EFFECT OF NITROGEN AND BORON ON THE GROWTH AND YIELD OF WHEAT (*Triticum aestivum L*.) BARI gom-28

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CERTIFICATE

This is to certify that the thesis entitled, **"EFFECT OF NITROGEN AND BORON ON THE GROWTH AND YIELD OF WHEAT (*Triticum aestivum* L.) BARI Gom-28"** *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 SOIL SCIENCE,** *embodies the result of a piece of bonafide research work carried out by* **SHAH JALAL MIAJEE; Registration No. 10-04068,** *under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

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

Dated: June, 2016
Dhaka, Bangladesh

(Professor Mst. Afrose Jahan)
Supervisor

Dedicated to

My

Beloved Parents

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ABSTRACT

A field experiment was conducted at the Sher-e- Bangla Agricultural University Farm Dhaka 1207 during the rabi season from November 2015 to March 2016 to study the effect of N and B to alone and combined on the growth and yield of BARI Gom-28. The experiment comprised of four levels of N viz., 0, 40, 80 and 120 kg ha^{-1} and three levels of B viz., 0, 1 and 1.5 kg ha^{-1}. The experiment was laid out in a Randomized Complete Block Design with three replications. The results of the experiment showed that there were significant effect on yield and yield attributes of wheat due to the application of N and B. Nitrogen showed significant effect on yield and yield attributes of wheat. Application of nitrogen @ 120 kg N ha^{-1} produced the highest plant height, number of total tillers $plant^{-1}$, spike length, number of spikelet $spike^{-1}$, number of grain $spike^{-1}$, 1000-grain weight, grain yield, straw yield and harvest index. In all the cases lower response was found from the control treatment. Boron fertilizer also had significant effect on yield and yield attributes of wheat. Application of boron @ 1 kg B ha^{-1} gave the highest plant height, number of total tillers $plant^{-1}$, spike length, number of spikelet $spike^{-1}$, number of grain $spike^{-1}$, 1000-grain weight, grain yield, straw yield and harvest index. In all cases the lower response was found from the control treatment. Interaction effect of N and B for yield and yield attributes of wheat was found significant. The highest plant height, number of total tillers $plant^{-1}$, spike length, number of spikelet $spike^{-1}$, number of grain $spike^{-1}$, 1000-grain weight, grain yield, straw yield and harvest index of wheat were obtained from the treatment combination of 120 kg N and 1 kg B ha^{-1}. On the other hand, in all the cases lower response was found from the control treatment. Results showed that grain yield of wheat was increased with increasing levels of both N and B up to 120 kg ha^{-1} and 1 kg ha^{-1}, respectively. The interaction effect of N and B on both the parameters was significant.

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ABBREVIATION	ELABORATION
AEZ	Agro-Ecological Zone
ANOVA	Analysis of Variance
@	At the rate of
B	Boron
BARI	Bangladesh Agricultural Research Institute
BAU	Bangladesh Agricultural University
BBS	Bangladesh Bureau of Statistics
BINA	Bangladesh Institute of Nuclear Agriculture
BST	Boot Stage Tissue
cv.	Cultivar(s)
CV%	Percentage of Coefficient of Variance
CIMMYT	International Maize and Wheat Improvement Center
CRI	Crown Root Initiation
DAS	Days After Sowing
DMRT	Duncan's Multiple Range Test
e.g	As for Example
et al.	and others
FAO	Food and Agricultural Organization
FYM	Farm Yard Manure
g	Gram
i.e	that is
IFPRI	International Food Policy Research Institute
K	Potassium

ABBREVIATION	ELABORATION
kg	Kilogram
Kg ha^{-1}	Kilogram per hectare
LSD	Least Significant Difference
S	Sulphur
TSP	Triple Super Phosphate
m	Meter
MP	Muriate of Potash
N	Nitrogen
P	Phosphorus
NS	Non Significant
OM	Organic Matter
pH	Hydrogen ion Concentration
RARS	Regional Agricultural Research Center
RCBD	Randomized Complete Block Design
SAU	Sher-e-Bangla Agricultural University
USDA	United States Department of Agriculture
t ha^{-1}	Ton Per hectare

INTRODUCTION

Wheat (*Triticum aestivum L.*) is one of the most important food grain crop grown in the world. It ranks first both in area (21,360 thousand hectares) and production (5,76,317 thousand metric ton) of the world (FAO, 2014) cereal crops accounting for 30% of all cereal food worldwide and is a staple food for over 10 billion people in as many as 43 countries of the World. Wheat ranks second in Bangladesh accounting for 20% of all cereal food of Bangladesh and is cultivated on large scale in the country. Once wheat was a food for the poorer in Bangladesh. Most of people used to take wheat as Chapati (locally known as ruti). The dietary habit of people of Bangladesh has changed to a considerable extent during the past decade. Wheat has now become an indispensable food item of the people of Bangladesh and it continues to fill the food gap caused by possible failure of rice crop. Within a period of 30 years of time, wheat has been firmly established as a secure crop in Bangladesh, mainly due to stable market price and two million farmers are currently involved in wheat production (Karim *et al*., 2010).

According to USDA (2014) one cup whole wheat grain contains 33% Protein, 29% Carbohydrate, 5% Fat and currently about 65% of wheat crop is used for food, 17% for animal feed and 12% in industrial applications (FAO, 2013). CIMMYT predicted that demand for wheat in the developing world is projected to increase 60% by 2050 from now (CIMMYT, 2013). Wheat covers the more earth's surface area than any other food crop and wheat production is the third largest cereal production in the world, after maize and rice (FAO, 2013). FAO (2013) identified wheat as the key to the emergence of urban societies for millennia.

In Bangladesh, wheat is the second important cereal crop next to rice (Al-Musa *et al.,* 2012) and the area under wheat cultivation during 2012 was about 0.47 million ha and producing 1.38 million ton of wheat with an average yields of 3.32 t ha^{-1} (BBS, 2013).

Wheat is grown under different environmental condition ranging from humid to arid, subtropical to temperate zone (Saari, 1998). It is grown under a wide range of climatic and soil conditions. It, however, grows well in clayey loam soils. In Bangladesh, it is a crop of Rabi season, requires dry weather and bright sunlight. Well distributed rainfall between 40 and 110 cm is congenial for its growth. It is cool-loving crop and adopted for cultivation in regions with cooler climatic conditions. Its grain growth and development rely on temperature range of 150/100 to 180/150 (Throne *et al*., 1968), the best time of wheat sowing is the second half of November that needed around 110-120 days to complete its life cycle.

Wheat production has increased steadily from around 0.115 million tons in 1971-72 and gradually decreased to 0.73 million tons in 2005-06 (BBS, 2006). It is cultivated on an area of 4.16 lac hectares with an annual production of 12.54 lac tones and an average yield of 2.8 tons per hectare. (BBS, 2012-13). Among various constraints limiting wheat productivity in Bangladesh, delayed sowing, lack of varieties, lower fertilizer rate and water shortage, availability of good quality seed and sowing techniques is a major hindrance. Researchers from the International Food Policy Research Institute (IFPRI) and the International Maize and Wheat Improvement Centre (CIMMYT) recently examined the arguments for and against wheat production in Bangladesh. However, wheat production has generally stagnated due to, among other factors, high cost of production and low level of technology adoption in the wheat industry (Onsongo, 2003).

Fertilizers are indispensable for the crop production system of modern agriculture. It plays a very important role in utilizing the soils for an efficient crop production. Today inorganic fertilizers hold the key to success for increased crop productivity under Bangladesh agriculture.

Nitrogen is the most important nutrient element for plants and rate of nitrogen application has a great influence on growth, development and yield of wheat (Karamanos *et al*., 2005; Engel *et al*., 2001; Walley *et al*., 2001). Grain yield of wheat increases with increasing nitrogen level up to 120 kg ha^{-1} (Singh *et al*., 2013). Nitrogen helps to promote plant height, number of tillers and number of grains and is needed to maximize the spike number as much as possible at early and mid tillering stage and these parameters are adversely affected due to deficiency of nitrogen as the formation of enzymes, chlorophyll and proteins necessary for growth and development, gets restricted (Reddy, 2004). Nitrogen is the major nutrient added to increase crop yield (Camara *et al.,* 2003). Consequently, to get more production, nitrogen application is essential in the form of chemical fertilizer. Nitrogen fertilizer is known to affect the number of tillers m^{-2}, number of spikelet $spike^{-1}$, number of grains $spike^{-1}$, spike length and 1000-grain weight. Seed obtained from nitrogen applied plots showed increased germination percentage and more vigor. The protein content in the wheat grains increased with an increased in nitrogen. But urea is a fast releasing nitrogenous fertilizer which after application causes considerable losses as ammonia volatilization, immobilization, denitrification and surface runoff etc. and as such land experiences deficient in nitrogen. Lower soil nitrogen contents result in low protein content in wheat grain (Froloy *et al.,* 1989). Nitrogen fertilization increases wheat protein content (Ortiz- Monasterio, 1997) which increases grain quality and vigor. There are innumerable reports on the negative effects of weeds on crop plants (Javaid *et al.,* 2007) thus they cause huge yield losses (Rathore *et al.,* 2014). In wheat, weed infestation may reduce wheat yield by 42-56% (El-Hamid *et al.,* 1998), 45.5 to 63.9% (Reddy and Reddi, 2002), 25% to 30% (Norsworthy *et al*., 2004), 25.35% (Dangwal *et al.,* 2010), 40.3% (Rajeev *et al*., 2012). Grain yield of wheat was reduced up to 92% by competition from ryegrass (Dickson *et al.,* 2011), 17-62% due to wild oat (Avena ludoviciana) (Marwat *et al.,* 2011).

The soils of Bangladesh in some areas are deficient in some micro elements and boron is one of them. Boron is essential for growth and yield of crops. It is relatively mobile in plants and is absorbed as BO_3^-. Vitosh *et al.* (1997) expressed that B is involved in carbohydrates metabolism and it is essentially necessary for protein synthesis, pollen germination and seed and cell wall formation. Boron plays an important role in the physiological process of wheat plant such as cell elongation, cell maturation, sugar translocation, meristematic tissues development, protein synthesis and ribosome for maturation (Mengel and Kirkby, 1987). Rehem *et al.,* (1998) stated that B plays a key role in water and nutrients transportation from root to shoot. They believe that boron shortage causes barren stalks and small, twisted ears and grain yield reduction through impaired development of anthers and ultimately failure of seed setting. Boron helps to develop root system, fruit setting and grain formation. Most of the amino acids increase with an increase in B supply (Iqtidar and Rehman, 1984). However, there are a few reports on the effects of boron in wheat in Bangladesh (BINA, 1993; BARI, 1978).

Boron deficiency is reported on some soils and crops (Jahiruddin *et al.,* 1991). The primary function of boron is related to cell wall formation, so boron deficient plant may be stunted. It may induce male sterility in wheat. The deficiency of B causes grain set in wheat to fail higher crop yields naturally have higher requirement of nutrients due to more pressure on the land for available forms of nutrients. Its deficiency also results in impaired crop growth and development. Different experiments have been conducted to evaluate the response of wheat genotypes to boron application and a wide range of genotypic variation in response to B deficiency and toxicity (Paul *et al.,* 1991) have been reported. Jahiruddin *et al.* (1995), Abedin *et al.* (1994), and Rerkasem *et al.* (1989) obtained higher yield of wheat with the application of B to the crop. Grain sterility of wheat as per world literature may be associated with the deficiency of some micronutrients, especially B (Mandal and Das, 1988, Rerkasem *et al.,* 1991 and Jahiruddin *et al.,* 1992). Boron deficiency was much reported for rabi crops, especially mustard, wheat and chickpea (Ahmed *et al.,* 1991; Jahiruddin *et al.,* 1995).

In view of the above mentioned circumstances, this research work was undertaken with the following objectives:

(a) To observe the suitable doses of N & B on the growth and yield of wheat.

(b) To know the interaction effect of N & B on the growth and yield of wheat.

REVIEW OF LITERATURE

An attempt has been made in this chapter to present a brief review of researches in relation to the effect of nitrogen & boron level on growth and yield of wheat. However, information available in these aspects of wheat have been reviewed and presented in this section.

2.1 **Effect of nitrogen on the growth parameters of wheat**

2.1.1 **Plant height**

Ali et al. (2011) carried out a field study to determine the influence of' varying nitrogen levels (0, 70, 140 and 210 kg ha^{-1}) applied to wheat cultivar i.e. lnqilab-91 and Bakhar-2000. Data for various growth and yield parameter of· the crops were collected and analyzed. Bakhar-2000 produced significantly more and taller plants throughout the crop growth stages and each increment of nitrogen increased plant height significantly. Significantly higher number of' tillers and fertile tillers was recorded in Bakhar-2000 and nitrogen applied at the rate of 210 kg ha^{-1}. This cultivar produced higher 1000-grain weight as well as grain yield than that of Inqlab-91.

