RESPONSE OF WHEAT (*Triticum aestivum* L.) ON BORON FERTILIZATION

BY

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CERTIFICATE

This is to certify that the thesis entitled **"Response of Wheat (*Triticum aestivum* L.) to Boron Fertilization"** submitted to the Faculty of Agriculture, 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 bonafide research work carried out by **Laila Easmin**, Registration number: **04-01426** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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TO

MY BELOVED PARENTS

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ABSTRACT

The experiment was carried out in Sher-e-Bangla Agricultural University, Dhaka during the period from December 2011 to April 2012 to observe the response of wheat to boron fertilization. The experiment comprised four levels of boron (0, 1.0, 1.5 and 2.0 kg B ha^{-1}). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on different yield contributing characters and yield were recorded and statistically significant variation was recorded for different levels of boron. At 30-70 DAS and at harvest the longest plant (23-90 cm) and the maximum number of tillers $plant^{-1}$ (2.37-5.40) was recorded from 2.0 kg B ha^{-1}, while the shortest plant (17.6-74.18 cm) and minimum number of tillers $plant^{-1}$ (1.8-3.77) from 0 kg B ha^{-1}. The highest number of spikelets $spike^{-1}$ (21.67) was recorded from 2.0 kg B ha^{-1}, whereas the lowest number (18.83) from 0 kg B ha^{-1}. The highest number of total grains $spike^{-1}$ (52.06) was recorded from 2.0 kg B ha^{-1}, while the lowest number (35.87) was found from 0 kg B ha^{-1}. The highest 1000-seed weight (44.79 g) was obtained from 2.0 kg B ha^{-1} and the lowest (40.31 g) from 0 kg B ha^{-1}. The highest grain yield $hectare^{-1}$ (3.88 ton) was observed from 2.0 kg B ha^{-1}, while the lowest (3.14 ton) was found from 0 kg B ha^{-1}. The highest straw yield $hectare^{-1}$ (4.96 ton) was observed from 2.0 kg B ha^{-1}, whereas the lowest (3.49 ton) from 0 kg B ha^{-1}. In grain sample, the highest N, P, K and B content was found from 2.0 kg B ha^{-1} (0.139, 0.36, 0.47 and 0.83% respectively), while the lowest values were obtained from control (0.103, 0.28, 0.34 and 0.64% respectively).

LIST OF ABBREVIATED TERMS

ABBREVIATION	FULL NAME
AEZ	Agro-Ecological Zone
et al.	and others
BBS	Bangladesh Bureau of Statistics
°C	Degree Celsius
DAS	Days After Sowing
FAO	Food and Agriculture Organization
g	Gram
kg	Kilogram
M	Meter
mm	Millimeter
MOP	Muriate of Potash
%	Percent
RCBD	Randomized Complete Block Design
m^2	Square meter
TSP	Triple Superphosphate
UNDP	United Nations Development Program

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Introduction

CHAPTER I

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops as well as staple food all over the world. About two third of the total world's population consume wheat as staple food (Majumder, 1991). It is an important protein containing cereal with high amount of carbohydrate which is cultivated throughout the world. The crop is grown under different environmental conditions ranging from humid to arid, subtropical to temperate zone (Saari, 1998). Dubin and Ginkel (1991) reported that the largest area of wheat cultivation in the warmer climates exists in the South-East Asia including Bangladesh, India and Nepal. In Bangladesh, wheat is the second most important cereal crop that contributes to the national economy by reducing the volume of import of cereals for fulfilling the food requirements of the country (Razzaque *et al.*, 1992). BARI (2009) reported that wheat supplies mainly carbohydrate (69.60%) and reasonable amount of protein (12%), fat (1.72%), and also minerals (16.20%).

In the environmental condition of Bangladesh wheat is a well adapted cereal crop for its vegetative growth and development. Though the crop was introduced in Bangladesh during the period of former East Pakistan in 1967, its reputation increased after 1975. Now the popularity of wheat as staple food is increasing day by day in our country. Wheat cultivation has been increased manifolds to meet up the food shortage in the country. But, in spite of its importance, the yield of the crop in the context of our country is low (2.2 t ha^{-1}) in comparison to other countries of the world (FAO, 2010). The area, production and yield of wheat have been increasing dramatically during the last two decades, but its present yield is too low in comparison to some developed countries like Japan, France, Germany and UK producing 3.76, 7.12, 7.28, and 8.00 t ha^{-1}, respectively (FAO, 2010). At present about 707.56 thousand hectares of land in Bangladesh is covered by wheat with the annual production of 1,578 thousand tons (BBS, 2008).

Yield and quality of seeds of wheat are very low in Bangladesh and this low yield is not an indication of low yielding potentiality of this crop, but may be attributed to a number of reasons viz. unavailability of quality seeds of high yielding varieties, delayed sowing after the harvest of transplanted aman rice, fertilizer management, disease and insect infestation and improper or limited irrigation facilities. Among the reasons fertilizer management especially micronutrient is an important one and as a micronutrient deficiency in Bangladesh boron ranks second after zinc. Late sowing coupled with B deficiency might be the principal reason for low productivity of wheat in Bangladesh (Jahiruddin *et al*., 1992; Hossain *et al*., 1994).

Total boron content of soil varies from 2 to 200 ppm. Boron plays an important role for plant growth and its deficiency causes many anatomical, physiological and biochemical changes in plants (Blevins and Lukaszewski, 1998). This element activates certain dehyrogenase enzymes, facilitates sugar translocation and synthesis of nucleic acids and plant hormones, which is essential for cell division and development. Boron is generally immobile in plant. The element has more influence on reproductive development than on vegetative.

Cheng and Rerkasem (1992) found that B deficiency in wheat, the pollen did not accumulate starch and the nuclei and became abnormal. Rerkasem *et al.* (1997) observed that the fertility of both male and female organs of the wheat florets appeared to be affected by boron deficiency. Subedi *et al.* (1997) reported that there was a significant reduction in percent sterility with the application of boron. Bodruzzaman *et al.* (2003) reported yield benefits due to the application of 2 kg B ha^{-1} from borox and boric acid and reported that 3 kg B ha^{-1} from borax and boric acid showed upto 23% increase in yield over control. B deficiency causes the poor development of anthers and pollen, and the failure of pollen germination in wheat has been identified as male sterility, resulting in grain set failure (Rerkasem *et al.*, 1997; Rerkasem and Jamjod, 1997) with losses of grain yield and quality. Although B is essential for crop growth, the range of proper application is rather narrow, and its harmful effect can be induced by slightly excessive application (Eguchi and Yamada, 1997). Cooke (1982) reported that when it was more than 1.0 mg kg^{-1} soil, deficiency was unlikely and B treatment was not necessary; and when it was 3-5 mg kg^{-1} soil, crop might be poisoned from excess B. Thus, a careful and judicious application of boron is necessary.

Considering the above facts the present study was conducted to fulfill the following objectives-

1. To determine the effect of boron on growth parameter of wheat;
2. To find out the judicial dose of boron for higher yield of wheat and;
3. To compare the boron and other nutrient N, P and K content in wheat grain due to varying dose of B.

Chapter 2

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Wheat is the second most important cereal crop in Bangladesh. The crop has acknowledged much concentration by the researchers on various aspects of its production. Very few studies on the related to the effect of boron on yield and yield contributing characters of wheat have been carried out in many countries of the world. The work so far done in Bangladesh and is not adequate and conclusive. Nevertheless, some of the important and informative works and research findings so far been done at home and abroad on this aspect have been reviewed in this chapter.

Rerkasem and Longeragan (1990) stated that boron deficiency could depress wheat yield through the failure of grain setting. The highest grain yield was obtained by wheat plants from soil fertilized only by NO_3N^- during the reproductive stage combined with foliar spraying with boron.

Mitra and Jana (1991) found that number of effective tillers plant^{-1}, number of grains panicle^{-1}, 1000-grain weight was significantly increased by boron application up to 20 kg borax ha^{-1} and thereafter a negative effect was noticed.

Ahmed *et al.* (1991) carried out a fertilizer trial in Old Brahmaputra Floodplain soil to examine the effect of sulphur, zinc and boron on the growth, yield and nutrient content of wheat (cv. Kanchan). They observed that the grain yield of wheat responded significantly to boron treatments. The addition of boron alone resulted in a 38.05% yield increase over control as against the yield increment of

42.10% by the combined treatment of sulphur, zinc and boron. The grain yield of wheat was positively dependent on the number of grains spike^{-1}, indicating that the added nutrients especially boron had a considerable influence on grain set which in turn resulted in higher grain yield. Boron played a significant role in improving the protein content of grain.

Jahiruddin *et al.* (1992) conducted a study with four field trials in two AEZs of Bangladesh to examine the effect of boron on grain set of wheat. Of the agronomic parameters studied, the two components viz., number of grains spike^{-1} and grain yield increased significantly due to boron treatment. Crop response to boron varied between locations.

Mandal (1993) carried out an experiment with 21 wheat varieties in the Tarai region of India in order to find out the effect of boron application on yield and other yield components of wheat. Most of the varieties showed positive response to boron with respect to grain yield, number of grain spike^{-1} and spike length. Grain yield was increased basically through the increase in number of grains spike^{-1}. However, varieties like BAU 2076, H 1968, BR 350 and BW 121 showed very small response or no response to boron for most of the trials.

