.19) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in F_3 (Boron @ 15 kg/ha + Zinc @ 20 kg/ha) treatment. The maximum, number of effective tillers hill^{-1} (17.72) was recorded in F_3 (Boron @ 15 kg/ha+ Zinc @ 20 kg/ha) treatment. The maximum, number of non effective tillers hill^{-1} (2.26) was recorded in F_0 (Control) treatment. The maximum panicle length (26.99 cm) was recorded in F_3 (Boron @ 15 kg/ha+ Zinc @ 20 kg/ha) treatment. The maximum number of filled grains panicle^{-1} (150.75) was recorded in F_3 (Boron @ 15 kg/ha+

Zinc @ 20 kg/ha) treatment. The maximum number of unfilled grains panicle^{-1} (22.41) was recorded in F_0 (Control) treatment. The maximum number of total grains panicle^{-1} (167.78), 1000 grains weight (28.39 g), grain yield (5.69 t ha^{-1}), straw yield (6.54 t ha^{-1}), biological yield (12.22 t ha^{-1}) and harvest index (46.38 %) were recorded in F_3 (Boron @ 15 kg/ha+ Zinc @ 20 kg/ha) treatment. The minimum plant height (26.63, 37.48, 60.30, 71.44 and 83.98 cm) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in F_0 (Control) treatment. The minimum tiller number hill^{-1} (2.53, 4.51, 10.51, 17.05 and 13.77) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in F_0 (Control) treatment. The minimum above ground dry matter weight hill^{-1} (2.89, 8.04, 11.08, 14.32 and 30.15 g) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in F_0 (Control) treatment. The minimum, number of effective tillers hill^{-1} (11.51) was recorded in F_0 (Control) treatment. The minimum, number of non effective tillers hill^{-1} (0.87) was recorded in F_3 (Boron @ 15 kg/ha+ Zinc @ 20) treatment. The minimum panicle length (24.71 cm) was recorded in F_0 (Control) treatment. The minimum number of filled grains panicle^{-1} (127.80) was recorded in F_0 (Control) treatment. The minimum number of filled grains panicle^{-1} (17.03) was recorded in F_3 (Boron @ 15 kg/ha+ Zinc @ 20 kg/ha) treatment. The minimum number of total grains panicle^{-1} (150.21), 1000 grains weight (22.51 g), grain yield (4.24 t ha^{-1}), straw yield (5.90 t ha^{-1}), biological yield (10.14 t ha^{-1}) and harvest index (41.74 %) were recorded in F_0 (Control) treatment.

In case of combined effect, The maximum plant height (38.78, 52.03, 81.02, 92.68 and 104.53 cm) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in V_3F_3 treatment combination. The maximum tillers number hill^{-1} (5.00, 6.20, 17.33, 23.97 and 20.10) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in V_1F_3 treatment combination. The maximum above ground dry matter weight hill^{-1} (3.93, 11.64, 17.06, 21.24 and 42.12) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in V_1F_3 treatment combination. The maximum number of effective tillers hill^{-1} (19.60) was recorded in V_1F_3 treatment combination. The maximum number of non effective tillers hill^{-1} (2.77) was recorded in V_2F_0 treatment combination. The maximum panicle length (28.67cm) was recorded in V_1F_3 treatment combination. The maximum number of filled grains panicle^{-1} (159.63) was recorded in V_1F_3 treatment combination. The maximum number of unfilled grains panicle^{-1} (25.50) was recorded in V_2F_0 treatment combination. The maximum number of total grains panicle^{-1} (174.83), 1000 grains weight (30.20 g), grain yield (6.86 t ha^{-1}), straw yield (7.56 t ha^{-1}), biological yield (14.42 t ha^{-1}) and harvest index (47.57 %) were recorded in V_1F_3 treatment combination. Whereas the minimum plant height (23.10, 32.05, 54.73, 64.70 and 76.75 cm) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in V_2F_0 treatment combination. The minimum tillers number hill^{-1} (2.00, 4.07, 9.20, 13.86 and 10.10) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in V_2F_0 treatment combination. The minimum above ground dry matter weight hill^{-1} (2.32, 7.56, 10.27 13.22 and 28.53 g) at 30, 45, 60, 75 DAT and at harvest respectively was recorded in V_2F_0 treatment combination. The minimum number of effective tillers hill^{-1} (7.33) was recorded in V_2F_0 treatment combination. The minimum number of non effective tillers hill^{-1} (0.50) was recorded in V_1F_3 treatment combination. The minimum panicle length (23.07 cm) was recorded in V_2F_0 treatment combination. The minimum number of filled grains panicle^{-1} (115.90) was recorded in V_2F_0 treatment combination. The minimum number of unfilled grains panicle^{-1} length (15.20 g) was recorded in V_1F_3 treatment combination. The minimum number of total grains panicle^{-1} (141.40), 1000 grains weight (20.33 g), grain yield (3.80 t ha^{-1}), straw yield (5.62 t ha^{-1}), biological yield (9.42 t ha^{-1}) and harvest index (40.34 %) were recorded in V_2F_0 treatment combination.

