EFFECT OF BORON FERTILIZATION ON WHEAT UNDER INORGANIC AND INTEGRATED NUTRIENT MANAGEMENT

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CERTIFICATE

This is to certify that the thesis entitled “Effect of boron fertilization on wheat under inorganic and integrated nutrient management” submitted to the Department of Soil Science, 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 bona-fide research work carried out by Reasat Sadat Hossain, Registration No. 10-04183 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2016
Dhaka, Bangladesh

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Dedicated To

My Beloved Parents

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ABSTRACT

An experiment was carried out at Sher-e-Bangla Agricultural University, Dhaka during the period from November 2015 to March 2016 to study the effect of boron fertilization on wheat under inorganic and integrated nutrient management. BARI Gom-24 (Prodip) was used as plant material. Six treatments were considered for the experiment *viz*. T_0 = Control (no fertilizer application), T_1 = 120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1}, T_2 = 120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 1.5 kg B ha^{-1}, T_3 = 120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 3.0 kg B ha^{-1}, T_4 = 70% NPKSZn from Inorganic fertilizer + 5 ton compost ha^{-1} + 1.5 kg B ha^{-1} and T_5 = 70% NPKSZn from Inorganic fertilizer + 5 ton compost ha^{-1} + 3.0 kg B ha^{-1}. The experiment was laid out in Randomized Complete Block Design with three replications. Results showed that the highest number of tillers $plant^{-1}$ (4.05), dry weight $plant^{-1}$ (37.96 g), spike length (11.60 cm), number of grains $spike^{-1}$ (38.43), 1000 seed weight (52.64 g), grain yield (4.28 t ha^{-1}), Stover yield (5.60 t ha^{-1}) and harvest index (43.32%) were found from T_2 (120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 1.5 kg B ha^{-1}) treatment where control treatment, T_0 (no fertilizer) gave the lowest results for all parameters.

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ABBREVIATIONS AND ACRONYMS

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

CHAPTER I

INTRODUCTION

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

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

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

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. The elements essential for plants are C, H, O, N, P, K, Ca, Mg, S, Fe, Cu, B, Mn, Mo, Zn, Cl. Out of these 16 elements, 9 essential elements have been classified as "macronutrients" as these are required in relatively large amount by the plants. These elements include C, H, O, N, P, K, C Mg, S. The remaining of the elements

(B, Cu, Fe, Cl, Mn, Mo and Zn) are called “trace elements” (Alloway, 1990; Brady and Weil, 2002). Essential trace elements are often called “micronutrients” because they are required in small, but in critical concentrations by living organisms.

Among different micronutrients, boron is an important element for proper crop growth and yield. Boron deficiency impairs grain setting in wheat, resulting in increased number of open spikelets and decreased number of grains per spike. The difference in the number of open spikelets under normal and boron deficient soil conditions has been used to compare wheat genotypes for boron efficiency (Rerkasem *et al*., 1993). Boron deficiency in crops is more pervasive than the deficiency of any other micronutrient (Gupta, 1993). Visual symptoms of Boron deficiency generally become evident in dicots, corn and wheat at tissue concentrations of less than 20-30, 10-20 and 10 mg kg^{-1} weight, respectively. Nutritional disorders attributed to boron deficiency are also prevalent among vegetables, fruit and nut trees. Marschner (1995) reported that Boron is essential for cell division and elongation in meristimatic tissues, floral organs and for flower male fertility, pollen tube germination along with its elongation and seed/fruit formation. In addition, in boron deficient soils seeds generate abnormal seedlings. Dell *et al*., 1997 stated that deficiency of boron inhibits root elongation through limiting cell enlargement and cell division in the growing zone of root tips. Deficiency of boron causes inhibition of leaf expansion and reduction in photosynthesis.

Integrated plant nutrient system (IPNS) has assumed a great importance and has vital significance for the maintenance of soil productivity. Now, increased attention is being paid to develop an integrated plant nutrition system that maintains and enhances soil productivity through balanced use of different sources of nutrients, including chemical fertilizers, organic fertilizers and biofertilizers. The basic concept, underlying the integrated plant nutrition system, is the adjustment of soil fertility and plant nutrient supply to an optimum level for sustaining desired crop productivity. This might optimize the benefits of all sources of plant nutrients in an integrated manner (Jen-Hshuan, 2006). Organic manure could help in decreasing wheat mineral fertilizer requirements (Askar *et al*, 1994 and Shabayek, 1997). Organic fertilization was found to be enhancing growth and productivity of wheat (Nawab *et al.*, 2006). Yakout *et al*., 1998 found that application of organic fertilizer increased grain protein content. Also, Kiani *et al*., 2005 found that combination of chemical fertilizers, with organic manures, helped in increasing the grain yield of wheat and implied a saving of 50% cost, compared to a system with only mineral fertilization.

Keeping this in view, the present investigation is planned to study the effect of boron fertilization on wheat under inorganic and integrated fertility management with the following objectives –

1. To know the effect of boron on the yield parameters of wheat with or without manure.

2. To know the effect of boron on the yield of wheat with inorganic and integrated nutrient management.

CHAPTER II

REVIEW OF LITERATURE

Wheat (*Triticum aestivum* L.) is one of the most key cereal crops in Bangladesh. A good number of research works have been done on this crop in different countries of the world in terms of different nutrient management practices. The role of macro and micronutrients are crucial in wheat production in order to achieve higher yields (Arif *et al*., 2006). Boron is the most important micronutrient elements which play a significant role in crop production. Micronutrients as boron with other integrated nutrient management in wheat cultivation may be productive for successful wheat production. Hence, the present study was under taken on boron fertilization on wheat under inorganic and integrated fertility management. Limited research works have been done before with this regard. An emphasis has been given to review the research works which have appeared in the recent literature.