Abedin *et al.* (1994) reported that the number of grains ear^{-1} and grain yield were significantly influenced by the boron treatments. Soil application of boron @ 4 kg ha^{-1} and the foliar spray at tillering plus booting stage of crop increased about 19% grain yield over control. The results indicated that the grain yield of wheat was depressed mainly by poor number of grains spike^{-1}, which resulted from male sterility induced by boron deficiency. The nitrogen and boron contents in grain were increased by soil application of boron but not by its foliar spray.

Ahamed and Alam (1994) conducted a green-house study on four soils of Bangladesh to determine the effect of zinc and boron application singly and incorporation on yield and nutrient content of wheat (cv. Kanchan). They reported significant increase in dry matter yield at Paba (calcareous soil) from combined application of 20 kg Zn with 5 kg B ha^{-1}.

Rerkasem and Longeragan (1994) found that flag leaf application boron at booting stage of wheat increased the number of grains $spikelet^{-1}$ at maturity, the critical level was determined to be 3 mg B kg^{-1} for field grown plant. They also pointed out that at the booting stage, the flag leaf boron concentration value with less than 5 mg kg^{-1} were deficient and more than 7 mg kg^{-1} were sufficient. Boron deficiency could depress wheat yield through the failure of grain setting, but susceptibility to boron deficiency varied with genotypes.

Roy and Pradhan (1994) conducted a field experiment on sandy loam soil during the winter season of 1991-92 at Pundibari, West Bengal, India. Wheat cultivar Up 232 was given 1.13 kg B ha^{-1} as borax at sowing, in 2 or 4 equal splits through foliar application or in various soil application + foliar application combinations. Results revealed that boron application increased grain yield compared with the control. They also found that application of half of the boron at sowing and in 2 equal splits by foliar spray at 45 and 75 days after sowing gave the highest seed yield of 2.78 t ha^{-1}.

Jahiruddin *et al.* (1995) conducted three identical field experiments to examine the effect of boron on grain set, yield and some other parameters of wheat cultivars grown in Old Brahmaputra Floodplain. The varieties were Aghrani, Kanchan and Sonalika. They found that boron had a marked positive influence on grain set and yield. The results also varied between varieties and between locations. In general, Kanchan variety and boron @ 3 kg ha^{-1} did the best. It was apparent that grain yield of wheat was highly dependent on the number of grains $spike^{-1}$.

Rawson (1996) found from reciprocal transfers of wheat plants between adequate and zero boron root media at different development stages, that the period during which florets were sterilized by boron insufficiency could be very short. It was shown that spikes could also be sterilized by enclosing the whole plant in a clear plastic bag during the critical period, even though the plants were growing with adequate boron provided in sub-irrigated gravel culture. It was observed that one of the effects of enclosure was to prevent transpiration and possibly the associated uptake and movement of boron to the reproductive growth centers. It appeared that a prior period in adequate boron had a different effect on sterility amongst genotypes.

Wei and Zuo (1996) reported that application of boron to the deficient soil in Yiduhe village in the suburbs of Beijing, China resulted in significant positive effects on winter wheat production. They reported that foliar application of boron increased the yield of winter wheat by 20% and rate of nitrogen us by 13.9%. They also reported that basal application of boron significantly increased the number of spikelets on the main stem, leaf area, photosynthesis, 1000 grain weight and N, P and K uptake. They also found that utilization efficiency of nitrogen and phosphoric acid by plants was improved by foliar application of boron (18 and 7.5% higher, respectively than control).

Karki (1996) conducted a field experiment in 1991 on two fertility soils, at Kalleritar and Baireni (Rahodic Ustochrepts and Ochric Fluvaquents), Nepal. Wheat was given 28 t FYM ha^{-1}, 28 t compost ha^{-1}, N P K mineral fertilizer or no fertilizer with or without 2.5 kg borax ha^{-1}. They found that application of boron (borax) improved grain yield in the well-drained, medium-textured soil at Kalleritar. Neither fertilizers nor boron increased the concentration; all were above the minimum requirement.

Hossain *et al.* (1997) conducted an experiment to evaluate the performance of wheat cultivars Kanchan, Aghrani and Akbar with or without application of 0 or 2 kg B ha^{-1}. They found the highest yield in Kanchan and boron application increased it.

Mandal and Ray (1999) conducted a field trial in 1990-91 at Coochbehar, West Bengal, India with 13 wheat cultivars which were given 0, 10, or 15 kg B ha^{-1}. Nine cultivars showed significant response to applied boron for major yield components. Cv. BW-36, HP-1376 and BR-2094 were non responsive to boron. Sonalika was non responsive to boron at the lower dose and its yield significantly decreased at the higher dose.

Mandal (2000) carried out an experiment with different local high yielding bread wheat varieties originating from Mexican, Semi-dwarf parents to determine the response of boron (0, and 12 kg Sodium borate ha^{-1}) with respect to yield and its component characters during the winter season of 1989-91, in west Bengal, India. He reported that most of the varieties responded well to boron for yield and important yield component characters.

Kataki *et al.* (2001) conducted a field experiment during 1997-98 and 1999-2000 at the Naldung rice wheat site of Kavre district of Nepal to study the effect of B and N on sterility in wheat cultivars. They found that application of B could double wheat yields in B-deficient areas of the mid-hill region of Nepal.

Mete *et al.* (2005) conducted an experiment during the winter (rabi) season of 2002-03 on old and new alluvial soils in Burdwan and Polba, Hooghly, respectively, in West Bengal, India, to study the effect of boron and lime on the growth and yield of wheat (*Triticum aestivum* cv. HP-1731). The application of boron (5 or 10 kg borax ha^{-1}) alone and in combination with lime (0.5 or 1.0 t ha^{-1}) to both soils significantly enhanced the 1000-grain weight and boron content of wheat plants. The number of grains $spike^{-1}$ and plant height was significantly increased with the application of boron and lime whether singly or in combination. The application of lime (1.0 t ha^{-1}) with boron (10 kg borax ha^{-1}) to both fields resulted in the highest wheat grain yields.

Lakshman *et al.* (2005) conducted a field experiment in the Terai region of West Bengal, India to evaluate the boron deficiency causing grain set failure and yield loss. This study evaluated the performance of ten cultivars of bread wheat (*Triticum aestivum L.*) in boron deficient (B_0) and boron supplemented conditions (B_1). Observations were recorded for plant height (cm), days to 50% flowering, number of filled grains per spike, chaffy grain (%) 1000-grain weight and yield plant^{-1} (g). Significant genetic variability for boron efficiency was observed for number of filled grains spike^{-1}, chaffy grain (%) and yield plant^{-1}. DBW 14 yielded the maximum mean values for yield plant^{-1} at both B1 and Bo levels, while the mean values were lowest for HP-1731 at BO and Sonalika at B-1. The high response to boron was found in DBW-14, POBW-343, HD-2285, HD-2643 and NW-1014, whereas Sonalika showed least response to boron application in respect to yield. The rest of the cultivars showed moderate response to boron.

Bhatta *et al.* (2005) conducted an experiment in Nepal and found the nature and extent of wheat sterility in Nepal, its relation to boron (B) deficiency in soil. Boron deficiency has been considered a major factor among the various factors causing wheat sterility. Application of boron fertilizer to the soil at sowing has a significant positive effect on the number of grains spike^{-1}, reduction of sterility and increased wheat grain yields.

Wrobel *et al.* (2006) conducted a pot experiment in 2001-2003 at the Department of Soil Tillage and Fertilization Techniques, Poland, to investigate the effect of boron (B) fertilizer application on spring wheat grown in light soil, deficient in B and subjected to periodic drought stress. Deficit in available boron in the soil revealed deficient amounts of boron in wheat grain, which decreased the quality of wheat grain as foodstuff or fodder. Application of boron fertilizer increased the grain weight and straw yields of spring wheat. This study demonstrated that boron is 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 the wheat grain.

The effect of foliar application of boron, manganese and zinc on spot disease in winter durum wheat was investigated by Simoglou and Dordas (2006) during a 2 years field study. Micronutrients were applied when plants were at the first node stage. In both years, in the sprayed plots the flag leaf had significantly fewer lesions than the untreated ones, at booting through milk stages. The treatment with B significantly reduced the number of lesions per leaf compared to the other treatments at booting stage in both years. There was no difference in the number of lesions per leaf between Mn and Zn treatments in the first year. In the second year, Zn treatment showed the lowest number of lesions at the booting and heading stage, whereas Mn treatment showed the lowest number of lesions at milk stage. There was a significant influence of Zn treatment on flag leaf area which might have negatively affected disease severity. In the case of Mn and B treatments there was no significant influence on flag leaf area. Moreover there was no significant difference in yield components. These findings suggest that foliar application of micronutrients can be used to reduce the severity of tan spot on wheat, however the physiological basis of this remains unknown.