Das (2003) steered out an experiment at the Agronomy Field Laboratory of the Bangladesh Agricultural University, Mymensingh to observe the effect of row spacing and nitrogen application on growth and yield of wheat. The experiment consists of four row spacing and four nitrogen levels. Results of the experiment showed that nitrogen had significant effect on plant height. At all growth stage the tallest plant was obtained from the 180 kg N ha^{-1}.

Sushila and Giri (2000) set an experiment with different nitrogen doses (0, 45, 90 kg ha^{-1}) and observed that plant height significantly increased with the increasing doses of nitrogen.

Kataria and Bassi (1999) conveyed a field experiment at Palampur during winter (Rabi) seasons of 1990-91 and 1991-92. The treatment consists of 3 levels of nitrogen (40, 80 and 120 kg ha^{-1}). They found that application of 80 kg N ha^{-1} produced significantly tallest plant than 40 kg N ha^{-1}.

Awasthi and Bhan (1993) noticed through an experiment that plant height of wheat increased significantly with increasing rates of nitrogen up to 60 kg ha^{-1}.

Patel and Upaddhyay (1993) reported that plant height was increased with increased N up to 150 kg N ha^{-1}.

Ahmed and Hossain (1992) reported that plant height of wheat were 79.9 cm, 82.3 cm and 84.4 cm with 45, 90 and 135 kg N ha^{-1}, respectively. Plant height progressively increased with the increase of nitrogenous fertilizer.

Meneses and Ivan (1992) reported that plant height increased significantly with 0 to 200 kg N ha^{-1}.

Islam *et al.* (2011) conducted a field experiment to find out the effect of appropriate dose of urea super granule on growth and yield of wheat. They found that plant height differed significantly due to variation in USG levels. Among the USG treatments, the tallest plant (95.77 cm) was recorded in BARI recommended dose applied as USG and the shortest plant (87.49 cm) was found in control.

Hasan (2011) conducted an experiment to find out the effect of different placement depth and sowing time of prilled urea (PU) and urea super granule (USG) on wheat. He concluded that plant height was affected significantly by the effect of different placement and sowing time of prilled urea and urea super granule at different days after sowing. In any treatment of USG was found better for plant height compare to those of prilled urea treatments.

Mattas *et al.* (2011) studied on the effect of increasing levels of nitrogen fertilization and its time of application on the growth, yield and N uptake of durum wheat. Three levels of N (120, 150 and 180 kg ha^{-1}) were given in the main plots and three times of nitrogen application: 1/2 at sowing + 1/2 at CRI, 1/3 at sowing + 1/3 at CRI + 1/3 at boot stage and 1/3 at sowing + 1/3 at CRI stage + 1/3 at anthesis stage were used in the subplots. Increasing level of nitrogen significantly increased the plant height.

Pasha (2005) reported that plant height did not vary significantly between two splits (one third N as basal + two third at first node stage) and three splits (half N as basal, one fourth N at tillering + one fourth N at tillering).

Rahman (2005) conducted an experiment to find out the effect of nitrogen, sulphur and boron fertilizer under irrigated and rainfed conduction on the yield and quality of wheat cv. Kanchan. The experiment included four levels of nitrogen viz.75, 100, 125, and 150 kg ha^{-1}. He observed that there were no significant responses of different levels of nitrogen in case of both plant height and number of effective spikelet $spike^{-1}$.

Akter (2005) carried out an experiment to examine the effect of nitrogen levels under rainfed and irrigated conditions on yield and seed quality of wheat. The experiment was involved with four nitrogen levels viz. 0 (control), 50, 100 and 150 kg ha^{-1}. She found progressive increased of plant height with the increasing levels of nitrogen.

Ram *et al.* (2004) conducted a field trial to find out the effects of different N levels (0, 40, 80, 120 and 160 kg ha^{-1}) on the growth and yield of wheat. They observed that plant height increased with increasing rate of nitrogen.

Ananda (2004) reported that split application of N as half basal + one fourth at 30 DAS + one fourth at 60 DAS recorded maximum plant height of wheat.

Kumar *et al.* (2003) conducted an experiment in India, to determine the effect of nitrogen application at 0, 50, 75, 100 and 150 kg ha^{-1} on the chlorophyll content, dry biomass of whole plant and plant height of late-sown winter wheat cv. HD 2285. Plant heights were found positively correlated with nitrogen levels up to 125 kg ha^{-1}.

Das (2003) carried out an experiment to observe the effect of row spacing and nitrogen application on the growth and yield of wheat. The experiment consists of four-row spacing and four nitrogen levels. Results of that experiment showed that nitrogen had significant effect on plant height. At growth stage the tallest plant was obtained from the 180 kg N ha^{-1}.

Wagan *et al*. (2002) conducted to assess the effect of source and schedule of nitrogenous fertilizer on wheat growth and yield contributing characters where variety Sarsabz was drilled to test various nitrogenous fertilizers (urea, ammonium nitrite and ammonium sulphate) applied in two and three splits with basal dose of P and K. The results revealed that nitrogen applied in three split doses significantly increased plant height.

Sushila and Giri (2000) set an experiment with different nitrogen doses (0, 45, 90 kg ha^{-1}) and observed that plant height significantly increased with the increasing doses of nitrogen.

Indira (2006) reported that application of 125 kg N ha^{-1} significantly increased plant height.

Bindia *et al.* (2005) evaluated that plant height increased with bio-fertilizer inoculation. FYM application and increase in the level of N up to 120 kg ha^{-1}. This statement was in conformity with many researchers (Kumar et al., 2003; Kumpawat and Rathore, 2003 and Patel et al., 1995).

Kumar *et al.* (1999) observed that plant height of winter wheat increased with increasing rates of N up to 180 kg ha^{-1}.

2.2 Effect of nitrogen on yield and yield contributing characters of wheat

2.2.1 Effect on total tillers

Islam *et al.* (2011) studied the effect of urea super granule on growth and yield of wheat. They found that the effective tillers $hill^{-1}$ was significantly influenced by USG levels. Among the treatments, the maximum effective tillers $hill^{-1}$ (4.13) was recorded in 100% nitrogen of BARI recommended dose applied as USG. The minimum effective tillers $hill^{-1}$ (2.64) was recorded in no nitrogen. Urea super granule application methods encouraged effective tillers production and for that reason effective tillers increased with the increase of USG treatments.

Rehman *et al*. (2010) found that the tillers m^{-2}increased linearly with the increase in NPK levels and maximum tillers m^{-2} (330) were noted at 80-60-60 kg NPK ha^{-1}.

Xiang *et al.* (2007) carried out a field experiment to study the effects of N application rates (180 and 240 kg ha^{-1}) and basic seedling number (90, 180, 270 and 360 × 104 ha-1) on grain yield in wheat cv. Ningyan 1. The effective tillers per unit area after flowering increased with the increase of nitrogen application.

Pandey *et al.* (2004) performed an experiment to investigate the effect of fertilizer levels and seed rate on the growth and yield of surface-seeded wheat. They used 0, 60, 90, 120 and 150 kg N ha^{-1} in the experiment and calculated that number of effective tillers per m2 increased significantly only up to 120 kg N ha^{-1} and further increased in fertilizer levels did not show significant effect.

Ali et al. (2011) a field trial was conducted at the research area of University College of Agriculture, Sargodha to determine the effect of different levels of nitrogen (N_0 = (control), N_1 = 80 kg ha^{-1}, N_2 = 130 kg ha^{-1}, and N_3 = 180 kg ha^{-1}) on growth and yield of wheat variety (Sahar-2006). Result showed that all the nitrogen treatments significantly increased the number of tillers m^{-2} than control but 130 kg N ha^{-1} (N_2) resulted into maximum number of tillers m^{-2} (375.8).

Liaqat *et al.* (2003) conducted an experiment in the Rabi season in Pakistan to evaluate the response of wheat cv. Uqab-2000 to N at 84, 128, 150, 175 and 200 kg ha^{-1}. The number of· productive tillers m^{-2} (408), 1000-grain weight (41.2 g) and crop yield (5160 kg ha^{-1}) were highest at a rate of 150 kg N ha^{-1}. N at 175 kg ha^{-1} resulted in the highest number of grain $spike^{-1}$. Maximum plant height was obtained at 200 kg N ha^{-1}.

Shen *et al.* (2007) conducted a field experiment in China to identify the effect of application rates (180 and 240 kg ha^{-1}) on grain yield, protein and its components in wheat cv. Ningyan 1. The grain number per spike increased with the increase of application rate while the 1000-grain weight decreased. The ear number per unit area, dry matter accumulation, after flowering, leaf area index at heading stage and grain yield increased with the increased of nitrogen application rate. When the rate was 180 kg ha^{-1} the ear number was highest.

Das (2002) showed the result through an experiment that nitrogen had significant effect on total tillers. The highest number of total tillers per plant was obtained from 180 kg N ha^{-1}.

Hameed *et al.* (2003) observed that application of 180 kg N ha^{-1} resulted into maximum number of tillers m^{-2} (369.0) and also observed that increasing nitrogen application increases the number of tillers m^{-2}.

Ayoub *et al.* (1994) conducted an experiment with four doses of nitrogen (0, 60, 120 and 180 kg N ha^{-1}) and reported increasing nitrogen fertilizer level significantly increased the number of tillers $plant^{-1}$.

Roy and Pradhan (1991) concluded that increasing N rate increased number of tillers $plants^{-1}$and ears number m^{-2} but number of grains ear^{-1} and 1000 grain weight were not changed.

Chaudhry *et al.* (1989) reported from years experimental result that application of N @ 150 kg ha^{-1} resulted in highest (408.0 and 416.0) number of tillers m^{-2} in both the year.

2.2.2 Effect on spike length (cm)

Rahman (2005) carried out an experiment to evaluate the effect of nitrogen sulphur and boron fertilizers on the yield and quality of wheat cv. Kanchan. The experiment included four levels of nitrogen viz. 75, 100, 125 and 150 kg N ha^{-1}. He reported that length of spike was significantly increased with the application of nitrogen at 1250 kg ha^{-1}.

Das (2002) set up an experiment to evaluate the effect of planting density and rate of nitrogen application on the yield of wheat *cv*. Ranchan. He used four level of nitrogen (0, 40, 80 and 120 kg ha^{-1}) and found that spike length increased with the increasing rate of nitrogen up to 120 kg N ha^{-1}.

Mozumder (2001) performed an experiment to investigate the effect of different levels of nitrogen and seed rate on the yield and yield contributing characters of wheat. Treatments of nitrogen in that experiment were 0, 30, 60, 90 and 120 kg ha^{-1}. He reported that spike length increased with increasing rate of nitrogen. The results indicated that the highest spike length was recorded when 120 kg N ha^{-1} was applied.

Ashoush and Toaima (2004) observed that the highest spike length was obtained from the highest N fertilizer level (80 kg fed^{-1}). [1 feddan = 0.42 ha]. The experiment consisted of 3 N levels (40, 60 and 80 kg fed^{-1}) using 3 sowing rates (40, 50 and 60 kg fed^{-1}).

2.2.3 Effect on number of spikelet spike^{-1}

Rahman (2005) carried out an experiment to investigate the effect of nitrogen sulphur and boron fertilizers on the yield and quality of wheat. The experiment included four levels of nitrogen viz. 75, 100, 125 and 150 kg nitrogen ha^{-1}. He observed that there was no significant response of different levels of nitrogen in case of number of effective spikelet spike^{-1}.

Imran *et al.* (2005) concluded that the application of N and P significantly increased number of spikelet spike^{-1}. Number of spikelet spike^{-1} significantly increased with N application up to 120 kg ha^{-1}.

Kumar *et al.* (1999) reported that the number of spikelet spike^{-1} of winter wheat increased with the increase of N level. The experiment consisted of 5 levels of N (0, 45, 90, 135 and 180 kg ha^{-1}) and 2 cutting management practices.

2.2.4 Effect on number of grains spike^{-1}

Mozumder (2001) reported that number of total filled grains spike^{-1} increased with the gradual increase if nitrogen from 0 to 120 kg N ha^{-1}.

Kumpawat and Rathore (2003) Number of grains spike^{-1} increased significantly up to 160 kg N ha^{-1}.

2.2.5 Effect on weight of 1000 grain (g)

Ashoush and Toaima (2004) reported that the highest weight of 1000 grains was obtained from the highest N fertilizer level (80 kg fed^{-1}). The experiment composed of 3 N levels (40, 60 and 80 kg fed^{-1}).

Islam *et al.* (2011) concluded that urea super granule levels showed significant variation in case of weight of 1000-grains (g). However, numerically the highest weight of 1000-grains (g) was found in 100% nitrogen of BARI recommended dose applied as USG (51.39 g) while the lowest weight of 1000-grains (g) was noticed in control (47.69 g).

Hasan (2011) found that the effect of prilled urea and urea super granules treatments showed significant difference in case of 1000-grain weight. The highest weight of 1000-grains (40.11 g) was recorded when urea super granules placed at 10 cm depth at 20 DAS and the lowest 1000-grain weight (32.84 g) was observed when prilled urea treatments.