Conclusions

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

i. Among different boro rice variety, BRRI dhan29 treatment performed the best and recorded the maximum number of effective tillers hill^{-1} (16.09), panicle length (26.72 cm), filled grains panicle^{-1} (148.45), number of total grains panicle^{-1} (166.19), 1000 grains weight (26.24 g), grain yield (5.92 t ha^{-1}), straw yield (7.08 t ha^{-1}), biological yield (12.99 t ha^{-1}) and harvest index (45.36 %).

ii. In case of different doses of zinc and boron fertilizers applications, the maximum, number of effective tillers hill^{-1} (17.72), panicle length (26.99 cm), filled grains panicle^{-1} (150.75), total grains panicle^{-1} (167.78), 1000 grains weight (28.39 g), grain yield (5.69 t ha^{-1}), straw yield (6.54 t ha^{-1}), biological yield (12.22 t ha^{-1}) and harvest index (46.38 %) were recorded in F_3 (Boron @ 15 kg/ha+ Zinc @ 20 kg/ha) treatment.

iii. In respect of treatment combination V_1F_3 treatment combination perform best and recorded the maximum number of effective tillers hill^{-1} (19.60), panicle length (28.67cm), number of filled grains panicle^{-1} (159.63), number of total grains panicle^{-1} (174.83), 1000 grains weight (30.20 g), grain yield (6.86 t ha^{-1}), straw yield (7.56 t ha^{-1}), biological yield (14.42 t ha^{-1}) and harvest index (47.57 %).

Thus for production of boro rice, cultivation of BRRI dhan29 along with application of Boron @ 15 kg/ha+ Zinc @ 20 kg/ha increasing the production of boro rice and considered as a suitable treatment combination for rice production comparable to other treatment combinations.

Recommendations

The following recommendations are proposed here under:

- ❖ Before making final conclusion, further trials with the same treatment combinations on different locations of Bangladesh would be useful. However, further investigation is necessary for the other soil types under different AEZ in Bangladesh.