Ahmed *et al.* (2007) conducted field experiments in several sand culture in order to screen out a number of Bangladeshi wheat varieties and advanced lines for boron (B) efficiency against Thai B efficient ("Fang 60") and inefficient ('SW41' and 'E12') varieties. Performances of wheat genotypes were evaluated with respect to flag leaf B concentration, pollen viability, grain set index, and grain yield. Wheat genotypes responded differently to boron deficiency. Pollen viability was found to be 67% in 'Kanchan', 35% in 'Gourab', 80% in 'Sourav', 90% in 'Fang 60', and 25% in SW 41' when B was not added. Pollen viability of all varieties was above 90% when B was applied. Based on grain set index and leaf B concentration, 'Sourav' was found to be the moderately B efficient variety. Thus, 'Sourav, can be regarded as a breeding material for development of new wheat varieties for tolerance to B deficiency.

Heiner *et al.* (2007) observed that boron deficiency was a widespread problem for field crops production where large losses of yield occur annually both quantitatively and qualitatively. Significant losses of yield or quality resulting from boron deficiency may occur as well in vegetable crops.

Sarkar *et al.* (2007) conducted an experiment to determine the timing and method of B application to increase use efficiency on typical B-deficient Entisols. Mustard (*Brassica campestris* L.), wheat (*Triticum aestivum* L.) and potato (*Solanum tuberosum* L.) were the test crops. There were seven treatment combinations of B, applied either to soil or foliar sprays at different doses and growth stages of the crops. For wheat, a single late application of B (at 45 or 60 days after sowing through soil or foliar spray, respectively) was more effective than the early or split application in increasing yields. Better use efficiency of B can thus be achieved if it is applied late for wheat with higher economic benefits.

Alloway (2008) found that boron deficiency was the second most widespread micronutrient problem. Dicotyledon species tended to be more sensitive to B deficiency than graminaceous crops. Whenever the supply of boron was inadequate, yields were reduced and the quality of crop products impaired, but crop species and cultivars varied considerably in their susceptibility to deficiencies.

Singh (2008) stated that the nature and extent of deficiencies varied with soil type, crop genotype, management and agro-ecological situations. Due to intensive cropping with high yielding varieties of rice and wheat deficiency of boron (B) initially in wheat, emerged as threats to sustaining high levels of food crop production. Analysis of soil and plant samples has indicated that 49% of soils in India are potentially deficient in Zn. 12% in 5% in Mn, 3% in copper (Cu), 33% in boron (B) and 11% in molybdenum (Mo).

Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The experiment was carried out at Sher-e-Bangla Agricultural University, Dhaka during the period from December 2011 to April 2012 to observe the response of wheat to boron fertilization. The details of the materials and methods followed to conduct the study has been presented below under the following headings:

3.1 Description of the experimental site

3.1.1 Location

The present piece of research work was conducted at the experimental field and in the agricultural chemistry laboratory of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. The location of the site was $23^0 74'$N latitude and $90^0 35'$E longitude with an elevation of 8.2 meter from sea level.

3.1.2 Climate

The geographical location of the experimental site was under the subtropical climate, characterized by three distinct seasons, winter season from November to February and the pre-monsoon period or hot season from March to April and monsoon period from May to October (Edris *et al.*, 1979). Details of the meteorological data of air temperature, relative humidity, rainfall and sunshine hour during the period of the experiment was collected from the Weather Station of Bangladesh, Sher-e Bangla Nagar, presented in Appendix I.

3.1.3 Soil

The soil belonged to "The Modhupur Tract", AEZ – 28 (FAO, 1988). Top soil was silty clay in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and had organic carbon 0.45%. The experimental area was flat having available irrigation and drainage system and above flood level. The selected plot was medium high land. The details have been presented in Appendix II.

3.2 Experimental details

3.2.1 Treatment of the experiment

The experiment comprised four levels of boron. Such as-

i. 0 kg B ha^{-1} (Control)

ii. 1.0 kg B ha^{-1}

iii. 1.5 kg B ha^{-1}

iv. 2.0 kg B ha^{-1}

3.2.2 Experimental design and layout

The experiment was laid out in single factor Randomized Complete Block Design (RCBD) with three replications. There were 12 plots having the size of 3 m × 3 m were randomly distributed different level of boron as per treatment.

3.3 Growing of crops

3.3.1 Seed collection

The seeds of wheat variety Shatabdi (BARI Gom-21) were collected from Bangladesh Agricultural Research Institute (BARI), Joydevpur, Gazipur.

3.3.2 Preparation of the main field

The piece of land selected for the experiment was opened in the second week of November 2011 with a power tiller, and was exposed to the sun for a week after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubbles were removed and finally a desirable tilth of soil was obtained for sowing of seeds.

3.3.3 Application of fertilizers and manure

The fertilizers N, P, K and S in the form of Urea, TSP, MoP and Gypsum, respectively were applied. The entire amount of TSP, MP and Gypsum, 2/3rd of urea were applied during the final preparation of land. Rest of urea was top dressed after first irrigation (BARI, 2006). The dose and method of application of fertilizer are presented below-

Table 1. Doses and method of application of fertilizers in wheat field

Fertilizers	Dose ha^{-1}	Application (%)	
		Basal	1st installment
Urea	160 kg	66.66	33.33
TSP	160 kg	100	--
MP	35 kg	100	--
Gypsum	80 kg	100	--
Cowdung	10 ton	100	--

Source: BARI, 2006: Krishi Projukti Hatboi, Joydebpur, Gazipur,

3.3.4 Seed sowing

Wheat seeds of BARI Gom-21 (Shatabdi) were sowing in the experimental field at 22 November through broadcasting.

3.3.5 Intercultural operation

After the germination of seeds, various intercultural operations such as irrigation and drainage, weeding, top dressing of fertilizer and plant protection measures were accomplished for better growth and development of the wheat seedlings as per the recommendation of BARI (2006).

3.3.5.1 Irrigation and drainage

Three flood irrigations at early stage of crop growth, tillering stage and panicle initiation stage were provided. Proper drainage system was also developed for draining out excess water.

3.3.5.2 Weeding

Weedings were done to keep the plots free from weeds which ultimately ensured better growth and development of wheat seedlings. The newly emerged weeds were uprooted carefully at tillering (30 DAS) and panicle initiation stage (55 DAS) manually.

3.3.5.3 Plant protection

The crop was attacked by different kinds of insects during the growing period. Triel-20 ml was applied on 5 January and sumithion-40 ml per 20 litre of water was applied on 23 January as plant protection measure.

3.4 Harvesting, threshing and cleaning

The crop was harvested manually depending upon the maturity at 3 April, 2012. The harvested crop of each plot was bundled separately, properly tagged and brought to threshing floor. Enough care was taken during threshing and cleaning period of wheat grain. Fresh weight of wheat grain and straw were recorded plot wise from 1 m^2 area. The grains were cleaned and weighed. The weight was adjusted to a moisture content of 14%. The straw was sun dried and the yields of wheat grain and straw m^{-2} were recorded and converted to t ha^{-1}.

3.5 Data collection

3.5.1 Plant height

The height of plant was recorded in centimeter (cm) at 20, 30, 40, 50, 70 Days after sowing (DAS) and at harvest. Data were recorded as the average of 10 plants selected at random from the inner rows of each plot. The height was measured from the ground level to the tip of the plant.

3.5.2 Tillers

The number of tillers $plant^{-1}$ was recorded at the time of 20, 30, 40, 50 and 70 DAS. Data were recorded by counting tillers from each plant and as the average of 10 plants selected at random from the inner rows of each plot.

3.5.3 Leaves

The total number of leaves $plant^{-1}$ was counted as the number of leaves from 10 randomly selected plants from each plot and average value was recorded.

3.5.4 Effective tillers

The total number of effective tillers $plant^{-1}$ was counted as the number of panicle bearing tillers $plant^{-1}$. Data on effective tillers $plant^{-1}$ were counted from 10 selected plants at harvest and average value was recorded.

3.5.5 Non-effective tillers

The total number of non-effective tillers plant^{-1} was counted as the number of tiller plant^{-1} without spike. Data on non-effective tillers plant^{-1} were counted from 10 selected plants at harvest and average value was recorded.

3.5.6 Total tillers

The total number of tillers plant^{-1} was calculated by adding effective and sterile tillers plant^{-1}. Data on total tillers hill^{-1} were counted from 10 selected plants at harvest and average value was recorded.

3.5.7 Ear length

The length (cm) of ear was measured with a meter scale from 10 selected panicles and the average value was recorded.

3.5.8 Spikelets

The total number of spikelets spike^{-1} was counted as the number of spikelets from 10 randomly selected spikes from each plot and average value was recorded.

3.5.9 Fertile florets

The number of fertile floret spikelets^{-1} was counted as the number of fertile floret from 10 randomly selected spikelets from each plot and average value was recorded.

3.5.10 Filled grains

The total number of filled grains spike^{-1} was counted as the number of filled grains from 10 randomly selected spikes from each plot and average value was recorded.

3.5.11 Unfilled grains

The total number of unfilled grains spike^{-1} was counted as the number of unfilled grains from 10 randomly selected spikes in each plot and recorded average value.

3.5.12 Total grains

The total number of grains spike^{-1} was counted by adding the number of filled and unfilled grains from 10 randomly selected spike from each plot and average value was recorded.

