INFLUENCE OF IRRIGATION AND FOLIAR APPLICATION OF BORON FERTILIZER ON GROWTH, YIELD AND NUTRIENTS CONTENT OF BARI GOM 26

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CERTIFICATE

This is to certify that the thesis entitled "Influence of irrigation and foliar application of boron fertilizer on growth, yield and nutrients content of BARI Gom26" submitted to the Department of Agricultural Chemistry, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Agricultural Chemistry, embodies the result of a piece of bona-fide research work carried out by Rabiul Islam Mondol, Registration No. 10-04161 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2017
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INFLUENCE OF IRRIGATION AND FOLIAR APPLICATION OF BORON FERTILIZER ON GROWTH, YIELD AND NUTRIENTS CONTENT OF BARI GOM 26

ABSTRACT

An experiment was conducted at the experimental site of Sher-e-Bangla Agricultural University (SAU) during the period from November 2016 to March 2017 to study the influence of irrigation and foliar application of boron fertilizer on growth, yield and nutrients content of BARI Gom 26. The experiment consists of two factors such as three irrigation level *viz*. (i) I_0 (No irrigation; Control), (ii) I_1 (One irrigation given at crown root initiation (CRI) stage; 18 DAS), (iii) I_2 (Two irrigations, one at CRI stage; 18 DAS and other at panicle initiation; PI stage; 55 DAS) and four levels of foliar application of boron (B) *viz*. (i) B_0 (0 kg H_3BO_3 ha^{-1}; Control), (ii) B_1 (1.5 kg H_3BO_3 ha^{-1}), (iii) B_2 (2.0 kg H_3BO_3 ha^{-1}) and (iv) B_3 (2.5 kg H_3BO_3 ha^{-1}). The experiment was laid out in a randomized complete block design with three replications. Results indicated that irrigation treatment I_2 (Two irrigations at CRI stage and PI stage) with the combination of B_2 (2.0 kg H_3BO_3 ha^{-1}) gave the highest dry weight $plant^{-1}$ (34.76 g), spike length (17.65 cm), number of spikelets $spike^{-1}$ (61.20) number of grains $spike^{-1}$ (41.63), 1000 grain weight (48.82 g), grain yield (4.66 t ha^{-1}), stover yield (6.42 t ha^{-1}), biological yield (11.08 t ha^{-1}) and highest harvest index (42.06%). Results also revealed that different levels of irrigation and foliar application of boron had no significant effect on concentration of N, P and S but significant effect was found in terms of concentration of K and B both in grain and straw. Combined effect of irrigation and foliar application of boron, I_1B_3 gave highest K concentration (0.855%) in grain but I_1B_2 gave highest K concentration (1.63) in straw. Again, I_2B_3 gave highest B concentration both grain and straw (14.80 and 20.10 μg g^{-1} respectively). The Overall Results sugest that B in the form of H_3BO_3 @ $2kgha^{-1}$ along with to irrigations at 18 and 55 DAS of can be advised to apply for getting maximum yield of BARIGOM 26 under the agro climatic conditions of SAU

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSIR	=	Bangladesh Council of Scientific Research Institute
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan’s Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agriculture Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m^2	=	Meter squares
ml	=	Milliliter
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celsius
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Milligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Littre
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Wheat (*Triticumaestivum*) is one of the leading cereals in the world. It belongs to the family Gramineae and it is the world's most widely cultivated cereal crop which ranks first followed by rice. It is preferable to rice for its higher seed protein content. It ranks first both in acreage and production among the grain crops of the world (FAO, 2008). About one third of the world population lives on wheat grains for their subsistence (FAO, 2007). Wheat grain is rich in food value containing 12% protein, 1.72% fat, 69.60% carbohydrate and 27.20% minerals (BARI, 2006).

Bangladesh is an over populated country. Increasing agricultural production per unit area of land is becoming most important step to cope with the present population growth in Bangladesh. Wheat can be a good supplement of rice and it can play a vital role to feed this vast population. From nutritional point of view, wheat is superior to rice for its higher protein content.

Bangladesh produces 1302998 metric tons of wheat per annum from 1061602 acres of land with an average yield of 3.03 t ha^{-1} (BBS, 2014) and it can be increased up to 6.8 t ha^{-1} (RARS, 2002). So, there is an ample opportunity to increase production of wheat per unit area through adoption of modern and improved agronomic practices such as proper irrigation practice optimum seed rate, timely sowing and judicious application of fertilizer and other inputs.

Among the factors responsible for low grain yield of wheat, different factors such as lack of irrigation water and plant nutrient, weed competition, insect attack, disease infection etc. are the most important. About 30% of wheat production is lost due to lack of irrigation water and 40% yield loss due to lack of nutrient supply in the country (Karim, 2007). However, enough irrigation water and nutrient supply can increase yield up to 70% in our country (Ahmed, 2006).

Among different factors irrigation facilities of wheat is one of the major reasons of yield reduction. In Bangladesh, wheat is grown during Rabi (winter) season and it is dry and as such, the inadequate soil moisture in this season limits the use of fertilizers, and consequently results in decreased grain yield. About 42.78% of the total wheat area in the country is irrigated and the rest of the area is cultivated under rainfed condition (BBS, 2011). Irrigation plays a vital role on proper growth and development of wheat. Insufficient soil moisture affects both the germination of seed and uptake of nutrients from the soil. Time of irrigation and its management are very important for successful cultivation of wheat. Supplement irrigation given to wheat improves the development of grain as well as yield (Singh and Singh, 2005). Irrigation frequency has a significant influence on the growth and yield of wheat. With the increase of irrigation frequencies the grain yield of wheat can be increased (Khajanij and Swivedi, 2007). Proper time of irrigation especially in crown root initiation (CRI) stage is very important for successful growth of wheat and it has a great impact on higher grain yield (Randhawa *et al*., 2004).These suggest that irrigation water should be supplied precisely at the peak period of crop growth, which may provide good yield of wheat.

Boron is an important micro plant nutrient for successful wheat production. Micronutrients take place in very small amounts in both soils and plants, but their role is frequently as important as the primary or secondary nutrients. The average total boron concentration in soils in the range of 20-200 ppm dry weight, most of which is unreachable to plants (Mengel and Kirkby, 2001). The available concentrations also vary greatly from soil to soil. Most soils have less than 10 ppm B and many areas of land are poor in B (Woods, 1994). Furthermore, the preponderance of this boron is immobilized in rocks and not ready available for plants.Boron is also vital mineral among micronutrients compulsory for plants growth (Brown *et al*., 2002). It is involved in many physiological processes in plants like RNA and carbohydrates metabolism (Herrera-Rodriguez *et al*., 2010; Siddiky *et al*., 2007) and development of cell wall. It has also a vital function in pollen tube growth and its germination, seed development, plasma membrane stimulation, floret fertility and anther development (Wang *et al*., 2003; Oosterhuis, 2001).

Boron insufficiency is also the main reason in reduction of plant height, plant total dry matter, number of reproductive parts during fruiting stage and leaf photosynthetic rate (Zhao and Oosterhuis, 2003). Its insufficiency also harms grain setting in wheat crop plants, resulted in improved open spikelet numbers as well as decreased grains per spike.

Foliar fertilization or foliar feeding is one of the most important methods of fertilizer application in agricultural practices because foliar nutrients facilitate easy and quick consumption of nutrients by penetrating the stomata or leaf cuticle and enters the cells. Foliar application of Boron single or shared with other micronutrients had positive effect on growth, yield and yield parameters of wheat crop. In optimizing fertilization strategies, addition of foliar application develops fertilizer use efficiency and reduces soil pollution (Hamzeh and Florin, 2014).

Boron soil application increased K concentration (Tariq and Mott, 2006). This was expected due to mutual synergistic interaction between B and K (Hosseini *et al*., 2007). Both N and B concentrations of grain were also significantly increased by boron application (Islam and Jahiruddin, 2008).

Time of irrigation and their frequencies along with foliar application of boron fertilizer would play a vital role for increasing maximum yield of wheat per unit area. Irrigation schedule based on physiological stage should be used properly and application of boron with optimum dose is very important in increasing wheat production (Cheng *et al*., 2006).

Researches on the influence of different time of irrigation and foliar application of boron in wheat and therefore, the present study was undertaken with the following objectives:

1. To evaluate the effects of different number of irrigation on BARI Gom 26 production
2. To observe the effectiveness of foliar application of boron on BARI Gom 26 cultivation
3. To find out the combined influence of irrigation and boron fertilization on growth, yield and nutrients content of BARI Gom 26

CHAPTER II

REVIEW OF LITERATURE

A brief review of research works in relation to influence of irrigation and foliar application of boron fertilizer on growth, yield and nutrients content of BARI Gom-26 has been presented in this chapter. It is an established fact that balanced fertilization (macro and micro nutrients) is the most important to plant nutrition and water management increases crop growth and gives higher yield. Some of the pertinent findings of the research on time of irrigation and foliar application of boron on the growth and yield of wheat are reviewed in this chapter.

2.1 Effect of irrigation

Wu *et al*. (2011) studied the effect of compensate irrigation on the yield and water use efficiency of winter wheat and found that the soil was obviously short of moisture when the irrigation was managed in the former stage, and the layer of 20-40 cm was the lowest one in all of the layers. The spike volume per ha, the tillers and spikes per plant were increased by 16,500-699,000; 0.12-1.16 and 0.01-0.11, respectively. For the effect of irrigation on plant height, spike length and spike grains, the combinative treatment of irrigation in the former stage and medium irrigation compensation in the latter were better. The wheat yield was increased by 2.54%-13.61% compared to control and the treatments, irrigation of 900 m^3/ha at the elongation stage and of 450 m^3/ha at the booting stage or separate irrigation of 900 m^3/ha at the two stage were the highest.

Malik *et al*. (2010) conducted field trials to estimate the effect of number of irrigations on yield of wheat crop in the semiarid area. The study comprised of three treatments including four irrigations (T_1) at crown root development, booting, milking and grain development; five irrigations (T_2) at crown root development, tillering, milking, grain development and dough stage and six irrigations (T_3) at crown root development, tillering, milking, grain development, dough stage and at maturity. The results revealed that the grain yield and yield contributing parameters were significantly higher when crop was irrigated with five irrigations (T_2), while 1000-grain weight, germination count m^{-2} and number of tillers m^{-2} were not affected significantly. The highest grain yield was recorded with five irrigations at different critical growth stages of wheat crop. The possible reason might be availability of more moisture. The results revealed that the application of irrigation at tillering stage played a vital role to increase wheat yield and contrarily the application of irrigation at maturity caused decrease in wheat yield.

Naeem *et al*. (2010) conducted a field study pertaining to the effect of different levels of irrigation on yield and yield components of wheat cultivars at Agronomic Research Area, University of Agriculture, Faisalabad. Treatments were three cultivars and five irrigation levels I_1 (irrigation at crown root stage), I_2 (irrigation at crown root + tillering), I_3 (irrigation at crown root + tillering + booting), I_4 (irrigation at crown root + tillering + booting + anthesis), and I_5 (irrigation at crown root + tillering + booting + anthesis + milking). Wheat crop supplied with five irrigations at crown root + tillering + booting + earing + milking recorded the highest grain yield (5696.8 kg ha^{-1}) which was significantly higher than all the other irrigation levels.

Field experiment was conducted by Mishra and Padmakar (2010) to study the effect of irrigation frequencies on yield and water use efficiency of wheat varieties during Rabi seasons. The irrigation treatment combinations comprised of four irrigation levels viz., I_1 (one irrigation at CRI stage), I_2 (two irrigations: one each at CRI and flowering stages), I_3 (three irrigations: one each at CRI, LT and flowering stages) and I_4 (four irrigations: one each at CRI + LT + LJ + ear head formation stages) along with the combination of three varieties viz., HUW-234, HD-2285 and PBW-154. Progressive increase in number of irrigations from 1 to 4 increased various yield contributing characters *viz*., effective tillers m^{-2}, ear length, number of grains ear^{-1} and test weight while three and four irrigations were found statistically at par with each other. The highest grain yield (40.65 q ha^{-1}) was credited to I_4 that was significantly superior over I_1 and I_2 but non-significant with I_3. Consumptive use of water increased while water use efficiency gradually decreased with increase in number of irrigations

Li *et al*. (2010) conducted a field experiment using semi-winter wheat Yumai 49-198 as experiment material, to investigate the leaf area index, dry matter accumulation, photosynthetic characteristics and yield of winter wheat under different irrigation stages and amounts. The results showed that, before the jointing stage, the leaf area index increased with the increase of irrigation amount. After jointing stage, all the indexes were good when the field water capacity maintained at 65%, while too much irrigation amount was unfavourable to the dry matter accumulation, especially to the photosynthetic rate of flag leaf and yield formation after anthesis.

Gao *et al*. (2009) conducted a field experiment to determine the reasonable and effective water-saving irrigation schemes in wheat production, the commercial wheat cvs. Shannong 15 and Yannong 21 were grown in in China and subjected to 3 water irrigation treatments: W_0 (with a relative water content of 60% in the 0-140 cm soil layer at the jointing stage and 55% at anthesis), W_1 (75% at the jointing stage and 65% at anthesis) and W_2 (75% at the jointing stage and 75% at anthesis). The highest irrigation water use efficiency was recorded in W_1 and the highest grain yield and water use efficiency (WUE) were achieved in W_2 for both cultivars. Under the conditions of this experiment, W_2 was the optimum water management treatment, which was beneficial to both of grain yield and WUE.

Kong *et al*., (2008) carried out an experiment to study the effect of irrigation on the yield of wheat and water use efficiency under limited irrigation. The irrigation treatments designed were: no irrigation (control); 30 mm of irrigation norm at elongation and booting stage; 45 mm at elongation and booting stage; 30 mm at filling stage; 45 mm at filling stage; 30 mm at elongation and 30 mm at filling stage; and 45 mm at elongation and booting stages and 45 mm at the filling stage. Irrigation increased the average yield of wheat by 13.0-39.6% and the water use efficiency by 7.0-18.0%. The physiological properties and yield compositions of winter wheat could be also improved. The number of ears of winter wheat could be increased by irrigation during the elongation and booting stages and the water use efficiency could also be improved. Irrigation at filling stage improved the 1000-grain weight and water use efficiency of wheat. It is concluded that the best time for limited irrigation is the elongation and booting stages.

Ju-Hui (2006) studied the impacts of single irrigation at different stage on wheat yield components. Results indicate that single irrigation at different stage has different contribution to wheat yield components. Irrigation at floret differentiation stage can increase the number of ears greatly, irrigation at quadrant stage significantly enhanced grains number per ear. Irrigation at heading stage increased 1000 grain weight. 1000 Grain weight was the key factor determining yield under water saving cultivation, the next was the number of grains per unit area. The irrigation at heading stage has the most grain number of population. Population was with small source and big sink while irrigation is at pistil-stamen differentiation stage and with big source and small sink while irrigation is at heading stage. The relationship of source and sink has relative good balance while irrigation at quadrant stage with highest level of grain yield.

Mushtaq and Muhammad (2005) conducted a field studies in Pakistan to determine the effect of different irrigation frequencies on the growth and yield of wheat cv. Uqaab-2000 on a clay loam soil. Results revealed that wheat receiving 5 irrigations at crown root + tiller + boot + milk + grain development stages produced significantly taller plants and maximum number of fertile tillers per unit area. It was, however, not significantly superior to 4 irrigations applied at crown root + boot + milk + grain development stages for number of grains per spike, 1000-grain weight and grain yield. Plant height, 1000-grain weight and wheat grain yield were significantly higher under 4 irrigations applied at crown root + boot + grain development and crown root + boot stages of plant growth, respectively. A grain yield reduction of 6.63 and 12.20% and increase of only 1.45% was obtained by applying 3, 2 and 5 irrigations, respectively, compared to 4 irrigations.

Limited precipitation restricts yield of winter wheat. Sun and Liu (2006) conducted an irrigation experiments during different growing stages of winter wheat (*Triticumaestivum* L.) at North China to identify suitable irrigation schedules for winter wheat. The aim was also to develop relationships between irrigation and yield, water-use efficiency (WUE), irrigation water-use efficiency (WUEi), net water-use efficiency (WUEet) and evapotranspiration (ET). A comparison of irrigation schedules for wheat suggested that for maximum yield, 300 mm is an optimal amount of irrigation, corresponding to an ET value of 426 mm. Results showed that with increasing ET, the irrigation requirements of winter wheat increase as do soil evaporation but excessive amounts of irrigation can decrease grain yield, WUE, and WUE. These results indicate that excessive irrigation might not produce greater yield or optimal economic benefit, thus, suitable irrigation schedules must be established.

Ali and Amin (2007) conducted a study in Bangladesh during rabi season to determine the effect of irrigation frequencies on the yield and yield attributes of the wheat cultivar Shatabdi. Irrigation treatments were given as: no irrigation, control (T0); one irrigation at 21 DAS (T1); two irrigations at 21 and 45 DAS (T2); three irrigations at 21, 45 and 60 DAS (T3); and four irrigation at 21, 45, 60 and 75 DAS (T4). Significant effects were observed on plant height, number of effective tillers per hill, spike length, number of spikelets per spike, filled grains per spike due to different levels of irrigation. Two irrigations at 21 and 45 DAS significantly enhanced the growth, yield attributes and yield of wheat over the other treatments. Results also showed that grain yield, straw yield and harvest index were significantly higher at T2 compared to the other treatments of the study.

Sher and Parvender (2006) carried out a field experiment during winter on sandy loam soils in Haryana, India, to evaluate the effects of irrigation regimes (IW/CPE 0.5, 0.7 and 0.9) on growth, yield and nutrient uptake of wheat under late-sown conditions. The irrigation level IW/CPE 0.9 (4 irrigations) being statistically at par with IW/CPE 0.7 (3 irrigations) produced significantly higher plant height, number of tillers/m^2, 1000-grain weight and straw yield than IW/CPE 0.5 (2 irrigations), which was at par with 3 irrigations. The irrigation regime IW/CPE 0.9 recorded significantly higher dry matter accumulation, grains per spike and grain yield than IW/CPE 0.7 and 0.5. The percentage increase in grain yield due to IW/CPE 0.9 over IW/CPE 0.7 and 0.5 was 14.1 and 21.3%, respectively. N, P and K uptake by both grain and straw also increased progressively with increasing number of irrigations.