Mazurkiewicz and Bojarczyk (2004) carried out an experiment to evaluate the effect of nitrogen fertilizer on yield of wheat. There were six levels of nitrogen viz. 0, 50, 100, 150, 200 and 250 kg ha^{-1} in that experiment. They found that differentiation of the level of nitrogen fertilization did not significantly influence the mass of 1000-grain.

Mozumder (2001) reported that thousand grain weights responded significantly following different levels of nitrogen. The highest 1000-grain weight was observed from 120 kg N ha^{-1}.

Kumpawat and Rathore (2003) reported that 1000-grain weight decreased as the level of nitrogen increased.

2.2.6 Effect on grain yield

Hasan (2011) observed a significant variation in case of grain yield due to various prilled urea and urea super granules treatments. The highest grain yield (4.0 t ha^{-1}) was recorded when urea super granules were placed at 10 cm depth at 20 DAS and the lowest grain yield (2.90 t ha^{-1}) was recorded from prilled urea broadcast.

Islam *et al.* (2011) studied the effect of urea super granules on growth and yield of wheat. Significantly the highest grain yield was recorded in 75% nitrogen of BARI recommended dose applied as USG (2.42 t ha^{-1}) and the lowest grain yield was recorded in no nitrogen (1.25 t ha^{-1}) where the second highest (2.28 t ha^{-1}) was recorded in 100% nitrogen of BARI recommended dose applied as USG.

Khalil *et al*. (2011) found that the deeper placement of USGs (5.0-7.5 cm) resulted in greater fertilizer-N recovery in the crop (70.5-78.0%) compared to the use of prills (56.6%). They concluded that the proper application of USGs can increase yields and fertilizer-N utilization of wheat and simultaneously decrease N-losses compared to equivalent use of prills.

Xiang *et al.* (2007) carried out a field experiment to study the effects of N application rates (180 and 240 kg ha^{-1}) and basic seedling number (90, 180, 270 and 360 × 104 ha^{-1}) on grain yield in wheat cv. Ningyan 1. They found that grain yield increased with the increase of N application.

Khalil *et al*. (2006) compared the influence of prilled urea (PU) mixed into soil with urea super granules (USG at 0.70 g), which was point-placed 2.5, 5.0 or 7.5 cm soil depths and found that higher deep placement produced the higher grain yield.

Rahman (2005) reported that most of the yield components and grain yield of wheat were significantly higher at 120 kg N ha^{-1}.

Yadav *et al.* (2005) carried out a field experiment during the winter seasons of 1999-2000 and 2000-2001 to assess the performance of zero tillage in wheat (*Triticum aestivum* L.) under varying levels of each successive increment of N 120 to 180 kg ha^{-1}. While grains yield increased significantly with 180 kg ha^{-1}. Effective tillers increased by 29.3% with 180 kg N ha^{-1} over 120 kg N ha^{-1}. Application of nitrogen up to 150 kg ha^{-1} significant increased the grain yield. The increase in grain yield was 12.3 and 17.3% with 150 and 180 kg N ha^{-1}, respectively over 120 kg N ha^{-1}.

Chandurkar *et al.* (2004) conducted a field experiment to determine the response of wheat to N content and uptake in grain and straw with increasing nitrogen fertilizer rates (90, 120 and 150 kg N ha^{-1}). The highest grain yield, nitrogen content, nitrogen uptake and protein content were obtained with 150 kg N ha^{-1}.

Pandey *et al.* (2004) conducted an experiment to study the effect of fertilizer levels and seed rate on growth and yield of surface-seeded wheat. They used 0, 60, 90, 120 and 150 kg N ha^{-1} and observed that grain yields differed significantly under varying fertilizer levels.

Knapowski and Ralcewicz (2004) conducted a field experiment to determine the influence of different rate of N (0, 80, 120 and 160 kg ha^{-1}) on grain yield and technological quality of two winter wheat cultivars (Begra and Korweta). An increase of grain yield of winter wheat was recorded with the application of N at 120 kg ha^{-1}.

Miah *et al.* (2004) found that the values of the parameters measured were higher with application of urea super granules compared to application of urea.

Ananda (2004) reported that among split application of nitrogen, nitrogen applied as half basal + one-fourth at 30 DAS + one-fourth at 60 DAS recorded higher wheat grain and straw yields as compared to nitrogen applied as half basal + half at 30 DAS.

Samra and Dhillon (2002) reported that application of nitrogen in two splits i.e. half at sowing and half at CRI stage remarkably improved the grain and straw yields of wheat on sandy loam soil at Ludhiana (Punjab) over all the other split application.

Das (2002) showed that nitrogen had significant effect on grain yield. Nitrogen application at the rate of 180 kg ha^{-1} produced the highest grain yield (3.13 t ha^{-1}). The grain yield increased gradually with the increase of nitrogen dose.

Das (2003) reported that deep placement of 76 kg USG ha^{-1} at 5 cm soil produced: significantly higher grain (4.31 t ha^{-1}) with highest mean nitrogen use efficiency (24.13 kg grain kg^{-1} N applied). The study suggested that 76 kg N ha^{-1} is the optimum rate of nitrogen as USG.

Sowinski and Kosak (2002) carried out an experiment to study the effect of N rate on the yield and quality of winter wheat cv. Kobra in Wroclaco, Poland, during 1998-2000. The treatments considered of 30, 60 or 90 kg N ha^{-1}. They found that seed yield increased by 7.5, 23.8 and 52.0% with application of nitrogen at 30, 60 and 90 kg ha^{-1}, respectively and the protein yield increased by 3.8 kg for each 1 kg of N applied.

Sarena and Jana (2001) concluded that application of nitrogen at 100 kg ha^{-1} half nitrogen as basal plus half nitrogen just after first irrigation as top dressing recorded higher grain of wheat as compared to nitrogen top dressed before irrigation leading to more leaching loss beyond the crop root zone depth.

Ahmed *et al.* (2000) revealed that urea super granule was more efficient than prilled urea at all respective levels of N in producing all yield components and in turn, grain and straw yields, placement of urea super granule @160 kg N ha^{-1} produced the highest grain yield (4.32 t ha^{-1}) which was statistically identical to that obtained from 120 kg N ha^{-1}as urea super granule and significantly superior to that obtained from any other level and source of N.

Halvorson *et al.* (2000) carried out a field experiment during 1984 on a Temvik-wilton silt loam soil on spring wheat with 3 doses of N (0, 22 and 45 kg N ha^{-1}). He found that increasing level of N gave significantly higher seed yield. Maximum seed yield was obtained at 45 kg N ha^{-1}.

Ottman *et al.* (2000) conducted a field experiment on a Casa Grande sandy loam soil in the 1995 and 1996 growing seasons at the University of Arizona Maricopa Agricultural Centre. The treatments consisted of 3 levels of N (0, 3.4 and 6.7 g N m^{-2}) until anthesis. They observed that nitrogen application near anthesis increased seed yield significantly with increasing rates of N up to 6.7 g N m^{-2}.

Iqtidar *et al.* (2006) showed that different N levels had significant effect on grain yield and maximum grain yield was obtained from 200 kg N ha^{-1}.

Bindia *et al.* (2005) Grain yield increased with bio-fertilizer inoculation and application with of FYM and N fertilizer.

Ashoush and Toaima (2004) the highest grain yield was obtained from the highest N fertilizer level of 80 kg fed^{-1}.

Indira (2006) reported that application of 125 kg N ha^{-1} significantly increased grain yield.

2.2.7 Effect on straw yield

Islam *et al.* (2011) concluded that urea super granules treatments level exerted significant influence on straw yield. The highest straw yield (4.06 t ha^{-1}) was obtained from 100% nitrogen of BARI recommended dose applied as USG, which was statistically identical with 75% nitrogen of BARI recommended dose applied as USG

(4.03 t ha^{-1}). Significantly the lowest straw yield (2.69 t ha^{-1}) was obtained in no nitrogen.

Rahman (2005) reported that most of the yield components of wheat including straw yield was significantly higher at 125 kg N ha^{-1}.

Pandey *et al.* (2004) conducted an experiment to study the effect of fertilizer levels and seed rate on growth and yield of surface-seeded wheat. They used 0, 60, 90, 120 and 150 kg N ha^{-1} and observed that straw yields differed significantly under varying fertilizer levels.

Sarena and Jana (2001) concluded that application of nitrogen at 100 kg ha^{-1} half nitrogen as basal plus half nitrogen just after first irrigation as top dressing recorded higher straw yields of wheat as compared to nitrogen top dressed.

Ashoush and Toaima (2004) the highest straw yield was obtained from the highest Nfertilizer level of 80 kg fed^{-1}.

Kumpawat and Rathore (2003) reported significant increase in straw yield with N application up to 160 kg ha^{-1}.

2.2.8 Effect on harvest index

Hira (2009) observed significant variation due to various level of nitrogen application. She found that the highest harvest index (36.73%) was observed in 115 kg N ha^{-1} and lowest harvest index (34.56%) observed in the case of 161 kg N ha^{-1}.

Sultana (2009) found significant influence of nitrogen level on the harvest index of wheat. She observed that the highest (41.40%) harvest index in the treatment of 115 kg N ha^{-1} and lowest (35.38) harvest index in the treatment of 0 kg N ha^{-1}.

Bindia *et al*. (2005) reported that the harvest index increased with FYM application and increasing level N up to 120 kg ha^{-1}.

Mehasen (1999) reported that harvest index increased with increasing N levels and application of bio fertilizers in comparison to the untreated control.

Awasthi and Bhan (1993) observed that increasing levels of N up to 60 kg N ha^{-1} influenced the harvest index. The experiment consisted of five varieties of wheat (K65, K78, K72, K8430 and C306) with four levels of N (0, 20, 40 and 60 kg N ha^{-1}).

2.3 Effect of Boron on growth and yield of wheat

Boron (B) is a micronutrient. It ranks second after zinc, as a micronutrient deficiency in Bangladesh. Mineral is the major source of boron in soils and tourmaline (borosilicate) is the dominant mineral. Tourmaline contains 3.4% B. Total boron content of soil varies from 2 to 200ppm. Boron fertilizers are applied to soils as boric acid (H_3BO_3), borax ($Na_2B_4O_7$. $10H_2O$) and solubor ($Na_2B_4O_7$. $10H_2O$ + $Na_2B_{10}O_{16}$. $10H_2O$). Boron has four available forms in soils such as H_3BO_3 (main), $B_4O_7^{2-}$, $H_2BO_3^-$ and HBO_3^{2-}. These forms exist in rocks and minerals, adsorbed on surfaces of clays and hydrous iron and aluminum oxides, combined with organic matter, and as free non-ionized boric acid (H_3BO_3) and $B(OH)_4$ in the soil solution. Less than 5% of the total soil boron is available to plants. Boron performs many functions in cell walls and cellular activities. Boron deficiency renders decrease in cell wall plasticity leading to failure of newly divided cells to enlarge. As far as plasma membrane is concerned, adequate level of boron stops the accumulation of phenolic and ceases the oxidation of components of plasma membrane. Further it is involved in the generation of H+ ATPase, which is a driving force for ion uptake. Hence, integrity and functionality of plasma membrane is ensured with adequate supply of B. There have been numerous studies in the world with respect to the effect of B on wheat. A review of literature of important works done on the effect of B on wheat is given below:

Marschner (1995) noted that boron is an important mineral nutrient stimulates a number of physiological processes in vascular plants. It is important for carbohydrate metabolism, translocation and development of cell wall and RNA metabolism.

Shorrocks (1997) noted that countries where B deficiency, based on responses to B application, in wheat has been reported included Bangladesh, Brazil, Bulgaria, China, Finland, India, Madagascar, Nepal, Pakistan, South Africa, Sweden, Tanzania, Thailand, USA, USSR, Yugoslavia, Zambia. Reports of B deficiency in wheat have also been reported from India (Singh *et al*., 1976; Mandal and Das, 1988 and Dwivedi *et al*., 1990).

Rashid *et al.* (2011) conducted an experiment on B deficiency in rainfed wheat in Pakistan. They reported a B deficiency incidence and spatial distribution in rainfed wheat (*Triticum aestivum* L.) in 1.82 Mha Pothohar plateau in Pakistan, 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; geostatistics aided contour maps delineated B deficient areas. In rainfed 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.

Rawson (1996) and Rerkasem (1997) stated that B deficiency is at least partially responsible for the induction of floret sterility and low grain set and its impact may be exacerbated by environmental factors.

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.

Alloway (2008) concluded that 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.

Subedi *et al*. (1997) and Pant *et al*.(1998) stated that the wheat plants with male sterility and grain set failure due to B deficiency may at the same time actually have more tillers and greater weight of the straw. This seems to agree with a lower requirement of B for vegetative than reproductive growth. In addition to the greater functional requirement of B in anthers and carpel, sensitivity to B deficiency of reproductive development in wheat and other Triticeae cereals, may also be related to B supply to these organs during critical time.

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^{-1}and weight of 1000 grains.

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.

BINA (1993) Plant height increased significantly by application of 1 kg B ha^{-1}.