3.5.13 1000-seed weight

One thousand seeds were counted randomly from the total cleaned harvested seeds of each individual plot and then weighed in grams and recorded.

3.5.14 Grain yield

Grains obtained from m^{-2} from each unit plot were sun-dried and weighed carefully. The dry weight of grains of central 1 m^2 area used to record grain yield m^{-2} and converted this into t ha^{-1}.

3.5.15 Straw yield

Straw obtained from m^{-2} from each unit plot were sun-dried and weighed carefully. The dry weight of straws of central 1 m^2 area was used to record straw yield m^{-2} and was converted this into t ha^{-1}.

3.5.16 Biological yield

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

Biological yield = Grain yield + Straw yield.

3.5.17 Harvest index

Harvest index was calculated from per hectare grain and straw yield that were obtained from each unit plot and expressed in percentage.

$$HI = \frac{\text{Economic yield (grain weight)}}{\text{Biological yield (Total dry weight)}} \times 100$$

3.6 Estimation of the amount of nitrogen from the supplied grain sample by Macro Kjeldahl method

Principle

The macro kjeldahl method was used to determine the total nitrogen consisting of organic and ammonium forms. It is a wet oxidation procedure where complex form of nitrogen in sample was converted to simple nitrogen. Three steps were involved in this method. These are as follows:

1. Digestion

In this step the organic nitrogen was converted to ammonium sulphate by sulphuric acid and digestion accelerators (Catalyst Mixture) at a temperature of 360-440^{0}C.

$$\text{N (organic form)} + H_2SO_4 \text{-------------------} (NH_4)_2SO_4$$

2. Distillation

In this step, the solution was made alkaline for the distillation of ammonia. The distillated ammonia was received in boric acid solution.

$$(NH_4)_2SO_4 + NaOH \longrightarrow Na_2SO_4 + NH_3 + H_2O$$

$$NH_3 + H_3BO_3 \longrightarrow (NH_4)_2BO_3 + H_2O$$

3. Titration

To determine the amount of NH_3, ammonium borate was titrated with standard sulphate acid.

$$(NH_4)_3BO_3 + H_2SO_4 \longrightarrow (NH_4)_2SO_4 + H_3BO_3$$

Apparatus Required

1. Kjedahl Flask	2. Distillation apparatus
3. Volumetric flask	4. Burette with stand
5. Pipette	6. Electric oven
7. Kjeldahl digestion stand	8. Conical flask
9. Measuring cylinder	10. Electric Balance
11. Dropper	12. Beaker

Chemicals Required

1. Sulphuric acid (H_2SO_4) – concentrated
2. Potassium sulphate (K_2SO_4) – AR grade
3. Copper sulphate ($CuSO_4.5H_2O$) – AR grade
4. Selenium powder
5. Sodium hydroxide (NaOH) Commercial
6. Boric acid (H_3BO_3)
7. Bromocresol green ($C_{21}H_{14}Br_4O_5S$)
8. Methyl red ($C_{15}H_{15}N_3O_2$)
9. Sodium carbonate (Na_2CO_3)

Preparation of different Reagents

1. Preparation of boric acid solution (4%)

20g H_3BO_3 was taken in a 500 mL volumetric flask containing about 150-200mL hot distilled water. The flask was shaken thoroughly and the volume was made up to the mark with distilled water.

2. Preparation of mixed indicator Solution

0.5 g bromocresol green and 0.1 g methyl red was taken in a 100mL volumetric flask containing about 30-40 mL ethanol/methanol. The flask was shaken thoroughly and the volume was made up to the mark with methanol/ethanol.

3. Preparation of sodium hydroxide solution (40%)

400g NaOH was taken in a one litre volumetric flask containing about 200mL distilled water. The flask was shaken thoroughly and then the volume was made up to the mark with distilled water.

4. Preparation of standard H_2SO_4 Solution (0.05 N)

Exactly 1.4 mL of concentrated H_2SO_4 (AR grade) was taken is a one litre volumetric flask containing about 300 mL distilled water. The flask was shaken thoroughly and the volume was made up to the mark with distilled water

5. Preparation of Na_2CO_3 solution (0.05 N)

Exactly 0.265g oven dried Na_2CO_3 (AR grade) was taken in a one litre volumetric flask containing about 30-40 mL distilled water. The flask was shaken thoroughly and then the volume was made up to the mark with distilled water. Then H_2SO_4 was standardized by this Na_2CO_3 solution.

Procedure

A. Digestion

1) Exactly 1.0 g grain sample was taken in a kjeldahl flask. The sample was previously oven dried.

2) About 5.0g catalysts mixer (K_2SO_4: $CuSO_4$. $5H_2O$: Se=100: 10:1) was added in to the flask.

3) About 25mL H_2SO_4 was also added in to the flask.

4) The flask was heated until the solution become clear.

5) The flask was then allowed to cool and the about 120mL of distilled water was added and 5-6 glass bead into the flask.

B. Distillation

1) After digestion 40% NaOH 125 mL was added in to the kjeldahl flask.

2) The flask was attached quickly to the distillation set and then the flask was heated continuously.

3) In the meantime. 25 mL of 4% boric acid solution and 2-4 drops of mixed indicator was taken in 500mL receiver conical flask.

4) About 150 mL distillate was collected into receiver conical flask.

5) The conical flask was then removed.

C. Titration

1) The distillate was titrated with standard H_2SO_4 taken from a burette until the green color completely turns to pink color at the end point.

2) The same procedure was followed for a blank sample.

3) The result was calculated using the following formula:

Calculation:

$$\% N = (T-B) \times N \times 1.4/S$$

Where,

T = Titration value for sample (ml.)

B = Titration value for blank (mL)

N = Normality of H_2SO_4

S = Weight of the sample (g)

1.4 = Conversion factor

Nitrogen % is converted into protein by multiplying with a factor 6.25 for pulses.

3.7 Available Phosphorus

Available phosphorus was extracted from the grain sample by Brey-1 method (Brey and Kurtz,1945) in the extract was determined by ascorbic acid blue color method (Murphy and Riley, 1962) with the help of a Spectrophotometer (LKB No. Vaspec, 4049).

3.8 Available Potassium

Available potassium was extracted from grain sample by 1N Ammonium acetate. The exchangeable potassium content in grain samples were determined by Flame Photometer (Black, 1965).

3.9 Available Boron

Available Boron (B) content in the grain samples were determined by the method described by Hunter (1984).The extracting agent used was mono calcium phosphate [$CaH_4(PO_4)_2.H_2O$] so, ution and colour was developed by curcumin solution. The absorbance was read O + N Spectrophotometer at 555 nm wave length.

3.10 Statistical Analysis

The data obtained for different characters were statistically analyzed to observe the significant difference among different B level on wheat. The mean values of all the characters were calculated and analysis of variance was performed. The significance of the difference among the treatment means was estimated by the Duncan Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

Chapter 4

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to identify the response of wheat on boron fertilization. Data on different yield contributing characters and yield were recorded. The analyses of variance (ANOVA) of the data on different parameters are presented in Appendix III-VII. The results have been presented with the help of table and graphs and possible interpretations have been given under the following headings:

4.1 Plant height

Different levels of boron showed statistically significant differences in terms of plant height at 30, 40, 50, 60, 70 days after sowing (DAS) and at harvest (Appendix III). The longest plants at 30, 40, 50, 60, 70 DAS and at harvest were 22.93, 46.62, 70.67, 85.45, 89.23 and 93.34 cm, respectively observed from 2.0 kg B ha^{-1} which were statistically identical to 1.5 and 1.0 kg B ha^{-1} (Table 2). While the shortest plants (17.60, 38.76, 58.20, 68.51, 72.48 and 74.18 cm) were obtained from 0 kg B ha^{-1} at different DAS and at harvest. From the above findings it was found that application of boron increased plant growth that ensure maximum plant height than the control treatment *i.e.* no application of boron. Mete *et al.* (2005) reported earlier that plant height was significantly increased with the application of boron. Similar results also reported by Wrobel *et al.* (2006) and Lakshman *et al.* (2005) earlier from their experiment.

Table 2. Effect of different levels of boron on plant height at different days after sowing (DAS) of wheat

Levels of Boron	Plant height (cm) at					
	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	Harvest
0 kg B ha^{-1}	17.60 b	38.76 b	58.20 b	68.51 b	72.48 b	74.18 b
1.0 kg B ha^{-1}	20.45 ab	44.02 ab	64.72 ab	80.04 a	85.24 a	88.91 a
1.5 kg B ha^{-1}	22.79 a	46.35 a	70.03 a	84.71 a	88.71 a	92.53 a
2.0 kg B ha^{-1}	22.93 a	46.62 a	70.67 a	85.45 a	89.23 a	93.34 a
Level of significance	*	*	**	*	**	**
$LSD_{(0.05)}$	3.396	5.307	6.779	10.53	8.813	9.527
CV(%)	8.12	6.05	5.15	6.61	5.26	5.47

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

**: Significant at 0.01 level of probability

*: Significant at 0.05 level of probability

4.2 Number of tillers

Number of tillers plant^{-1} at 30, 40, 50, 60 and 70 DAS showed statistically significant differences (Appendix IV) for different levels of boron under the present trial (Table 3). At 30, 40, 50, 60 and 70 DAS, the maximum number of tillers plant^{-1} (2.37, 3.50, 3.97, 4.83 and 5.40) were observed from 2.0 kg B ha^{-1} which was statistically similar to 1.5 and 1.0 kg B ha^{-1}. Again the minimum numbers were 1.80, 2.83, 3.03, 3.43 and 3.77 from 0 kg B ha^{-1}. From the above findings it was found that application of boron increases vegetative growth with maximum number of tillers per plant compare to the control treatment. Mitra and Jana (1991) found that number of tillers plant^{-1}, significantly increased by boron application up to 20 kg borax ha^{-1} and thereafter a negative effect was noticed.