Zhang *et al.*, (2005) conducted a field experiment on a loam soil to determine the grain yield, yield components, and water use characteristics of spring wheat in response to regulated deficit irrigation (RDI) schemes. Wheat grown under the RDI schemes produced 29% higher grain yield than wheat grown under water deficit-free control 6.2 t ha^{-1}). Among six RDI schemes studied, wheat having a high water deficit at the jointing stage, but free from water deficit from booting to grain-filling produced highest grain yield (7.26 t ha^{-1}). Compared with the control, wheat plants grown under the RDI schemes received 59 mm (or 15%) less water via irrigation, but they either extracted 41 mm more (or 74%) water from the soil profile. Grain yield increased as ET increased from 415 to 460 mm, and declined beyond 460 mm. The WUE values varied from 0.0116 to 0.0168 t ha^{-1} mm^{-1}, and wheat grown under the RDI had 26% greater WUE compared with the control. Grain yield and WUE of spring wheat can be greatly improved by regulated deficit irrigation with reduced amounts of water. This practice is particularly valuable in arid regions where wheat production relies heavily on irrigation.

Onyibe (2008) conducted a field trial to study the effect of irrigation regime (60, 75 and 90% Available Soil Moisture (ASM) on the growth and yield of two recently introduced wheat cultivars (Sietecerros and Pavon 76)). The result revealed that increase of irrigation regime from 60 to 90% ASM did not significantly affect most of the growth, yield and yield parameters evaluated in the study. Each increase in irrigation regime however increased days tomaturity, water use and thermal time but decreased water use efficiency. Pavon 76 produced superior grain yield than Siete ceros only in one season. Pavon 76 had a higher LAI, more tillers and spikes/m^2 and larger grain size, but had shorter plants, lower grain weight and grain number/spike and matured earlier than Sietecerros. Irrigation level of 60% ASM is recommended for both varieties in the Sudan savanna ecology. At this ASM the highest water use efficiency of 4.0-4.8 kg/mm/ha was obtained and grain yield was not significantly compromised. Grain yield was more strongly correlated with grain weight per spike than with grain number per spike.

Baghani and Ghodsi(2006)investigated drought tolerance levels in some wheat lines and cultivars based on uniform regional wheat yield trial (URWYT-M-75). The main plots (horizontal factor) were composed of 3 levels of irrigation (10, 20 and 30 days interval), while the sub-plots (vertical factor) were of 20 lines or cultivars of spring bread wheat set up for URWYT (M-75-1-20). Sowing date and sowing and fertilizer rates were under normal condition. Soil water content was also determined. The results showed that when irrigation interval was 10 days, the line yields of M-75-8, M-75-6, M-75-2 and M-75-16 were higher than other lines. When the irrigation interval was 20 days, the highest lines were observed for M-75-2, M-75-14, M-75-16 and M-75-12. In 30 days irrigation interval, the lines of M-75-15, M-75-4, M-75-2 and M-75-14 had maximum yields.

Abdorrahmani*et al*., (2005) studied the growth rate, yield and yield components of 4 wheat cultivars under rain fed conditions and 2 irrigation regimes (irrigation at planting time and ear emergence, and irrigation at planting time, ear emergence and grain filling). Drought stress reduced dry matter production, crop growth rate and relative growth rate. Green cover percentage, crop growth rate, and relative growth rate did not significantly vary among the cultivars. All traits except the number of grains per ear and harvest index were affected by water deficit. No significant variation was observed between irrigation regimes. The green cover percentage, plant height, crop growth rate, biological yield and productivity were significantly correlated with grain yield. The mean green cover had the greatest positive correlation with grain yield. This trait can be recommended as a suitable index for the evaluation of the field performance of various crops.

Ghodpage and Gawande (2008) conducted a field experiment in Maharashtra, India, during rabi season to investigate the effect of scheduling irrigation (2, 3, 4, 5 and 6 irrigations) at various physiological growth stages of late-sown wheat. The maximum grain yield of 2488 kg/ha was obtained in 6 irrigations treatment and it was significantly superior over all other treatments. In general, there was consistent reduction in grain yield due to missing irrigation. A yield reduction of 9.88% was recorded when no irrigation at dough stage was scheduled. Further, missing irrigation at tillering and milking stages resulted in 21.94% yield reduction. It was still worse when no irrigation was scheduled at tillering, milking and dough stages, recording 29.30% yield reduction. Approximately 50% loss in grain was observed when irrigation was missed at tillering, flowering, milking and dough stages. The ratio between consumptive use of water (Cu)/irrigation number was higher in 2-irrigation treatment compared to 6-irrigation treatment although the total value of Cu was higher for 6-irrigation treatment.

Chaudhary and Dahatonde (2007) carried out an experiment in Maharashtra, India to study the effects of irrigation frequency (irrigation at CRI [crown root initiation], jointing, flowering and milk stages or I4; I4 + irrigation at the tillering stage or I5; and I5 + irrigation at the dough stage) and quantity (irrigation at 100, 75 or 50% of the net irrigation requirement), and kaolin (0 or6% kaolin sprayed at 50 days after sowing) on the performance of wheat. Grain yield did not significantly vary with irrigation frequency. Irrigation at 100% of the net irrigation requirement resulted in the highest grain yield (27.32 quintal/ha). Water consumption increased with the increase in irrigation frequency and quantity. Water use efficiency was highest under I5 (87.74 kg ha^{-1} cm^{-1}) and irrigation at 100% of the net irrigation requirement (85.29 kg ha^{-1} cm^{-1}). Kaolin significantly reduced grain and straw yields, water consumption, and water use efficiency. [1 quintal=100 kg].

Pal and Upasani (2007) conducted a field experiment in India to determine the effects of irrigation on the growth and yield of wheat cv. HD 2285. The treatments comprised different irrigation frequency (2, 3 or 4 times) carried out during critical growth stages (crown-root initiation, highest tillering, booting and milking). Wheat plants which received 4 irrigations at the crown root initiation, highest tillering, booting and milking stages recorded the highest yield. Non-irrigation at the highest tillering stage caused the highest yield reduction (34.7%), followed by water stress at the milking (25.9%), booting (12.8%) and crown root initiation stage (6.8%). Reduction in the values of spike dry matter accumulation, grain growth rate and duration was also observed with the non-irrigation during the highest tillering, milking and booting stage, indicating that these stages are critical with respect to the water requirements of late sown wheat.

Alsohaibani (2007) conducted a field experiment to evaluate the effects of irrigation level (65, 100 and 170 mm accumulated vapour) on the growth and yield of different bread wheat lines (L.9, L.11 and L.18) and the local cultivar (Yecorarogo). Irrigation level had highly significant effect only on spike length, but had significant effect on biological and grain yields and their components. Grain yield reduction was 16.4% and biological yield reduction was 13-20% at 100 mm accumulated vapour. No significant differences in these parameters were observed between 65 and 100 mm accumulated vapour rates.

Jana and Mitra (2004) carried out an experiment on wheat cv. Sonalika giving irrigation at crown root initiation, tillering, flowering and dough stages. They found that irrigation increased plant height, number of effective tillers, ear plant^{-1} and grain and straw yields.

Hefni *et al*., (2000) found that irrigation plays a positive role in increasing the number of tillers, ear plant^{-1} and grain of wheat. Ear length and number of grains reduced significantly if irrigation is stopped at tillering and booting stages of wheat.

Singh and Singh (2001) reported that growth of wheat was poor when crop was grown under rain fed condition. Under this condition tiller number, panicle length, grain number and 1000-grain weight were lower.

Ashok and Sharma (2004) conducted field trials in the winter seasons of 1990-91 at Karnal, Haryana, India, where wheat cv. HD-2285 was irrigated at IW:CPE ratios or 0.6,0.9 or 1.2. It was observed that the irrigation treatments increased dry matter accumulation.

Mandal *et al*. (2002) conducted a field experiment in India during 1984-86 and 1986-87 on wheat with 2 levels of irrigation: one at crown root initiation (CRI) and at CRI + booting stages and reported that LAI increased significantly with increasing levels of irrigation.

Nahar and Paul (1998) reported that LAI was higher in irrigated plants than in the rain fed plants at all the vegetative phases in wheat (cv. Kanchan). They also found that LAI reached a certain Peak and then declined.

Pal *et al*. (2002) conducted a field experiment during winter season on sandy loam of Ranchi. The treatment consisted of three irrigation schedule (2 irrigation at CRI and maximum tillering, booting and milk stages). They observed that application of 4 irrigations gave higher crop growth rate (CGR) than 2 or3 irrigations.

El-Zahab*et al*. (2003) stated that RGR increased steadily during early growth stage and then decreases slowly. Grain and straw yields and yield contributing characters gradually increased with increasing number of irrigation (Islam, 2003). The highest grain and straw yields, the maximum plant height , the highest number of effective tillers, and the maximum number of grains spike^{-1} were obtained by three irrigations (I4) applied at 25, 50 and 70 days after sowing. The increased grain and straw yields in I4 treatment over control was 60.7% and 59.4% with irrigation.

Razi-us Shams (2001) observed that the effect 0f irrigation treatments on yield and yield contributing characters were statistically significant. When irrigation frequency was increased the grain and straw yields, number of tillers, panicle length, number of grains panicle^{-1} were gradually increased over control.

Jadhav and Jadhav (2000) reported that significantly higher number of spikelets spike^{-1} was obtained from 4 and 5 irrigations compared to 2irrigations.

Yadav *et al*. (2001) reported that two irrigation scheduled at CRI and milking stages gave the maximum number of grains spike^{-1} (65) of wheat, which was found to be at par with those at one irrigation. Eunus *et al*. (1998) observed higher number of grains in irrigated plots than in non- irrigated ones.

Ottman *et al*. (2000) conducted a field experiment on a Casa Grande sandy loam soil in 1995 and 1996 growing seasons at the University of Arizona Maricopa Agricultural Centre, USA. The treatments consisted of 3 levels of N (0, 2.4 and 6.7 gm m-2) until anthesis and irrigation based on 30%, 50% and 70% depletion of plant available soil water. It was observed that irrigation frequency during grain filling increased 1000-grain weight.

Upadhyaya and Dubey (2003) performed a field experiment on wheat where 3 irrigations frequencies viz. (a) one irrigation at CRI stage, (b) two irrigation one each at CRI and booting stages and (c) four irrigations one each at crown root initiation (CRI), booting, flowering and milking stage were included. They observed that grain yield varied significantly with irrigation frequencies. Four irrigations performed the maximum grain yield which was significantly greater than one or two irrigations.

Patil *et al*. (2002) conducted a field experiment with irrigation at Agricultural Research Station, Niphad, Maharashtra during the winter (rabi) season of 1992-93. There were 3 irrigations treatments viz. one irrigation at 42 days after sowing, two irrigations at 21 and 65 DAS and five irrigation at 21,42,65,85 and 105 DAS. They observed that grain yield of wheat was 1.17 t ha^{-1} when irrigated once at 42 DAS, 1.69 t $ha^{-1}$when irrigated twice at 21 and 65 DAS and 2.02 t $ha^{-1}$when irrigated five times at 21,42,65,85 and 105 DAS.

Ghosh *et al*. (2003) in Kalyani, West Bengal carried out experiment on wheat grown as pure and intercropping system and observed that without irrigation , with irrigation at 21 and 65 DAS and with irrigation at four critical growth stages crop gave grain yields of 2.08 tha^{-1}, 2.99 t ha^{-1}, 3.40 t ha^{-1}respectively.

Hosamani *et al*. (2003) conducted experiments at Dharwad, Karnataka, India where the treatment consisted of 3 irrigation frequencies one irrigation (at CRI), two irrigations (one each at CRI and tillering stages) and five irrigations (one each at CRI, tillering, booting, flowering and dough stages). They observed that mean grain yield was 1.04, 1.36 and 1.90 t $ha^{-1}$with one, two and five irrigation respectively.

BARI (2000) recorded maximum straw yields with three irrigations applied at CRI, maximum tillering and grain filling stages of crop. Irrigations given at CRI+ maximum tillering (MT), CRI+ Booting (BT) and CRI+grain filling (GR) were at par in respect of number of spikes m^{-2} and grains $spike^{-1}$, but had highest spikes and grains over CRI+MT stages.

Naser (1999) reported that two irrigations at 30 and 50 DAS significantly increased grain and straw yields over control. The highest grain and straw yields, the maximum number of tillering $plant^{-1}$, the highest spike length, the maximum number of grains $spike^{-1}$ were recorded in I4 treatment where two irrigations were applied. The I4 treatment increased grain and straw yields by 58.1% and 54.5% respectively over control. The control treatment showed the lowest result in all parameters.

Cooper (1998) reported that harvest index increases with increase in irrigation frequencies. Boogaard *et al.* (1999) carried out an experiment in a Mediterranean environment in North Syria with wheat under rain fed and irrigated conditions and reported that under rain fed conditions harvest index was increased.

The findings presented above indicate that irrigation influences growth and yield through affecting yield components at different phonological stages. Irrigation at different critical stages showed variable responses to growth, yield and yield contributing characters. The literature discussed above suggests that irrigation water should be applied at critical crop growth stages depending on the soil moisture situation to achieve higher yield of wheat crops.

2.2.2 Effect of Boron

Hamzeh and Florin (2014) observed from an experiment that foliar fertilization or foliar feeding is one of the most important methods of fertilizer application in agriculture practices because foliar nutrients facilitate easy and quick consumption of nutrients by penetrating the stomata or leaf cuticle and enters the cells. Foliar application of Boron single or shared with other micronutrients had positive effect on growth, yield and yield parameters of wheat crop. In optimizing fertilization strategies, addition of foliar application develops fertilizer use efficiency and reduces soil pollution. Foliar application of Boron single or shared with other micronutrients at different growth stages have been shown to be effective in efficient consumption of Boron by wheat and thus increase grain sitting and increase the grain yield, number of grains per spike, number of spiklet per spike and thousand grain weight. Preservation this in outlook, the literatures on foliar application of Boron on the yield and yield components of wheat are reviewed in this paper.

Singh *et al*. (2015) conducted an experiment to evaluate the effect of zinc levels and methods of application of boron on the growth, yield and protein content of wheat (*Triticum aestivum* L.). The treatments comprised three levels of zinc (0, 3.5 and7 kgha^{-1}) through zinc sulphate and four methods of application of boron (0, soil application @ 0.5 kg ha^{-1}, foliar spray @ 0.5kg ha^{-1} at 45 and 60 days after sowing and soil application @ 0.25 kg ha^{-1} + foliar spray @ 0.25 kg ha^{-1} at 45, 60 DAS. On the basis of the findings of the experiment, zinc @ 7 kg ha^{-1}, soil application of boron @ 0.25 kg ha^{-1} + foliar application of boron @ 0.25 kg ha^{-1} was found superior over all other treatments in relation to plant height, dry weight, effective tillers yield and yield attributes and protein content in grains, of wheat.

Nadim *et al*. (2013) conducted an experiment to investigate the effect of micronutrients and their application methods on wheat. Main plot possessed five micronutrients viz., Zn, Cu, Fe, Mn and B while application methods (side dressing, foliar application and soil application) were assigned to sub-plots. The results revealed that different micronutrients individually significantly increased leaf area index (LAI), crop growth rate (CGR), net assimilation rate (NAR) and grain yield. Soil application best interacted with B for producing higher number of tillers, grains spike^{-1}, grain yield and almost all the physiological traits.

Rashid *et al*. (2011) conducted an experiment on B deficiency in rain fed wheat in Pakistan. They reported a B deficiency incidence and spatial distribution in rain fed wheat (*Triticum aestivum* L.), its relationship with soil types, crop responses to B, and internal B requirement and B fertilizer use efficiency of wheat. Plant and soil analyses indicated deficiency in 64% of the 61 sample fields; geo-statistics aided contour maps delineated B deficient areas. In rain fed field experiments, B use increased wheat yields up to 11%. Fertilizer requirement was 1.2 kg B ha^{-1}.

Ahmad *et al*. (2011) carried out an experiment on the effect of B application time on the yield of wheat, rice and cotton crop in Pakistan. The results revealed that B application at sowing time to wheat increased significantly the number of tillers plant^{-1} (15%), number of grains spike^{-1} (11%), 1000 grain weight (7%) and grain yield (10%) over control. Among the treatments, B application at sowing time showed the best results followed by B application at the 1st irrigation and at booting stage.

Sultana (2010) conducted an experiment at BAU farm, Mymensingh to see the effect of foliar application of B on wheat. Boron application exerted significant influence on the yield and grain set of wheat. In a field experiment at BAU farm, Mymensingh observed that grain yield was significantly influenced by different rates of B.

Schnurbusch *et al*. (2010) investigated B toxicity tolerance in wheat and barley. In barley, they have identified genes controlling B toxicity tolerance at two of the four known B toxicity tolerance loci, both of which encode B transporters

Emon *et al*. (2010) conducted a study on molecular marker-based characterization and genetic diversity of wheat genotypes in relation to B use efficiency. The study found that INIA 66 and BAW1086 were the most B efficient genotypes and thus could be used for developing B efficient varieties.

Boron deficiency is the second most widespread micronutrient problem. Whenever the supply of boron is inadequate, yields will be reduced and the quality of crop products is impaired, but susceptibility varies considerably with crop species and cultivars (Alloway, 2008).

Ahmed *et al*. (2008) conducted two pot experiments to investigate the effect of spraying silicon (0, 250 and 1000ppm SiO_2) and/or B. They showed that both silicon levels either alone or combined with B significantly increased shoot height and leaf area as well as grain yield/plant and weight of 1000 grains.

Islam and Jahiruddin (2008) studied the effect of boron and different dates of sowing on some wheat cultivars. There were two boron treatments (0 and 1 kg B ha^{-1}), three wheat cultivars and four sowing dates. The grain samples were analyzed for N, P, K and B, while the straw samples were analyzed for P, K and B contents and uptake. Both N and B concentrations of grain were significantly increased by boron application.

Halder *et al*. (2007) conducted a field trial during rabi season in Calcareous Brown Floodplain Soils of Regional Agriculture Research Station (RARS), Jessore in Bangladesh with the objective of evaluating the response of wheat varieties to different levels of B and to determine the optimum dose of B for maximizing yield of wheat cultivars Protiva, Gourab and Sourav. They observed that Protiva along with 2 kg B ha^{-1} produced significantly the highest yield in both the years with the highest mean grain yield (5.3 t ha^{-1}) by 66% increase over B control.

Rahmatullah *et al*. (2006) carried out a field experiment during 2004-05 in Pakistan to investigate the effect of B application (@ 0, 1 and 2 kg ha^{-1}) on wheat system. Boron application significantly affected wheat grain yield that ranged from 2.70 to 3.49 t ha^{-1}, recording the highest increase of 19.9% over the control from 1 kg ha^{-1}. The number of tillers m^{-2}, spikes m^{-2}, spike length, plant height and 1000-grain weight of wheat also differed significantly from control for B treatment.