Rahman (1989) Plant height was found to increase by B application up to 3 kg B ha^{-1}.

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^{-1} may be beneficial for higher production of wheat in this region.

Jolanta Korzenniows (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^{-1}.

Rawson (1996) found from reciprocal transfers of wheat plants between adequate and zero B root media at different development stages, that the period during which florets are sterilized by B insufficiency can 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 B provided in sub-irrigated gravel culture. It was observed that one of the effects of enclosure is to prevent transpiration and possibly the associated uptake and movement of B to the reproductive growth centers. It appeared that a prior period in adequate B had different effect on sterility amongst genotypes. One genotype (Fang 60) showed evidence of a B reserve that could be utilized even after a period equivalent to 3 phyllochrons whereas others appeared to have no B pool. Spikes which were fully sterilized by inadequate B could have their fertility raised marginally by a spray of boric acid even several days after they had emerged.

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

Subedi *et al.* (1995) determined the effect of sowing time and B application on sterility in four different genotypes of wheat. They showed that added B had a significant effect on the number of grains $spike^{-1}$, spikelet $spike^{-1}$, sterility, 1000-seed weight and boron content in the flag leaf at anthesis but not on the grain yield. However, there were significant interactions between boron and genotypes for the number of grains per spike and sterility, because varieties susceptible to B deficiency (SW-41 and BL-1022) showed response to added boron for sterility but BL-1249 and Fang-6 were not affected by B application.

Hossain *et al*. (1994) conducted a fertilizer trial on Old Brahmaputra Floodplain soil at Jamalpur during winter season of 1992-93 to see the response of wheat to S, Zn, B and Mo. It appeared that the grain yield was significantly influenced by the fertilizer treatments. The treatment containing S, Zn, B and Mo together produced the highest yield (3632 kg ha^{-1}) and the control receiving none of them recorded the lowest (2361 kg ha^{-1}). As regards to the contribution of individual elements, performance of B was prominent.

Abedin *et al*. (1994) from a field trial at BAU farm, Mymensingh reported that soil application of B @ 4 kg ha^{-1} and the foliar spray at tillering plus booting stages of crop increased 19% grain yield over control. There was no variation in grain yield between the varieties used. 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 B deficiency. The N and B contents in grain were found to be increased by soil application of B but not by foliar spray of B.

Soylu *et al.* (2005) reported that B application significantly increased spike length. The experiment consisted of 6 durum and 6 bread wheat cultivars in soils with low extractable B (0.19 mg ha^{-1}).

Mete *et al.* (2005) reported that the application of B (5 or 10 kg borax ha^{-1}) alone and in combination with lime (0.5 or 1.0 t ha^{-1}) significantly increased number of fertile spikelet spike^{-1}.

Boron application @ 2.9 kg ha^{-1} to wheat cultivar Giza 157, increase the number of spikelet per spike (Saleh *et al*., 1982).

Mandal (1993) observed that pollen of B resistant genotype germinated on the stigmata of B susceptible genotype, the pollen tube came across the stigmatic pathway but did not proceed further and thus its growth was restricted to the stigma. Thus, B is the medium for successful way of overcoming the styler incompatibility of B susceptible genotypes. A study was performed on selection criterion to assess wheat B tolerance of wheat at seedling stage. On average, excess B reduced root length and number and had no effect on the number of days from inhibition to germination and germination percentage; however, significant differences have been found among the genotypes. The imposed B treatments demonstrated 5.2% stronger effect on lateral root length in comparison to primary root length. Therefore, total root length reduction may be more valuable selection criterion for B tolerance in wheat.

Jahiruddin *et al*. (1992) conducted a series of field experiments with B in wheat at several locations in Bangladesh. The results show that B deficiency might be a causative factor for floret sterility in wheat. The yield of wheat after B treatment increased by more than 30% and this was related to the increase in the number of grains per spike. Response of wheat to B varied from one location to another. Soil application appeared to be a better method of B treatment compared to foliar spray. Such study indicates that non-viable pollen grains can result from deficiency of B.

Mitra and Jana (1991) reported from a 3-year field experiments in India that application of B increased the yield attributes of wheat. Significant response was obtained from application up to 20 kg borax ha^{-1} which gave an additional grain yield of 18.90 kg ha^{-1} over control. Among the methods of B application half soil + half foliar produced significantly more effective tillers which in turn gave 6.6 and 8.8 percent higher grain yield than soil and foliar methods of application, respectively.

Rehem *et al.* (1998) stated that B plays a key role in water and nutrients transportation from root to shoot. They believe that B shortage causes barren stalks and small, twisted ears.

Vitosh *et al.* (1997) expressed that B is involved in carbohydrates metabolism and it is essentially necessary for protein synthesis, pollen germination, seed and cell wall formation.

Alam (1995) conducted a field trial in Mymensingh on wheat variety (Kanchan, Aakbar and Agrani) with 100 kg N, 80 kg P, 30 kg K, 4 kg Zn, 2 kg Mo ha^{-1} respectively. He observed that application B deficiency, they are nevertheless useful as indicators of the lower limit of B sufficiency. For example, wheat plants with >4 mg B kg^{-1} in the ear (Rerkasem and Lordkaew, 1992) or >7 mg B kg^{-1} in the flag leaf at boot stage are unlikely to be affected by B deficiency In wheat, B deficiency causes poor anther and pollen development and low grain set. In vitro germination tests also showed that B was required for pollen germination and tube growth in wheat.

Abedin *et al.* (1994) reported that application of B to B deficient brown soil results in significant positive effects on number of total tillers plant-1.Grain yield of wheat is depressed by poor number of grains ear^{-1} which may result from B deficiency.

Mandal (1993) carried out an experiment with 21 wheat varieties in the Tarai region of India in order to find out the effect of B application on grain yield and other yield component. Most of the varieties showed positive response to B with respect to grain yield, number of grains per spike and spike length. Grain yield was increased basically through the increase innumber of grains per spike. However, varieties like BAU 2076, HI 968. BR 350 and BW 121 showed very small response to B for most of the trials.

Razzaque and Hossain (1991) opined that along with N, P, K, S and Zn, some other elements e.g. B, Mn and Mo might be the limiting for low wheat yield of this country. The yield of wheat increased with low B content in irrigation water but decreased at higher level. The effect was pronounced on sandy soil than on clay soil.Four trials were conducted in two AEZs of Bangladesh to examine the effect of B on grain set of wheat and observed that number of grains spike-1 and grain yield responded significantly to B treatment. Crop response to B varied between the locations.

Mitra and Jana (1991) reported that the number of total tillers plant-1 significantly increased by B application up to 20 kg borax ha^{-1}. The problem can be corrected by B application to the soil. Thus B deficiency can cause yield reduction by reducing grain set through impaired development of anther and pollen grain.

Rerkasem (1989) found genotype variation in the response of wheat to B. He observed five genotypes responded to added B (1.1 kg B ha^{-1}). Some information on the assessment of grain set failure and diagnosis of B deficiency in wheat. They found that basal floret fertility (average number of grains in the two basal florets, $F_1 + F_2$ of 10 central spikelet) was a good index for assessment of grain set failure (Rerkasem, 1991).

Thalooth *et al*. (1989) observed that regardless the source of N fertilization of wheat plants with B, increasing plant height. Plant height increased significantly by application of 1 kg B ha^{-1} (BINA, 1993).

Rahman (1989) demonstrated that the application of 3 kg B ha^{-1} significantly increased plant height, number of spikes per sqm, number of filled grains per spike, 1000-grain weight, grain yield and straw yield. Omission of boron from the complete treatment reduced the wheat yield by 20.4%.
Galrao and Sousa (1988) and observed that the low yield of wheat was associated with male sterility (51.8%), which was aggravated by high temperature and low relative humidity of air during heading stage. The application of B reduced the male sterility by 94% and increased the grain yield by 1230 kg ha^{-1}.

Boron helps to develop root system, fruit setting and grain formation. The B content in wheat is 8.5 to 18.5ppm. The deficiency and toxicity level of B is 15ppm and above 200ppm, respectively. The younger leaves of wheat grown in B deficient soil become white, rolled and frequent trapped at the apex within the rolled subtending leaf (Stevenson, 1985).

White and Collins (1982) observed that insufficient B supply during seed development resulted in poor grain or seed yield of wheat in spite of sufficient Boron supply at early stage of development for normal growth. Field trials at Benisenf in 1978-79 Boron application depressed growth but 1.2 kg B per feddan increased grain number and weight spike-1 although higher rates depressed their yield components. Grain protein contents were increased by B application (Saleh *el al.*, 1982).

Boron is essential for translocation of sugars, development of meristematic tissues, syntheses of protein, RNA and auxin and formation of ribosome (Gupta, 1972 and Mengel and Kirkby, 1982).

Lal and Lal (1980) reported that grain yield of wheat was increased with increased in the Boron concentration from 0.7 to 1.7ppm in irrigation water. The critical level of B in soils was 0.25ppm for spring wheat and < 0.1ppm B caused complete grain sterility. Boron application @ 2.9 kg ha^{-1} to wheat cultivar Giza.157 increased the number of spikelet $spike^{-1}$and the number of filled grain and grain $spike^{-1}$.

Singh and Singh (1976) observed increased grain yield of wheat because of B treatment. An experiment with three cultivars of wheat (Janak, UP 262, and Sonalika) was conducted. They observed that boron application increased yield of all three cultivars.

Boron is necessary for growth and yield of wheat. It has both direct and indirect effects on fertilization. Indirect effects are related to increase in amount and change in sugar composition of nectar, where by the flowers of species that rely on pollinating insects become more attractive to insects (Smith and Johnson, 1969).

Soylu *et al.* (2005) reported that agronomic parameters such as grain yield sterility, number of grains per spike, number of spikes m^{-2}, 1000-kernel weight and flag leaf B concentration were affected by the application of 3 kg B ha^{-1} as spray of boric acid.

2.4 Interaction effect of nitrogen and boron on growth and yield of wheat

Debnath *et al.* (2014) conducted an experiment at the Agronomy Field Laboratory, Bangladesh Agricultural University, Mymensingh from November 2011 to March 2012 to find out the effect of nitrogen (N) and boron (B) fertilization on the performance of wheat. The experiment comprised of four levels of N viz., 0, 80, 120, 160 kg ha^{-1} and three levels of B viz., 0, 1 and 2 kg ha^{-1}. The experiment showed that there were significant differences in yield due to the application of N and B though some of the yield attributes were not found significant. Grain yield was found to be significantly and positively correlated with number of effective tillers $plant^{-1}$, number of fertile spikelets $spike^{-1}$, number of gains $spike^{-1}$ and straw yield. A result showed that grain yield of wheat was increased with increasing levels of both N and B up to 120 kg ha^{-1} and 2 kg ha^{-1}, respectively. The interaction effect of N and B on both the parameters was significant.

Sharma *et al.* (2016) conducted a field investigation was carried out at Palampur with sixteen treatment combinations consisting of four levels of N (0, 50,100 and150% of recommended dose), two levels of Zn (0 and 10 kg ha^{-1}) and two levels of B (0 and 1 kg ha^{-1}) to study the response of wheat to these critical nutrients. Plant height, dry matter accumulation, total and effective tillers, grains/ear and grain yield significantly increased with increase in nitrogen application upto 150% of recommended dose. 150% of recommended dose of nitrogen increased grain yield (45.83 q ha^{-1}) of wheat by 84.8% over control. Similarly, application of B (1 kg ha^{-1}) significantly improved these growth, yield attributes and yield of wheat. Boron application @ 1 kg ha^{-1} increased grain yield by 8.1%.

Gupta *et al*. (1973) conducted in field experiments, 4.48 kg B/ha added to the soil decreased the grain yield of wheat (Triticum aestivum L.). Under greenhouse conditions, 0.5 ppm, added B reduced wheat yields. The B toxicity in wheat in 1974 at 2.24 kg B ha^{-1} as associated with reduced yield was alleviated somewhat by the additions of N to the soil in field experiments, but the effect was not significant. Under greenhouse conditions, addition of 50 ppm N or more reduced B uptake and alleviated B toxicity. In general, the B toxicity symptoms on the foliage under field conditions were associated with >11 ppm B in wheat boot stage tissue (BST). Added B increased the N concentration of grain where yields were decreased due to B toxicity. Wheat yields increased with increased rates of N application in all field experiments. In field experiments the highest B value was 34 ppm. Concentrations as high as 312 ppm B were found in greenhouse experiments.

Arif *et al.* (2006) reported that the role of macro and micronutrients is crucial in crop nutrition and thus important for achieving higher yields. Due to increased cropping intensity along with minimal use of fertilizers inputs, a serious depletion of both macro and micronutrients from soils is occurring.