2.1 Effect of boron wheat

Wheat is more prone to B deficiency than rice and maize, and some dicotyledonous including soybean and mungbean. Boron deficiency adversely affects many processes of wheat growth and development; it mainly limits reproductive growth more than vegetative growth of wheat. Boron deficiency depresses wheat yield primarily through grain set failure, which is in turn caused by male sterility and male sterility is associated with poorly developed pollen and anthers.

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

Raza *et al*. (2014) reported that foliar application of boron was significant affected on grain yield, number of grains spike^{-1}and 1000 grain weight. The highest grain yield of wheat (6.5 ton h^{-1}) was observed when 20 mg L^{-1} boron was applied.

Nadim *et al*. (2012) carried out an experiment to evaluate growth and yield response of wheat variety Gomal-8 using micronutrients and their application methods. Results revealed that application of boron @ 2 kg ha^{-1} produced higher crop growth rate (23.58 g m^{-2} day^{-1}), net assimilation rate (2.82 mg m^{-2} day^{-1}), number of tillers (234.5 m^{-2}), number of grains (52.92 spike^{-1}) and grain yield (3.14 t ha^{-1}). Also, boron had significant effect on number of tillers and leaf area index (LAI).

Pandey and Gupta (2013) reported that foliar application of boron at all stages increased the yield parameters like number of pods, pod size and number of seeds formed per plant, also improved the seed yield and seed quality in terms of storage seed proteins and carbohydrates in black gram.

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}.

Kandi *et al*. (2012) found that B foliar application on safflower plant had the highest positive effect on plant biological yield, harvest index and seed boron content.

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.

Ahmad and Irshad (2011) observed that soil application of boron fertilizer has positive impact on the yield and different yield components of wheat, rice and cotton crop. Thirty one field experiments were conducted to evaluate the response of wheat, rice and cotton to boron application the results showed that the soil application of boron fertilizer has positive impact on the yield and different yield components of wheat, rice and cotton crop. Soil application not only considerably raises yield of these crops but it is as well inexpensive and effortless to utilize for the farmers.

Zahoor *et al*. (2011) carried out a field experiment to determine the effect of different application rates of B on yield and quality of cotton. The results showed that B application at any stage improved plant growth and photosynthetic rate, leaf nitrogen, achene oil, seed yield and protein contents of sunflower plant.

Moeinian *et al*. (2011) found that foliar 1% boron increased grain yield of wheat under drought stress. Also found that the proline content of grain and gluten percentage of the grain was significantly affected with boron foliar spraying and irrigation treatments.

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.

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.

Tahir *et al*. (2009) showed that, foliar application of boron in wheat at four different growth stages i.e at tillering, jointing, booting and anthesis increased number of grain per spike over control. The maximum number of grain per spike was obtained in treatment where boron was sprayed at booting growth stage. Number of grain per spike increased 11.73 percent as compared to control. Effects of boron application on harvest index were claimed the most effective in wheat. Grain yield of wheat crop is the result of combined effect of various yield contributing components. While Mitra and Jana (1991) who reported that boron application significantly increased the number of grains per spike.

Kamal (2009) conducted an experiment at BAU farm to find the different methods of boron application on grain set and yield of wheat. The result showed that combination of seed priming plus foliar spray of boron at tillering, booting and flowering stages of crop is more effective method to overcome B deficiency and to increase the grain set and yield of wheat.

Wrobel (2009) conducted an experiment on response of spring wheat to foliar fertilization with boron under reduced boron availability. It was demonstrated that foliar application of boron was effective in modifying the unfavourable wheat growth and nutrient uptake conditions (drought and soil reaction change). Fertilization alleviated the results of the limited availability of boron, significantly increasing the grain and straw yield mass and enriching the yields with boron. The highest rates of boron used for foliar application (7 and 9 cm^3 0.3% H_3BO_3/pot) raised the concentration of this clement in wheat grain up to a level comparable to the reference data.

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 crop species and cultivars vary considerably in their susceptibility to B deficiency (Alloway, 2008).

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

Ahmed *et al.* (2007) performed several sand culture and field experiments to screen out a number of Bangladeshi wheat varieties and advanced lines for boron (B) efficiency against Thai B efficient (Fang 60) and inefficient (SW41 and E12) varieties. Performance of wheat genotypes were evaluated with respect to flag leaf B concentration, pollen viability, grain set index and grain yield. Wheat genotypes responded differently to boron deficiency. Pollen variability was found to be 67% in ‘Kanchan’, 35% in ‘Gourab’, 80% in Sourav. 90% in Fang 60 and 25% in SW4I when B was not added. Pollen variability of all varieties was above 90% when B was applied. Based on grain set index and leaf B concentration ‘Sourav’ was found to be the moderately B efficient variety. Thus, ‘Sourav’ can be regarded as breeding material for development of new wheat varieties for tolerance to B deficiency.

Haider *et al.* (2007) conducted a field trial at Calcareous Brown Floodplain Soils of Jessore Regional Agriculture Research Station in Bangladesh during the rabi season with the objective to evaluate the response of wheat varieties to different levels of boron 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 produced significantly the highest yield in both the years with the highest mean seed yield (5.3 t/ha) showing a 66% yield increase over the boron control.

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

Jahiruddin *et al.* (2007) reported that the boron deficiency in a major reason for lower yield of wheat and mustard in Bangladesh. This element deficiency has arisen mainly due to continuous mining of soil nutrients for increased cropping intensity without adequate replenishment.

Haquc (2007) carried out an experiment in Old Brahmaputra Floodplain soil at BAU farm, Mymensingh in rabi season with a view to examining the effect of different methods of boron application on wheat. The results revealed that there was a significant positive effect of B on grain yield. Soil application @ 1 kg B/ha and foliar spray at tillering and booting stages of crop showed the best performance. There was no variation in grain yield between the varieties.