Ghatak *et al*. (2006) studied the effect of B on yield, and grain concentration and uptake of N, P and K of wheat in red and laterite soils of West Bengal. Application of 15 to 20 kg borax ha^{-1} recorded higher values of yield attributes and yield. The increase in grain yield over control was 4.5 to 7.7 percent. The optimum dose of borax was 14 kg ha^{-1}during the first year and 10.4 kg ha^{-1} in the second year. Thus, a dose of 10 to 15 kg borax/ha may be beneficial for higher production of wheat in this region.

Jolanta (2006) conducted a field trial, involving foliar application of B to evaluate the effect of foliar spray of B on different cultivars of wheat. Foliar fertilization treatments caused a significant grain yield increase of four out of ten winter wheat cultivars. The average yield increment ranged between 9 and 15%.

Wrobel *et al*. (2006) conducted a pot experiment in Poland, to investigate the effect of B fertilizer application on spring wheat grown in light soil, deficient in B and subjected to periodic drought stress. Application of B fertilizer increased the grain and straw yields of spring wheat. This study demonstrated that B was able to mitigate drought effects, and its application to soil during tillering stage improved the parameters of the main yield components, thus increasing yield level and enriching the chemical composition of wheat grain.

Mete *et al*. (2005) reported that the plant height was significantly increased with the application of B and lime whether singly or in combination.

Bhatta *et al*. (2005) reported that application of B fertilizer to the soil at sowing had a significant positive effect on the number of grains per spike, reduction of sterility and grain yield of wheat.

Gunes *et al*. (2003) had a one-year (2000-01) field study during the cropping season on the effect of B on yield and some yield components of bread (*Triticum aestivum* cv. Bezostaia) and durum wheat (*T. durum* cv. Kiziltan) cultivars in B-deficient soil (0.68 mg kg, NH_4OAC-extractable). Boron was applied to soil as H_3BO_3 at 0, 0.5, 1.0, 1.5, 2.0 and 2.5 mg ha^{-1} in the greenhouse, and 0, 1.0, 2.0, 3.0, 4.0 and 5.0 kg ha^{-1} in the field. In the field, the grain yield increased from 3668 to 5475 kg ha^{-1} at 4.0 kg B ha^{-1} in Bezoslaja and from 4668 to 4360 kg ha^{-1} at 2.0 kg B ha^{-1} in Kizillan. At higher B levels, the grain yield of the cultivars decreased. The results show that B fertilizer application should be considered in fertilizer recommendations after additional research under different soil, genotype and environmental conditions.

Kataki *et al*. (2001) reported that the soil application of B at sowing reduced sterility by more than 50% and doubled wheat yield by increasing grain set.

El-Magid *et al*. (2000) carried out an experiment on clay soil in Egypt during 1990-99 and 1999-2000 to investigate the effect of micronutrient spraying during jointing stage, 45 days after emergence. The treatments were: control; B as boric acid at 0.06%; Cu as EDTANA-Cu at 0.10%; Zn EDTANA-Zn at 0.10%; Mn as EDTANA-Mn at 0.10% and Fe as EDTANA-Fe at 0.10%. Spraying with Fe, Zn, Mn or B increased shoot height, while Cu had little effect on this parameter. The nutrients increased the number of tillers per plant and shoot weight. Elements Fe, Cu, Zn and Mn increased grain and straw yields, while B increased only the straw yield. Zinc, Mn or Fe increased N concentrations from 17.15 mg/100 g in the control to 17.61, 17.32 and 17.28 mg/100 g, respectively, while Cu and B reduced B content. Zinc, Mn, B, Fe and Cu increased plant P and K contents.

Islam *et al*. (1999) initiated a field experiment in 1992/93 on alluvial soils in Bangladesh, with wheat cv. Kanchan giving 20 kg S ha^{-1}, 4 kg Zn ha^{-1} and 2 kg B ha^{-1}, singly and in all possible combinations. Grain yield and yield component values generally increased by application of S, Zn and B. Sulphur had the greatest effect on grain yield, followed by B and Zn. Application of three elements together (S+ Zn+ B) produced the highest grain yield. Application of each element increased the plant content of that element.

Hossain *et al*. (1997) conducted an experiment to evaluate the performance of wheat cv. Kanchan, Aghrani and Akbar with and without application of B. Yield was highest in cv. Kanchan and was increased by B applied @ 2 kg/ha.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2016 to March 2017. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations, data recording and their analyses.

3.1 Site description

The experiment was conducted at the Sher-e-Bangla Agricultural University farm, Dhaka, under the Agro-ecological zone of Modhupur Tract, AEZ-28 during the Rabi season of 2007. The land area is situated at 23°41′N latitude and 90°22′E longitude at an altitude of 8.6 meter above sea level.

3.2 Climate

The experimental area is under the sub-tropical climate that is characterized by high temperature, high humidity and heavy rainfall with occasional gusty winds in kharif season (April-September) and less rainfall associated with moderately low temperature during the Rabi season (October-March). The weather data during the study period of the experimental site is shown in Appendix I.

3.3 Soil

Shallow Red Brown Terrace Soils is belonged in the under Tejgaon Series. Top soils were clay loam in texture. The experimental area was flat having available irrigation and drainage system. The land was above flood level and sufficient sunshine was available during the experimental period.

3.4 Collection and preparation of initial soil sample

The initial soil samples from the main field were collected before land preparation from a 0-15 cm soil depth. The samples were collected by means of an auger from different locations covering the whole experimental plot and mixed thoroughly to make a composite sample. After collection of soil samples, the plant roots, leaves were picked up and removed. Then the sample was air-dried and sieved through a 10-mesh sieve and stored in a clean plastic container for physical and chemical analysis. The analyses were done by Soil Resources and Development Institute (SRDI), Dhaka. The physicochemical properties of the soil are presented in Appendix II.

3.5 Planting material

Wheat (*Triticum aestivum* L.) variety BARI Gom26 was used as plant material. BARI developed this variety and released in 2010. It is a most popular variety now due to its high yielding potentials and suitable for early and late planting (up to second week of December). This variety attains a height of 92-96 cm and it resistant to leaf rust disease. The number of tillers plant^{-1} is 3-4 and the leaves are wide and deep green in color. It requires 60-63 days to heading. Grains are amber in color and bright. Its yield is 3.5-4.5 t ha^{-1} and 1000 grain weight is 48-52 g. The seeds of this variety were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur. Seeds contain 60 - 65% carbohydrate.

3.6 Seed collection

Seeds of BARI Gom 26 were collected from Bangladesh Agriculture Research Institute (BARI), Joydebpur, Gazipur, Bangladesh.

3.7 Land preparation

The land was first opened with the tractor drawn disc plough. Ploughed soil was then brought into desirable fine tilth by 4 operations of ploughing and harrowing with country plough and ladder. The stubble and weeds were removed. The first ploughing and the final land preparation were done on 18 November and 22 November 2016, respectively. Experimental land was divided into unit plots following the design of experiment. The plots were spaded one day before seed sowing and the basal dose of fertilizers was incorporated thoroughly before seed sowing.

3.8 Fertilizer application

The unit plots were fertilized with 150 kg, N, 125 kg TSP, 67 kg MOP and Gypsum 80 kg ha^{-1} respectively. Boron fertilizer as boric acid was applied to the crop by foliar spray. Urea, triple super phosphate (TSP) and muriate of potash (MOP) were used as source of nitrogen, phosphorus and potassium, respectively. Boron was applied as per experimental specification through boric acid (17% B) as foliar spray. The whole amount of TSP, MOP, gypsum and one third of the urea were applied at the time of final land preparation prior to sowing. The remaining two-thirds of urea were top-dressed in two equal splits on 20 and 55 days after sowing (DAS) the seed.

3.9 Treatments of the experiment

Two factors experiment was conducted as follows:

3.9.1 Factor A: Three levels of irrigation

1. I_0 = No irrigation (Control)
2. I_1 = One irrigation given at crown root initiation (CRI) stage (18 DAS)
3. I_2 = Two irrigations, one at CRI stage (18 DAS) and other at panicle initiation (PI) stage (55 DAS)

3.9.2 Factor B: Four levels B

1. B_0 = 0 kg H_3BO_3 ha^{-1} (Control)
2. B_1 = 1.5 kg H_3BO_3 ha^{-1}
3. B_2 = 2.0 kg H_3BO_3 ha^{-1}
4. B_3 = 2.5 kg H_3BO_3 ha^{-1}

3.9.3 Combination of two factors: 12 treatment combinations

I_0B_0	I_1B_0	I_2B_0
I_0B_1	I_1B_1	I_2B_1
I_0B_2	I_1B_2	I_2B_2
I_0B_3	I_1B_3	I_2B_3

3.10 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design (RCBD). Each treatment was replicated three times. The size of a unit plot was 3m×2m. The distance between two adjacent replications (block) was 1m and row-to-row distance was 0.5 m. The inter block and inter row spaces were used as foot path and irrigation/drainage channels. Layout of the experimental field has been presented in Appendix III.

3.11 Sowing of seeds in the field

The seeds of wheat were sown in rows made by hand plough on November 24, 2016. The seeds were sown in solid rows in the furrows having a depth of 2-3 cm from the soil surface and then covered properly with soil. The line to line distance for wheat was 20 cm and plant to plant distance was 4 - 5 cm.

3.12 Intercultural operations

3.12.1 Irrigation and weeding

Three levels of irrigations were applied according to the treatments during the entire growing period.

3.12.2 Weeding

The crop field was weeded twice; first weeding was done at 25 DAS (Days after sowing) and second weeding at 40 DAS. Demarcation boundaries and drainage channels were also kept weed free.

3.12.3 Protection against insect and pest

At early stage of growth, few worms (*Agrotisipsilon*) and virus vectors (Jassid) attacked the young plants. To control these pests, Dimacron 50 EC was sprayed at the rate of 1litre per ha. The wheat crop was also infested by Aphid and rodent. Therefore, contact insecticide (Malathion @ 22.2 mm per 10 litres of water) was given two times and 2% zinc sulphide was applied because wheat field was infested by rodent.

3.12.4 General observation of the experimental field

The field was observed time to time to detect visual difference among the treatment and any kind of infestation by weeds, insects and diseases so that considerable losses by pest was minimized.

3.12.5 Harvesting and post- harvest operation

Maturity of crop was determined when 90% of the grains became golden yellow in color. Ten plants per plot were preselected randomly from which different growth and yield attributes data were collected and 1 m^2 areas from middle portion of each plot was harvested separately and bundled, properly tagged and then brought to the threshing floor for recording grain and straw yield. Threshing was done by using pedal thresher. The grains were cleaned and sun dried to a moisture content of 12%. Straw was also sun dried properly.

3.13 Recording of data

Experimental data were recorded from 45 days of sowing and continued up to harvest. The following data were recorded during the experimentation.

3.132.1. Crop growth characters

1) Plant height (cm)
2) Number of tillers plant^{-1}
3) Leaf area index (LAI)
4) Dry weight plant^{-1}

3.13.2. Yield and yield components

1) Length of spike (cm)
2) Number of spikelets spike^{-1}
3) Number of grains spike^{-1}
4) Weight of 1000 grains (g)
5) Grain yield (t ha^{-1})
6) Straw yield (t ha^{-1})
7) Biological yield (t ha^{-1})
8) Harvest index (%)

3.13.3 Nutrient content of grain and straw

1) Nutrient content of N, P, K, S and B in grain
2) Nutrient content of N, P, K, S and B in straw

3.14 Detailed procedures of recording data

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

3.14.1 Plant height

Plant height was measured at 20 days interval starting from 40 days after sowing (DAS) and continued up to harvest. The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf before heading, and to the tip of spike after heading. The collected data were finally averaged.

3.14.2 Number of tillers plant^{-1}

Number of tillers plant^{-1} were counted at 20 days interval starting from 40 DAS and up to harvest and finally averaged as their number plant^{-1}.

3.14.3 Leaf area index (LAI)

Leaf area index was estimated measuring the length and width of leaf and multiplying by a factor 0.75 as suggested by Yoshida (1981).

3.14.4 Dry weight plant^{-1}

Five plants at different days after sowing (40, 60, 80 DAS and at harvest) were collected and dried at 70° C for 24 hours. The dried samples were then weighed and averaged.

3.14.5 Spike length

Spike length were counted from five plants from basal node of the rachis to apex of each spike and then averaged. This was taken at harvesting.

3.14.6 Number of spikelets spike^{-1}

Number of spikelets were counted from 5 spikes and averaged to determine the number spikelets spike^{-1}.

3.14.7 Number of grains spike^{-1}

The number of grains spike^{-1} was counted from 10 spike and number of grains spike^{-1} was measured by the following formula

$$\text{Number of grains spike}^{-1} = \frac{\text{Total number of grains}}{\text{Number of spike}}$$

3.14.8 Weight of 1000 grains

One thousand cleaned dried grains were counted randomly from each plot and weighed by using a digital electric balance when the grains retained 12% moisture and the mean weight was expressed in gram.

3.14.9 Grain yield

Grain yield was determined from the central 1 m^2 area of each plot and expressed as t ha^{-1} on 12% moisture basis. Grain moisture content was measured by using a digital moisture tester.

3.14.10 Straw yield

Straw yield was determined from the central 1 m^2 area of each plot, after separating the grains. The sub-samples were oven dried to a constant weight and finally converted to t ha^{-1}.

3.14.11 Biological yield

Biological yield was calculated by the following formula:

Biological yield = Grain yield + Stover yield

3.14.12 Harvest index (%)

It denotes the ratio of economic yield to biological yield and was calculated with the following formula.

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

3.15. Chemical analysis of grain and straw

Chemical analysis of grain and straw samples were completed in the laboratory of Soil Science Division of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.15.1 Preparation of samples

Grain and straw samples were dried in an oven at 65°C for 48 hours and after cooling they were ground by a grinding machine. The prepared samples were then put into paper bags and kept into the desiccators until used.

3.15.2 Digestion of grain and straw samples

Exactly 1 g of finely ground plant material was taken into a 250 mL conical flask and 10 mL of di-acid mixture (HNO_3: $HClO_3$=2:1) was added to it. Then it was placed on the electric hot plate for heating at 180-200°C unit the solid particles nearly disappeared and white fumes were evolved from the flask. It was then cooled at room temperature, the flasks were washed with distilled water repeatedly to ensure that all the elements have been transferred and filtered into a 100 mL volumetric flask through What man No. 42 filter paper and the volume was made upto the mark with distilled water. The grain and straw extract were preserved separately in plastic bottles for the analysis of different elements (Jackson, 1973).

3.15.3 Nitrogen content in grain and straw

Total nitrogen in grain and straw was determined by the Macro Kjeldahl method by digestion with conc. H_2SO_4 and catalyst mixture (K_2SO_4: $CuSO_4.5H_2O$: Se powder = 100:10:1) and distilling with 40% NaOH followed by titration of the distillate trapped in H_3BO_3 with 0.01 N (H_2SO_4) (Page *et al..* 1989).

3.15.4 Phosphorus content in grain and straw

Phosphorus content was determined form the digest by adding ammonium molybdate [$(NH_4)_6Mo7O_{24}.4H_2O$] and $SnCl_2$ solution and measuring the colour with the help of spectrophotometer at 660 ɳm wave length (Olsen *et al.* 1954).

3.15.5 Potassium content in grain and straw

Potassium concentration in grain and straw digests were determined directly with the help of a flame spectrophotometer using appropriate potassium filter. About 5 ml of extract of each sample was taken in a 50 ml beaker and was aspirated in a gas flame. The intensity of light emitted by potassium at 768 ɳm was directly proportional to the concentration of potassium present in plant samples. The percent emission for potassium was recorded following the procedure suggested by Black (1965).

3.15.6 Sulphur content in grain and straw

Sulphur concentration in the digest of grain and straw were determined by adding acid seed solution and precipitation with $BaCl_2$ and measuring the turbidity with the help of spectrophotometer at 420 ɳm wave length (Page, *et al.*, 1989).

3.15.7 Boron content in grain and straw

The content of boron in samples was determined by spectrophotometric method using Azomethine-H reagent. Exactly a 5 ml of extract was taken in a 25 ml volumetric flask then 4 ml buffer masking solution and 4 ml Azomethine-H was added. Then the volume was made up to the mark. After one hour, absorbance was measured at 420 ɳm wave length with help of spectrophotometer following the analytical technique (Tandm, 1995).

3.16 Statistical analysis

The data collected on different parameters were statistically analyzed with split plot design using the MSTAT-e computer package program developed by Russel (1986). Least Significant Difference (LSD) technique at 5% level of significance was used by DMRT to compare the mean differences among the treatments (Gomez and Gomez, 1984).

HAPTER IV

RESULTS AND DISCUSSIN

Considering growth, yield contributing parameters and yield of wheat affected by different level of irrigation and foliar application of boron, the results obtained from the present study for different characters and analyses have been presented and discussed in this chapter under the following headings:

4.1 Growth parameters

4.1.1 Plant height

4.1.1.1 Effect of irrigation

Plant height of wheat was statistically significant affected by the different levels of irrigation at different growth stages (Appendix IV and Fig.1). It was found that plant height increased with more irrigation frequencies compared to less or no irrigation. Results revealed that the tallest plant (48.04, 74.5, 91.13 and 94.18 cm at 40, 60, 80 DAS and at harvest respectively) was obtained from I_2 (Two irrigations at CRI stage and PI stage) followed by I_1 (One irrigation at CRI stage). On the other hand, the shortest plant (45.29, 69.59, 85.51 and 87.82 cm at 40, 60, 80 DAS and at harvest respectively) was achieved from I_0 (No irrigation; Control). It was also observed that single irrigation showed intermediate results at all growth stages. This finding was supported by Mushtaq and Muhammad (2005) who obtained increased plant height with increased irrigation treatments. Zhai *et al*. (2003) reported that water stress significantly inhibited the growth and yield of winter wheat. Gupta *et al.* (2001) reported that when water stress was imposed at booting stage caused a greater reduction in plant height. Islam (1997) reported that plant height increased with increasing number of irrigations.