Sarwat *et al.* (2011) reported that the highest concentration of nitrogen in wheat grains was obtained at 90 kg N fed^{-1} in the presence of potassium and spraying with boron. Increasing nitrogen levels increased the amount of nitrogen uptake by grains of wheat. Also the crude protein (%) in grains increased gradually with increasing nitrogen level in the presence of potassium and spraying with boron. The highest concentration of K in grains of wheat was obtained at the high levels of nitrogen in the presence of potassium and spraying with boron. Also the highest amounts of K uptake by the grains of wheat were recorded by the high levels of nitrogen in the presence of potassium and spraying of boron.

Bazzaz *et al*. (2008) conducted a field experiment at Gazipur during November. 2003 to March 2004. The experiment was aimed at evaluating the effect of nitrogen and boron fertilizers on growth dynamics, dry matter production and yield in wheat. The experiment was designed in split-plot with three replication. Four nitrogen levels 0, 60. 120 and 180 kg ha^{-1}were assigned in main plots and four levels of boron 0, 0.5, 1 and 1.5 kg ha^{-1} was in sub-plots. Application up to 120 kg N ha^{-1} and 1.0 kg B ha^{-1} significantly increased the dry matter production, leaf area index and Crop growth rate. The restive growth rate as well as net assimilation rate also responded well earh120 kg SI $ha^{-1}$and 1.0 kg 13 ha^{-1}. The highest grain yield was reported with 120 kg N ha^{-1} and 1 kg B ha^{-1} because most of the yield contributing attributes yielded higher with this rate.

MATERIALS AND METHODS

The study was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from November 2015 to March 2016 to determination of the effect of nitrogen and boron on the growth and yield of wheat. This chapter includes a brief description of the experimental soil, wheat variety, land preparation, experimental design, treatments, cultural operations, collection of soil and plant samples etc. and analytical methods followed in the experiment.

3.1 Experimental site

The research work relating to the study of the effect of nitrogen and Boron on the growth and yield of wheat was conducted at the Sher-e-Bangla Agricultural University Farm, Dhaka - 1207 during the *Rabi* season of 2015-2016.

3.2 Location of the study

3.2.1 Geographical Location

The experimental area was situated at 23°77'N latitude and 90°33'E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004).

3.2.2 Agro-Ecological Region

The experimental field belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28 (Anon., 2003a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as `islands' surrounded by floodplain (Anon., 2003b).

3.2.3 Climate

The area has subtropical climate, characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in kharif season (april-september) and scanty rainfall associated with moderately low temperature during the rabi season (october-march).

3.3 Characteristics of soil

The soil of the experimental site belongs to the General Soil Type, Deep Red Brown Terrace Soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH was 5.6 and had organic matter 0.965%. The experimental area was flat having available irrigation and drainage system and above flood level. Composite soil samples from 0-15 cm depth were collected from experimental field. The analysis were done at Sher-e-Bangla Agricultural University (SAU) Laboratory, Dhaka. The physicochemical properties of the soil are presented in Table 3.1.

Table 3.1 Initial physical and chemical properties of the experimental soil

Soil properties	Value
A. Physical properties Particle size analysis of soil.	
% Sand	29
% Silt	41
% Clay	30
Soil textural class	Clay loam
Bulk density(g/cc)	1.45
Particle density(g/cc)	2.52
Consistency	Granular & friable when dry
B. **Chemical properties**	
Soil pH	5.6
CEC(cmol/kg)	17.8
Organic matter (%)	0.965
Total N (%)	0.09
Available P (ppm)	15.41
Exchangeable K (meq/100g soil)	0.12
Available S (ppm)	24.73
Available B (ppm)	0.59

3.4 Description of soil

The soil of the experimental field belongs to the Tejgaon series under the Agroecological Zone, Madhupur Tract (AEZ- 28) and the General Soil Type is Deep Red Brown Terrace Soils. A composite sample was made by collecting soil from several spots of the field at a depth of 0-15 cm before the initiation of the experiment. The collected soil was air-dried, ground and passed through 2 mm sieve and analyzed for some important physical and chemical parameters. Morphological characteristics of the soil are shown in table 3.2.

Table **3.2 Morphological characteristics of experimental field**

Morphological features	**Characteristics**
Location	Sher-e-Bangla Agricultural University Farm, Dhaka-1207
AEZ	AEZ-28 (Modhupur Tract)
General Soil Type	Deep Red Brown Terrace Soil
Soil Series	Tejgaon
Topography	Fairly leveled
Depth of Inundation	Above flood level
Drainage condition	Well drained
Land type	High land

3.5 Description of the wheat variety

BARI Gom-28, a high yielding variety of wheat was used as the test crop in this experiment. The seeds of this variety were collected from Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. This variety was released by Bangladesh Agricultural Research Institute, Joydebpur, Gazipur in 2012. Life cycle of this variety ranges from 102 to 108 days. Maximum yield is 4-5.5 ton ha^{-1}. The variety is resistant to diseases and heat.

3.6 Preparation of the field

The field selected for the experiment was opened by power tiller on the 25thNovember 2015, afterwards the land was ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubbles were removed, and the large clods were broken into smaller pieces to obtain a desirable tilth of soil for sowing of seeds. Finally, the land was leveled and the experimental field was partitioned into the unit plots in accordance with the experimental design on the 28th November 2015.

3.7 Layout of the experiment

The experiment was laid out in a two factor Randomized Complete Block Design with three replications. The total numbers of plots were 36, each measuring 3m x 2m ($6m^2$). The treatment combination of the experiment was assigned at random into 12plots of each at 3 replications. The distance maintained between two rows was 100 cm and between two columns was 50 cm.

3.8 Treatments

The experiment consists of 2 Factors i.e. rate of nitrogen and rate of boron having four levels and three levels respectively. Details of factor and their combinations are presented below:

3.8.1 Factor A: Rates of nitrogen

No = 0 kg N ha^{-1} (No nitrogen)

N_1 = 40 kg N ha^{-1}

N_2 = 80 kg N ha^{-1}

N_3 **=** 120 kg N ha^{-1}

3.8.2 Factor B: Rates of boron

Bo = 0 kg B ha^{-1} (No boron)

B_1 = 1 kg B ha^{-1}

B_2 **=** 1.5 kg B ha^{-1}

3.8.3 Treatment combination

N_oB_0 = Control (without N and B)

NoB_1 = 0 kg N ha^{-1} + 1 kg B ha^{-1}

N_0B_2 = 0 kg N ha^{-1} + 1.5 kg B ha^{-1}

N_1B_0 = 40kg N ha^{-1} + 0 kg B ha^{-1}

N_1B_1 = 40 kg N ha^{-1} + 1 kg B ha^{-1}

N_1B_2 = 40 kg N ha^{-1} + 1.5 kg B ha^{-1}

N_2B_0 = 80 kg N ha^{-1} + 0 kg B ha^{-1}

N_2B_1 = 80 kg N ha^{-1} + 1 kg B ha^{-1}

N_2B_2 = 80 kg N ha^{-1} + 1.5 kg B ha^{-1}

N_3B_0 = 120 kg N ha^{-1} + 0 kg B ha^{-1}

N_3B_1 = 120 kg N ha^{-1} + 1 kg B ha^{-1}

N_3B_2 = 120 kg N ha^{-1}+ 1.5 kg B ha^{-1}

3.9 Application of fertilizers:

Recommended fertilizer dose for wheat

Urea = as per treatment

TSP = 160 kg ha^{-1}

MoP = 45 kg ha^{-1}

Gypsum = 110 kg ha^{-1}

$ZnSO_4$ = 5 kg ha^{-1}

Boric Acid = as per treatment

The whole calculated and required amounts of P, K, Zn, S fertilizers and 1/3 of the N fertilizer (urea) were uniformly spread on the surface of the individual plot following the treatment combinations. The applied fertilizers in the individual plot were mixed with soil properly by hand spading. The remaining 2/3 of N (urea) was applied in two splits (20 and 40 days after sowing). The required amounts of B (Boric acid) applied as per treatment combinations uniformly in the wheat field. The sources of. N, P, K, Zn, S and B fertilizers were Urea, TSP, MoP, $ZnSO_4$, Gypsum and Boric acid respectively.

3.10 Seed sowing

Wheat seeds were sown on the 1st December 2015 in lines at the rate of 140 kg ha^{-1}. Seeds were then covered properly with soil. The line per plot is 10 and line to line distance was maintained by 20 cm.

3.11 Cultural and management practices

Various intercultural operations such as thinning of plants and weeding were accomplished whenever required to keep the plants healthy and the field weed free. Special care was taken to protect the crop from birds especially after sowing and germination stages and at the ripening stage of the crop. The crop was irrigated four times (7, 22, 37 and 50 days after sowing) of growth of the crop.

3.12 Harvesting

The crop was harvested at maturity on 17th March 2016. The harvested crop of each individual plot was bundled separately. Grain and straw yields were recorded plot wise and the yields were expressed in t ha^{-1}.

3.13Recording of data

The following data were recorded from the experiment

1. Plant height (cm)
2. Number of total tillers $plant^{-1}$
3. Spike length of wheat (cm)

4. Number of spikelet spike^{-1}
5. Number of Grain spike^{-1}
6. Weight of 1000 grain (g)
7. Grain yield (t ha^{-1})
8. Straw yield (t ha^{-1})
9. Harvest index (%)

3.14 Procedure of recording data

The detail outline of data recording is given below:

3.14.1 Plant height (cm)

The plant height was measured from the ground level to the top of the panicle, Plants of 5 hills were randomly measured from each plot and averaged. It was done at the growth and ripening stage of the crop.

3.14.2 Number of total tillers plant^{-1}

Number of total tillers/plant from each plot was counted from five plants one week before harvested and their averages were calculated.

3.14.3 Spike length (cm)

Spike lengths were randomly counted from five plants and then averaged. This was taken at different days after reproductive stage separately.

3.14.4 Number of spikelet spike^{-1}

Total number of effective spikelet spike^{-1} was calculated from five randomly selected plant, from each plot and was observed the number of effective spikelet spike^{-1} and then averaged.

3.14.5 Number of grain spike^{-1}

Number grain spike^{-1} was counted taking five spike from five selected plants of each plot and the average number was recorded.

3.14.6 Weight of 1000 grain

Thousand seed of wheat were counted randomly and then weighed plot wise.

3.14.7 Grain yield

Grains obtained from 1 m^2 from the centre of each unit plot was dried, weighed carefully and then converted into t ha^{-1}

3.14.8 Straw yield

Straw obtained from each individual plot was dried, weighed carefully and the yield was expressed in t ha^{-1}.

3.14.9 Harvest index

Harvest index was calculated on the ratio of economic yield (grain yield) to biological yield and expressed in terms of percentage. It was calculated by using the following formula (Donald, 1963).

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

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

3.15 Collection of samples

3.15.1 Soil Sample

The initial soil samples were collected randomly from different spots of the field selected for the experiment at 0-15 cm depth before the land preparation and mixed thoroughly to make a composite sample for analysis. The samples were air-dried, ground and sieved through a 2 mm (10 mesh) sieve and kept for analysis.

3.16 Soil sample analysis

3.16.1 Mechanical analysis

Mechanical analysis was done by hydrometer method. The textural class was determined following Marshall's triangular coordinate using USDA system.

3.16.2 Soil pH

Soil pH was measured with the help of a glass electrode pH meter, the soil water ratio being 1:2.5 as described by Jackson (1973).

3.16.3 Organic carbon

Soil organic carbon was determined by Walkley and Black's wet oxidation method as outlined by Jackson (1973) from the samples collected before sowing and also after harvesting the crop.

3.16.4 Organic matter

The organic matter content was calculated by multiplying the percent organic carbon with Van Bemmelen factor 1.73 (Piper, 1950).

3.16.5 Total nitrogen

Total nitrogen of soil samples were estimated by Micro-Kjeldahl method where soils were digested with 30% H_20_2 conc. H_2SO_4 and catalyst mixture (K_2S0_4: $CuSO_4$. 51-120: Selenium powder in the ratio 100:10:1 respectively). Nitrogen in the digests were determined by distillation with 40% NaOH followed by titration of the distillate absorbed in H_3B0_3 with 0.01N H_2SO_4 (Jackson, 1973).

3.16.6 Total Boron

For B the extractant of $CaH_4(PO_4)_2$, HCl and phenol was used (Hunt, 1980). Boron concentration was measured by adding 2 ml Curcumin solution plus 0.5 ml concentrated H,SO_4 and 15 ml Methanol (Meth: water = 3:2) solution before taking reading. The concentration in the extract was read at 555 nm wave length in a double beam spectrophotometer (Model No. 200-20, Hitachi, Japan).

3.16.7 Available phosphorous

Available phosphorous was extracted from the soil by Bray-1 method (Bray and Kurtz, 1945). Phosphorous in the extract was determined by ascorbic acid blue color method (Murphy and Riley, 1962) with the help of a Spectrophotometer.

3.16.8 Exchangeable potassium

Exchangeable potassium in the soil sample was extracted with 1N neutral ammonium acetate and the potassium content was determined by flame photometer.

3.16.9 Available sulphur

Available sulphur was extracted from the soil with $Ca(H_2PO_4)_2$. H_2O (Fox, et al., 1964). Sulphur in the extract was determined by the turbidimetric method as described by Hunt (1980) using a Spectrophotometer.