4.3 Leaf

Leaf plant^{-1} showed significant differences (Appendix V) for different levels of boron in this trial (Figure 1). The maximum number of leaf plant^{-1} (5.73) was recorded from 2.0 kg B ha^{-1} which was statistically similar to 1.5 kg B ha^{-1} and the minimum number (4.77) was recorded from 0 kg B ha^{-1}. Jahiruddin *et al.* (1992) reported that boron increased the number of leaf per plant.

Table 3. Effect of different levels of boron on number of tillers $plant^{-1}$ at different days after sowing (DAS) of wheat

Levels of Boron	Number of tillers $plant^{-1}$ at				
	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS
0 kg B ha^{-1}	1.80 b	2.83 b	3.03 b	3.43 b	3.77 b
1.0 kg B ha^{-1}	2.17 ab	3.27 ab	3.67 a	4.23 a	4.73 a
1.5 kg B ha^{-1}	2.32 a	3.43 a	3.90 a	4.75 a	5.27 a
2.0 kg B ha^{-1}	2.37 a	3.50 a	3.97 a	4.83 a	5.40 a
Level of significance	*	*	*	*	*
$LSD_{(0.05)}$	0.374	0.572	0.379	0.669	0.654
CV(%)	8.68	8.80	5.18	7.75	6.81

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

*: Significant at 0.05 level of probability

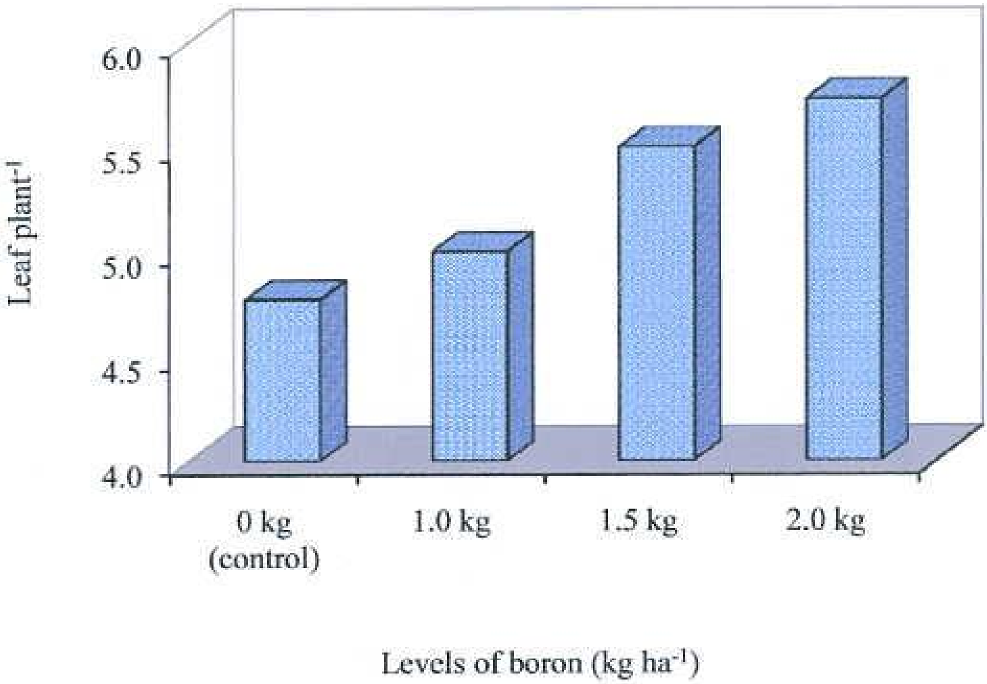

Fig. 1. Effect of different levels of boron on number of leaves plant^{-1} of wheat

4.4 Effective tillers

Effective tillers hill^{-1} showed statistically significant (Appendix V) variations for different levels of boron under the present trial (Table 4). The highest number of effective tillers hill^{-1} (4.77) was observed from 2.0 kg B ha^{-1} which was statistically similar to 1.5 kg B ha^{-1}, while the lowest number (3.63) was recorded from 0 kg B ha^{-1}. Mitra and Jana (1991) found that number of effective tillers plant^{-1} was significantly increased by boron application up to 20 kg borax ha^{-1} and thereafter a negative effect was noticed.

4.5 Non-effective tillers

Statistically significant variations (Appendix V) for different levels of boron was recorded in terms of non-effective tillers hill^{-1} (Table 4). The lowest number of non-effective tillers hill^{-1} (0.70) was observed from 2.0 kg B ha^{-1} which was statistically identical with 1.5 and 1.0 kg B ha^{-1}, while the highest number (0.90) was recorded from 0 kg B ha^{-1}. Mete *et al.* (2005) reported that application of B reduced the number of non-effective tillers.

4.6 Total tillers

Total tillers hill^{-1} varied significantly (Appendix V) for different levels of boron under the present trial (Table 4). The highest number of total tillers hill^{-1} (5.47) was recorded from 2.0 kg B ha^{-1} which was statistically identical with 1.5 kg B ha^{-1}, again the lowest number (4.53) was recorded from 0 kg B ha^{-1} which was statistically similar to 1.0 kg B ha^{-1}. Mandal (2000) reported that B application increased the number of total tillers.

Table 4. Effect of different levels of boron, number of tillers at harvest, spikelets spike^{-1}, fertile floret spikelet^{-1} of wheat

Levels of Boron	Number of tillers at harvest hill^{-1}			Spikelets Spike^{-1}	Fertile florets Spikelet^{-1}
	Effective	Non-effective	Total		
0 kg B ha^{-1}	3.63 c	0.90 a	4.53 b	18.83 b	2.27 c
1.0 kg B ha^{-1}	4.13 b	0.83 ab	4.97 b	19.27 b	2.40 bc
1.5 kg B ha^{-1}	4.70 a	0.73 b	5.43 a	21.23 a	2.73 ab
2.0 kg B ha^{-1}	4.77 a	0.70 b	5.47 a	21.67 a	2.80 a
Level of significance	**	*	**	*	*
$LSD_{(0.05)}$	0.424	0.141	0.442	1.846	0.357
CV(%)	4.91	9.18	4.32	4.56	7.04

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

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

4.7 Ear length

Ear length (cm) showed statistically significant (Appendix V) variation for different level of boron under the present study (Figure 2). The longest ear (15.941 cm) was found from 2.0 kg B ha^{-1} which was statistically identical with 1.5 and 1.0 kg B ha^{-1} whereas the shortest ear (13.95 cm) from 0 kg B ha^{-1}. From the above findings it was found that application of boron increased vegetative growth that ensured highest ear length than the control treatment. Mandal (1993) carried out an experiment with 21 wheat and found showed positive response to boron with respect to ear length.

4.8 Spikelets

Different levels of boron varied significantly (Appendix V) in terms of spikelets $spike^{-1}$ under the present study (Table 4). The highest number of spikelets $spike^{-1}$ (21.67) was recorded from 2.0 kg B ha^{-1} which was statistically identical to 1.5 kg B ha^{-1}, whereas the lowest number (18.83) from 0 kg B ha^{-1} which was statistically similar to 1.0 kg B ha^{-1}. From the above findings it was found that application of boron increased vegetative growth which leads to attain maximum reproductive growth with maximum number of spikelet $spike^{-1}$ compared to the control condition *i.e.* no application of boron. Wei and Zuo (1996) reported that basal application of boron significantly increased the number of spikelets.