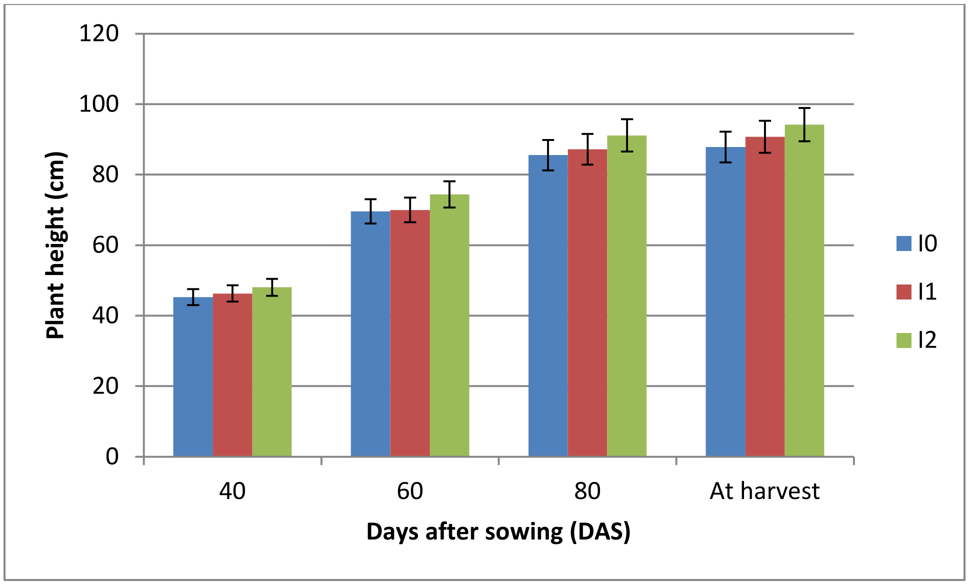

Fig. 1. Plant height of wheat at different growth stages affected by different levels of irrigations

I_0 = No irrigation (Control), I_1 = One irrigation given at crown root initiation (CRI) stage (18 DAS) and I_2 = Two irrigations, one at CRI stage (18 DAS) and other at panicle initiation (PI) stage (55 DAS)

4.1.1.2 Effect of foliar application of boron

Foliar application of boron at different doses had significant effect on plant height of wheat at different crop duration (Appendix IV and Fig. 2). Results showed that the tallest plant (49.56, 75.125, 91.23 and 93.71 cm at 40, 60, 80 DAS and at harvest respectively) was obtained from B_3 (2.5 kg H_3BO_3 ha^{-1}) treatment followed by B_2 (2.0 kg H_3BO_3 ha^{-1}) where the shortest plant (43.69, 67.63, 84.65 and 87.99 cm at 40, 60, 80 DAS and at harvest respectively) was produced from B_0 (0 kg H_3BO_3 ha^{-1}; Control) treatment followed by B_1 (1.5 kg H_3BO_3 ha^{-1}). Mete *et al*. (2005) reported that the plant height was significantly increased with the application of B. Singh *et al*. (2015), Ahmed *et al*. (2008) and Rahmatullah *et al*. (2006) also reported that application of B significantly increased plant height.

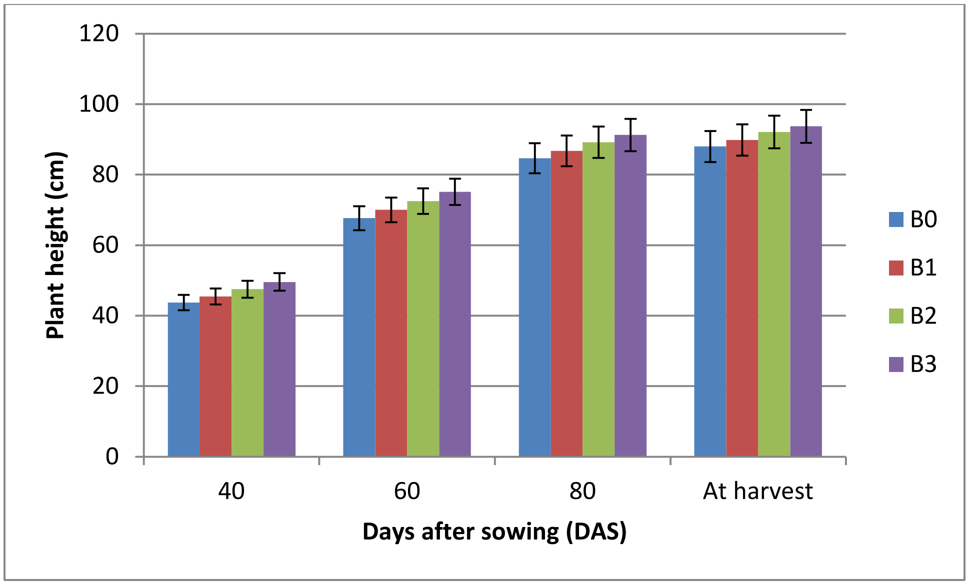

Fig. 2. Plant height of wheat at different growth stages affected by different levels of foliar application of boron

B_0 = 0 kg H_3BO_3 ha^{-1} (Control), B_1 = 1.5 kg H_3BO_3 ha^{-1}, B_2 = 2.0 kg H_3BO_3 ha^{-1} and B_3 = 2.5 kg H_3BO_3 ha^{-1}

4.1.1.3 Combined effect of irrigation and foliar application of boron

The combined effect of different levels of irrigation and foliar application of boron had significant effect on plant height of wheat at different crop duration (Appendix IV and Table 1). It was observed that the tallest plant (50.94, 78.91, 95.10 and 97.53 cm at 40, 60, 80 DAS and at harvest respectively) was obtained from I_2B_3 followed by I_2B_2 and I_1B_3. The shortest plant (43.25, 66.87, 82.94 and 85.33 cm at 40, 60, 80 DAS and at harvest respectively) was obtained from I_0B_0 followed by I_0B_1 and I_0B_2.

Table 1. Plant height of wheat at different growth stages affected by combined effect of different levels of irrigations and foliar application of boron

Treatment	Plant height (cm)			
	40 DAS	60 DAS	80 DAS	At harvest
I_0B_0	43.25 f	66.87 h	82.94 h	85.33 h
I_0B_1	44.28 ef	68.63 f-h	84.73 f-h	87.15 g
I_0B_2	45.53 de	70.27 ef	86.31 e-g	88.68 fg
I_0B_3	48.10 bc	72.59 cd	88.07 de	90.13 ef
I_1B_0	43.18 f	66.81 h	84.13 gh	87.77 g
I_1B_1	44.89 ef	67.80 gh	85.53 fg	89.59 ef
I_1B_2	47.41 cd	71.44 de	88.58 c-e	92.03 cd
I_1B_3	49.65 ab	73.87 c	90.51 bc	93.47 c
I_2B_0	44.63 ef	69.20 fg	86.87 ef	90.86 de
I_2B_1	47.07 cd	73.53 c	89.97 cd	92.73 c
I_2B_2	49.53 ab	75.75 b	92.56 b	95.59 b
I_2B_3	50.94 a	78.91 a	95.10 a	97.53 a
$LSD_{0.05}$	1.798	1.857	2.111	1.643
CV (%)	7.489	8.215	10.347	11.348

I_0 = No irrigation (Control), I_1 = One irrigation given at crown root initiation (CRI) stage (18 DAS) and I_2 = Two irrigations, one at CRI stage (18 DAS) and other at panicle initiation (PI) stage (55 DAS)

B_0 = 0 kg H_3BO_3 ha^{-1} (Control), B_1 = 1.5 kg H_3BO_3 ha^{-1}, B_2 = 2.0 kg H_3BO_3 ha^{-1} and B_3 = 2.5 kg H_3BO_3 ha^{-1}

4.1.2 Number of tillers plant^{-1}

4.1.2.1 Effect of irrigation

Number of tillers plant^{-1} of wheat was statistically significant at different growth stages influenced by the different levels of irrigation (Appendix V and Fig.3). It was found that that number of tillers plant^{-1} increased with increased irrigation compared to less or no irrigation. Results revealed that the highest number of tillers plant^{-1} (2.06, 3.56, 5.80 and 5.55 at 40, 60, 80 DAS and at harvest respectively) was obtained from I_2 (Two irrigations at CRI stage and PI stage) followed by I_1 (One irrigation at CRI stage). Alternatively, the lowest number of tillers plant^{-1} (0.89, 2.38, 3.95 and 3.72 at 40, 60, 80 DAS and at harvest respectively) was achieved from I_0 (No irrigation; Control). It was also observed that single irrigation, I_1 (One irrigation at CRI stage) showed intermediate results at all growth stages. The results of the present study is an agreement with Sher and Parvender (2006), Malik *et al*. (2010) and Wu *et al*. (2011) who observed that number of tillers plant^{-1} increased by increased levels of irrigation to at a certain level and duration.

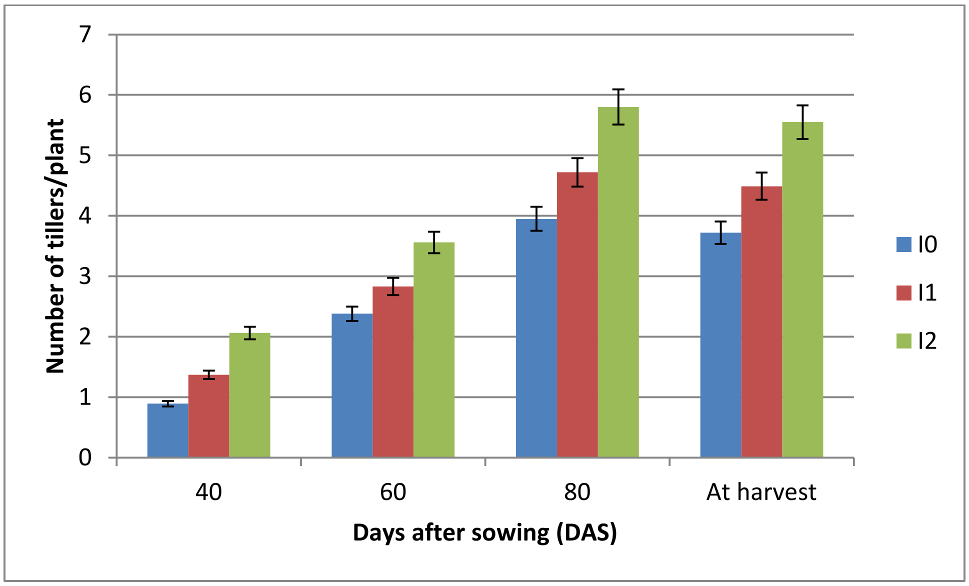

Fig. 3. Number of tillers plant^{-1} of wheat at different growth stages affected by different levels of irrigations

I_0 = No irrigation (Control), I_1 = One irrigation given at crown root initiation (CRI) stage (18 DAS) and I_2 = Two irrigations, one at CRI stage (18 DAS) and other at panicle initiation (PI) stage (55 DAS)

4.1.2.2 Effect of foliar application of boron

Foliar application of boron at different doses had significant effect on number of tillers plant^{-1} of wheat at different crop duration (Appendix V and Fig. 4). Results showed that the highest number of tillers plant^{-1} (1.97, 3.53, 5.43 and 5.20 at 40, 60, 80 DAS and at harvest respectively) was obtained from B_3 (2.5 kg H_3BO_3 ha^{-1}) treatment which was statistically identical with B_2 (2.0 kg H_3BO_3 ha^{-1}) at all growth stages where the lowest number of tillers plant^{-1} (0.87, 2.26, 4.18 and 3.93

at 40, 60, 80 DAS and at harvest respectively) was produced from B_0 (0 kg H_3BO_3 ha^{-1}; Control) treatment. Similar result was also observed by Singh *et al*. (2015) and Rahmatullah *et al*. (2006) who reported that number of effective tillers significantly increased with increased B application.

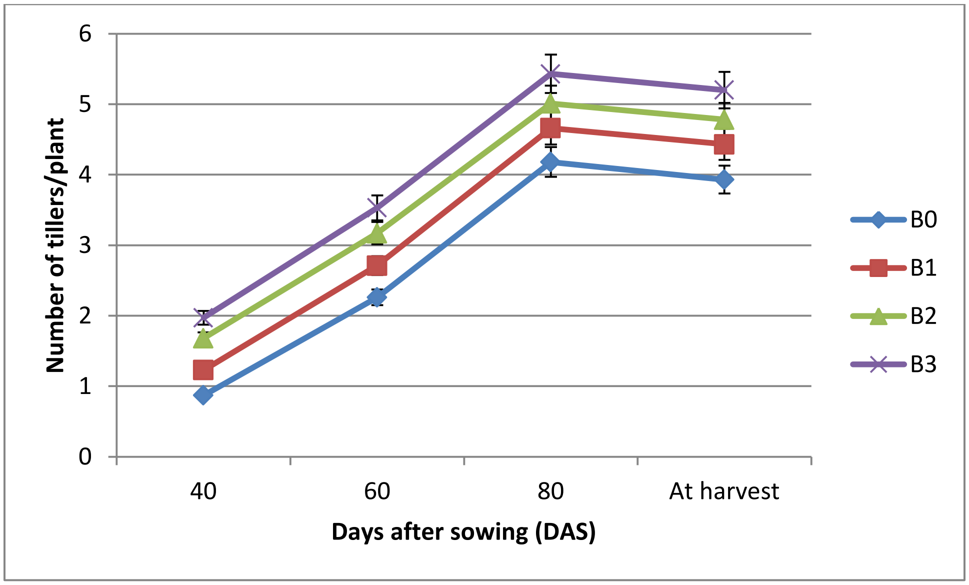

Fig. 4. Number of tillers $plant^{-1}$ of wheat at different growth stages affected by different levels of foliar application of boron

B_0 = 0 kg H_3BO_3 ha^{-1} (Control), B_1 = 1.5 kg H_3BO_3 ha^{-1}, B_2 = 2.0 kg H_3BO_3 ha^{-1} and B_3 = 2.5 kg H_3BO_3 ha^{-1}

4.1.2.3 Combined effect of irrigation and foliar application of boron

The combined effect of different levels of irrigation and foliar application of boron had significant effect on number of tillers $plant^{-1}$ of wheat at different crop duration (Appendix V and Table 2). It was observed that the highest number of tillers $plant^{-1}$ (2.63, 4.13, 6.23 and 6.00 at 40, 60, 80 DAS and at harvest respectively) was obtained from I_2B_3 which was statistically identical with I_2B_2 at all growth stages. Treatment combination of I_2B_1 also showed significantly same result at 80 DAS and at harvest with I_2B_3. The lowest number of tillers $plant^{-1}$ (0.50, 1.87, 3.26 and 3.03 at 40, 60, 80 DAS and at harvest respectively) was obtained from I_0B_0 which was statistically identical with I_0B_1 at 80 DAS and at harvest.

Table 2. Number of tillers plant^{-1} of wheat at different growth stages affected by combined effect of different levels of irrigations and foliar application of boron

Treatment	Number of tillers plant^{-1}			
	40 DAS	60 DAS	80 DAS	At harvest
I_0B_0	0.50 f	1.87 g	3.26 g	3.03 g
I_0B_1	0.80 ef	2.17 fg	3.56 g	3.33 g
I_0B_2	0.97 de	2.47 ef	4.20 ef	3.97 ef
I_0B_3	1.27 cd	3.00 cd	4.76 cd	4.53 cd
I_1B_0	0.74 ef	2.10 fg	4.06 f	3.83 f
I_1B_1	1.10 de	2.60 e	4.63 de	4.40 de
I_1B_2	1.64 bc	3.13 b-d	4.90 b-d	4.67 bc
I_1B_3	2.00 b	3.47 b	5.30 b	5.07 b
I_2B_0	1.37 cd	2.81 de	5.23 bc	4.93 bc
I_2B_1	1.80 b	3.37 bc	5.80 a	5.57 a
I_2B_2	2.44 a	3.91 a	5.93 a	5.70 a
I_2B_3	2.63 a	4.13 a	6.23 a	6.00 a
$LSD_{0.05}$	0.435	0.491	0.371	0.394
CV (%)	6.778	8.541	8.783	9.315

I_0 = No irrigation (Control), I_1 = One irrigation given at crown root initiation (CRI) stage (18 DAS) and I_2 = Two irrigations, one at CRI stage (18 DAS) and other at panicle initiation (PI) stage (55 DAS)

B_0 = 0 kg H_3BO_3 ha^{-1} (Control), B_1 = 1.5 kg H_3BO_3 ha^{-1}, B_2 = 2.0 kg H_3BO_3 ha^{-1} and B_3 = 2.5 kg H_3BO_3 ha^{-1}

4.1.3 Leaf area index (LAI)

4.1.3.1 Effect of irrigation

Leaf area index (LAI) was influenced significantly at different growth stages by the different levels of irrigation except 40 DAS (Appendix VI and Fig. 5). It was found that LAI was decreased with decreased irrigation compared to higher irrigation frequencies. Results revealed that the highest LAI (1.81, 2.83, 3.92 and 3.62 at 40, 60, 80 DAS and at harvest respectively) was obtained from I_2 (Two irrigations at CRI stage and PI stage) followed by I_1 (One irrigation at CRI stage). Again, the lowest LAI (1.60, 2.53, 3.30 and 3.13 at 40, 60, 80 DAS and at harvest respectively) was achieved from I_0 (No irrigation; Control). It was also observed that single irrigation, I_1 (One irrigation at CRI stage) showed intermediate results at all growth stages. This result is in accord with that of Abdorrahmani *et al*. (2005), Onyibe (2008), Mandal *et al*. (2002) and Nahar and Paul (1998) who reported that LAI increased significantly with increasing levels of irrigation.