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

Ghatak *et al.* (2006) conducted a field experiment to study the effect of boron on yield, concentration and uptake of N, P and K by wheat in red and laterite soils of West Bengal. They showed application of 15 to 20 kg borax/ha recorded higher values of yield attributes and yield. The increase in grain yield over control was 4.5 to 7.7 per cent. The optimum dose of borax was 14 kg during the first year and 10.4 kg/ha in the second year. Thus a dose of 10 to 15 kg borax/ha may be beneficial for higher production of wheat in this region.

Jolanta (2006) conducted a field trial, involving foliar application of boron to evaluate the effect of foliar spray of boron 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 boron 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 weight and straw yields produced by spring wheat. This study demonstrated that B is able to mitigate drought effects, and its application to soil during tillering stage improved the parameters of the main yield components, thus increasing yield level and enriching the chemical composition of the wheat grain.

Soylu *et al.* (2005) conducted field experiments to study the response of 6 durum and 6 bread wheat cultivars to B application when grown in soils with low extractable B (0.19 mg/kg). Agronomic characteristics such as grain yield, sterility, number of grains per spike, number of spikes per m^2, 1000-kernel weight and flag leaf B concentration were investigated as affected by the application of 3 kg B/ha as a spray of boric acid (H_3BO_3) to soil. Agronomic characteristics of bread and durum wheat cultivars varied remarkably with the application of B. Its deficiency in the soil, and seasonal conditions. Boron application increased grain yield by 9.6% on an average in durum wheat and by 10.9% in bread wheat.

2.2 Effect of integrated nutrient management on wheat

Leghari *et al*. (2016) found from a field experiment that the maximum plant height 86.7, more tillers 418.0 m^2, increased spike length 11.6 cm, grains $spike^{-1}$ 51.0 and 49.0, grain weight $plant^{-1}$ 7.9 g, seed index (1000 grain weight) 41.7 g, biological yield 9131.7 kg ha^{-1}, grain yield 3880.0 kg ha^{-1} and harvest index 42.5 were noted at NPK-120-60-60 kg ha^{-1} + B 2% at tillering phase, whereas, all growth and yield parameters were measured poor under control (un-treated) plots. Hence, it was decided from the results that use of NPK = 120:60:60 kg ha^{-1} and 2% foliar application of boron at tillering stage proved better as compared to other treatments.

Sheoran *et al*. (2015) found that application of nitrogen at 150 mg kg^{-1} soil significantly increased the grain and straw yield of wheat from 2.70 to 8.24 and 4.97 to 9.44 g pot^{-1}, respectively over control. Addition of vermicompost at 1% alone increased the grain and straw yield of wheat from 2.70 to 4.81 and 4.97 to 6.60 g pot^{-1} respectively over control and in combination with N at 150 mg kg^{-1} soil further improved from 4.81 to 10.73 and 6.60 to 11.89 g pot^{-1}, respectively. The grain and straw yield of wheat also decreased significantly with the application of herbicide (Clodinafop propargyl) (60 to 90 g a.i./ha) in presence of both vermicompost and N. Nitrogen, phosphorus and potassium uptake by grain and straw increased significantly with the increase in each successive dose of N up to the level of 200 mg kg^{-1} soil and highest uptake of NPK by grain were 149.56, 57.59 and 40.87 mg pot^{-1}, respectively and that of by straw the highest value recorded were 54.72, 18.24 and 143.78 mg pot^{-1}, respectively. Application of vermicompost at 1% significantly increased NPK uptake in both grain and straw over control.

Islam *et al*. (2014) conducted an experiment to evaluate the effect of integrated use of manures and fertilizers on the growth, yield and nutrient uptake by wheat. There were six treatments such as T_0 (Control), T_1 [STB-CF (HYG)], T_2 [CD + STB-CF (HYG)], T_3 [PM + STB-CF (HYG)], T_4 [COM + STB-CF (COM)] and T_5 [FP (Farmers' practice)]. The integrated use of manures and fertilizers significantly influenced the yield attributes as well as grain and straw yields of wheat. The treatment T_1 [STB-CF (HYG)] produced the tallest plant of 90.17 cm which was identical with T_3 [PM +STB-CF (HYG)] and the lowest value was found in control. The 1000-grain weight followed the similar pattern but the tillers hill^{-1}, spike length and spikelets spike^{-1} did not follow any definite trend. The treatment T_3 [PM + STB-CF (HYG)] produced the highest grain yield of 4362 kg ha^{-1} (90.4% increase over control) and straw yield of 5492 kg ha-1 (84.79% increase over control). The lowest grain yield (2291 kg ha-1) and straw yield (2972 kg ha^{-1}) were found in T_0 (Control). The NPKS uptake by wheat was markedly influenced by combined use of manures and fertilizers and the treatment T_3 demonstrated superior performance to other treatments.

Patel *et al*. (2014) conducted a field experiment to study the effect of integrated nutrient management on wheat and its residual effect on green gram. There were twenty-four treatment combinations comprising combination of three organic manure treatments (Control, Vermicompost@5 t/ha and FYM @ 10 t/ha) with four phosphorus/bio-fertilizer treatments (60 kg P_2O_5/ha, 20 kg P_2O_5/ha + PSB, 40 kg P_2O_5/ha + PSB and PSB alone) and two sulphur levels (0 kg S/ha and 40 kg S/ha) were tested. Application of organic manures, i.e., FYM@10 t/ha and vermicompost 5 t/ha with 60 kg P_2O_5/ha or 40 kg P_2O_5/ha + PSB and 40 kg S/ha produced maximum wheat grain and straw yield. Significantly higher green gram grain and straw yield was recorded in organic manure treatment with application of 60 kg P_2O_5/ha or 40 kg P_2O_5/ha + PSB and 40 kg S/ha in succeeding crop. Treatment FYM@10 t/ha with 60 kg P_2O_5 and 40 kg S/ha recorded higher grain and straw yield under residual nutrient. In wheat-green gram cropping sequence treatment FYM@10 t/ha with 60 kg P_2O_5 and 40 kg S/ha recorded higher net realization.