3.17 Statistical analysis

The data obtained from the experiment were analyzed statistically to find out the significance of the difference among the treatments. The mean values of all the characters were evaluated and analysis of variance was performed by the 'F' (variance ratio) test. The significance of the differences among pairs of treatment means was estimated by the least significant difference (LSD) test at 5% and 1% level of probability and DMRT was calculated (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

The study was carried out in order to find out the effect of N and B on growth and yield of wheat cv. BARI Gom-28. This chapter reports results of the experiment. The data are presented in the form of tables and figures. The mean results of the experiment on the effect of N and B along with different interactions, summaries of analysis of variance (ANOVA) on various characters and different matrix are presented in Tables 4.1 to 4.4, Fig. 1 to 2 and Appendices II to V, respectively. The results are discussed and interpreted under the following subheads.

4.1 Plant height (cm)

The plant height varied significantly with different N levels (Table 4.1 and Fig. 1). The result showed that the tallest plant was obtained in N_3 (35.22 cm, 50.20 cm, 64.14cm and 86.29 cm at 30 DAS, 50 DAS, 70 DAS and harvesting time, respectively) when the crop fertilized with 120 kg N ha^{-1}which was statistically similar with N_2 (63.65 cm and 86.08 cm at 70 DAS and harvesting time, respectively) when the crop fertilized with 80 kg N ha^{-1} and the shortest plant was found in N_0 (31.50 cm, 46.90 cm, 59.18 cm and 83.80 cm at 30 DAS, 50 DAS, 70 DAS and harvesting time respectively) from control. From the above findings, it is shown that plant height was markedly affected by N application. Several researchers showed that plant height increased significantly by application of 125 kg N ha^{-1} than other lower doses (Indira, 2006, Bindia *et al.*, 2005 and Kumar *et al.*, 2003). Variation in plant height was found to be significant due to B fertilization (Table 4.1 and Fig. 2). The tallest plant was obtained in B_1 (34.54 cm, 50.04 cm, 63.70 cm and 86.55 cm at 30 DAS, 50 DAS, 70 DAS and harvesting time respectively) when the crop received 1 kg B ha^{-1}. The shortest plant was produced in B_0 (31.26 cm, 46.89 cm, 59.78 cm and 84.68 cm at 30 DAS, 50 DAS, 70 DAS and harvesting time respectively) by no B fertilization. These results are in agreement with the findings of Mete *et al.* (2005) who reported that plant height was found to increase by B application up to 2 kg B ha^{-1}. On the other hand, BINA (1993) showed that plant height increased significantly by application of 1kg B ha^{-1}.

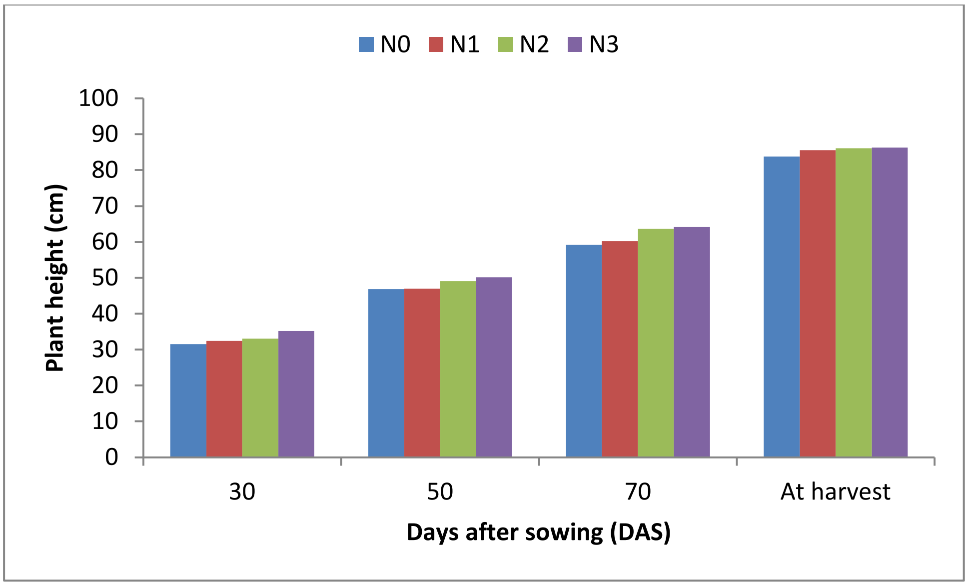

Fig. 1 Plant height of wheat influenced by nitrogen

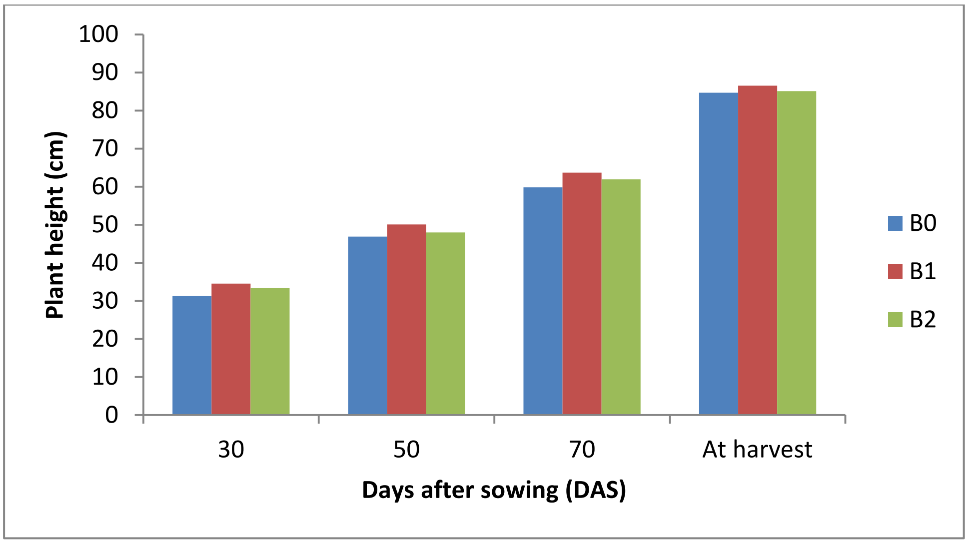

Fig. 2 Plant height of wheat influenced by boron

Table 4.1 **Effect of N and B on plant height 0f wheat**

Treatment	Plant height (cm)			
	30 DAS	50 DAS	70 DAS	At harvest
Effect of nitrogen				
N_0	31.50 c	46.90 c	59.18 c	83.80 b
N_1	32.38 b	46.94 c	60.21 b	85.56 a
N_2	33.08 b	49.13 b	63.65 a	86.08 a
N_3	35.22 a	50.20 a	64.14 a	86.29 a
$LSD_{0.05}$	0.8667	0.844	1.028	0.8085
CV (%)	6.539	8.662	7.349	11.266
Effect of boron				
B_0	31.26 c	46.89 c	59.78 c	84.68 b
B_1	34.54 a	50.04 a	63.70 a	86.55 a
B_2	33.33 b	47.95 b	61.90 b	85.06 b
$LSD_{0.05}$	0.5441	0.606	0.7824	0.819
CV (%)	6.539	8.662	7.349	11.266
Combined effect of nitrogen and boron				
N_0B_0	29.28 g	42.81 i	53.72 h	82.07 e
N_0B_1	30.02 fg	45.88 h	58.32 g	83.74 d
N_0B_2	30.05fg	46.12 gh	60.22 f	83.81 d
N_1B_0	30.62 f	47.08 fg	60.45 ef	83.91 d
N_1B_1	32.37 e	48.46 de	61.76 d	85.41 c
N_1B_2	32.17 e	47.74 ef	61.46 de	84.06 d
N_2B_0	33.37 d	48.57 de	61.84 d	85.54 c
N_2B_1	33.71 d	48.64de	62.10 d	85.57 c
N_2B_2	34.15 d	48.88 d	63.59 c	85.95 c
N_3B_0	35.16 c	49.95 c	64.34bc	87.00 b
N_3B_1	38.95 a	53.52 a	68.56 a	89.26 a
N_3B_2	36.69 b	51.88 b	65.15 b	88.86 a
$LSD_{0.05}$	0.823	0.982	1.053	0.907
CV (%)	6.539	8.662	7.349	11.266

In a column tables having similar letters do not differ significantly whereas tables with dissimilar letters differ significantly as per DMRT.

4.2 Number of total tillers plant^{-1}

The number total tillers plant^{-1} was significantly affected by N application (Table 4.2). The highest number of total tillers plant^{-1} N_3 (4.54) was produced at 120 kg N ha^{-1} and the lowest number of total tillers plant^{-1} N_0 (3.60) was produced by control. Similar results also published by Iqtidar *et al*. (2006). B had a significant influence on number of total tillers plant^{-1} (Table 4.2). Among the treatments, 1 kg B ha^{-1} produced the highest number of total tillers plant^{-1} (4.80). The lowest number of total tillers plant^{-1} (3.60) was found when the crop was fertilized with 0 kg B ha^{-1}. It is evident from the results that number of total tillers plant^{-1} was influenced by B fertilizer. Positive effects of B application on tillering of wheat were reported by Mishra *et al.* (1989).

The interaction effect of N and B on number of total tillers plant^{-1} was significant (Table 4.2). Among the treatments N_3B_1 (120 kg N ha^{-1} + 1 kg B ha^{-1}) gave the highest number of tillers plant^{-1} (5.60)), which was statistically similar with N_2B_1 treatment and the lowest (3.20) was on control treatment which is statistically similar with N_0B_2 treatment. Present results showed that the treatment combination of N and B helps to increase the number of total tillers plant^{-1}.

4.3 Spike length (cm)

Spike length was significantly affected by different levels of N application (Table 4.2). The longest spike 10.34 cm (N_3) was obtained from 120 kg N ha^{-1} and the shortest spike 8.85 cm was noticed at control. Ashoush and Toaima (2004) published that the longest spike was obtained from highest N fertilizer level and shortest from control. Different levels of B produced a significant variation in spike length (Table 4.2). B_1 treatment produced the longest spike length 9.88 cm. The shortest spike length (9.00 cm) was obtained from B_0 treatment which is statistically similar to B_2 treatment. The results showed that B had positive effect on spike length. This is in conformity with that of Mandal (1993).

The interaction effect of N and B was significant for spike length (Table 4.2). The longest spike (13.4 cm) was found in N_3B_1 (120 kg N ha^{-1} + 2 Kg B ha^{-1}) and the shortest (8.26 cm) in control treatments combination which is statistically identical with N_0B_2 (8.52 cm). From the above findings, it is concluded that both N and B promote the spike length.

4.4 Number of spikelet spike^{-1}

The application of N significantly increased the number of spikelet spike^{-1} (Appendix III) N at the rate of 120 kg ha^{-1} produced maximum number of spikelet spike^{-1} N_3(41.07) whereas control (N_0) treatment produced the lowest 34.87 (Table 4.2). Therefore, it is clear that number of spikelet spike^{-1} was influenced by N fertilization. Imran *et al.* (2005) reported that number of spikelet spike^{-1} significantly increased with N application up to 120 kg ha^{-1}. Number of spikelet spike^{-1} differs significantly due to different levels of B application (Appendix III). The highest number of spikelet spike^{-1} 39.61 was observed when the crop was fertilized with 1 kg B ha^{-1} which is statistically similar with B_2 treatment and the lowest 35.41 was attained on control (Table 4.2). The results showed that the number of spikelet spike^{-1} was affected by B application. Saleh *et al.* (1982) reported that 2.9 kg B ha^{-1} increased the number of spikelet spike^{-1}. After continuous rise, number of fertile spikelet spike^{-1} fell down at 4 kg B ha^{-1}. It might be due to toxic effect of B above 3 kg B ha^{-1}.

The treatment combination of N and B had significant variation on the number of spikelet spike^{-1} (Appendix III). The highest number of spikelet spike^{-1} 44.81 was achieved by 120 kg N ha^{-1} + 1 kg B ha^{-1} which is statistically similar with N_1B_1 (44.61) and the lowest 29.21 was found from control. The above trials indicate that number of spikelet spike^{-1} was enhanced by N and B interaction.