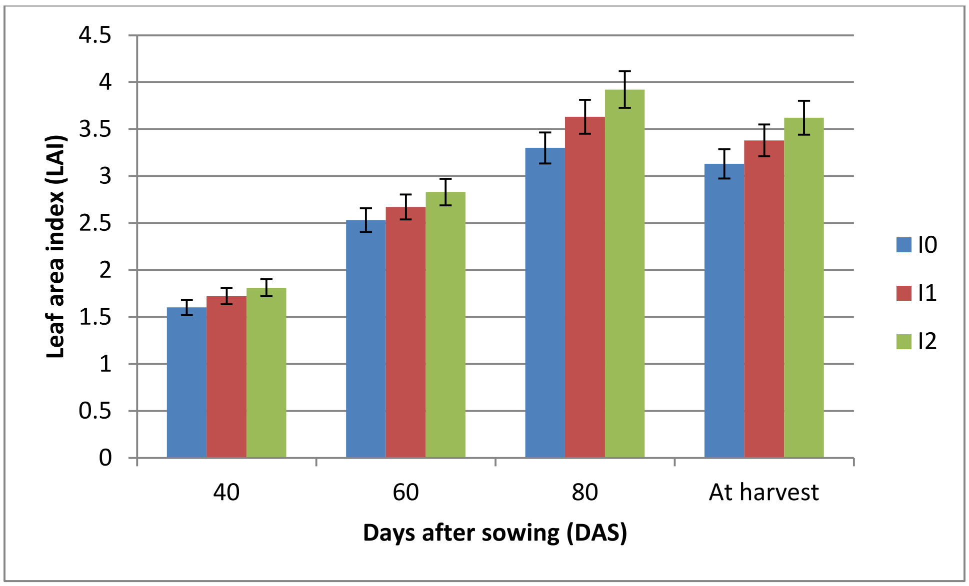

Fig. 5. Leaf area index (LAI) of wheat at different growth stages affected by different levels of irrigations

I_0 = No irrigation (Control), I_1 = One irrigation given at crown root initiation (CRI) stage (18 DAS) and I_2 = Two irrigations, one at CRI stage (18 DAS) and other at panicle initiation (PI) stage (55 DAS)

4.1.3.2 Effect of foliar application of boron

Foliar application of boron at different doses had significant effect on leaf area index (LAI) at different crop duration except 40 DAS (Appendix VI and Fig. 6). Results indicated that the highest LAI (1.80, 2.79, 3.84 and 3.53 at 40, 60, 80 DAS and at harvest respectively) was obtained from B_3 (2.5 kg H_3BO_3 ha^{-1}) treatment which was statistically identical with B_2 (2.0 kg H_3BO_3 ha^{-1}) at the time of harvest.

The lowest LAI (1.63, 2.56, 3.35 and 3.17 at 40, 60, 80 DAS and at harvest respectively) was obtained from B_0 (0 kg H_3BO_3 ha^{-1}; Control) treatment followed by B_1 (1.5 kg H_3BO_3 ha^{-1}). Ahmed *et al*. (2008) reported that boron application significantly increase the leaf area in wheat.

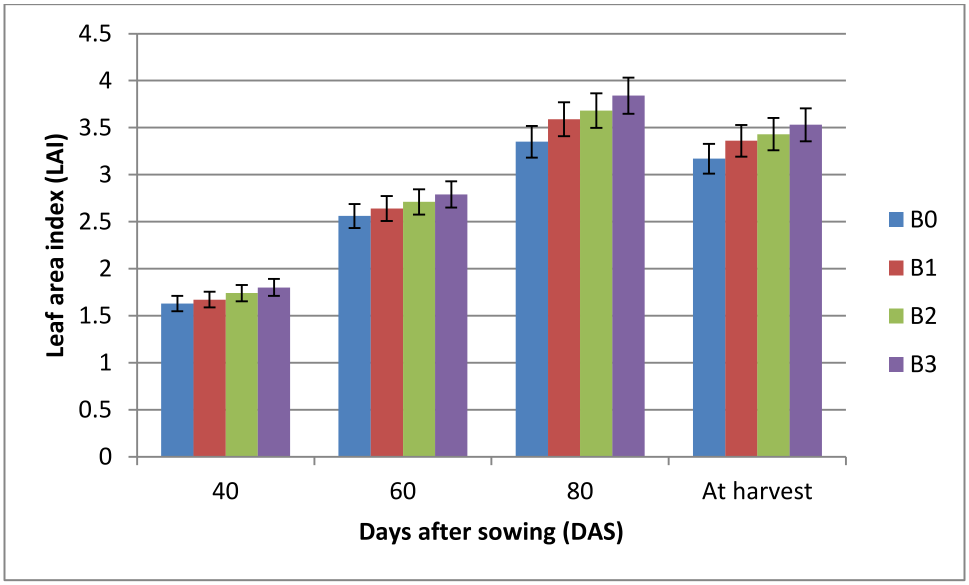

Fig. 6. Leaf area index (LAI) of wheat at different growth stages affected by different levels of foliar application of boron

B_0 = 0 kg H_3BO_3 ha^{-1} (Control), B_1 = 1.5 kg H_3BO_3 ha^{-1}, B_2 = 2.0 kg H_3BO_3 ha^{-1} and B_3 = 2.5 kg H_3BO_3 ha^{-1}

4.1.3.3 Combined effect of irrigation and foliar application of boron

The combined effect of different levels of irrigation and foliar application of boron had significant effect on leaf area index (LAI) of wheat at different crop duration except 40 DAS (Appendix VI and Table 3). It was observed that the highest LAI (1.97, 4.02, 4.54 and 4.18 at 40, 60, 80 DAS and at harvest respectively) was obtained from I_2B_3 which was statistically identical with I_2B_2 at all growth stages followed by I_2B_1 and I_1B_3 treatment combination. The lowest LAI (1.54, 2.43, 3.17 and 3.02 at 40, 60, 80 DAS and at harvest respectively) was obtained from I_0B_0 which was statistically similar with the treatment combination of I_0B_1 and I_0B_2.

Table 3. Leaf area index (LAI) of wheat at different growth stages affected by combined effect of different levels of irrigations and foliar application of boron

Treatment	Leaf area index (LAI)			
	40 DAS	60 DAS	80 DAS	At harvest
I_0B_0	1.54	2.43 f	3.17 f	3.02 g
I_0B_1	1.57	2.49 ef	3.25 f	3.09 fg
I_0B_2	1.63	2.55 ef	3.31 ef	3.15 fg
I_0B_3	1.67	2.63 d-f	3.45 d-f	3.29 d-f
I_1B_0	1.65	2.59 ef	3.40 ef	3.21 e-g
I_1B_1	1.71	2.77 d-f	3.58 c-e	3.43 de
I_1B_2	1.76	2.84 de	3.71 b-d	3.52 cd
I_1B_3	1.77	3.22 bc	3.83 bc	3.68 bc
I_2B_0	1.69	2.95 cd	3.45 d-f	3.40 de
I_2B_1	1.74	3.46 b	3.94 b	3.76 b
I_2B_2	1.83	3.88 a	4.33 a	4.06 a
I_2B_3	1.97	4.02 a	4.54 a	4.18 a
$LSD_{0.05}$	NS	0.321	0.262	0.227
CV (%)	4.871	7.019	6.114	7.559

I_0 = No irrigation (Control), I_1 = One irrigation given at crown root initiation (CRI) stage (18 DAS) and I_2 = Two irrigations, one at CRI stage (18 DAS) and other at panicle initiation (PI) stage (55 DAS)

B_0 = 0 kg H_3BO_3 ha^{-1} (Control), B_1 = 1.5 kg H_3BO_3 ha^{-1}, B_2 = 2.0 kg H_3BO_3 ha^{-1} and B_3 = 2.5 kg H_3BO_3 ha^{-1}

4.1.4 Dry weight plant^{-1}

4.1.4.1 Effect of irrigation

Dry weight plant^{-1} of wheat was significantly differed at different growth stages influenced by the different levels of irrigation (Appendix VII and Fig.7). Results revealed that the highest dry weight plant^{-1} (13.81, 16.01, 22.99 and 29.30 g at 40, 60, 80 DAS and at harvest respectively) was obtained from I_2 (Two irrigations at CRI stage and PI stage) followed by I_1 (One irrigation at CRI stage). Alternatively, the lowest dry weight plant^{-1} (8.45, 10.66, 15.25 and 21.56 g at 40, 60, 80 DAS and at harvest respectively) was achieved from I_0 (No irrigation; Control). It was also observed that single irrigation, I_1 (One irrigation at CRI stage) showed intermediate results at all growth stages. This finding was supported by the findings of Ashok and Sharma (2004), Li *et al*. (2010), Sher and Parvender (2006) and Abdorrahmani *et al*. (2005). They found that dry matter production increased with the increase of irrigation amount and scarcity of water reduced dry matter production, crop growth rate and relative growth rate.

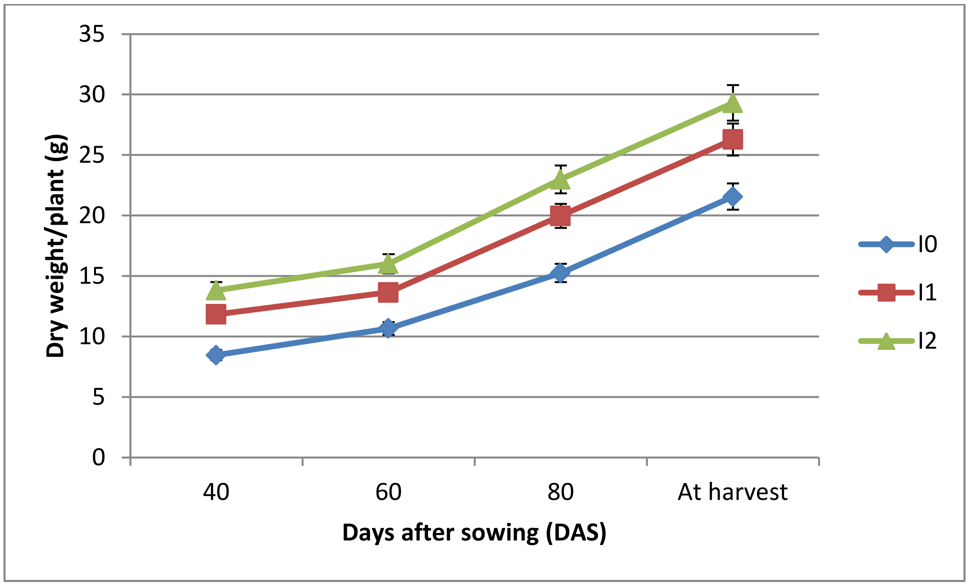

Fig. 7. Dry weight plant^{-1} of wheat at different growth stages affected by different levels of irrigations

I_0 = No irrigation (Control), I_1 = One irrigation given at crown root initiation (CRI) stage (18 DAS) and I_2 = Two irrigations, one at CRI stage (18 DAS) and other at panicle initiation (PI) stage (55 DAS)

4.1.4.2 Effect of foliar application of boron

Foliar application of boron at different doses had significant effect on dry weight plant^{-1} of wheat at different crop duration (Appendix VII and Fig. 8). Results showed that the highest dry weight plant^{-1} (14.00, 15.99, 23.43 and 29.74 g at 40, 60, 80 DAS and at harvest respectively) was obtained from B_2 (2.0 kg H_3BO_3 ha^{-1}) treatment which was statistically identical with B_3 (2.5 kg H_3BO_3 ha^{-1}) at all growth stages. The lowest dry weight plant^{-1} (8.22, 10.20, 13.33 and 19.64 g at 40, 60, 80 DAS and at harvest respectively) was achieved from B_0 (0 kg H_3BO_3 ha^{-1}; Control) treatment. Singh *et al*. (2015) found that B had significant effect on significantly higher dry matter production.

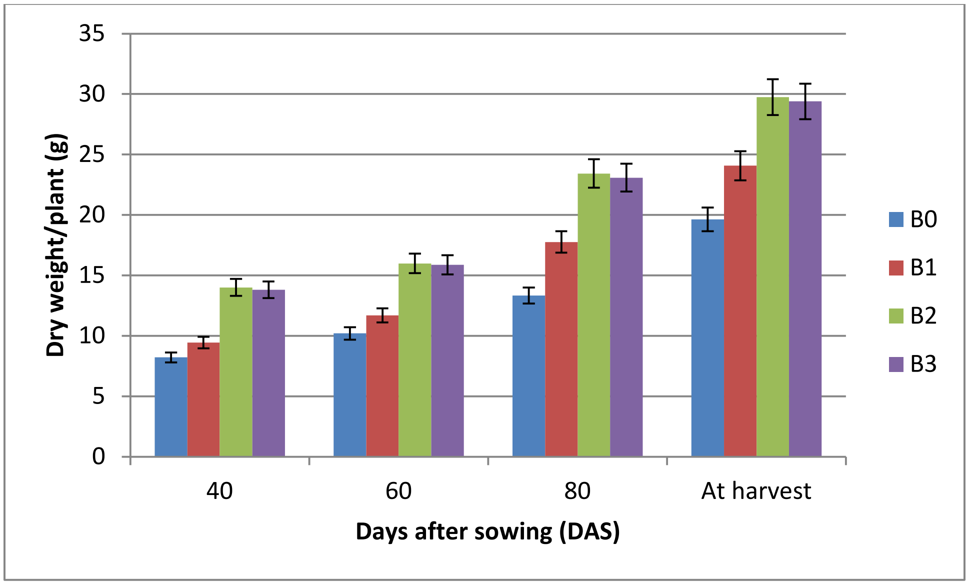

Fig. 8. Dry weight $plant^{-1}$ of wheat at different growth stages affected by different levels of foliar application of boron

B_0 = 0 kg H_3BO_3 ha^{-1} (Control), B_1 = 1.5 kg H_3BO_3 ha^{-1}, B_2 = 2.0 kg H_3BO_3 ha^{-1} and B_3 = 2.5 kg H_3BO_3 ha^{-1}

4.1.4.3 Combined effect of irrigation and foliar application of boron

The combined effect of different levels of irrigation and foliar application of boron had significant effect on dry weight $plant^{-1}$ of wheat at different crop duration (Appendix VII and Table 4). It was observed that the highest dry weight $plant^{-1}$ (17.63, 20.24, 28.46 and 34.76g at 40, 60, 80 DAS and at harvest respectively) was obtained from I_2B_2 followed by the treatment combination of I_2B_3. The lowest dry weight $plant^{-1}$ (5.93, 7.38, 10.93 and 17.24 g at 40, 60, 80 DAS and at harvest respectively) was obtained from I_0B_0 which was statistically identical with I_0B_1.

Table 4. Dry weight plant^{-1} of wheat at different growth stages affected by combined effect of different levels of irrigations and foliar application of boron

Treatment	Dry weight plant^{-1}			
	40 DAS	60 DAS	80 DAS	At harvest
I_0B_0	5.93 g	7.38 h	10.93 h	17.24 h
I_0B_1	6.40 g	8.85 g	12.05 h	18.35 h
I_0B_2	8.85 f	11.54 f	17.55 fg	23.86 fg
I_0B_3	12.63 d	14.86 d	20.45 de	26.77 de
I_1B_0	8.24 f	10.53 f	13.25 h	19.56 h
I_1B_1	10.70 e	12.64 e	19.26 ef	25.57 ef
I_1B_2	14.92 c	16.19 c	24.28 bc	30.59 bc
I_1B_3	13.46 d	15.21 cd	23.09 c	29.39 c
I_2B_0	10.48 e	12.68 e	15.81 g	22.13 g
I_2B_1	11.23 e	13.59 e	21.97 cd	28.28 cd
I_2B_2	17.63 a	20.24 a	28.46 a	34.76 a
I_2B_3	15.91 b	17.53 b	25.71 b	32.02 b
$LSD_{0.05}$	0.990	1.024	2.434	2.478
CV (%)	7.335	8.419	8.836	10.219

I_0 = No irrigation (Control), I_1 = One irrigation given at crown root initiation (CRI) stage (18 DAS) and I_2 = Two irrigations, one at CRI stage (18 DAS) and other at panicle initiation (PI) stage (55 DAS)

B_0 = 0 kg H_3BO_3 ha^{-1} (Control), B_1 = 1.5 kg H_3BO_3 ha^{-1}, B_2 = 2.0 kg H_3BO_3 ha^{-1} and B_3 = 2.5 kg H_3BO_3 ha^{-1}

4.2 Yield contributing parameters

4.2.1 Spike length

4.2.1.1 Effect of irrigation

Length of spike at harvest was significantly influenced by different levels of irrigation (Appendix VIII and Table 5). It was observed that the longest spike at harvest (16.42 cm) was obtained from I_2 (Two irrigations at CRI stage and PI stage) followed by I_1 (One irrigation at CRI stage) where the lowest spike length (14.51 cm) at harvest was obtained from I_0 (No irrigation; Control). This was similar to that of Alsohaibani (2007), Wu *et al*. (2011) and Ali and Amin (2007).

They observed that spike length was significantly influenced by different levels of irrigation and two irrigations significantly enhanced spike length.

4.2.1.2 Effect of foliar application of boron

Foliar application of boron at different doses had significant effect on spike length at harvest (Appendix VIII and Table 5). Results revealed that the highest spike length (16.23 cm) was obtained from B_2 (2.0 kg H_3BO_3 ha^{-1}) treatment which was statistically identical with B_3 (2.5 kg H_3BO_3 ha^{-1}). The lowest spike length (14.47 cm) was achieved from B_0 (0 kg H_3BO_3 ha^{-1}; Control) treatment followed by B_1 (1.5 kg H_3BO_3 ha^{-1}). Rahmatullah *et al*. (2006) found that spike length of wheat differed significantly with B treatment.

4.2.1.3 Combined effect of irrigation and foliar application of boron

The combined effect of different levels of irrigation and foliar application of boron had significant effect on spike length at harvest (Appendix VIII and Table 5). It was observed that the highest spike length (17.65 cm) was obtained from I_2B_2. The lowest spike length (13.57 cm) was obtained from I_0B_0 treatment combination.

4.2.2 Number of spikelets spike^{-1}

4.2.2.1 Effect of irrigation

Significant influence was found for number of spikelets spike^{-1} at harvest affected by different levels of irrigation (Appendix VIII and Table 5). It was observed that the highest number of spikelets spike^{-1} at harvest (12.54) was obtained from I_2 (Two irrigations at CRI stage and PI stage) followed by I_1 (One irrigation at CRI stage) where the lowest number of spikelets spike^{-1} (45.90) at harvest was obtained from I_0 (No irrigation; Control). This finding was supported by the findings of Ali and Amin (2007) who reported that two irrigations significantly increase number of spikelets spike^{-1} than single irrigation.

4.2.2.2 Effect of foliar application of boron

Different levels of boron application by foliar spray had significant influence on number of spikelets spike^{-1} at harvest (Appendix VIII and Table 5). It was observed that the highest number of spikelets spike^{-1} (54.69) was obtained from B_2 (2.0 kg H_3BO_3 ha^{-1}) treatment followed by B_3 (2.5 kg H_3BO_3 ha^{-1}). The lowest number of spikelets spike^{-1} (45.84) was achieved from B_0 (0 kg H_3BO_3 ha^{-1}; Control) treatment followed by B_1 (1.5 kg H_3BO_3 ha^{-1}). Hamzeh and Florin (2014) observed that boron application significantly increased the number of spiklet per spike.