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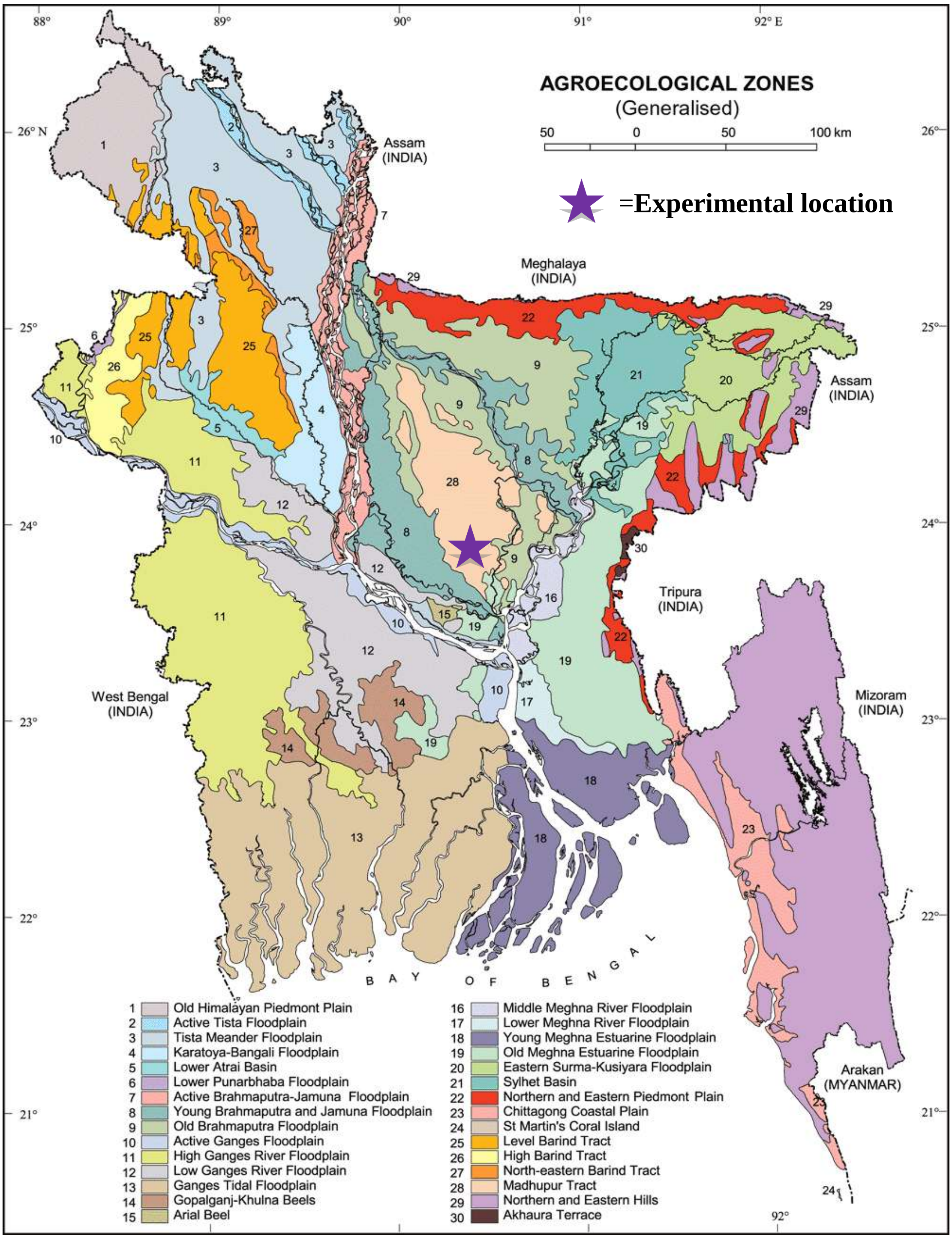
APPENDICES