Essam and Abd El-Lattief (2014) conducted a field experiment on sandy soil to study the effect of integrated nutrient management (INM) on productivity and grain protein content of wheat. The recommended NPK, FYM and biofertilizer (*Azotobacter chroococcum*) were applied alone and in various combinations among them. The study revealed that the integration of organic manures in combination with biofertilizer and chemical fertilizers was found significant in improving the overall yield attributes, grain yield, straw yield and grain protein content than the sole application of either of these nutrients. Maximum grain yield (2356 kg ha^{-1}) and straw yield (3614 kg ha^{-1}) were observed with treatment T_6 (half of the recommended NPK + 10 tons FYM + biofertilizer). Like grain and straw yields, the highest grain protein content (11.95%) observed from T_6.

Shah and Ahmad (2006) carried out a field experiment to assess the effect of integrated use of urea and Farm Yard Manure on yield and N uptake of wheat. Urea and FYM were combined in a way to supply N at 120 kg ha^{-1} from both sources in 0:0, 100:0, 75:25, 50:50, 25:75 and 0:100 ratios arranged. Wheat (variety: Ghaznavi) was planted in rows. The results indicated that maximum biological (10952 kg ha^{-1}), straw (7710 kg ha^{-1}), and grain (3242 kg ha^{-1}) yields of wheat were obtained in treatment receiving N from urea and FYM in 75:25 ratio. The next higher yield was obtained in treatment receiving N from the two sources in 50:50 ratio. Comparing with other fertilizer treatments, the yields were significantly lower in treatments where N from urea source was below 50 %. Similarly, the N uptake in grain (47.66 kg ha^{-1}) and straw (19.28 kg ha^{-1}) was also significantly ($P<0.05$) greater in treatments receiving 75 or 50 % N from urea and 25 or 50% from FYM. The data on crop yields and N uptake in response to integrated use of urea and FYM supported each other. The residual soil organic fertility after crop harvest was proportional to the level of FYM used. Our data thus suggest that integrated use of urea and FYM at 75:25 or 50:50 ratios (N basis) has produced maximum yields and is therefore recommended for profitable wheat yield and sustainable soil fertility.

Khaddar and Yadav (2006) conducted a field trial for two consecutive years in a soybean-wheat cropping sequence. The microbial population in soil was estimated by dilution plate count method. Application of biofertilizers significantly showed higher bacterial population during both the years of study. The fungal population increased in treated plot over control. Among the organics, biofertilizer increased fungal population at 25 day stage of the crop, while there was slight decrease in fungal population. Integrated use of chemical fertilizer with organics could ameliorate the soil and improve the productivity of a soybean-wheat cropping sequence resulting in eco-friendly farming system.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted at the Soil Science field of Sher-e-Bangla Agricultural University, Dhaka during the period from November 2015 to March 2016 to study the effect of boron fertilization on wheat under inorganic and integrated fertility management. This chapter deals with a brief description on experimental site, climate, soil, land preparation, layout, experimental design, intercultural operations, data recording and their analyses.

3.1 Experimental site

The experiment was conducted at the Sher-e-Bangla Agricultural University farm, Dhaka, under the Agro-ecological zone of Modhupur Tract, AEZ-28 during the Rabi season of 2015. The land area is situated at 23°41′ N latitude and 90°22′ E longitude at an altitude of 8.6 meter above sea level. The experimental site is shown in the AEZ Map of Bangladesh in Appendix I.

3.2 Climate

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

3.3 Soil

The farm belongs to the general soil type, Shallow 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. The experimental area was flat having available irrigation and drainage system. The land was above flood level and sufficient sunshine was available during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done by Soil Resources Development Institute (SRDI), Dhaka. The physicochemical properties of the soil are presented in Appendix III.

3.4 Planting material

Wheat (*Triticum aestivum* L.) variety BARI Gom-24 (Prodip) was used as plant material. BARI developed this variety and released in 2012. It is a most popular variety now due to its high yielding potentials and suitable for early and late planting (up to second week of December). This variety attains a height of 92-96 cm and it resistant to leaf rust disease. The number of tillers plant^{-1} is 3-4 and the leaves are wide and deep green in color. It requires 60-63 days to heading. Grains are amber in color and bright. Its yield is 4-5 t ha^{-1} and 1000 grain weight is 48-52 g. The seeds of this variety were collected from Bangladesh Agricultural Research Institute (BARI), Gazipur.

3.5 Land preparation

The land was first opened with the tractor drawn disc plough. Ploughed soil was then brought into desirable fine tilth by 4 operations of ploughing and harrowing with country plough and ladder. The stubble and weeds were removed. The first ploughing and the final land preparation were done on 5 November and 12 November 2015, respectively. Experimental land was divided into unit plots following the design of experiment. The plots were spaded one day before seed sowing and the basal dose of fertilizers was incorporated thoroughly before seed sowing.

3.6 Fertilizer application

The unit plots were fertilized with organic and inorganic fertilizers. Compost was used as organic fertilizer. Urea, TSP MoP, gypsum, $ZnSO_4$ and boric acid were used as inorganic fertilizer. Urea, TSP MoP, Gypsum, $ZnSO_4$ and boric acid were used as source of N, P, K, S, Zn and B respectively. All fertilizers both organic and inorganic were used as per treatment. The whole amount of TSP, MoP, gypsum, zinc sulphate, boric acid and one third of the urea were applied at the time of final land preparation prior to sowing. The remaining two-thirds of urea were top-dressed in two equal splits.