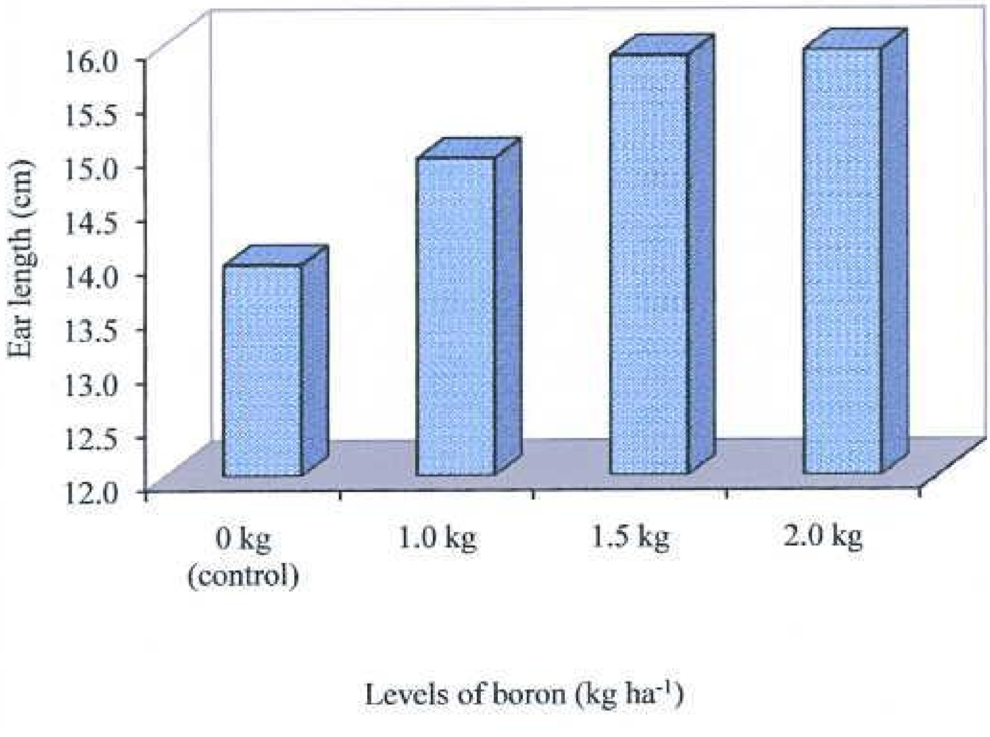

Fig. 2. Effect of different levels of boron on ear length of wheat

4.9 Fertile florets

Fertile florets spikelet^{-1} showed significant difference (Appendix V) for different levels of boron in this study (Table 4). The highest number of fertile florets spikelet^{-1} (2.80) was found from 2.0 kg B ha^{-1} which was statistically identical with 1.5 kg B ha^{-1}, whereas the lowest number (2.27) from 0 kg B ha^{-1}. Karki (1996) reported that application of boron (borax) improved fertile floret spikelet^{-1}.

4.10 Number of filled grains

Statistically significant variation was recorded (Appendix VI) for number of filled grains spike^{-1} for different levels of boron (Table 5). The highest number of filled grains spike^{-1} (48.17) was observed from 2.0 kg B ha^{-1} which was statistically identical with 1.5 kg B ha^{-1}, whereas the lowest number (29.87) from 0 kg B ha^{-1}. Abedin *et al.* (1994) reported that the number of grains ear^{-1} was significantly influenced by the boron treatments.

4.11 Number of unfilled grains

Number of unfilled grains spike^{-1} showed statistically significant (Appendix VI) variation for different levels of boron (Table 5). The lowest number of unfilled grains spike^{-1} (3.89) was observed from 2.0 kg B ha^{-1} which was statistically identical with 1.5 and 1.0 kg B ha^{-1}, while the highest number (6.00) from 0 kg B ha^{-1}. From the above findings it was found that application of boron increased vegetative growth with maximum number of unfilled grains spike^{-1} compare to the control treatment. Mandal and Ray (1999) showed significant response to applied boron for number of unfilled grains.

Table 5. Effect of different levels of boron on no. of filled grains spike^{-1}, no. of unfilled grains spike^{-1}, no. of total grains spike^{-1}, grain and straw yield ha^{-1} of wheat

Levels of Boron	No. of filled grains spike^{-1}	No. of unfilled grains spike^{-1}	No. of total grains spike^{-1}	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})
0 kg B ha^{-1}	29.87 b	6.00 a	35.87 b	3.10 b	3.49 b
1.0 kg B ha^{-1}	38.40 ab	4.53 b	42.93 ab	3.52 ab	3.92 b
1.5 kg B ha^{-1}	46.70 a	4.23 b	50.93 a	3.86 a	4.93 a
2.0 kg B ha^{-1}	48.17 a	3.89 b	52.06 a	3.88 a	4.96 a
Level of significance	**	**	**	**	**
$LSD_{(0.05)}$	9.606	1.046	8.867	0.438	0.632
CV(%)	11.79	11.22	9.77	6.12	7.29

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

**: Significant at 0.01 level of probability

*: Significant at 0.05 level of probability

4.12 Number of total grains

Statistically significant variation (Appendix VI) was recorded for number of total grains spike^{-1} for different levels of boron under the present trial (Table 5). The highest number of total grains spike^{-1} (52.06) was recorded from 2.0 kg B ha^{-1} which was statistically identical with 1.5 kg B ha^{-1}, while the lowest number (35.87) was found from 0 kg B ha^{-1}. Mitra and Jana (1991) found that number of grains panicle^{-1} was significantly increased by boron application up to 20 kg borax/ha and thereafter a negative effect was noticed.

4.13 1000-seed weight

Statistically significant variation was recorded in terms of 1000-seed weight for different levels of boron under the present trial (Appendix VI, Figure 3). The highest 1000-seed weight (44.79 g) was obtained from 2.0 kg B ha^{-1} which was statistically similar to 1.5 kg B ha^{-1}. On the other hand, the lowest (40.31 g) was found from 0 kg B ha^{-1}. From the above findings it was found that application of boron increased vegetative and reproductive growth that ensured healthy grain and the ultimate results was the highest 1000-seed weight than the control treatment. Mitra and Jana (1991) found that 1000-grain weight was significantly increased by boron application up to 20 kg borax ha^{-1} and thereafter a negative effect was noticed.

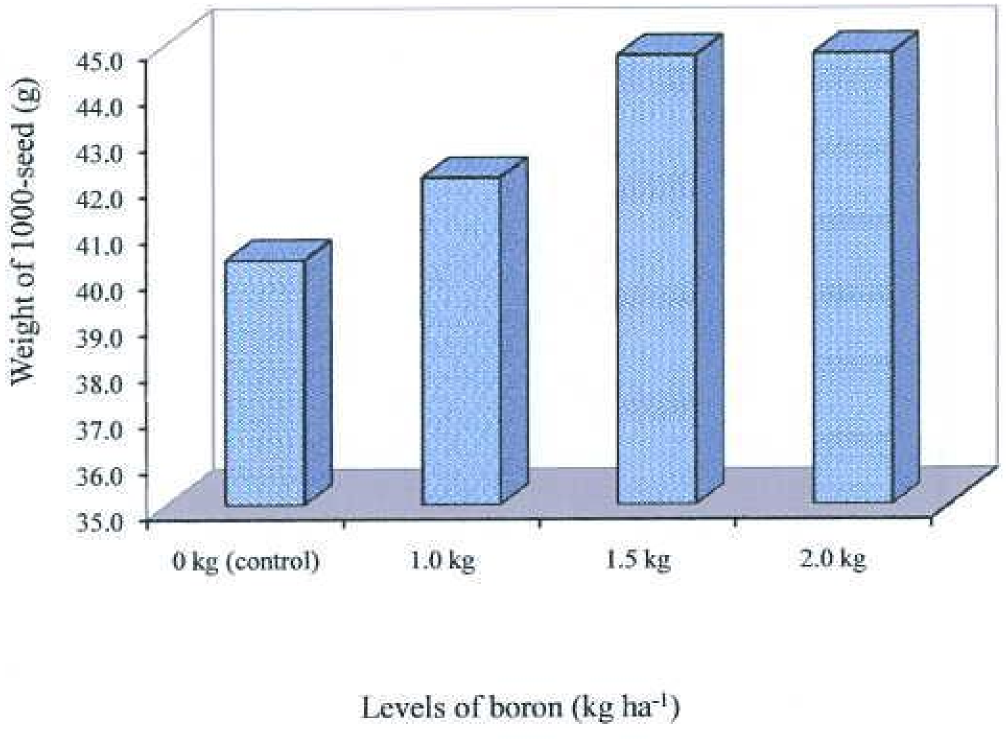

Fig. 3. Effect of different levels of boron on of 1000-seed weight of wheat

4.14 Grain yield

Grain yield hectare^{-1} showed statistically significant variations (Appendix VI) for different levels of boron under the present trial (Table 5). The highest grain yield hectare^{-1} (3.88 ton) was observed from 2.0 kg B ha^{-1} which was statistically identical to 1.5 kg B ha^{-1}, while the lowest (3.14 ton) was found from 0 kg B ha^{-1}. From the above findings it was found that application of boron increased vegetative and reproductive growth that ensures healthy grain and the ultimate results was the highest grain yield per hectare than the control treatment. Rerkasem and Longeragan (1990) stated that the highest grain yield was obtained by wheat plants from soil fertilized only by N during the reproductive stage combined with foliar spraying with boron. Mandal (1993), Abedin *et al.* (1994) reported the similar findings from another experiment.

4.15 Straw yield

Straw yield hectare^{-1} showed statistically significant variations for different levels of boron under the present trial (Appendix VI, Table 5). The highest straw yield hectare^{-1} (4.96 ton) was observed from 2.0 kg B ha^{-1}, which was statistically similar to 1.5 kg B ha^{-1}, while the lowest (3.49 ton) was found from 0 kg B ha^{-1}. From the findings it was found that application of boron increased vegetative and reproductive growth that ensures healthy straw and the ultimate results was the highest straw yield per plant and also per hectare than the control treatment. Jahiruddin *et al.* (1995) found that boron had a marked positive influence on straw yield.