Appendix I. Map showing the experimental location under study



Appendix II. Soil characteristics of the experimental field

A. Morphological features of the experimental field

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

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

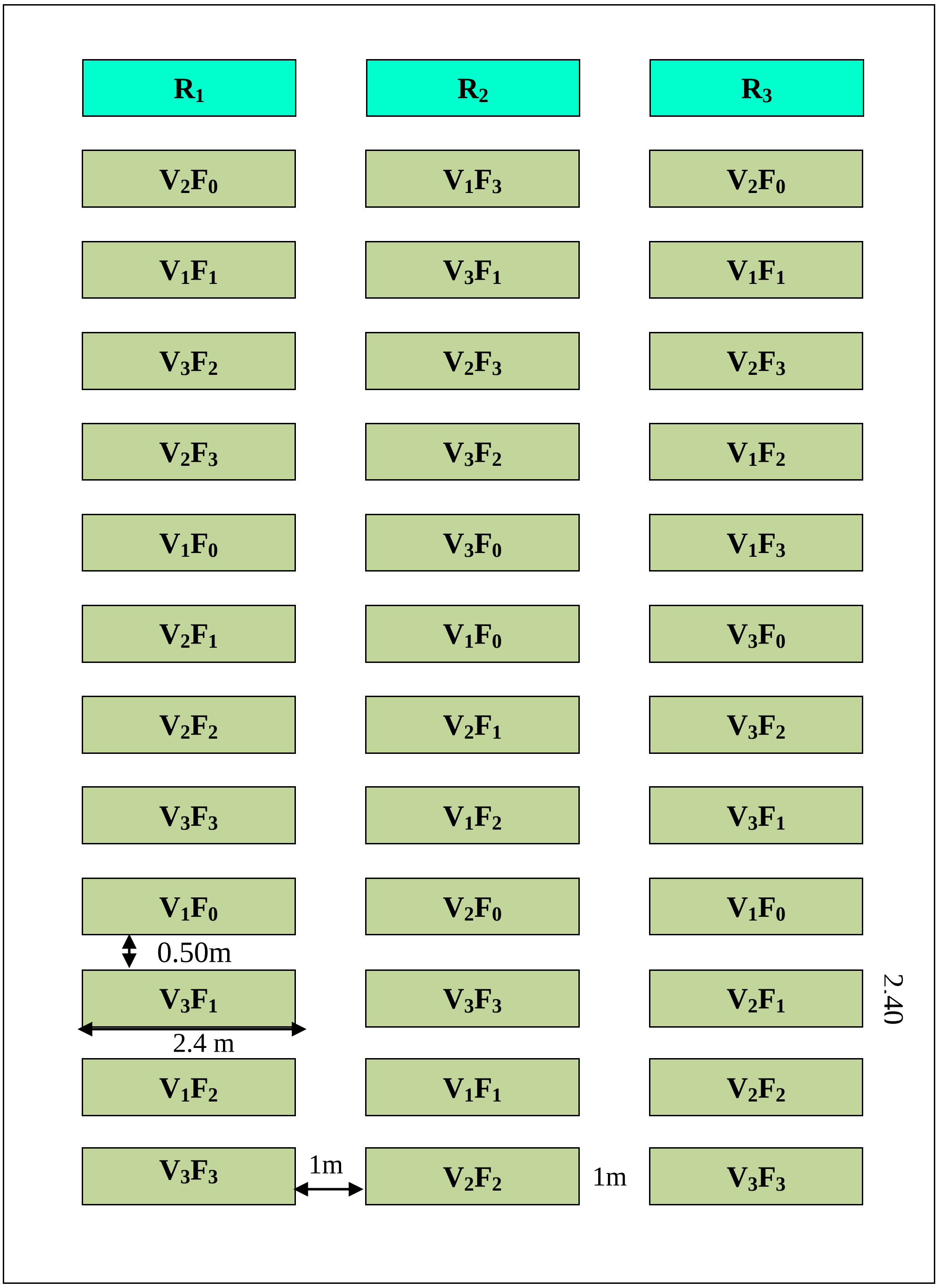
Physical characteristics	
Constituents	**Percent**
Clay	29 %
Sand	26 %
Silt	45 %
Textural class	Silty clay
Chemical characteristics	
Soil characteristics	**Value**
Available P (ppm)	20.54
Exchangeable K (mg/100 g soil)	0.10
Organic carbon (%)	0.45
Organic matter (%)	0.78
pH	5.6
Total nitrogen (%)	0.03

Appendix III. Monthly meteorological information during the period from November, 2019 to April 2020.

Year	Month	Air temperature (^0C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2019	November	29.6	19.8	53	00
	December	28.8	19.1	47	00
2020	January	25.5	13.1	41	00
	February	25.9	14	34	7.7
	March	31.9	20.1	38	71
	April	32.7	23.8	74	168

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

Appendix IV. Layout of the experimental field



LEGENDS
Here, V_1: BRRI dhan 29, V_2: BRRI dhan50 V_3: BRRI dhan55, F_0: Control, F_1: Boron @ 15 kg/ha, F_2: Zinc @ 20 kg/ha and F_3:Boron @ 15 kg/ha + Zinc @ 20 kg/ha