3.7 Treatments of the experiment

The experiment was conducted by using different fertilizer treatment as follows:

1) T_0 = Control (No fertilizer was used)
2) T_1 = 120 kg nitrogen, 30 kg phosphorus, 90 kg potassium, 20 kg sulfur and 1.5 kg zinc per ha
3) T_2 = 120 kg nitrogen, 30 kg phosphorus, 90 kg potassium, 20 kg sulfur and 1.5 kg zinc per ha + 1.5 kg boron per ha
4) T_3 = 120 kg nitrogen, 30 kg phosphorus, 90 kg potassium, 20 kg sulfur and 1.5 kg zinc per ha + 3.0 kg boron per ha
5) T_4 = 70% NPKSZn from inorganic fertilizer + 5 ton compost per ha + 1.5 kg boron per ha
6) T_5 = 70% NPKSZn from Inorganic fertilizer + 5 ton compost per ha + 3.0 kg boron per ha

3.8 Experimental design and layout

The experiment was laid out in a Randomized Complete Block Design. Each treatment was replicated three times. Thus the total number of unit plots was 6×3=18. The size of the unit plot was 3m × 2m. The distance maintained between two unit plots was 0.5m and that between blocks was 1m. The treatments were randomly assigned to the plots within each replication. The layout of the experiment field is shown in Appendix IV.

3.9 Sowing of seeds

Seeds were sown on 16th November, 2015 by hand. Seeds were sown in line and then covered properly with soil. The line to line distance for wheat was 20 cm and plant to plant distance was 4 - 5 cm.

3.10 Intercultural operations

3.10.1 Weeding

During plant growth period two hand weedings were done. First weeding was done at 20 days after sowing followed by second weeding at 15 days after first weeding.

3.10.2 Irrigation and weeding

Two times of irrigations were done at 20 and 55 DAS (Days after sowing).

3.10.3 Plant protection measures

The wheat crop was infested by Aphid and rodent. Therefore, contact insecticide (Malathion @ 22.2 mm per 10 litres of water) was given two times and 2% zinc sulphide was applied in some times because wheat field was highly infested by rodent.

3.10.4 General observation of the experimental field

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

3.10.5 Harvesting and post harvest operation

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

3.11 Recording of data

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

3.11.1 Crop growth characters

a. Plant height (cm)
b. Number of tillers plant^{-1}
c. Total dry matter

3.11.2 Yield and yield components

a. Length of spike (cm)
b. Number of grains spike^{-1}
c. Weight of 1000 grains (g)
d. Grain yield (t ha^{-1})
e. Straw yield (t ha^{-1})
f. Harvest index (%)

3.12 Detailed procedures of recording data

3.12.1 Crop growth characters

3.12.1.1 Plant height

Plant height was measured at 15 days interval starting from 45 days after sowing (DAS) and continued up to harvest. The height of the plant was determined by measuring the distance from the soil surface to the tip of the leaf before heading, and to the tip of spike after heading. The collected data were finally averaged.

3.12.1.2 Number of tillers plant^{-1}

Number of tillers plant^{-1} were counted at 15 days interval starting from 45 DAS and up to harvest and finally averaged as their number plant^{-1}.

3.12.1.5 Dry weight plant^{-1}

Five plants at different days after sowing (30, 50, 75 DAS and at harvest) were collected and dried at 70° C for 24 hours. The dried samples were then weighed and averaged.

3.12.2 Yield and yield contributing characters

3.12.2.1 Spike length (cm)

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

3.12.2.2 Number of grains spike^{-1}

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

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

3.12.2.3 Weight of 1000 grains

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

3.12.2.4 Grain yield

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

3.12.2.5 Straw yield

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

3.12.2.6 Harvest index (%)

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

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

Where, Biological yield = Grain yield + Stover yield

3.13 Statistical analysis

The data collected on different parameters were statistically analyzed with Randomized Complete Block Design (RCBD) using the MSTAT-C computer package program developed. Least Significant Difference (LSD) technique at 5% level of significance was used by DMRT to compare the mean differences among the treatments (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSIN

The research work was accomplished to investigate the wheat yield response to integrated nutrient management and boron application. Some of the data have been presented and expressed in table(s) and others in figures for easy discussion, comparison and understanding. The results of each parameter have been discussed and possible interpretations where ever necessary have been given under the following headings:

4.1 Growth parameters

4.1.1 Plant height

Under the present study, plant height was significantly influenced by the application of integrated nutrient management with or without boron application (Table 1). At different days after sowing (DAS), plant height differed and it was found that the tallest plant (38.44, 52.80, 85.70 and 87.32 cm at 30, 50, 70 DAS and at harvest respectively) was achieved from the treatment T_3 (120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 3.0 kg B ha^{-1}) which was significantly different from all other treatments followed by T_5 (70% NPKSZn from Inorganic fertilizer + 5 ton Compost ha^{-1} + 3.0 kg B ha^{-1}) and T_2 (120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 1.5 kg B ha^{-1}) where the shortest plant (22.62, 38.55, 64.63 and 65.71 cm at 30, 50, 70 DAS and at harvest respectively) was obtained from the control treatment T_0 (Table 1).

Rahmatullah *et al.* (2006) and Ahmed *et al.* (2008) found similar result in respect of boron application. They found that plant height significantly varied due to boron application at different rates. Rahmatullah *et al.* (2006) found 1 kg ha^{-1} gave the highest plant height. Leghari *et al.* (2016) noted maximum plant height 86.7

cm at NPK-120-60-60 kg ha^{-1} + B 2% at tillering phase where Chopra *et al*. (2016) also found integrated nutrient management practices significantly influenced plant height at all growth stages.