Table 4.2 **Effect of N and B on yield contributing parameters of wheat**

Treatment	Number of total tillers plant^{-1}	Spike length (cm)	Number of Spikelet spike^{-1}	Number of grains spike^{-1}	1000 grain weight (g)
Effect of nitrogen					
N_0	3.60 c	8.85 c	34.87 d	22.66 c	43.31 d
N_1	4.14 b	9.08 b	37.74 c	26.97 b	45.29 b
N_2	4.20 b	9.05 b	38.67 b	26.23 b	44.81 c
N_3	4.54 a	10.34 a	41.07 a	30.57 a	45.58 a
$LSD_{0.05}$	0.107	0.152	0.5210	0.341	0.237
CV (%)	5.834	8.339	7.042	8.728	9.314
Effect of boron					
B_0	3.60 c	9.00 b	35.41 b	23.58 c	43.54 c
B_1	4.80 a	9.88 a	39.61 a	29.36 a	45.75 a
B_2	3.95 b	9.11 b	39.26 a	26.88 b	44.95 b
$LSD_{0.05}$	0.101	0.448	0.675	1.366	0.248
CV (%)	5.834	8.339	7.042	8.728	9.314
Combined effect of nitrogen and boron					
N_0B_0	3.20 f	8.26 g	29.21 f	21.23 g	42.73 g
N_0B_1	3.60 e	8.65 f	34.61 e	22.13 fg	43.46 ef
N_0B_2	3.20 f	8.52 fg	33.82 e	23.43 ef	43.41 f
N_1B_0	3.61 e	8.74 ef	36.81 d	24.63 de	43.73 ef
N_1B_1	4.21 bc	9.10 de	44.61 a	30.63 b	46.81 a
N_1B_2	4.01 cd	9.06 de	39.00 c	25.65 d	44.54 d
N_2B_0	4.00 cd	8.86 ef	38.60 c	25.03 de	44.18 de
N_2B_1	5.40 a	9.78 b	40.62 b	30.83 b	45.70 bc
N_2B_2	4.40 b	9.52 bc	39.60 bc	28.04 c	46.32 ab
N_3B_0	3.81 de	8.78 ef	36.40 d	24.65 de	43.85 def
N_3B_1	5.60 a	13.4 a	44.81 a	36.45 a	47.02 a
N_3B_2	4.41 b	9.28 cd	39.00 c	26.64 cd	45.21 c
$LSD_{0.05}$	0.2272	0.3552	1.357	1.972	0.6688
CV (%)	5.834	8.339	7.042	8.728	9.314

In a column tables having similar letters do not differ significantly whereas tables with dissimilar letters differ significantly as per DMRT.

4.5 Number of grains spike^{-1}

Variation in number of grains spike^{-1} showed significant effect due to N application (Appendix (IV) and Table 4.2). Number of grains spike^{-1} was highest 30.57 at 120 kg N ha^{-1} and the lowest 22.66 was at control. The results are in conformity with that of Indira (2006) and Kumpawat and Rathore (2003) who reported that 125 kg N ha^{-1} increased grain number spike^{-1}. Different B levels showed significant effect on number of grains spike^{-1}. The results presented in Table 4.2 showed that the highest number of grains spike^{-1} 29.36 was produced by application of 1 kg B ha^{-1} and the lowest 23.58 was found at control. The highest number of grains spike^{-1} was probably attributed to reduction of sterility of wheat as B reduces male sterility of wheat. Similar results were also reported by Ganguly (1979), Mandal (1987) and Mandal and Das (1988) and Rahman (1989). Interaction effect of N and B showed significant variation on the number of significant variation spike^{-1} (Table 4.2). The number of grains spike^{-1} varied from 36.45 to 21.23 depending on the various treatments used. The treatment N_3B_1 produced the highest number of grains spike^{-1} (36.45) and the lowest 21.23 was obtained from control treatment.

4.6 1000-grain weight (g)

1000-grain weight showed significant variation due to N application (Table 4.2). The highest 1000-grain weight 45.58 g was found from N_3 treatment and lowest 43.31 g was obtained from N_0 treatment. 1000-grain weight was influenced significantly due to different levels of B application (Table 4.2). However, numerically the highest 1000-grain weight 45.75 g was noted at 1 kg B ha^{-1} and lowest 43.54 g was obtained from 0 kg B ha^{-1}. This results explain that the weight of 1000-grains do not dependent on the B fertilization. Mete *et al.* (2005) and Soylu *et al.* (2005) reported that the weight of 1000 grains increased significantly with the increased B fertilization.

The interaction effect of N and B was significant for 1000-grain weight (Appendix IV and Table 4.2). However, the highest 1000-grain weight 47.02 g was obtained from 120 kg N ha^{-1} + 1 kg B ha^{-1} which is statistically similar with N_1B_1 (46.81 g) and statistically identical with N_2B_2 treatment. The lowest 1000-grain weight (42.73 g) was found from control treatment.

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

Grain yield showed a significant variation for different N levels (Appendix IV). Among the treatments 120 kg N ha^{-1} produced the highest grain yield 3.93 t ha^{-1} and the lowest 3.37 t ha^{-1} was found from the control (Table 4.3). The second highest was obtained from 80 kg N ha^{-1}. Many authors showed that grain yield increased significantly with increasing N levels. (Iqtidar et al., 2006 and Bindia et al., 2005) Grain yield was influenced significantly due to the different levels of B application (Appendix IV). Grain yield was increased upto the application of 1 kg B ha^{-1}. The highest grain yield 4.00 t ha^{-1} was observed at 1 kg B ha^{-1} and the lowest grain yield 3.5 t ha^{-1} was obtained from the control treatment (Table 4.3). The increased yield was mainly attributed probably to production of more number of grains spike^{-1} having higher 1000-grain weight. This result was in accordance with that of Singh and Singh (1984), Mandal (1987), Galrao and Sousa (1988), Rahman (1989), BINA (1993), Ahmed *et al.* (1991) and Jahiruddin *et al.* (1995).

Interaction effect of N and B was significant regarding grain yield (Appendix IV). The highest grain yield 4.87 t ha^{-1} was recorded in 120 kg N ha^{-1} + 1 kg B ha^{-1} and the lowest (3.1 t ha^{-1}) was found from control (Table 4.3). It is clear from the trail that N in conjunction with B produces higher grain yield.

Table 4.3 **Effect of N and B on yield parameters of wheat**

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
Effect of nitrogen			
N_0	3.37 d	2.65 d	42.00 b
N_1	3.67 c	3.03 c	42.18 b
N_2	3.87 b	3.19 b	42.65 a
N_3	3.93 a	3.25 a	42.75 a
$LSD_{0.05}$	0.045	0.044	0.263
CV (%)	5.681	6.663	6.729
Effect of boron			
B_0	3.50 c	2.88 b	41.75 c
B_1	4.00 a	3.40 a	43.00 a
B_2	3.63 b	2.81 c	42.44 b
$LSD_{0.05}$	0.043	0.047	0.536
CV (%)	5.681	6.663	6.729
Combined effect of nitrogen and boron			
N_0B_0	3.17 h	2.52 h	40.48 e
N_0B_1	3.34 g	2.91 f	41.22 d
N_0B_2	3.30 g	2.62 g	41.67 cd
N_1B_0	3.43 f	2.57 gh	42.88 b
N_1B_1	3.86 c	3.37 b	41.82 cd
N_1B_2	3.72 d	3.17 d	41.84 cd
N_2B_0	3.63 e	3.07 e	41.72 cd
N_2B_1	3.96 b	3.27 c	42.90 b
N_2B_2	3.84 c	3.07 e	43.10 b
N_3B_0	3.61 e	2.54 h	44.29 a
N_3B_1	4.87 a	4.06 a	44.56 a
N_3B_2	3.82 c	3.22 cd	42.26 c
$LSD_{0.05}$	0.081	0.078	0.6011
CV (%)	5.681	6.663	6.729

In a column tables having similar letters do not differ significantly whereas tables with dissimilar letters differ significantly as per DMRT.

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

Different levels of N also showed significant effect on straw yield (Appendix IV). The production of highest straw yield was 3.25 t ha^{-1} in 120 kg N ha^{-1} (Table 4.3) might be due to the fact that N tends primarily to encourage vegetative growth. On the other hand, N has also the most pronounced effect on plant growth. The lowest straw yield 2.65 t ha^{-1} was obtained from control treatment. The findings for this character agree with the result obtained by Bindia et al. (2005). Similar results were also found by Kumpawat and Rahtore (2003). Boron application showed significant effect on the straw yield (Appendix III). The highest straw yield 3.40 t ha^{-1} was obtained from 1 kg B ha^{-1} and the lowest straw yield 2.81 t ha^{-1} was obtained from control (Table 4.3). The present result concurs with the findings observed by Rahman (1989). Similar findings were also found by Malewar *et al.* (2001). On the other hand, the results differ from that of Panwar et al. (1998) who reported that straw yield was less affected by high levels of B.

The interaction effect of N and B in relation to straw yield showed significant effect (Appendix IV). From the interaction treatments it is clear that 120 kg N ha^{-1} + 1 kg B ha^{-1} produced the highest straw yield 4.06 t ha^{-1} and the lowest 2.52 t ha^{-1} performance in respect of straw yield found in N_0B_0 treatment which is statistically identical with N_1B_0 treatment and statistically similar with N_3B_0 treatment (Table 4.3).

4.9 Harvest index (%)

Results presented in the Table (4.3), revealed that N had significant effect on harvest index. The highest harvest index 42.75% was observed in 120 kg N ha^{-1} which is statistically similar with N_2 treatment was obtained by 80 kg N ha^{-1} and the lowest 42.00% from control treatment which is statistically similar with N_1 (42.18%) was obtained by 40 kg N ha^{-1}. Similar result also published by Mehasen (1999). Harvest index was significantly varied due to the application of B. From Table (4.3), it is clear that 1 kg B ha^{-1} produced the highest harvest index (43.00%) and control treatment produced lowest harvest index (41.75%). It is evident from the results that harvest index was influenced by the B application.

Interaction effect of N and B was significantly influenced in respect of harvest index (Table 4.3). The result exhibits that 120 kg N ha^{-1} + 1 kg B ha^{-1} produced the highest harvest index 44.56% which is statistically similar with N_3B_0 treatment as compared to control 40.48%. It might be due to the combination N and B and more biological yield and grain yield.

4.10 Effect of N and B on total nitrogen concentrations in postharvest soil

4.10.1 Effect of N on nitrogen content in soil

The effect of different doses of N fertilizers showed statistically non-significant variation in the nitrogen concentration in soil (Table 4.4). But it was observed that among the different doses of N, the highest nitrogen concentration in soil (0.08%) was recorded in N_3 treatment. On the other hand, the lowest nitrogen concentration in soil (0.04%) was recorded in the No treatment where no N was applied.

4.10.2 Effect of B on nitrogen content in soil

The effect of different doses of B fertilizer showed statistically non-significant variation in the nitrogen concentration in soil (Table 4.4). The highest nitrogen concentration (0.06%) among different doses of B fertilizer was observed with B_1 treatment which is statistically identical with B_2 (0.06%). On the other hand the lowest nitrogen concentration (0.05%) in soil was observed in B_0 treatment where no fertilizer was applied.

4.10.3 Interaction effect of N and B on nitrogen concentrations in soil

Non-significant effect of combined application of different doses of N and B fertilizers on the nitrogen concentration was observed in the soil (Table 4.4). The highest concentration of nitrogen in the soil (0.08%) was recorded in N_3B_1 treatment which were statistically identical with N_3B_2 treatment. On the other hand, the lowest nitrogen concentration (0.03%) in soil was found with N_0B_0 treatment.

Table 4.4 **Postharvest analysis of soil**

Treatment	% N	Available P (ppm)	Exchangeable K (meq/100 g soil)	Available B (ppm)
Effect of nitrogen				
N_0	0.04	13.85 c	0.05	0.35 c
N_1	0.05	14.42 b	0.06	0.59 b
N_2	0.05	13.05 d	0.05	0.63 a
N_3	0.08	15.03 a	0.06	0.65 a
$LSD_{0.05}$	NS	0.314	NS	0.033
CV (%)	5.261	7.352	4.388	6.137
Effect of boron				
B_0	0.05	11.35 c	0.04	0.35 c
B_1	0.06	15.12 b	0.07	0.63 b
B_2	0.06	15.80 a	0.07	0.68 a
$LSD_{0.05}$	NS	0.261	NS	0.041
CV (%)	5.261	7.352	4.388	6.137
Combined effect of nitrogen and boron				
N_0B_0	0.03	10.44 j	0.03	0.32 f
N_0B_1	0.04	16.92 ab	0.05	0.36 e
N_0B_2	0.05	14.18 f	0.07	0.38 e
N_1B_0	0.04	11.26 hi	0.04	0.34 ef
N_1B_1	0.07	15.52 c	0.08	0.70 c
N_1B_2	0.05	16.48 b	0.06	0.72 c
N_2B_0	0.05	11.59 h	0.04	0.38 e
N_2B_1	0.04	12.37 g	0.07	0.77 ab
N_2B_2	0.05	15.20 de	0.05	0.80 a
N_3B_0	0.07	12.10 g	0.04	0.36 e
N_3B_1	0.08	15.67 c	0.06	0.70 c
N_3B_2	0.08	17.32 a	0.08	0.82 a
$LSD_{0.05}$	NS	0.287	NS	0.023
CV (%)	5.261	7.352	4.388	6.137

In a column tables having similar letters do not differ significantly whereas tables with dissimilar letters differ significantly as per DMRT.

NS = Non significant

treatment. The results obtained from the rest of the treatment were significantly different from all other treatment combinations.