4.16 Biological yield

Biological yield (ton) ha^{-1} varied significantly for different levels of boron under the present trial (Appendix VI, Figure 4). The highest biological yield ha^{-1} (8.84 ton) was found from 2.0 kg B ha^{-1} which was statistically identical to 1.5 kg B ha^{-1}, again the lowest (6.59 ton) was recorded from 0 kg B ha^{-1}, which was statistically similar (7.44 ton) to 1.0 kg B ha^{-1}. Roy and Pradhan (1994) found that application of half of the boron at sowing and in 2 equal splits by foliar spray at 45 and 75 days after sowing gave the highest straw yield.

4.17 Harvest index

Harvest index (%) showed statistically significant variation for different levels of boron under the present trial (Appendix VI, Figure 5). The highest harvest index (29.82%) was obtained from 2.0 kg B ha^{-1} which was statistically similar to 1.5 kg B ha^{-1}, whereas the lowest (23.82%) was found from 0 kg B ha^{-1}. Ahamed and Alam (1994) recorded significant increase in harvest index.

4.18 Concentration on N, P, K and B in grain sample

Concentration of N, P, K and B showed statistically significant variation for different levels of boron under the present trial (Table 6). The highest nitrogen concentration (0.139%) was obtained from 2.0 kg B ha^{-1} which was statistically similar to 1.5 kg B ha^{-1}, whereas the lowest (0.103%) was found from 0 kg B ha^{-1}. In case of P concentration, the highest amount of P (0.36%) was obtained from 2.0 kg B ha^{-1} which was closely followed by 1.5 kg B ha^{-1}, whereas the lowest (0.28%) was found from 0 kg B ha^{-1}.

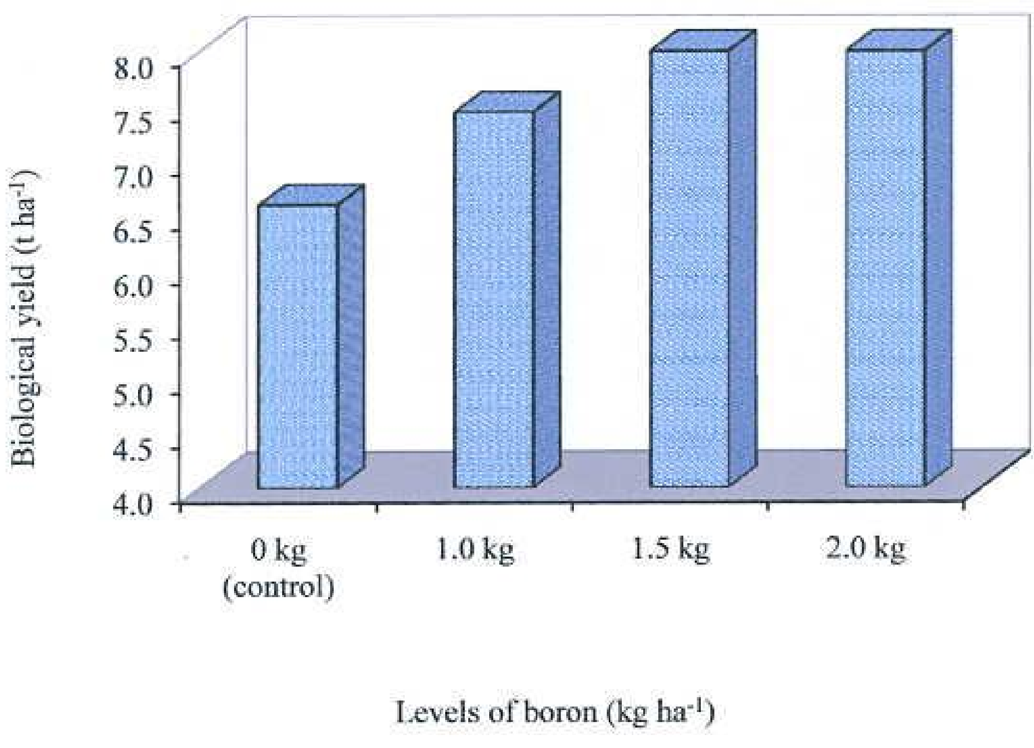

Fig. 4. Effect of different levels of boron on biological yield of wheat

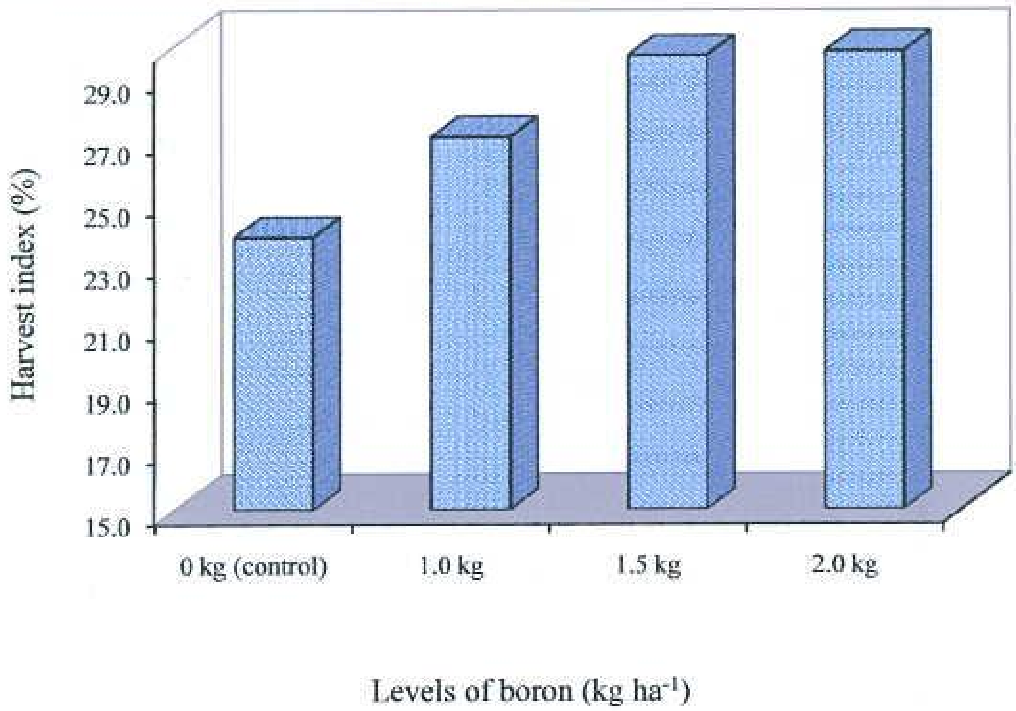

Fig. 5. Effect of different levels of boron on harvest index of wheat

Table 6. Effect of different levels of boron on concentration of N, P, K and B in grains of wheat

Levels of Boron	Concentration (%) in grain sample			
	Nitrogen	P	K	B
0 kg B ha^{-1}	0.103 b	0.28 d	0.34 b	0.64 b
1.0 kg B ha^{-1}	0.128 a	0.32 c	0.43 a	0.74 a
1.5 kg B ha^{-1}	0.135 a	0.34 b	0.45 a	0.79 a
2.0 kg B ha^{-1}	0.139 a	0.36 a	0.47 a	0.83 a
$LSD_{(0.05)}$	0.020	0.020	0.063	0.089
Level of significance	0.01	0.05	0.01	0.01
CV(%)	5.50	6.15	6.68	6.07

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

**: Significant at 0.01 level of probability

*: Significant at 0.05 level of probability

In case of K, the highest K concentration (0.47%) was obtained from 2.0 kg B ha^{-1} which was statistically similar to 1.5 kg B ha^{-1}, whereas the lowest (0.34%) was found in 0 kg B ha^{-1}. B concentration in grain sample, the highest amount of B (0.83%) was obtained from 2.0 kg B ha^{-1} which was statistically similar to 1.5 kg B ha^{-1}, whereas the lowest (0.64%) was found from 0 kg B ha^{-1} (Appendix VII). Abedin *et al.* (1994) reported that the nitrogen and boron contents in grain were increased by soil application of boron but not by its foliar spray. Ahamed and Alam (1994) reported that zinc and boron application singly and incorporation on soil increased the nutrient content of wheat grain.

Chapter 5

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was carried out at Sher-e-Bangla Agricultural University, Dhaka during the period from December 2011 to April 2012 to observe the response of wheat to boron fertilization. The experiment comprised of different level of boron such as- 0 (control); 1.0, 1.5 and 2.0 kg B ha^{-1}. The experiment was laid out in single Factor Randomized Complete Block Design (RCBD) with three replications. The studied parameter were plant height, number of tillers, leaf, effective tillers, non-effective tillers, total tillers, ear length, spikelets, fertile florets, number of filled grains, number of unfilled grains, number of total grains, 1000-seed weight, grain yield, straw yield, biological yield, harvest index and concentration on N, P, K and B in grain.