Table 1. Plant height of wheat under inorganic and integrated nutrient management influenced by boron fertilization

Treatment	Plant height (cm)			
	30 DAS	50 DAS	70 DAS	At harvest
T_0	22.62 e	38.55 f	64.63 f	65.71 e
T_1	29.33 d	44.88 d	73.84 e	74.82 d
T_2	33.40 c	46.68 c	79.33 b	80.08 c
T_3	38.44 a	52.80 a	85.70 a	87.32 a
T_4	30.67 d	42.70 e	76.80 cd	78.52 c
T_5	35.00 b	49.39 b	81.10 b	82.12 b
$LSD_{0.05}$	1.604	1.538	2.147	2.368
CV(%)	6.59	8.52	9.31	8.87

In a column figures having similar letter(s) do not differ significantly at 5% level of significance where dissimilar letter(s) differ significantly as per LSD.

T_0 = Control (No fertilizer was used)
T_1 = 120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1}
T_2 = 120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 1.5 kg B ha^{-1}
T_3 = 120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 3.0 kg B ha^{-1}
T_4 = 70% NPKSZn from Inorganic fertilizer + 5 ton compost ha^{-1} + 1.5 kg B ha^{-1}
T_5 = 70% NPKSZn from Inorganic fertilizer + 5 ton compost ha^{-1} + 3.0 kg B ha^{-1}

4.1.2 Number of tillers plant^{-1}

Significant variation was observed in terms of number of tillers plant^{-1} of wheat by the application of inorganic and integrated nutrient management with or without boron application (Appendix VI). Results revealed that at different days after sowing (DAS), the highest number of tillers plant^{-1} (1.50, 3.18, 4.05 and 4.00 at 30, 50, 70 DAS and at harvest respectively) was found from the treatment, T_2 (120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 1.5 kg B ha^{-1}) which was significantly different from all other treatments at whole crop duration followed by T_4 (70% NPKSZn from Inorganic fertilizer + 5 ton Compost ha^{-1} + 1.5 kg B ha^{-1}) (Table 2). The lowest number of tillers plant^{-1} (0, 1.30, 2.32 and 2.24 at 30, 50, 70 DAS and at harvest respectively) was obtained from the control treatment T_0 followed by T_1 (120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1}).

Similar results were also found by different researchers in case of intrigerated nutrient management practices with or without boron application. Nadim *et al*. (2012), Ahmad *et al*. (2011) and Tahir *et al*. (2009) found that boron had significant effect on number of tillers per plant. Again, Leghari *et al*. (2016), Chopra *et al*. (2016) and Islam *et al*. (2014) stated that maximum tiller can be achieved by boron application with integrated nutrients of NPKSZn during crop duration.

Table 2. Number of tillers plant^{-1} of wheat under inorganic and integrated nutrient management influenced by boron fertilization

Treatment	Number of tillers plant^{-1}			
	30 DAS	50 DAS	70 DAS	At harvest
T_0	0.00 e	1.30 e	2.32 f	2.24 e
T_1	0.67 d	2.52 d	3.33 e	3.30 d
T_2	1.50 a	3.18 a	4.05 a	4.00 a
T_3	1.00 bc	2.72 c	3.72 c	3.67 b
T_4	1.20 b	2.90 b	3.90 ab	3.72 b
T_5	0.60 d	2.70 c	3.53 d	3.50 c
$LSD_{0.05}$	0.081	0.184	0.147	0.138
CV(%)	5.21	7.36	6.53	6.73

In a column figures having similar letter(s) do not differ significantly at 5% level of significance where dissimilar letter(s) differ significantly as per LSD.

T_0 = Control (No fertilizer was used)
T_1 = 120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1}
T_2 = 120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 1.5 kg B ha^{-1}
T_3 = 120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 3.0 kg B ha^{-1}
T_4 = 70% NPKSZn from Inorganic fertilizer + 5 ton compost ha^{-1} + 1.5 kg B ha^{-1}
T_5 = 70% NPKSZn from Inorganic fertilizer + 5 ton compost ha^{-1} + 3.0 kg B ha^{-1}

4.1.3 Dry weight plant^{-1}

Data obtained from the present study on dry weight plant^{-1} was significantly affected by inorganic and integrated nutrient management with or without boron application at all crop duration (Appendix VII). Results revealed that the highest dry weight plant^{-1} (6.10, 20.55, 30.90 and 37.96 g at 30, 50, 70 DAS and at harvest respectively) was found from the treatment, T_2 (120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 1.5 kg B ha^{-1}) which was significantly different from all other treatments followed by T_4 (70% NPKSZn from Inorganic fertilizer + 5 ton Compost ha^{-1} + 1.5 kg B ha^{-1}) (Table 3). The lowest dry weight plant^{-1} (3.74, 10.60, 18.33 and 24.18 g at 30, 50, 70 DAS and at harvest respectively) was obtained from the control treatment T_0 followed by T_1 (120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1}). Chopra *et al*. (2016) found that dry matter production was found to be significant at integrated nutrient management practices with boron application.

Table 3. Dry weight $plant^{-1}$ of wheat under inorganic and integrated nutrient management influenced by boron fertilization

Treatment	Dry weight $plant^{-1}$ (g)			
	30 DAS	50 DAS	70 DAS	At harvest
T_0	3.74 e	10.60 e	18.33 e	24.18 e
T_1	5.10 d	14.90 d	23.84 d	30.52 d
T_2	6.10 a	20.55 a	30.90 a	37.96 a
T_3	5.76 bc	16.88 bc	26.48 c	33.60 c
T_4	5.85 ab	17.75 b	28.46 b	34.88 b
T_5	5.20 d	15.20 d	24.78 d	31.56 d
$LSD_{0.05}$	0.226	1.105	1.041	1.144
CV(%)	6.35	6.15	8.52	9.38

In a column figures having similar letter(s) do not differ significantly at 5% level of significance where dissimilar letter(s) differ significantly as per LSD.