4.11 Available phosphorus concentrations in soil

4.11.1 Effect of N on phosphorus content in soil

A statistically significant variation was observed in phosphorus concentration in soil with different doses of nitrogen (Table 4.4). It was observed that the highest phosphorus concentration in soil (15.03 ppm) was recorded in N_3 (120 kg N ha^{-1}) and the lowest phosphorus concentration in soil (13.05 ppm) was recorded in the N_2 treatment.

4.11.2 Effect of B on phosphorus content in wheat plant

The effect of different doses of B fertilizers showed statistically significant variation in the phosphorus concentration in soil (Table 4.4). The result showed that the highest phosphorus concentration (15.80 ppm) among different doses of B fertilizers was in B_2 (1.5 kg B ha^{-1}) and the lowest phosphorus concentration (11.35 ppm) was in B_0 (0 kg B ha^{-1}) treatment.

4.11.3 Interaction effect of N and B fertilizers on phosphorus concentrations in wheat plant

Significant effect of combined application of different doses of N and B fertilizers on the phosphorus concentration was observed in the soil (Table 4.4). It was observed that the highest concentration of phosphorus in soil (17.32 ppm) was recorded with the N_3B_2 treatment which is statistically similar with N_0B_1 (16.92 ppm) and the lowest phosphorus concentration (10.44 ppm) in soil was found in N_0B_0 (no N and B application).

4.12 Exchangeable potassium concentrations in soil

4.12.1 Effect of N on potassium content in soil

Statistically non-significant variation was observed in potassium concentration in soil with different doses of nitrogen (Table 4.4). The highest potassium concentration among the different doses of nitrogen (0.06 meq/100 gm soil) was recorded in N_3 (120 kg N ha^{-1}) which was statistically identical with N_1 (0.06 meq/100 gm soil) obtained by 80 kg N ha^{-1}. On the other hand the lowest potassium concentration (0.05 meq/100 gm soil) was recorded in the N_0 obtained by control treatment which is statistically identical with N_2 (0.05 meq/100 gm soil) obtained by 80 kg N ha^{-1} treatment.

4.12.2 Effect of B on potassium content in soil

The effect of different doses of B fertilizer showed statistically non-significant variation on the potassium concentration in soil (Table 4.4). The highest potassium concentration among the different doses of B fertilizer (0.07 meq/100 gm soil) was recorded with B_2 (1.5 kg B ha^{-1}) treatment which was statistically identical with B_1 (1 kg B ha^{-1}). On the other hand, the lowest potassium concentration (0.04 meq/100 gm soil) was observed in B_0 (0 kg B ha^{-1}) treatment.

4.12.3 Interaction effect of N and B on exchangeable potassium content in soil

Non-significant effect of combined application of different doses of N and B fertilizers on the potassium concentration was observed in the soil (Table 4.4). The highest concentration of potassium in soil (0.08 meq/100 gm soil) was recorded in the N_3B_2 (120 kg N ha^{-1} + 1.5 kg B ha^{-1}) treatment which statistically identical with N_1B_1 (0.08 meq/100 gm soil). On the other hand, the lowest potassium concentration (0.03 meq/100 gm soil) was found in N_0B_0 (no N and B application) treatment.

4.13 Effect of N and B on the available boron concentrations in soil

4.13.1 Effect of N on boron content in soil

A statistically significant variation was observed in boron concentration in soil with different doses of N (Table 4.4). It was observed that among the different doses of N the highest boron concentration in plant soil (0.65 ppm) was recorded in N_3 (120 kg N ha^{-1}) treatment which is statistically identical with N_2 (0.63 ppm). On the other hand the lowest boron concentration (0.35 ppm) was recorded in the control treatment.

4.13.2 Effect of B on boron content in soil

The effect of different doses of B fertilizer showed a statistically significant variation in the boron concentration in soil (Table 4.4). It was observed that the highest boron concentration in soil (0.68 ppm) among different doses of B fertilizer was recorded in B_2 (1.5 kg B ha^{-1}) and the lowest boron concentration (0.35 ppm) was observed in the treatment B_0 where no B fertilizer was applied.

4.13.3 Interaction effect of N and B on boron content in soil

Significant effect of combined application of different doses of N and B fertilizers on the boron concentration was observed in soil (Table 4.4). It was observed that the highest concentration of boron in soil (0.82 ppm) was recorded with the N_3B_2 (120 kg N ha^{-1} + 1.5 kg B ha^{-1}) treatment which is statistically identical with N_2B_2 (0.80 ppm) and statistically similar with N_2B_1 (0.77). On the other hand the lowest boron concentration (0.32 ppm) was found in N_0B_0 treatment where no N and B were applied which is statistically similar with N_1B_0 (0.34 ppm).

SUMMARY AND CONCLUSION

5.1 Summary

An experiment was conducted at the Sher-e-Bangla Agricultural University Farm Dhaka 1207 during the rabi season from November 2015 to March 2016 with a view to investigating the effect of N and B fertilizers on growth and yield of wheat. The experimental land was high land with clay loam soil texture having pH 5.6 and organic carbon content of 0.56%. The experiment consisted of the following treatments. (i) four nitrogen levels viz., 0, 40, 80, and 120 kg N ha^{-1} (ii) three boron levels viz., 0, 1 and 1.5 kg B ha^{-1}. The experiment was laid out in randomized complete block design with 12 treatment combinations. Each treatment was replicated thrice. The size of each plot was 3m x 2 m. The elements N and B were applied in the form of urea and boric acid, respectively. The treatments were N_0B_0 (without N and B), N_0B_1 (0 kg N ha^{-1} + 1 kg B ha^{-1}), N_0B_2 (O kg N ha^{-1} + 1.5 kg B ha^{-1}) N_1B_0 (40 kg N ha^{-1} + 0 kg B ha^{-1}), N_1B_1 (40 kg N ha^{-1} + 1 kg B ha^{-1}), N_1B_2 (40 kg N ha^{-1} + 1.5 kg B ha^{-1}), N_2B_0 (80 kg N ha^{-1} + 0 kg B ha^{-1}), N_2B_1 (80 kg N ha^{-1} + 1 kg B ha^{-1}), N_2B_2 (80 kg N ha^{-1} + 1.5 kg B ha^{-1}), N_3B_0 (120 kg N ha^{-1} + 0 kg B ha^{-1}), N_3B_1 (120 kg N ha^{-1} + 1 kg B ha^{-1}) and N_3B_2 (120 kg N ha^{-1} + 1.5 kg B ha^{-1}).

Wheat variety BARI Gom-28 was used as the test variety. Seeds were sown line wise by hand in 20 cm apart rows on 1st December 2015 and at full maturity stage crop was harvested on 17th March 2016. The data were collected plot-wise yield and data on yield attributes were recorded. The parameters recorded were plant height, number of total tillers $plant^{-1}$, spike length, number of spikelet $spike^{-1}$, number of grains $spike^{-1}$, 1000 grain weight, grain yield, straw yield and harvest index.

The postharvest soil samples from 0-15 cm depth were collected plot wise and analyzed for N, P, K and B contents. All the data were analyzed statistically and mean differences were adjudged by DMRT. The findings of the experiment are stated below.

The effect of different levels of N and B individually was significant in relation to yield. In case of nitrogen application, yield and yield attributing characters were significantly influenced. The highest plant height (35.22 cm, 50.20 cm, 64.14 cm and 86.29 cm at 30 DAS, 50 DAS, 70 DAS and harvesting time respectively), number of total tillers plant^{-1} (4.54), grain yield (3.93 t ha^{-1}), straw yield (3.25 t ha^{-1}) and harvest index (42.75%) were obtained from 120 kg N ha^{-1}. The highest spike length (10.34 cm), number of spikelet spike^{-1} (41.07), number of grains spike^{-1} (30.57) and 1000-grain weight (45.58 g) were found at 120 kg N ha^{-1}. The control treatment indicated the lowest value for the yield and yield attributing characters.

In case of boron application, plant height, number of total tillers plant^{-1}, spike length, number of spikelet spike^{-1}, number of grains spike^{-1}, grain yield and straw yield were found significant. The highest plant height (34.54 cm, 50.04 cm, 63.70 cm, 86.55 cm at 30 DAS, 50 DAS, 70 DAS and harvesting time respectively), number of effective tillers plant^{-1} (4.80), spike length (9.88 cm), number of spikelet spike^{-1} (39.61), number of grains spike^{-1} (26.88), 1000-grain weight (44.95 g), grain yield (4.00 t ha^{-1}), straw yield (3.40 t ha^{-1}) and harvest index (43.00%) were obtained from 1 kg B ha^{-1}. The control treatment indicated the lowest value for the yield and yield attributing characters.

Interaction effect of N and B showed significant variation in relation to yield and yield attributes. The highest plant height (38.95 cm, 53.52 cm, 68.56 cm, 89.26 cm at 30 DAS, 50 DAS, 70 DAS and harvesting time respectively), number of total tiller plant^{-1} (5.60), spike length (13.4 cm), number of spikelet spike^{-1} (44.81), number of grains spike^{-1} (36.45), 1000-grains (47.02), grain yield (4.87 t ha^{-1}), straw yield (4.06 t ha^{-1}) and harvest index (44.56%) were achieved by N_3B_1 treatment. All the yield and yield attributing characters were found lowest in control treatment.

Nutrient content in postharvest soil was also influenced by different levels of N and B application. The total N, available P, exchangeable K and available B of postharvest soil varied from 0.09 to 0.08%, 15.41 to 17.32 ppm, 0.12 to .08 meq/100 gm soil and

0.59 to 0.82 ppm respectively due to combined application of N and B at different levels. The addition of N and B not only increased the yield but also protect the soil from total exhaustion of nutrients.

5.2 Conclusion

From the above results of the present study, it might be stated that wheat cultivar BARI Gom-28 was grown successfully for obtaining maximum yield with 120 kg N ha^{-1} and 1 kg B ha^{-1} individually or in combination along with recommended rates of TSP, MoP, Gypsum and $ZnSO_4$ fertilizers to ensure optimum requirement of nutrients for commercial wheat cultivation, further study should be undertaken on a priority basis because the fertility status of Bangladesh soils may vary from place to place or region to region. In order to obtain higher grain yield of wheat, farmers may be advised to apply 120 kg N and 1 kg B ha^{-1} from urea and boric acid, respectively.

Before making final conclusion, further trails with the same treatment combinations on different AEZs of Bangladesh will be useful.

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APPENDICES

Appendix I. Monthly record of air temperature, relative humidity, rainfall and sunshine hour of the experimental site during the period from November 2015 to March 2016

Month	*Air temperature (ºc)		*Relative humidity (%)	Total Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
November, 2015	25.9	16.2	79	00	6.3
December, 2015	22.6	13.7	75	00	6.4
January, 2016	24.7	12.8	67	00	5.8
February, 2016	27.2	16.5	69	30	6.5
March, 2016	28.3	19.6	70	00	6.8

* Monthly average,

* Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka 1207.

Appendix II. Effect of N and B on plant height of wheat

Source of variation	Degrees of freedom	Mean square of plant height (cm)			
		30 DAS	50 DAS	70 DAS	At harvest
Replication	2	0.023	0.083	0.059	0.102
Factor A	3	22.709*	24.408*	54.989*	11.547*
Factor B	2	33.107*	30.783*	46.212*	11.667*
AB	6	24.507*	20.449*	31.303**	15.449**
Error	22	2.346	3.082	3.001	3.204

* Significant at 5% level of probability

** Significant at 1% level of probability

Appendix III. Effect of N and B on yield contributing parameters of wheat

Source of variation	Degrees of freedom	Mean square of				
		Number of total tillers plant^{-1}	Spike length (cm)	Number of Spikelet spike^{-1}	Number of grains spike^{-1}	1000 grain weight (g)
Replication	2	0.421	0.216	0.302	1.521	0.453
Factor A	3	1.350*	4.149*	59.126*	14.177*	1.372**
Factor B	2	4.546*	2.728**	65.223*	12.736*	14.283*
AB	6	0.974**	7.084*	54.718*	17.099*	10.424*
Error	22	0.042	0.561	3.114	1.539	1.742

* Significant at 5% level of probability

** Significant at 1% level of probability

Appendix IV. Effect of N and B on yield parameters of wheat

Source of variation	Degrees of freedom	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)
Replication	2	0.194	0.361	1.194
Factor A	3	4.519*	6.407*	14.532*
Factor B	2	9.528*	12.028*	19.668*
AB	6	5.935**	8.324*	12.914*
Error	22	1.861	2.028	1.861

* Significant at 5% level of probability

** Significant at 1% level of probability

Appendix V. Post-harvest analysis of soil

Source of variation	Degrees of freedom	% N	Available P (μg g^{-1})	Exchangeable K (μg g^{-1})	Available B (μg g^{-1})
Replication	2	0.00	0.153	0.001	0.042
Factor A	3	NS	5.317*	NS	4.116*
Factor B	2	NS	8.229*	NS	7.138*
AB	6	NS	4.316***	NS	2.511**
Error	22	0.003	0.571	0.004	0.311

* Significant at 5% level of probability

** Significant at 1% level of probability

NS = Non Significant