At 30, 40, 50, 60, 70 days after sowing (DAS) and at harvest the longest plants were 22.93, 46.62, 70.67, 85.45, 89.23 and 93.34 cm, respectively was recorded from 2.0 kg B ha^{-1}, while the shortest plants (17.60, 38.76, 58.20, 68.51, 72.48 and 74.18 cm) from 0 kg B ha^{-1}. At 30, 40, 50, 60 and 70 DAS, the maximum number of tillers $plant^{-1}$ (2.37, 3.50, 3.97, 4.83 and 5.40) were observed from 2.0 and the minimum number (1.80, 2.83, 3.03, 3.43 and 3.77) from 0 kg B ha^{-1}, respectively. The maximum number of leaves $plant^{-1}$ (5.73) was recorded from 2.0, whereas the minimum number (4.77) from 0 kg B ha^{-1}, respectively. The highest number of effective tillers $hill^{-1}$ (4.77) was observed from 2.0 kg B ha^{-1}, while the lowest number (3.63) was recorded from 0 kg B ha^{-1}. The lowest number of non-effective tillers hill^{-1} (0.70) was observed from 2.0 kg B ha^{-1}, while the highest number (0.90) from 0 kg B ha^{-1}. The highest number of total tillers hill^{-1} (5.47) was recorded from 2.0 kg B ha^{-1}, again the lowest number (4.53) from 0 kg B ha^{-1}.

The longest ear (15.941 cm) was found from 2.0 kg B ha^{-1} while the shortest ear (13.95 cm) from 0 kg B ha^{-1}. The highest number of spikelets spike^{-1} (21.67) was recorded from 2.0 kg B ha^{-1}, whereas the lowest number (18.83) from 0 kg B ha^{-1}. The highest number of fertile florets spikelet^{-1} (2.80) was found in 2.0 kg B ha^{-1}, whereas the lowest number (2.27) was recorded from 0 kg B ha^{-1}. The highest number of filled grains spike^{-1} (48.17) was observed from 2.0 kg B ha^{-1}, whereas the lowest number (29.87) from 0 kg B ha^{-1}. The lowest number of unfilled grains spike^{-1} (3.89) was observed from 2.0 kg B ha^{-1}, while the highest number (6.00) was recorded from 0 kg B ha^{-1}. The highest number of total grains spike^{-1} (52.06) was recorded from 2.0 kg B ha^{-1}, while the lowest number (35.87) was found from 0 kg B ha^{-1}. The highest 1000-seed weight (44.79 g) was obtained from 2.0 kg B ha^{-1} and the lowest (40.31 g) from 0 kg B ha^{-1}. The highest grain yield ha^{-1} (3.88 ton) was observed from 2.0 kg B ha^{-1}, while the lowest (3.14 ton) was found from 0 kg B ha^{-1}. The highest straw yield hectare^{-1} (4.96 ton) was observed from 2.0 kg B ha^{-1}, while the lowest (3.49 ton) from 0 kg B ha^{-1}. The highest biological yield ha^{-1} (8.84 ton) was found from 2.0 kg B ha^{-1}, again the lowest (6.59 ton) was recorded from 0 kg B ha^{-1}.

In grain sample content of nitrogen concentration, the highest nitrogen (0.139%) was obtained from 2.0 kg B ha^{-1}, whereas the lowest (0.103%) was found from 0 kg B ha^{-1}, respectively. In case of P concentration, the highest P (0.36%) was obtained from 2.0 kg B ha^{-1}, whereas the lowest (0.28%) was found from 0 kg B ha^{-1}. In K concentration in grain sample, the highest K (0.47%) was obtained from 2.0 kg B ha^{-1}, whereas the lowest (0.34%) was found from 0 kg B ha^{-1}. B concentration in grain sample, the highest B (0.83%) was obtained from 2.0 kg B ha^{-1}, whereas the lowest (0.64%) was found from 0 kg B ha^{-1}.

Conclusion:

At 30-70 DAS and at harvest the longest plant (23-90 cm) and the maximum number of tillers plant^{-1} (2.37-5.40) was recorded from 2.0 kg B ha^{-1}, while the shortest plant (17.6-74.18 cm) and minimum number of tillers plant^{-1} (1.8-3.77) from 0 kg B ha^{-1}. The highest number of spikelets spike^{-1} (21.67) was recorded from 2.0 kg B ha^{-1}, whereas the lowest number (18.83) from 0 kg B ha^{-1}. The highest number of total grains spike^{-1} (52.06) was recorded from 2.0 kg B ha^{-1}, while the lowest number (35.87) was found from 0 kg B ha^{-1}. The highest 1000-seed weight (44.79 g) was obtained from 2.0 kg B ha^{-1} and the lowest (40.31 g) from 0 kg B ha^{-1}. The highest grain yield hectare^{-1} (3.88 ton) was observed from 2.0 kg B ha^{-1}, while the lowest (3.14 ton) was found from 0 kg B ha^{-1}. The highest straw yield hectare^{-1} (4.96 ton) was observed from 2.0 kg B ha^{-1}, whereas the lowest (3.49 ton) from 0 kg B ha^{-1}. In grain sample, the highest N, P, K and B content was found from 2.0 kg B ha^{-1} (0.139, 0.36, 0.47 and 0.83% respectively), while the lowest values were obtained from control (0.103, 0.28, 0.34 and 0.64%

respectively). From the above findings, it was found that highest result was recorded from 2.0 kg B ha^{-1}, which was statistically similar to 1.5 kg B ha^{-1}. So, 1.5 kg B ha^{-1} is suitable and economical for wheat cultivation.

Considering the results of the present experiment, further studies in the following areas may be suggested:

1. Such study is needed to be repeated in different agro-ecological zones (AEZ) of Bangladesh for the evaluation of regional adaptability,
2. Other levels of boron fertilizer besides Borax may be examined for further study.

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Appendices

APPENDICES

Appendix I. Monthly record of air temperature, relative humidity, rainfall, and sunshine of the experimental site during the period from December 2011 to April 2012

Month	*Air temperature (°c)		*Relative humidity (%)	*Rain fall (mm) (total)	*Sunshine (hr)
	Maximum	Minimum			
December, 2011	22.4	13.5	74	00	6.3
January, 2012	24.5	12.4	68	00	5.7
February, 2012	27.1	16.7	67	30	6.7
March, 2012	31.4	19.6	54	11	8.2
April, 2012	34.2	23.4	61	112	8.1

* Monthly average,

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1212

Appendix II. Physical characteristics of field soil analyzed in Soil Resources Development Institute (SRDI) laboratory, Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy field, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: Soil Resources Development Institute (SRDI)

Appendix III. Analysis of variance of the data on plant height at different days after sowing (DAS) of wheat as influenced by different levels of boron

Source of variation	Degrees of freedom	Mean square Plant height (cm) at					
		30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	Harvest
Replication	2	0.197	1.323	1.757	2.013	5.194	1.410
Treatment	3	18.772*	39.894*	100.381**	183.559*	183.807*	238.621**
Error	6	2.889	7.057	11.512	27.778	19.457	22.739

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

Appendix IV. Analysis of variance of the data on number of tillers plant^{-1} at different days after sowing (DAS) of wheat as influenced by different levels of boron

Source of variation	Degrees of freedom	Mean square Number of tillers plant^{-1} at				
		30 DAS	40 DAS	50 DAS	60 DAS	70 DAS
Replication	2	0.027	0.203	0.003	0.057	0.001
Treatment	3	0.197*	0.270*	0.543**	1.242**	1.651**
Error	6	0.035	0.082	0.036	0.112	0.107

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

Appendix V. Analysis of variance of the data on yield contributing characters of wheat as influenced by different levels of boron

Source of variation	Degrees of freedom	Mean square						
		Leaf (No.)	Number of tillers at harvest $hill^{-1}$			Spikelets $Spike^{-1}$	Fertile florets $Spikelet^{-1}$	Ear length
			Effective	Non-effective	Total			
Replication	2	0.053	0.006	0.001	0.007	0.370	0.030	0.225
Treatment	3	0.592**	0.850**	0.025**	0.584**	5.947*	0.199*	2.648*
Error	6	0.075	0.045	0.005	0.049	0.854	0.032	0.820

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

Appendix VI. Analysis of variance of the data on yield contributing characters and yield of wheat as influenced by different levels of boron

Source of variation	Degrees of freedom	Mean square							
		No. of filled grains $spike^{-1}$	No. of unfilled grains $spike^{-1}$	No. of total grains $spike^{-1}$	1000-seed weight (g)	Grain yield ($t\ ha^{-1}$)	Straw yield ($t\ ha^{-1}$)	Biological yield	Harvest index
Replication	2	11.316	0.125	13.322	2.731	0.005	0.099	0.081	0.278
Treatment	3	214.411**	2.584**	171.94*	14.324*	0.404**	1.627**	3.605**	23.912**
Error	6	23.116	0.274	19.696	2.111	0.048	0.100	0.242	2.849

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

Appendix VII. Analysis of variance of the data on N, P, K and B in grain sample of wheat as influenced by different levels of boron

Source of variation	Degrees of freedom	Mean square			
		Concentration (%) in grain sample			
		Nitrogen	P	K	B
Replication	2	0.0001	0.0001	0.001	0.005
Treatment	3	0.001**	0.003**	0.010**	0.021**
Error	6	0.0001	0.0001	0.001	0.002

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