T_0 = Control (No fertilizer was used)
T_1 = 120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1}
T_2 = 120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 1.5 kg B ha^{-1}
T_3 = 120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 3.0 kg B ha^{-1}
T_4 = 70% NPKSZn from Inorganic fertilizer + 5 ton compost ha^{-1} + 1.5 kg B ha^{-1}
T_5 = 70% NPKSZn from Inorganic fertilizer + 5 ton compost ha^{-1} + 3.0 kg B ha^{-1}

4.2 Yield contributing parameters

4.2.1 Spike length

Spike length of wheat significantly influenced by different inorganic and integrated nutrient management practices with or without boron application (Appendix VIII). Results exposed that the highest spike length (11.60 cm) was found from the treatment, T_2 (120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 1.5 kg B ha^{-1}) which was significantly different from other treatments (Table 4). The highest spike length (11.60cm) was obtained to the T_2 treatment .

Again, the lowest spike length (6.88 cm) was obtained from the control treatment T_0 .

Spike length is an important yield contributing character for higher crop yield and spike length can be maximized with suitable rate of boron application (Rahmatullah *et al.*, 2006). Leghari *et al*. (2016), Chopra *et al*. (2016) and Islam *et al*. (2014) also found higher spike length at integrated nutrient management condition with boron application where without boron application at integrated nutrient management condition gave lower spike length.

4.2.2 Number of grains spike^{-1}

Significant variation for number of grains spike^{-1} of wheat was observed by different inorganic and integrated nutrient management practices with or without boron application (Table 4 and Appendix VIII). Results indicated that the highest number of grains spike^{-1} (38.43) was found from the treatment, T_2 (120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 1.5 kg B ha^{-1}) which was significantly different from all other treatments followed by T_5 (70% NPKSZn from Inorganic fertilizer + 5 ton Compost ha^{-1} + 3.0 kg B ha^{-1}) (Table 4). Again, the lowest number of grains spike^{-1} (20.75) was obtained from the control treatment, T_0 .

Rahmatullah *et al., (*2006) found that number of grains spike^{-1} can be maximized with suitable rate of boron application. Higher number of grains spike^{-1} at integrated nutrient management condition with boron application was also found by Leghari *et al*. (2016), Chopra *et al*. (2016) and Islam *et al*. (2014).

4.2.3 Weight of 1000 seeds

Weight of 1000 seeds was significantly influenced by different inorganic and integrated nutrient management practices with or without boron application (Table 4 and Appendix VIII). Results showed that the highest 1000 seed weight (52.64 g) was found from the treatment, T_2 (120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 1.5 kg B ha^{-1}) which was significantly different from all other treatments followed by T_4 (70% NPKSZn from Inorganic fertilizer + 5 ton Compost ha^{-1} + 1.5 kg B ha^{-1}) (Table 4). Again, the lowest 1000 seed weight (45.44 g) was obtained from the control treatment, T_0 followed by T_1 (120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1}).

Raza *et al*. (2014), Ahmad *et al*. (2011) and Rahmatullah *et al.* (2006) reported that foliar application of Boron affect 1000 grain weight. Leghari *et al*. (2016) and Islam *et al*. (2014) also found that integrated nutrient management practices with boron application can maximize 1000 grain weight.

Table 4. Yield contributing characters of wheat under inorganic and integrated nutrient management influenced by boron fertilization

Treatment	Yield contributing characters		
	Spike length (cm)	Number of grain $spike^{-1}$	1000 seed weight (g)
T_0	6.88 d	20.75 e	45.44 e
T_1	9.28 c	28.86 d	48.72 d
T_2	11.60 a	38.43 a	52.64 a
T_3	9.20 c	31.91 c	50.32 c
T_4	10.14 b	32.80 c	51.81 b
T_5	11.52 a	35.14 b	50.48 c
$LSD_{0.05}$	1.114	1.384	0.749
CV(%)	8.35	8.63	9.54

In a column figures having similar letter(s) do not differ significantly at 5% level of significance where dissimilar letter(s) differ significantly as per LSD.

T_0 = Control (No fertilizer was used)
T_1 = 120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1}
T_2 = 120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 1.5 kg B ha^{-1}
T_3 = 120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 3.0 kg B ha^{-1}
T_4 = 70% NPKSZn from Inorganic fertilizer + 5 ton compost ha^{-1} + 1.5 kg B ha^{-1}
T_5 = 70% NPKSZn from Inorganic fertilizer + 5 ton compost ha^{-1} + 3.0 kg B ha^{-1}

4.3 Yield parameters

4.3.1 Grain yield

Significant variation was observed in terms of grain yield due to application of different inorganic and integrated nutrient management practices with or without boron application (Table 5). Results revealed that the highest grain yield (4.28 t ha^{-1}) was found from the treatment, T_2 (120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 1.5 kg B ha^{-1}) which was significantly different from all other treatments followed by T_4 (70% NPKSZn from Inorganic fertilizer + 5 ton Compost ha^{-1} + 1.5 kg B ha^{-1}) (Table 5) where the lowest grain yield (1.78 t ha^{-1}) was obtained from the control treatment, T_0 followed by T_1 (120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1}).

Similar results were also found on grain yield of wheat with boron application by Hamzeh and Florin (2014), Raza *et al*. (2014), Nadim *et al*. (2012), Pandey and Gupta (2013), Rashid *et al*. (2011) and Ahmad and Irshad (2011). They found that Boron single or shared with other micronutrients had positive effect on yield and yield parameters of wheat crop. With or with boron application significantly affect wheat yield found by Leghari *et al*. (2016), Chopra *et al*. (2016), Sheoran *et al*. (2015) and Islam *et al*. (2014). They found that boron application with integrated nutrient management practices maximize wheat yield where no boron with integrated nutrient management practices shows lower yield.