4.2.2.3 Combined effect of irrigation and foliar application of boron

Number of spikelets spike^{-1} at harvest was significantly varied due to combined effect of different levels of irrigation and foliar application of boron (Appendix VIII and Table 5). It was observed that the highest number of spikelets spike^{-1} (61.20) was obtained from I_2B_2 followed by the treatment combination of I_2B_3 and I_1B_2. The lowest number of spikelets spike^{-1} (41.20) was obtained from I_0B_0 treatment combination.

4.2.3 Number of grains spike^{-1}

4.2.3.1 Effect of irrigation

Significant influence was found for number of grains spike^{-1} at harvest affected by different levels of irrigation (Appendix VIII and Table 5). It was observed that the highest number of grains spike^{-1}at harvest (39.38) was obtained from I_2 (Two irrigations at CRI stage and PI stage) followed by I_1 (One irrigation at CRI stage) where the lowest number of grains spike^{-1} (33.91) at harvest was obtained from I_0 (No irrigation; Control). This result is in accord with that of Sher and Parvender (2006), Wu *et al*. (2011) and Mushtaq and Muhammad (2005) who recorded that higher irrigation frequencies gave higher number of grains per spike.

4.2.3.2 Effect of foliar application of boron

Different levels of boron application by foliar spray had significant influence on number of grains spike^{-1}at harvest (Appendix VIII and Table 5). It was observed that the highest number of grains spike^{-1} (39.34) was obtained from B_2 (2.0 kg H_3BO_3 ha^{-1}) treatment which was statistically identical with B_3 (2.5 kg H_3BO_3 ha^{-1}). The lowest number of grains spike^{-1} (32.91) was achieved from B_0 (0 kg H_3BO_3 ha^{-1}; Control) treatment. Hamzeh and Florin (2014) observed that boron application significantly increased the number of grains per spike.

4.2.3.3 Combined effect of irrigation and foliar application of boron

Number of grains spike^{-1}at harvest was significantly varied due to combined effect of different levels of irrigation and foliar application of boron (Appendix VIII and Table 5). It was observed that the highest number of grains spike^{-1} (41.63) was obtained from I_2B_2 which was statistically similar with the treatment combination of I_2B_3 and I_1B_2 and I_2B_1. The lowest number of grains spike^{-1} (30.52) was obtained from I_0B_0 treatment combination.

4.2.4 Weight of 1000 grains

4.2.4.1 Effect of irrigation

Different levels of irrigation had significant influence on 1000 grain weight (Appendix VIII and Table 5). It was observed that the highest 1000 grain weight at harvest (46.88 g) was obtained from I_2 (Two irrigations at CRI stage and PI stage) where the lowest 1000 grain weight (42.39 g) at harvest was obtained from I_0 (No irrigation; Control) which was statistically similar with I_1 treatment. The result is in conformity with that Sher and Parvender (2006) Mushtaq and Muhammad (2005) who reported 1000 grain weight increased with more irrigation. But Islam (1996) observed that irrigation had no influence of 1000-grain weight.

Table 5. Effect of different levels of irrigation and foliar application of boron and their interaction on length of spike, number of spikelets spike^{-1} and number of grains spike^{-1}

Treatment	Yield contributing parameters			
	Spike length (cm)	Number of spikelets spike^{-1}	Number of grains spike^{-1}	1000 grains weight (g)
Effect of irrigation				
I_0	14.51 c	45.90 c	33.91 c	42.39 b
I_1	15.67 b	50.83 b	37.05 b	43.38 b
I_2	16.42 a	54.98 a	39.38 a	46.88 a
$LSD_{0.05}$	0.562	2.311	1.671	2.016
CV (%)	4.715	5.312	4.119	4.663
Effect of foliar application of boron				
B_0	14.47 c	45.84 d	32.91 c	42.40 c
B_1	15.32 b	48.81 c	36.02 b	44.17 b
B_2	16.23 a	54.69 a	39.34 a	45.25 a
B_3	16.11 a	52.92 b	38.86 a	45.04 a
$LSD_{0.05}$	0.488	1.539	2.047	1.008
CV (%)	4.886	6.322	4.517	4.334
Combined effect of irrigation and foliar application of boron				
I_0B_0	13.57 f	41.20 h	30.52 f	41.47 e
I_0B_1	14.48 e	44.33 g	32.68 e	41.85 de
I_0B_2	14.57 de	49.00 ef	34.12 de	43.19 cd
I_0B_3	15.43 cd	49.07 ef	38.33 c	43.04 cd
I_1B_0	14.65 de	47.53 f	32.97 e	42.59 c-e
I_1B_1	15.34 c-e	50.63 de	35.54 d	43.64 c
I_1B_2	16.48 b	53.87 c	40.83 ab	43.78 c
I_1B_3	16.22 bc	51.27 d	38.87 bc	43.53 c
I_2B_0	15.18 de	48.80 ef	35.24 d	43.12 cd
I_2B_1	16.15 bc	51.47 d	39.83 a-c	47.04 b
I_2B_2	17.65 a	61.20 a	41.63 a	48.82 a
I_2B_3	16.68 b	58.43 b	40.81 ab	48.55 a
$LSD_{0.05}$	0.8191	1.806	1.914	1.369
CV (%)	7.582	9.574	8.648	7.896

I_0 = No irrigation (Control), I_1 = One irrigation given at crown root initiation (CRI) stage (18 DAS) and I_2 = Two irrigations, one at CRI stage (18 DAS) and other at panicle initiation (PI) stage (55 DAS)

B_0 = 0 kg H_3BO_3 ha^{-1} (Control), B_1 = 1.5 kg H_3BO_3 ha^{-1}, B_2 = 2.0 kg H_3BO_3 ha^{-1} and B_3 = 2.5 kg H_3BO_3 ha^{-1}

4.2.4.2 Effect of foliar application of boron

Different levels of boron application by foliar spray had significant influence on 1000 grain weight at harvest (Appendix VIII and Table 5). It was observed that the highest 1000 grain weight (45.25 g) was obtained from B_2 (2.0 kg H_3BO_3 ha^{-1}) treatment which was statistically identical with B_3 (2.5 kg H_3BO_3 ha^{-1}). The lowest 1000 grain weight (42.40 g) was achieved from B_0 (0 kg H_3BO_3 ha^{-1}; Control) treatment. Ahmed *et al*. (2008) and Rahmatullah *et al*. (2006) and Hamzeh and Florin (2014) found that B fertilizer significantly increased 1000 grain weight.

4.2.4.3 Combined effect of irrigation and foliar application of boron

Combined effect of different levels of irrigation and foliar application of boron showed significantly variation on 1000 grain weight at harvest (Appendix VIII and Table 5). It was evident that the highest 1000 grain weight (48.82 g) was obtained from I_2B_2 which was statistically identical with the treatment combination of I_2B_3. The lowest 1000 grain weight (41.47 g) was obtained from I_0B_0 treatment combination.

4.3 Yield parameters

4.3.1 Grain yield

4.3.1.1 Effect of irrigation

Significant influence was found for grain yield at harvest affected by different levels of irrigation (Appendix IX and Table 6). It was observed that the highest grain yield at harvest (3.75 t ha^{-1}) was obtained from I_2 (Two irrigations at CRI stage and PI stage) followed by I_1 (One irrigation at CRI stage) where the lowest grain yield (2.48 t ha^{-1}) at harvest was obtained from I_0 (No irrigation; Control). This result is in accord with that of Onyibe (2008), Sher and Parvender (2006) and Zhang et al., (2005). They found that two or more irrigation gave higher grain yield than single irrigation.

4.3.1.2 Effect of foliar application of boron

Different levels of boron application by foliar spray had significant influence on grain yield at harvest (Appendix IX and Table 6). It was observed that the highest grain yield (3.68 t ha^{-1}) was obtained from B_2 (2.0 kg H_3BO_3 ha^{-1}) treatment followed by B_3 (2.5 kg H_3BO_3 ha^{-1}). The lowest grain yield (2.36 t ha^{-1}) was achieved from B_0 (0 kg H_3BO_3 ha^{-1}; Control) treatment followed by B_1 (1.5 kg H_3BO_3 ha^{-1}). Similar results were also observed by Singh *et al*. (2015), Hamzeh and Florin (2014), Ahmed *et al*. (2008) and Rahmatullah *et al*. (2006) who observed that B fertilizer had significant effect on grain yield of wheat and significantly increase the grain yield.

4.3.1.3 Combined effect of irrigation and foliar application of boron

Grain yield at harvest was significantly varied due to combined effect of different levels of irrigation and foliar application of boron (Appendix IX and Table 6). It was found that the highest grain yield (4.66 t ha^{-1}) was obtained from I_2B_2 followed by the treatment combination of I_2B_3 and I_1B_2. The lowest grain yield (2.06 t ha^{-1}) was obtained from I_0B_0 which was statistically similar with the treatment combination of I_0B_1 followed by I_1B_0 treatment combination.

4.3.2 Stover yield

4.3.2.1 Effect of irrigation

Significant influence was found for stover yield at harvest affected by different levels of irrigation (Appendix IX and Table 6). It was observed that the highest stover yield at harvest (6.18 t ha^{-1}) was obtained from I_2 (Two irrigations at CRI stage and PI stage) followed by I_1 (One irrigation at CRI stage) where the lowest stover yield (5.59 t ha^{-1}) at harvest was obtained from I_0 (No irrigation; Control). The results of the present study are in agreement with Chaudhary and Dahatonde (2007).

4.3.2.2 Effect of foliar application of boron

Different levels of boron application by foliar spray had significant influence on stover yield at harvest (Appendix IX and Table 6). It was observed that the highest stover yield (6.18 t ha^{-1}) was obtained from B_2 (2.0 kg H_3BO_3 ha^{-1}) treatment. The lowest stover yield (5.58 t ha^{-1}) was achieved from B_0 (0 kg H_3BO_3 ha^{-1}; Control) treatment.

4.3.2.3 Combined effect of irrigation and foliar application of boron

Stover yield at harvest was significantly varied due to combined effect of different times of irrigation and foliar application of boron (Appendix IX and Table 6). It was found that the highest stover yield (6.42 t ha^{-1}) was obtained from I_2B_2 which was statistically similar with the treatment combination of I_2B_3 and I_1B_2. The lowest stover yield (5.35 t ha^{-1}) was obtained from I_0B_0 which was statistically similar with the treatment combination of I_0B_1 followed by I_1B_0 treatment combination.

4.3.3 Biological yield

4.3.3.1 Effect of irrigation

Significant influence was found for biological yield at harvest affected by different times of irrigation (Appendix IX and Table 6). It was observed that the highest biological yield at harvest (9.92 t ha^{-1}) was obtained from I_2 (Two irrigations at CRI stage and PI stage) followed by I_1 (One irrigation at CRI stage) where the lowest biological yield (8.07 t ha^{-1}) at harvest was obtained from I_0 (No irrigation; Control). This result is in accord with that of Abdorrahmani *et al*., (2005) who reported that biological yield was significantly correlated with grain yield.

4.3.3.2 Effect of foliar application of boron

Different levels of boron application by foliar spray had significant influence on biological yield at harvest (Appendix IX and Table 6). It was observed that the highest biological yield (9.83 t ha^{-1}) was obtained from B_2 (2.0 kg H_3BO_3 ha^{-1}) treatment followed by B_3 (2.5 kg H_3BO_3 ha^{-1}). The lowest biological yield (7.94 t ha^{-1}) was achieved from B_0 (0 kg H_3BO_3 ha^{-1}; Control) treatment.

4.3.3.3 Combined effect of irrigation and foliar application of boron

Biological yield at harvest was significantly varied due to combined effect of different levels of irrigation and foliar application of boron (Appendix IX and Table 6). It was found that the highest biological yield (11.08 t ha^{-1}) was obtained from I_2B_2 treatment combination. The lowest biological yield (7.41 t ha^{-1}) was obtained from I_0B_0 which was statistically similar with the treatment combination of I_0B_1.

4.3.4 Harvest index

4.3.4.1 Effect of irrigation

Significant influence was found for harvest index at harvest affected by different levels of irrigation (Appendix IX and Table 6). It was observed that the highest harvest index at harvest (37.35 %) was obtained from I_2 (Two irrigations at CRI stage and PI stage) where the lowest harvest index (30.54 %) at harvest was obtained from I_0 (No irrigation; Control). This result is in accord with that of Ali and Amin (2007) and Abdorrahmani *et al*., 2005).

4.3.4.2 Effect of foliar application of boron

Different levels of boron application by foliar spray had significant influence on harvest index at harvest (Appendix IX and Table 6). It was observed that the highest harvest index (37.11%) was obtained from B_2 (2.0 kg H_3BO_3 ha^{-1}) treatment which was statistically identical with B_3 (2.5 kg H_3BO_3 ha^{-1}). The lowest harvest index (29.67%) was achieved from B_0 (0 kg H_3BO_3 ha^{-1}; Control) treatment.

4.3.4.3 Combined effect of irrigation and foliar application of boron

Harvest index at harvest was significantly varied due to combined effect of different levels of irrigation and foliar application of boron (Appendix IX and Table 6). It was found that the highest harvest index (42.06%) was obtained from the treatment combination of I_2B_2 followed by the treatment combination of I_2B_3 and I_1B_2. The lowest harvest index (27.80%) was obtained from the treatment combination of I_0B_0.

4.4 Nutrient concentration of grain and straw

Both grain and straw of wheat (cv. BARI Gom-26) were analyzed for the determination of N. P. K, S and B concentrations. The results are presented in Tables 7 and 8.

4.4.1 Nitrogen (N) concentration in grain

4.4.1.1 Effect of irrigation

Different levels of irrigation had no significant effect on the grain N concentrations of wheat (Appendix X and Table 7). However, the N concentration in grain varied from 1.96% to 2.15%. The highest N concentration (2.15%) in grain was measured with I_2 (Two irrigations at CRI stage and PI stage) where the lowest N concentration (1.96%) was recorded from I_0 (No irrigation; Control).

4.4.1.2 Effect of foliar application of boron

Different levels of foliar application of boron had no significant influence on N concentrations of wheat in grain (Appendix X and Table 7). However, the N concentration in grain varied from 1.97% to 2.15%. It was observed that the highest N concentration (2.15%) in grain was found from B_3 (2.5 kg H_3BO_3 ha^{-1}) where the lowest N concentration (1.97%) was recorded from B_0 (0 kg H_3BO_3 ha^{-1}; Control).

Table 6. Effect on yield characters showing grain yield, stover yield, biological yield and harvest index affected by different levels of irrigation and foliar application of boron and their interaction

Treatment	Yield parameters			
	Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Effect of irrigation				
I_0	2.48 c	5.59 c	8.07 c	30.54 c
I_1	3.17 b	5.97 b	9.14 b	34.33 b
I_2	3.75 a	6.18 a	9.92a	37.35 a
$LSD_{0.05}$	0.216	0.381	0.517	1.104
CV (%)	3.074	3.627	4.266	4.571
Effect of foliar application of boron				
B_0	2.36 d	5.58 c	7.94 d	29.67 c
B_1	2.83 c	5.81 b	8.64 c	32.50 b
B_2	3.68 a	6.18 a	9.83 a	37.11 a
B_3	3.65 b	6.08 b	9.76 b	37.00 a
$LSD_{0.05}$	0.029	0.074	0.062	2.217
CV (%)	4.086	4.319	4.568	5.116
Combined effect of irrigation and foliar application of boron				
I_0B_0	2.06 j	5.35 f	7.41 j	27.80 i
I_0B_1	2.21 ij	5.42 ef	7.63 ij	28.96 h
I_0B_2	2.51 gh	5.58 e	8.09 h	31.03 g
I_0B_3	3.14 e	6.00 d	9.14 ef	34.35 e
I_1B_0	2.32 hi	5.46 ef	7.78 hi	29.82 h
I_1B_1	2.91 f	5.97 d	8.88 fg	32.77 f
I_1B_2	3.87 c	6.25 ab	10.12 c	38.24 c
I_1B_3	3.58 d	6.21 bc	9.78 d	36.50 d
I_2B_0	2.71 fg	5.92 d	8.63 g	31.40 g
I_2B_1	3.36 de	6.05 cd	9.42 e	35.77 d
I_2B_2	4.66 a	6.42 a	11.08 a	42.06 a
I_2B_3	4.24 b	6.32 ab	10.56 b	40.15 b
$LSD_{0.05}$	0.227	0.186	0.3213	1.012
CV (%)	7.516	8.219	8.717	10.247

I_0 = No irrigation (Control), I_1 = One irrigation given at crown root initiation (CRI) stage (18 DAS) and I_2 = Two irrigations, one at CRI stage (18 DAS) and other at panicle initiation (PI) stage (55 DAS)

B_0 = 0 kg H_3BO_3 ha^{-1} (Control), B_1 = 1.5 kg H_3BO_3 ha^{-1}, B_2 = 2.0 kg H_3BO_3 ha^{-1} and B_3 = 2.5 kg H_3BO_3 ha^{-1}

4.4.1.3 Combined effect of irrigation and foliar application of boron

N concentrations of wheat in grain affected by combined effect of different levels of irrigation and foliar application of boron was not statistically significant (Appendix X and Table 7). However, the N concentration in grain varied from 1.88% to 2.26%. It was observed that the highest N concentration (2.26%) in grain was found from I_2B_3 treatment combination where the lowest N concentration (1.88%) was recorded from treatment combination of I_0B_0.

4.4.2 Phosphorus (P) concentration in grain

4.4.2.1 Effect of irrigation

Different levels of irrigation had no significant effect on the grain P concentration of wheat in grain (Appendix X and Table 7). However, the P concentration in grain varied from 0.215% to 0.243%. The highest P concentration (0.243%) in grain was measured with I_2 (Two irrigations at CRI stage and PI stage) where the lowest P concentration (0.215%) was recorded from I_0 (No irrigation; Control).

4.4.2.2 Effect of foliar application of boron

Different levels of foliar application of boron had no significant influence on P concentration of wheat grain (Appendix X and Table 7). However, the P concentration in grain varied from 0.211% to 0.241%. It was observed that the highest P concentration (0.241%) in grain was found from B_3 (2.5 kg H_3BO_3 ha^{-1}) where the lowest P concentration (0.211%) was recorded from B_0 (0 kg H_3BO_3 ha^{-1}).

4.4.2.3 Combined effect of irrigation and foliar application of boron

P concentration in wheat grain affected by combined effect of different times of irrigation and foliar application of boron was not statistically significant (Appendix X and Table 7). However, the P concentration in grain varied from 0.201% to 0.256%. It was observed that the highest P concentration (0.256%) in grain was found from I_2B_3 treatment combination where the lowest P concentration (0.201%) was recorded from treatment combination of I_0B_0.