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

Mean square of plant height at						
Source	Df	30 DAT	45 DAT	60 DAT	75 DAT	At harvest
Replication (R)	2	2.083	6.333	4.083	7.000	3.583
Variety (A)	2	225.43**	276.28**	444.84**	452.93**	553.17**
Boron & Zinc fertilizers (B)	3	94.24**	192.46**	229.67**	314.78**	204.23**
(A × B)	6	4.34*	16.454*	40.77**	54.313**	61.19**
Error	18	4.356	11.788	8.538	14.273	7.40
Total	35					

**: Significant at 0.01 level of probability

* : Significant at 0.05 level of probability

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

Mean square of number of tillers hill^{-1} at						
Source	Df	30 DAT	45 DAT	60 DAT	75 DAT	At harvest
Replication (R)	2	0.01083	0.03583	0.0391	0.1944	0.6044
Variety (A)	2	1.1259**	3.9041**	43.678**	89.244**	32.983**
Boron & Zinc fertilizers (B)	3	4.6356**	2.8359**	45.718**	46.691**	41.274**
(A × B)	6	2.6506**	0.1001*	3.238**	1.965**	3.799*
Error	18	0.0272	0.03583	0.2491	0.5581	0.3077
Total	35					

**: Significant at 0.01 level of probability

* : Significant at 0.05 level of probability

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

Mean square of above ground dry matter weight hill^{-1} at						
Source	Df	30 DAT	45 DAT	60 DAT	75 DAT	At harvest
Replication (R)	2	0.01701	0.148	0.3508	0.8033	2.170
Variety (A)	2	2.0188**	19.983**	56.014**	27.935**	231.61**
Boron & Zinc fertilizers (B)	3	0.5672**	5.7663**	15.828**	21.849**	61.88**
(A × B)	6	0.0804**	0.4593*	1.3025**	2.351*	5.54*
Error	18	0.0137	0.1364	0.3327	0.7488	2.079
Total	35					

**: Significant at 0.01 level of probability
* : Significant at 0.05 level of probability

Appendix VIII. Analysis of variance of the data of effective, non-effective tillers hills^{-1}, panicle length, filled, unfilled and total grains panicle^{-1} of boro rice

Mean square value of				
Source	Df	Effective tillers hill^{-1} (No.)	Non-effective tillers hill^{-1} (No.)	Panicle length (cm)
Replication (R)	2	0.5437	0.00333	1.08333
Variety (A)	2	44.6063**	1.18390**	7.51397**
Boron & Zinc fertilizers (B)	3	65.2825**	2.93500**	7.90962**
(A × B)	6	4.7419**	0.38160**	1.99238**
Error	18	0.3552	0.01233	0.53788
Total	35			

**: Significant at 0.01 level of probability
* : Significant at 0.05 level of probability

Appendix IX. Analysis of variance of the data of filled, unfilled, total grains panicle^{-1} and 1000-grains weight of boro rice

Mean square of above ground dry matter weight hill^{-1} at					
Source	Df	Filled grains panicle^{-1} (No.)	Unfilled grains panicle^{-1} (No.)	Total grains panicle^{-1} (No.)	1000-grains Weight (g)
Replication (R)	2	18.86	2.3333	8.361	0.5437
Variety (A)	2	1088.68**	31.2954**	756.877**	31.6163**
Boron & Zinc fertilizers (B)	3	957.51**	44.9295**	654.710**	62.5442**
(A × B)	6	48.66*	4.6439*	28.189*	1.1186*
Error	18	17.04	1.2424	10.179	0.3552
Total	35				

**: Significant at 0.01 level of probability
* : Significant at 0.05 level of probability

Appendix X. Analysis of variance of the data of grain, straw, biological yield and harvest index of boro rice

Mean square of					
Source	**Df**	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication (R)	2	8.13409	5.89889	27.5857	26.0863
Variety (A)	2	3.78676**	0.80174**	8.0499**	37.9134**
Boron & Zinc fertilizers (B)	3	0.19293**	0.17339**	0.6834**	1.0530**
(A × B)	6	0.03574**	0.05194*	0.1290**	0.4100*
Error	18				
Total	35				

**: Significant at 0.01 level of probability
* : Significant at 0.05 level of probability

PLATES

Plate 1: Photograph showing transplanting of boro rice

Plate 2: Photograph showing grain filling stage of boro rice