4.4.3 Potassium (K) concentration in grain

4.4.3.1 Effect of irrigation

Significant variation was observed for K concentration of wheat grain influenced by different levels of irrigation (Appendix X and Table 7). The K concentration in grain varied from 0.676% to 0.779%. Results revealed that the highest K concentration (0.779%) in grain was identified from I_1 (One irrigation at CRI stage) which was statistically identical with I_2 (Two irrigations at CRI stage and PI stage) where the lowest K concentration (0.676%) was recorded from I_0 (No irrigation; Control).

4.4.3.2 Effect of foliar application of boron

Different levels of foliar application of boron had significant influence on K concentration of wheat grain (Appendix X and Table 7). It was evident that the K concentration in grain varied from 0.649% to 0.801%. It was found that the highest K concentration (0.801%) in grain was found from B_3 (2.5 kg H_3BO_3 ha^{-1}) which was statistically identical with B_2 (2.0 kg H_3BO_3 ha^{-1}) where the lowest K concentration (0.649%) was recorded from B_0 (0 kg H_3BO_3 ha^{-1}; Control).

4.4.3.3 Combined effect of irrigation and foliar application of boron

K concentration of wheat grain was significantly varied due to combined effect of different levels of irrigation and foliar application of boron (Appendix X and Table 7). The K concentration in grain varied from 0.609% to 0.855%. Results exposed that the highest K concentration (0.855%) in grain was found from I_1B_3 treatment combination which was statistically identical with I_2B_2 and statistically similar with I_2B_3 treatment combination. The lowest K concentration (0.609%) was recorded from treatment combination of I_0B_0.

4.4.4 Sulphur (S) concentration in grain

4.4.4.1 Effect of irrigation

Different levels of irrigation had no significant effect on the grain S concentration of wheat grain (Appendix X and Table 7). However, the S concentration in grain varied from 0.123% to 0.145%. The highest S concentration (0.145%) in grain was measured with I_2 (Two irrigations at CRI stage and PI stage) where the lowest S concentration (0.123%) was recorded from I_0 (No irrigation; Control).

4.4.4.2 Effect of foliar application of boron

Different levels of foliar application of boron had no significant influence on S concentration of wheat grain (Appendix X and Table 7). However, the S concentration in grain varied from 0.113% to 0.154%. It was observed that the highest S concentration (0.154%) in grain was found from B_3 (2.5 kg H_3BO_3 ha^{-1}) where the lowest S concentration (0.113%) was recorded from B_0 (0 kg H_3BO_3 ha^{-1}; Control).

4.4.4.3 Combined effect of irrigation and foliar application of boron

S concentrations of wheat grain affected by combined effect of different levels of irrigation and foliar application of boron was not statistically significant (Appendix X and Table 7). However, the S concentration in grain varied from 0.096% to 0.158%. It was observed that the highest S concentration (0.158%) in grain was found from I_2B_3 treatment combination where the lowest S concentration (0.096%) was recorded from treatment combination of I_0B_0.

4.4.5 Boron (B) concentration in grain

4.4.5.1 Effect of irrigation

Significant variation was observed for B concentration of wheat grain influenced by different levels of irrigation (Appendix X and Table 7). The B concentration in grain varied from 11.65 μg g^{-1} to 13.01 μg g^{-1}. Results revealed that the highest B concentration (13.01 μg g^{-1}) in grain was identified from I_2 (Two irrigations at CRI stage and PI stage) where the lowest B concentration (11.65 μg g^{-1}) was recorded from I_0 (No irrigation; Control).

4.4.5.2 Effect of foliar application of boron

Different levels of foliar application of boron had significant influence on B concentration of wheat grain (Appendix X and Table 7). It was evident that the B concentration in grain varied from 10.01 % to 14.27 %. It was found that the highest B concentration (14.27 μg g^{-1}) in grain was found from B_3 (2.5 kg H_3BO_3 ha^{-1}) where the lowest B concentration (10.01 μg g^{-1}) was recorded from B_0 (0 kg H_3BO_3 ha^{-1}; Control).

4.4.5.3 Combined effect of irrigation and foliar application of boron

B concentration of wheat grain was significantly varied due to combined effect of different levels of irrigation and foliar application of boron (Appendix X and Table 7). The B concentration in grain varied from 9.50 μg g^{-1} to 14.80 μg g^{-1}. Results exposed that the highest B concentration (14.80 μg g^{-1}) in grain was found from I_2B_3 treatment combination which was statistically similar with I_2B_2, I_1B_3 and I_1B_2 treatment combination. The lowest B concentration (9.50 μg g^{-1}) was recorded from treatment combination of I_0B_0 which was statistically identical with I_1B_0 followed by I_2B_0.

4.4.6 Nitrogen (N) concentration in straw

4.4.6.1 Effect of irrigation

Different levels of irrigation had no significant effect on N concentration in straw of wheat (Appendix XI and Table 8). However, the N concentration in straw varied from 0.514% to 0.531%. The highest N concentration (0.531%) in straw was measured with I_2 (Two irrigations at CRI stage and PI stage) where the lowest N concentration (0.514 %) was recorded from I_0 (No irrigation; Control).

Table 7. Effect on nutrient concentration of grain showing N, P, K, S and B concentrations affected by irrigation and foliar application of boron and their interaction

Treatment	Nutrient concentration of grain				
	% N	% P	% K	% S	B ($\mu g\ g^{-1}$)
Effect of irrigation					
I_0	1.96	0.215	0.676 b	0.123	11.65 c
I_1	2.14	0.225	0.779 a	0.141	12.69 b
I_2	2.15	0.243	0.762 a	0.145	13.01 a
$LSD_{0.05}$	NS	NS	0.052	NS	0.416
CV (%)	2.104	1.843	2.617	2.049	3.441
Effect of foliar application of boron					
B_0	1.97	0.211	0.649 c	0.113	10.01 d
B_1	2.00	0.222	0.726 b	0.133	12.12 c
B_2	2.03	0.236	0.779 a	0.145	13.39 b
B_3	2.15	0.241	0.801 a	0.154	14.27 a
$LSD_{0.05}$	NS	NS	0.046	NS	0.529
CV (%)	2.264	2.013	3.118	2.319	4.611
Combined effect of irrigation and foliar application of boron					
I_0B_0	1.88	0.201	0.609 h	0.096	9.50 f
I_0B_1	1.94	0.207	0.669 g	0.120	11.40 e
I_0B_2	2.10	0.224	0.701 ef	0.134	12.10 de
I_0B_3	1.93	0.229	0.723 de	0.140	13.60 bc
I_1B_0	2.04	0.211	0.655 g	0.116	10.16 f
I_1B_1	2.11	0.216	0.740 cd	0.136	12.22 de
I_1B_2	2.16	0.232	0.799 b	0.150	13.96 ab
I_1B_3	2.23	0.239	0.855 a	0.163	14.40 ab
I_2B_0	2.08	0.221	0.683 fg	0.128	10.36 f
I_2B_1	2.04	0.244	0.769 c	0.142	12.75 cd
I_2B_2	2.20	0.251	0.837 a	0.152	14.12 ab
I_2B_3	2.26	0.256	0.825 ab	0.158	14.80 a
$LSD_{0.05}$	NS	NS	0.029	NS	0.9815
CV (%)	5.112	4.793	5.221	4.539	6.047

I_0 = No irrigation (Control), I_1 = One irrigation given at crown root initiation (CRI) stage (18 DAS) and I_2 = Two irrigations, one at CRI stage (18 DAS) and other at panicle initiation (PI) stage (55 DAS)

B_0 = 0 kg H_3BO_3 ha^{-1} (Control), B_1 = 1.5 kg H_3BO_3 ha^{-1}, B_2 = 2.0 kg H_3BO_3 ha^{-1} and B_3 = 2.5 kg H_3BO_3 ha^{-1}

4.4.6.2 Effect of foliar application of boron

Different levels of foliar application of boron had no significant influence on N concentrations of wheat in straw (Appendix XI and Table 8). However, the N concentration in straw varied from 0.512% to 0.536%. It was observed that the highest N concentration (0.536%) in straw was found from B_3 (2.5 kg H_3BO_3 ha^{-1}) where the lowest N concentration (0.512%) was recorded from B_0 (0 kg H_3BO_3 ha^{-1}; Control).

4.4.6.3 Combined effect of irrigation and foliar application of boron

N concentrations of wheat straw affected by combined effect of different levels of irrigation and foliar application of boron was not statistically significant (Appendix XI and Table 8). However, the N concentration in straw varied from 0.504% to 0.548%. It was observed that the highest N concentration (0.548%) in straw was found from I_2B_3 treatment combination where the lowest N concentration (0.504%) was recorded from treatment combination of I_0B_0.

4.4.7 Phosphorus (P) concentration in straw

4.4.7.1 Effect of irrigation

Different levels of irrigation had no significant effect on the straw P concentration of wheat (Appendix XI and Table 8). However, the P concentration in straw varied from 0.014 % to 0.022 %. The highest P concentration (0.022 %) in straw was measured with I_2 (Two irrigations at CRI stage and PI stage) where the lowest P concentration (0.014 %) was recorded from I_0 (No irrigation; Control).

4.4.7.2 Effect of foliar application of boron

Different levels of foliar application of boron had no significant influence on P concentration of wheat straw (Appendix XI and Table 8). However, the P concentration in straw varied from 0.013% to 0.021%. It was observed that the highest P concentration (0.021%) in straw was found from B_2 (2.0 kg H_3BO_3 ha^{-1})

where the lowest P concentration (0.013%) was recorded from B_0 (0 kgH_3BO_3 ha^{-1}; Control).

4.4.7.3 Combined effect of irrigation and foliar application of boron

P concentration in wheat straw affected by combined effect of different levels of irrigation and foliar application of boron was not statistically significant (Appendix XI and Table 8). However, the P concentration in straw varied from 0.011% to 0.028%. It was observed that the highest P concentration (0.028%) in straw was found from I_2B_3 treatment combination where the lowest P concentration (0.011%) was recorded from treatment combination of I_0B_0.

4.4.8 Potassium (K) concentration in straw

4.4.8.1 Effect of irrigation

Significant variation was observed for K concentration of wheat straw influenced by different levels of irrigation (Appendix XI and Table 8). The K concentration in straw varied from 1.20% to 1.49%. Results revealed that the highest K concentration (1.49%) in straw was identified from I_1 (One irrigation at CRI stage) which was statistically identical with I_2 (Two irrigations at CRI stage and PI stage) where the lowest K concentration (1.20%) was recorded from I_0 (No irrigation; Control).

4.4.8.2 Effect of foliar application of boron

Different levels of foliar application of boron had significant influence on K concentration of wheat straw (Appendix XI and Table 8). It was evident that the K concentration in straw varied from 1.23% to 1.48%. It was found that the highest K concentration (1.48%) in straw was found from B_2 (2.0 kg H_3BO_3 ha^{-1}) which was statistically identical with B_3 (2.5 kg H_3BO_3 ha^{-1}) where the lowest K concentration (1.23%) was recorded from B_0 (0 kg H_3BO_3 ha^{-1}; Control).

4.4.8.3 Combined effect of irrigation and foliar application of boron

K concentration of wheat straw was significantly varied due to combined effect of different levels of irrigation and foliar application of boron (Appendix XI and Table 8). The K concentration in straw varied from 0.94% to 1.63%. Results exposed that the highest K concentration (1.63%) in straw was found from I_1B_2 treatment combination which was statistically similar with I_2B_1 treatment combination. The lowest K concentration (0.94%) was recorded from treatment combination of I_0B_0 followed by I_0B_1 treatment combination.

4.4.9 Sulphur (S) concentration in straw

4.4.9.1 Effect of irrigation

Different levels of irrigation had no significant effect on the straw S concentration of wheat straw (Appendix XI and Table 8). However, the S concentration in straw varied from 0.092% to 0.112%. The highest S concentration (0.112%) in straw was measured with I_2 (Two irrigations at CRI stage and PI stage) where the lowest S concentration (0.092%) was recorded from I_0 (No irrigation; Control).

4.4.9.2 Effect of foliar application of boron

Different levels of foliar application of boron had no significant influence on S concentration of wheat straw (Appendix XI and Table 8). However, the S concentration in straw varied from 0.084% to 0.122%. It was observed that the highest S concentration (0.122%) in straw was found from B_2 (2.0 kg H_3BO_3 ha^{-1}) where the lowest S concentration (0.084%) was recorded from B_0 (0 kg H_3BO_3 ha^{-1}).

4.4.9.3 Combined effect of irrigation and foliar application of boron

S concentrations of wheat straw affected by combined effect of different levels of irrigation and foliar application of boron was not statistically significant (Appendix XI and Table 8). However, the S concentration in straw varied from 0.072% to 0.124%. It was observed that the highest S concentration (0.124%) in straw was found from I_2B_3 treatment combination where the lowest S concentration (0.072%) was recorded from treatment combination of I_0B_0.

4.4.10 Boron (B) concentration in straw

4.4.10.1 Effect of irrigation

Significant variation was observed for B concentration of wheat straw influenced by different levels of irrigation (Appendix XI and Table 8). The B concentration in straw varied from 17.64 μg g^{-1} to 18.73 μg g^{-1}. Results revealed that the highest B concentration (18.73 μg g^{-1}) in straw was identified from I_2 (Two irrigations at CRI stage and PI stage) which was statistically identical with I_1 (One irrigation at CRI stage) where the lowest B concentration (17.64 μg g^{-1}) was recorded from I_0 (No irrigation; Control) treatment.

4.4.10.2 Effect of foliar application of boron

Different levels of foliar application of boron had significant influence on B concentration of wheat straw (Appendix XI and Table 8). It was evident that the B concentration in straw varied from 17.27% to 19.45%. It was found that the highest B concentration (19.45 μg g^{-1}) in straw was found from B_3 (2.5 kg H_3BO_3 ha^{-1}) where the lowest B concentration (17.27 μg g^{-1}) was recorded from B_0 (0 kg H_3BO_3 ha^{-1}; Control).

4.4.10.3 Combined effect of irrigation and foliar application of boron

B concentration of wheat straw was significantly varied due to combined effect of different levels of irrigation and foliar application of boron (Appendix XI and Table 8). The B concentration in straw varied from 17.06 μg g^{-1} to 20.10 μg g^{-1}. Results exposed that the highest B concentration (20.10 μg g^{-1}) in straw was found from I_2B_3 treatment combination which was statistically identical with I_1B_3 treatment combination. The lowest B concentration (17.06 μg g^{-1}) was recorded from treatment combination of I_0B_0 which was statistically identical with I_0B_1 and statistically similar with I_1B_0 and I_2B_0 treatment combinations.

Table 8. Effect on nutrient concentration of straw showing N, P, K, S and B concentrations affected by irrigation and foliar application of boron and their interaction

Treatment	Nutrient concentration of straw				
	% N	% P	% K	% S	B ($\mu g\ g^{-1}$)
Effect of irrigation					
I_0	0.514	0.014	1.20 b	0.092	17.64 b
I_1	0.527	0.016	1.49 a	0.110	18.52 a
I_2	0.531	0.022	1.48 a	0.112	18.73 a
$LSD_{0.05}$	NS	NS	0.142	NS	0.263
CV (%)	2.075	1.203	2.243	2.117	3.716
Effect of foliar application of boron					
B_0	0.512	0.013	1.23 c	0.084	17.27 d
B_1	0.518	0.017	1.37 b	0.099	17.82 c
B_2	0.531	0.019	1.48 a	0.112	18.65 b
B_3	0.536	0.021	1.46 a	0.122	19.45 a
$LSD_{0.05}$	NS	NS	0.086	NS	0.374
CV (%)	2.113	1.371	2.386	2.281	3.834
Combined effect of irrigation and foliar application of boron					
I_0B_0	0.504	0.011	0.94 g	0.072	17.06 f
I_0B_1	0.511	0.013	1.08 f	0.082	17.27 f
I_0B_2	0.524	0.015	1.26 e	0.104	17.80 de
I_0B_3	0.518	0.017	1.52 bc	0.110	18.44 c
I_1B_0	0.510	0.013	1.33 de	0.087	17.34 ef
I_1B_1	0.526	0.014	1.45 c	0.106	18.02 cd
I_1B_2	0.532	0.017	1.63 a	0.115	18.90 b
I_1B_3	0.541	0.019	1.49 bc	0.133	19.80 a
I_2B_0	0.523	0.014	1.42 cd	0.094	17.42 ef
I_2B_1	0.516	0.023	1.58 ab	0.110	18.16 cd
I_2B_2	0.536	0.024	1.50 bc	0.118	19.24 b
I_2B_3	0.548	0.028	1.42 cd	0.124	20.10 a
$LSD_{0.05}$	NS	NS	0.093	NS	0.454
CV (%)	4.019	3.886	4.226	4.734	5.847

I_0 = No irrigation (Control), I_1 = One irrigation given at crown root initiation (CRI) stage (18 DAS) and I_2 = Two irrigations, one at CRI stage (18 DAS) and other at panicle initiation (PI) stage (55 DAS)

B_0 = 0 kg H_3BO_3 ha^{-1} (Control), B_1 = 1.5 kg H_3BO_3 ha^{-1}, B_2 = 2.0 kg H_3BO_3 ha^{-1} and B_3 = 2.5 kg H_3BO_3 ha^{-1}

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the experimental site of Sher-e-Bangla Agricultural University (SAU) during the period from November 2016 to March 2017 to study the influence of irrigation and foliar application of boron fertilizer on growth, yield and nutrients content of BARI Gom26. The experiment consists of two factors as Factor A: three irrigation level *viz*. (i) I_0 = No irrigation (Control), (ii) I_1 = One irrigation given at crown root initiation (CRI) stage (18 DAS), (iii) I_2 = Two irrigations, one at CRI stage (18 DAS) and other at panicle initiation (PI) stage (55 DAS) and Factor B: four levels of foliar application of boron (B) *viz*. (i) B_0 = 0 kg H_3BO_3 ha^{-1} (Control), (ii) B_1 = 1.5 kg H_3BO_3 ha^{-1}, (iii) B_2 = 2.0 kg H_3BO_3 ha^{-1}, (iv) B_3 = 2.5 kg H_3BO_3 ha^{-1}. The experiment was laid out in a randomized complete block design with three replications. There were 36 unit plots and the size of the unit plot was 3m × 2m i.e. $6m^2$. There were 12 treatments combination. Wheat seed of cv. BARI Gom-26 was sown as test crop. Data on different growth, yield and yield contributing parameters and also on nutrient concentration in grain and straw were recorded and analyzed statistically.

In terms of different levels of irrigation, the highest plant height (48.04, 74.5, 91.13 and 94.18 cm at 40, 60, 80 DAS and at harvest respectively), number of tillers $plant^{-1}$ (2.06, 3.56, 5.80 and 5.55 at 40, 60, 80 DAS and at harvest respectively), LAI (1.81, 2.83, 3.92 and 3.62 at 40, 60, 80 DAS and at harvest respectively) and dry weight $plant^{-1}$ (13.81, 16.01, 22.99 and 29.30 g at 40, 60, 80 DAS and at harvest respectively) were obtained from I_2 (Two irrigations at CRI stage and PI stage) treatment. Again, the highest spike length (16.42 cm), number of spikelets $spike^{-1}$ (12.54), number of grains $spike^{-1}$ (39.38), 1000 grain weight (46.88 g), grain yield (3.75 t ha^{-1}), stover yield (6.18 t ha^{-1}), biological yield (9.92 t ha^{-1}) and harvest index at the time of harvest (37.35 %) were also obtained from I_2

(Two irrigations at CRI stage and PI stage) treatment. Control treatment (I_0; No irrigation) gave the lowest plant height (45.29, 69.59, 85.51 and 87.82 cm at 40, 60, 80 DAS and at harvest respectively), number of tillers plant^{-1} (0.89, 2.38, 3.95 and 3.72 at 40, 60, 80 DAS and at harvest respectively), LAI (1.60, 2.53, 3.30 and 3.13 at 40, 60, 80 DAS and at harvest respectively), dry weight plant^{-1} (8.45, 10.66, 15.25 and 21.56 g at 40, 60, 80 DAS and at harvest respectively), spike length (14.51 cm), number of spikelets spike^{-1} (45.90), number of grains spike^{-1} (33.91), 1000 grain weight (42.39 g), grain yield (2.48 t ha^{-1}), stover yield (5.59 t ha^{-1}), biological yield (8.07 t ha^{-1}) and lowest harvest index (30.54 %).

Considering different levels of foliar application of boron, highest plant height (49.56, 75.125, 91.23 and 93.71 cm at 40, 60, 80 DAS and at harvest respectively), number of tillers plant^{-1} (1.97, 3.53, 5.43 and 5.20 at 40, 60, 80 DAS and at harvest respectively) and LAI (1.80, 2.79, 3.84 and 3.53 at 40, 60, 80 DAS and at harvest respectively) were obtained from B_3 (2.5 kg H_3BO_3 ha^{-1}). Similarly, the highest dry weight plant^{-1} (14.00, 15.99, 23.43 and 29.74 g at 40, 60, 80 DAS and at harvest respectively), highest spike length (16.23 cm), highest number of spikelets spike^{-1} (54.69), highest number of grains spike^{-1} (39.34), highest 1000 grain weight (45.25 g), highest grain yield (3.68 t ha^{-1}), highest stover yield (6.18 t ha^{-1}), highest biological yield (9.83 t ha^{-1}) and the highest harvest index (37.11 %) was obtained from B_2(2.0 kg H_3BO_3 ha^{-1}) where control treatment B_0 (0 kg H_3BO_3 ha^{-1}) showed lowest plant height (43.69, 67.63, 84.65 and 87.99 cm at 40, 60, 80 DAS and at harvest respectively), number of tillers plant^{-1} (0.87, 2.26, 4.18 and 3.93 at 40, 60, 80 DAS and at harvest respectively), LAI (1.63, 2.56, 3.35 and 3.17 at 40, 60, 80 DAS and at harvest respectively), dry weight plant^{-1} (8.22, 10.20, 13.33 and 19.64 g at 40, 60, 80 DAS and at harvest respectively), spike length (14.47 cm), number of spikelets spike^{-1} (45.84), number of grains spike^{-1} (32.91), 1000 grain weight (42.40 g), grain yield (2.36 t ha^{-1}), stover yield (5.58 t ha^{-1}), biological yield (7.94 t ha^{-1}) and lowest harvest index (29.67 %).

In case of combined effect of different levels of irrigation and foliar application of boron, the highest plant height (50.94, 78.91, 95.10 and 97.53 cm at 40, 60, 80 DAS and at harvest respectively), number of tillers plant^{-1} (2.63, 4.13, 6.23 and 6.00 at 40, 60, 80 DAS and at harvest respectively) and highest LAI (1.97, 4.02, 4.54 and 4.18 at 40, 60, 80 DAS and at harvest respectively) was obtained from the treatment combination of I_2B_3 but the highest dry weight plant^{-1} (17.63, 20.24, 28.46 and 34.76g at 40, 60, 80 DAS and at harvest respectively), spike length (17.65 cm), number of spikelets spike^{-1} (61.20) number of grains spike^{-1} (41.63), 1000 grain weight (48.82 g), grain yield (4.66 t ha^{-1}), stover yield (6.42 t ha^{-1}), biological yield (11.08 t ha^{-1}) and highest harvest index (42.06%) was obtained from the treatment combination of I_2B_2. Again, the lowest plant height (43.25, 66.87, 82.94 and 85.33 cm at 40, 60, 80 DAS and at harvest respectively), number of tillers plant^{-1} (0.50, 1.87, 3.26 and 3.03 at 40, 60, 80 DAS and at harvest respectively), LAI (1.54, 2.43, 3.17 and 3.02 at 40, 60, 80 DAS and at harvest respectively), dry weight plant^{-1} (5.93, 7.38, 10.93 and 17.24 g at 40, 60, 80 DAS and at harvest respectively), spike length (13.57 cm), number of spikelets spike^{-1} (41.20), number of grains spike^{-1} (30.52), 1000 grain weight (41.47 g), grain yield (2.06 t ha^{-1}), stover yield (5.35 t ha^{-1}), biological yield (7.41 t ha^{-1}) and lowest harvest index (27.80%) was obtained from the treatment combination of I_0B_0.

In terms of nutrient concentration of N, P, K, S and B in grain and straw affected by different levels irrigation and foliar application of boron, results revealed that different levels irrigation, foliar application of boron and their combination had no significant effect on concentration of N, P and S. But significant effect was found in terms of concentration of K and B both in grain and straw affected by different levels irrigation and foliar application of boron. Results signified that the treatment, I_1 (One irrigation at CRI stage) gave the highest K concentration both in grain and straw (0.779% and 1.49% respectively) where I_0 (No irrigation; Control) gave the lowest (0.676% and 1.20% respectively). But regarding B concentration in grain and straw I_2 (Two irrigations at CRI stage and PI stage) gave the best performance (13.01 and 18.73 μg g^{-1} respectively) where I_0 (No irrigation; Control) gave the lowest results (11.65 and 17.64 μg g^{-1} respectively). Again, in terms of foliar application of boron, B_3 (2.5 kg H_3BO_3 ha^{-1}) showed highest K concentration (0.801%) in grain but B_2 (2.0 kg H_3BO_3 ha^{-1}) showed highest K concentration (1.48%) in straw where control treatment, B_0 (0 kg H_3BO_3 ha^{-1}; Control) gave lowest results both in grain and straw (0.649% and 1.23% respectively). Regarding B concentration in grain and straw, B_3 (2.5 kg H_3BO_3 ha^{-1}) gave the highest results (14.27 and 19.45 μg g^{-1} respectively) where B_0 (0 kg H_3BO_3 ha^{-1}; Control) gave the lowest results (10.01 and 17.27 μg g^{-1} respectively). Combined effect of different irrigation and foliar application of boron, I_1B_3 gave highest K concentration (0.855%) in grain but I_1B_2 gave highest K concentration (1.63) in straw. Again, I_2B_3 gave highest B concentration both grain and straw (14.80 and 20.10 μg g^{-1} respectively). Both in grain and straw, I_0B_0 gave the lowest K concentration (0.609% and 0.94% respectively) and B concentration (9.50 and 17.06 μg g^{-1} respectively).

Considering the overall above presented results of the present study demonstrated that wheat may be grown successfully for obtaining maximum yield with the application of B_2 (2.0 kg H_3BO_3 ha^{-1}) as foliar spray with I_2 (Two irrigations at CRI stage and PI stage). However, before making conclusion concerning the optimum levels of irrigation and appropriated dose of B fertilizer for foliar spray, the study needs further investigation in other Agro Ecological Zones (AEZs) of Bangladesh for country-wide recommendation.

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APPENDICES

Appendix I. Monthly records of air temperature, relative humidity, rainfall and sunshine during the period from November 2016 to March 2017

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)	Sunshine (Hours)
		Max.	Min.	Avg.			
2016	November	27.30	16.22	21.76	68.60	2.00	212.00
2016	December	25.40	17.30	21.35	72.70	Trace	196.00
2017	January	30.20	20.40	25.30	70.50	Trace	223.00
2017	February	32.60	21.80	27.20	66.40	2.00	220.00
2017	March	27.30	16.22	21.76	68.60	3.00	212.00

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix II. The mechanical and chemical characteristics of soil of the experimental site as observed prior to experimentation

Particle size constitution:

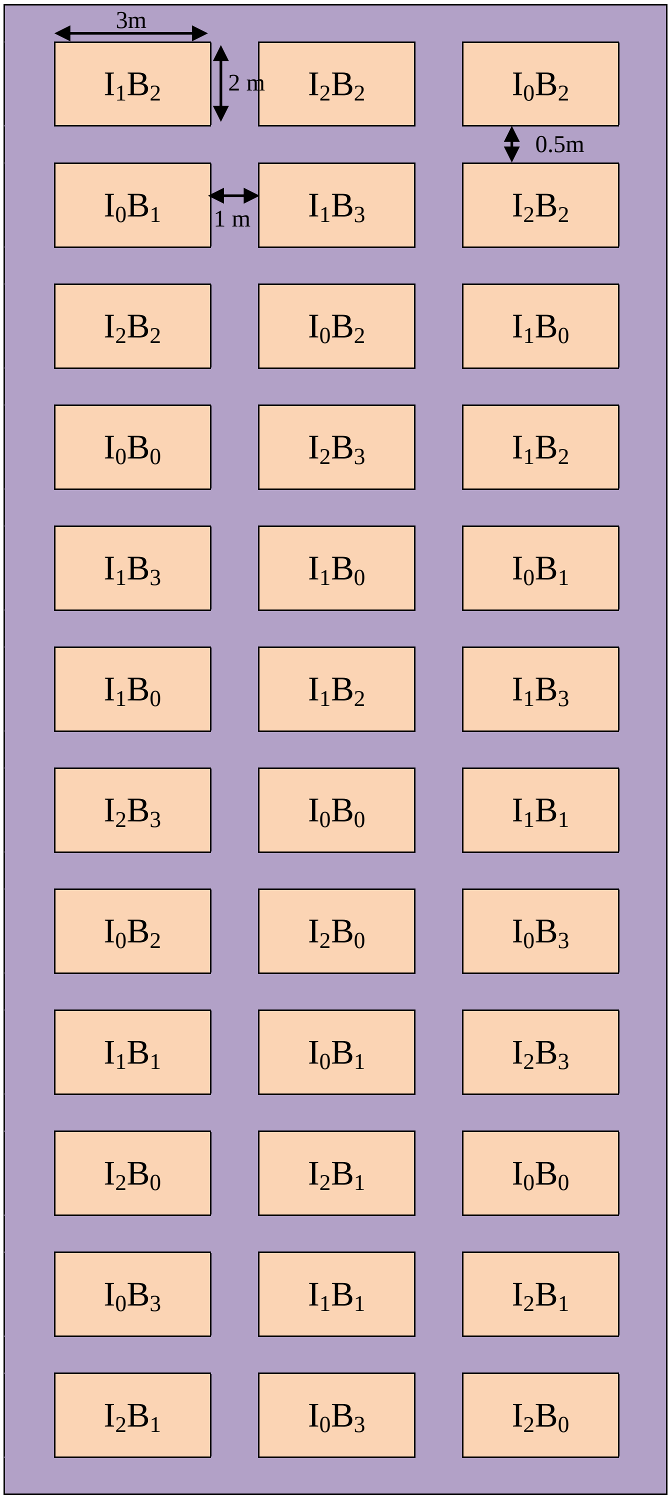
Sand	:	40 %
Silt	:	40 %
Clay	:	20 %
Texture	:	Loamy

Chemical composition:

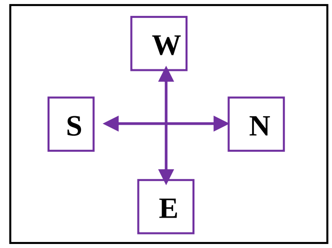
P^H	:	5.45-5.61
Total N (%)	:	0.42
Available P (µ gm/gm)	:	18.49
Exchangeable K (µ gm/gm)	:	0.07
Available S (µ gm/gm)	:	20.82
Available B (µ gm/gm)	:	0.94
Organic matter (%)	:	0.83

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

Appendix III. Layout of the experiment field



LEGEND



Layout:

Plot size: 3 m × 2 m

Plot spacing: 0.5 m

Between block: 1 m

Treatments:

Factor A: Irrigation

1. I_0 = No irrigation; Control
2. I_1 = One irrigation at CRI stage
3. I_2 = Two irrigations at CRI stage and PI stage

Factor B: Boron

1. B_0 = Control
2. B_1 = 1.5 kg H_3BO_3 ha^{-1}
3. B_2 = 2.0 kg H_3BO_3 ha^{-1}
4. B_3 = 2.5 kg H_3BO_3 ha^{-1}

Fig. 9. Layout of the experimental plot

Appendix IV. Plant height of wheat at different growth stages affected by time of irrigations and foliar spray of boron

Source of variation	Degrees of freedom	Mean square of plant height			
		40 DAS	60 DAS	80 DAS	At harvest
Replication	2	0.520	0.661	0.634	0.735
Factor A	2	7.710*	12.70**	14.307*	15.681*
Factor B	3	8.142*	15.591*	11.081**	11.545*
AB	6	3.122**	7.043*	5.121*	6.614*
Error	22	0.324	1.222	1.268	1.333

NS = Non- significant * = Significant at 5% level ** = Significant at 1% level

Appendix V. Number of tillers plant^{-1} of wheat at different growth stages affected by time of irrigations and foliar spray of boron

Source of variation	Degrees of freedom	Mean square of Number of tillers plant^{-1}			
		40 DAS	60 DAS	80 DAS	At harvest
Replication	2	0.061	0.032	0.056	0.144
Factor A	2	4.307**	5.148**	8.331*	9.231*
Factor B	3	2.166*	7.614*	10.105*	11.202*
AB	6	1.217*	3.84*	5.036**	6.331**
Error	22	0.114	0.231	0.216	0.304

NS = Non- significant * = Significant at 5% level ** = Significant at 1% level

Appendix VI. Leaf area index (LAI) of wheat at different growth stages affected by time of irrigations and foliar spray of boron

Source of variation	Degrees of freedom	Mean square of leaf area index (LAI)			
		40 DAS	60 DAS	80 DAS	At harvest
Replication	2	0.058	0.044	0.048	0.062
Factor A	2	NS	6.261**	8.244*	10.211*
Factor B	3	NS	8.349*	7.106*	7.384*
AB	6	NS	3.215*	4.037**	5.119**
Error	22	0.138	0.217	0.364	0.351

NS = Non- significant * = Significant at 5% level ** = Significant at 1% level

Appendix VII. Dry weight plant^{-1} of wheat at different growth stages affected by time of irrigations and foliar spray of boron

Source of variation	Degrees of freedom	Mean square of Dry weight plant^{-1}			
		40 DAS	60 DAS	80 DAS	At harvest
Replication	2	0.003	0.023	0.035	0.078
Factor A	2	1.214**	4.311**	5.014*	8.611*
Factor B	3	0.259*	2.164*	7.532*	6.164*
AB	6	0.178**	0.513*	1.346*	3.381*
Error	22	0.048	0.414	0.244	0.336

NS = Non- significant * = Significant at 5% level ** = Significant at 1% level

Appendix VIII. Effect of different time of irrigation and foliar spray of boron and their interaction on length of spike, number of spikelets spike^{-1} and number of grains spike^{-1}

Source of variation	Degrees of freedom	Mean square of yield contributing parameters			
		Spike length (cm)	Number of spikelets spike^{-1}	Number of grains spike^{-1}	1000 grains weight (g)
Replication	2	1.045	0.462	1.132	0.751
Factor A	2	7.758*	10.38**	12.62*	13.53*
Factor B	3	5.882*	5.712*	7.403*	10.56**
AB	6	2.931*	3.114*	5.552*	6.824*
Error	22	0.617	0.289	1.317	1.174

NS = Non- significant * = Significant at 5% level ** = Significant at 1% level

Appendix IX. Effect on yield characters showing grain yield, straw yield, biological yield and harvest index affected by irrigation and foliar spray of boron and their interaction

Source of variation	Degrees of freedom	Mean square of yield parameters			
		Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Replication	2	0.054	0.563	0.614	1.014
Factor A	2	7.342**	9.721*	10.53*	13.42*
Factor B	3	5.264*	6.529*	8.447*	8.621*
AB	6	2.327*	3.514*	4.328*	5.511*
Error	22	0.216	1.025	1.472	1.107

NS = Non- significant * = Significant at 5% level ** = Significant at 1% level

Appendix X. Effect on nutrient content of grain showing N, P, K, S and B concentrations affected by irrigation and foliar spray of boron and their interaction

Source of variation	Degrees of freedom	Mean square of Nutrient concentration of grain				
		% N	% P	% K	% S	B ($\mu g\ g^{-1}$)
Replication	2	0.012	0.023	0.004	0.035	0.124
Factor A	2	NS	NS	4.216**	NS	7.518**
Factor B	3	NS	NS	2.074**	NS	5.634**
AB	6	NS	NS	0.638**	NS	2.671**
Error	22	0.037	0.126	0.052	0.117	0.106

NS = Non- significant * = Significant at 5% level ** = Significant at 1% level

Appendix XI. Effect on nutrient content of straw showing N, P, K, S and B concentrations affected by irrigation and foliar spray of boron and their interaction

Source of variation	Degrees of freedom	Mean square of Nutrient concentration of straw				
		% N	% P	% K	% S	B ($\mu g\ g^{-1}$)
Replication	2	0.008	0.011	0.027	0.006	0.144
Factor A	2	NS	NS	6.071**	NS	9.435**
Factor B	3	NS	NS	3.116**	NS	6.367**
AB	6	NS	NS	1.342**	NS	3.593**
Error	22	0.018	0.048	0.089	0.102	0.217

NS = Non- significant * = Significant at 5% level ** = Significant at 1% level

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