4.3.2 Stover yield

Significant variation was found in terms of Stover yield due to application of different inorganic and integrated nutrient management practices with or without boron application (Table 5). Results revealed that the highest Stover yield (5.60 t ha^{-1}) was found from the treatment, T_2 (120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5

kg Zn ha^{-1} + 1.5 kg B ha^{-1}) which was significantly different from all other treatments followed by T_4 (70% NPKSZn from Inorganic fertilizer + 5 ton Compost ha^{-1} + 1.5 kg B ha^{-1}) (Table 5) where the lowest Stover yield (3.88 t ha^{-1}) was obtained from the control treatment, T_0 followed by T_1 (120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1}).

Similar findings were found by Islam *et al*. (2014) and Patel *et al.* (2014). They found that application of integrated nutrients with or with boron increased straw yield.

4.3.3 Harvest index

Harvest index was significantly varied due to application of different inorganic and integrated nutrient management practices with or without boron application (Table 5). Results revealed that the highest harvest index (43.32%) was found from the treatment, T_2 (120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 1.5 kg B ha^{-1}) which was significantly similar with T_4 (70% NPKSZn from Inorganic fertilizer + 5 ton Compost ha^{-1} + 1.5 kg B ha^{-1}) (Table 5) where the lowest harvest index (31.45%) was obtained from the control treatment, T_0 followed by T_3 (120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 3.0 kg B ha^{-1}).

Kandi *et al*. (2012) found that B foliar application had the highest positive effect on biological yield, harvest index which was also supported by Tahir *et al*. (2009). Leghari *et al*. (2016) also found integrated nutrient management practices showed increased harvest index.

Table 5. Yield parameters of wheat under inorganic and integrated nutrient management influenced by boron fertilization

Treatment	Yield parameters		
	Grain yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Harvest index (%)
T_0	1.78	3.88 e	31.45 e
T_1	3.60 d	4.90 d	42.35 c
T_2	4.28 a	5.60 a	43.32 a
T_3	3.98 c	5.51 b	41.94cd
T_4	4.15 b	5.53 b	42.87 ab
T_5	3.66 d	5.14 c	42.07 c
$LSD_{0.05}$	0.114	0.126	0.447
CV(%)	5.74	8.31	7.56

In a column figures having similar letter(s) do not differ significantly at 5% level of significance where dissimilar letter(s) differ significantly as per LSD.

T_0 = Control (No fertilizer was used)
T_1 = 120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1}
T_2 = 120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 1.5 kg B ha^{-1}
T_3 = 120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 3.0 kg B ha^{-1}
T_4 = 70% NPKSZn from Inorganic fertilizer + 5 ton compost ha^{-1} + 1.5 kg B ha^{-1}
T_5 = 70% NPKSZn from Inorganic fertilizer + 5 ton compost ha^{-1} + 3.0 kg B ha^{-1}

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during the period from November 2015 to March 2016 to study the effect of boron fertilization on wheat under inorganic and integrated nutrient management. Wheat (*Triticum aestivum* L.) variety BARI Gom-24 (Prodip) was used as plant material. Six treatments were considered for the experiment *viz*. T_0 = Control (no fertilizer application), T_1 = 120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1}, T_2 = 120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 1.5 kg B ha^{-1}, T_3 = 120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 3.0 kg B ha^{-1}, T_4 = 70% NPKSZn from Inorganic fertilizer + 5 ton Compost ha^{-1} + 1.5 kg B ha^{-1} and T_5 = 70% NPKSZn from Inorganic fertilizer + 5 ton Compost ha^{-1} + 3.0 kg B ha^{-1}. The experiment was laid out in a Randomized Complete Block Design with three replications.

Different growth and yield parameters were considered for data collection. Data were recorded on plant height (cm), number of tillers plant^{-1}, total dry matter (g), length of spike (cm), number of grains spike^{-1}, weight of 1000 grains (g), grain yield (t ha^{-1}), straw yield (t ha^{-1}) and harvest index (%). Significant variation was found for all the treatments.

Results revealed that the tallest plant (38.44, 52.80, 85.70 and 87.32 cm at 30, 50, 70 DAS and at harvest respectively) was achieved from the treatment T_3 (120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 3.0 kg B ha^{-1}) but the highest number of tillers plant^{-1} (1.50, 3.18, 4.05 and 4.00 at 30, 50, 70 DAS and at harvest respectively) and highest dry weight plant^{-1} (6.10, 20.55, 30.90 and 37.96 g at 30, 50, 70 DAS and at harvest respectively) were obtained from the treatment, T_2 (120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 1.5 kg B ha^{-1}) where the shortest plant (22.62, 38.55, 64.63 and 65.71 cm at 30, 50, 70 DAS and at harvest respectively), lowest number of tillers plant^{-1} (0, 1.30, 2.32 and 2.24 at 30, 50, 70 DAS and at harvest respectively) and lowest dry weight plant^{-1} (3.74, 10.60, 18.33 and 24.18 g at 30, 50, 70 DAS and at harvest respectively) were obtained from the control treatment T_0 (No fertilizer).

Again, the highest spike length (11.60 cm) highest number of grains spike^{-1} (38.43), highest 1000 seed weight (52.64 g), highest grain yield (4.28 t ha^{-1}), highest stover yield (5.60 t ha^{-1}) and highest harvest index (43.32%) were found from the treatment, T_2 (120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 1.5 kg B ha^{-1}) where the lowest spike length (6.88 cm), lowest number of grains spike^{-1} (20.75), lowest 1000 seed weight (45.44 g), lowest grain yield (1.78 t ha^{-1}), lowest Stover yield (3.88 t ha^{-1}) and lowest harvest index (31.45%) were obtained from the control treatment, T_0 (no fertilizer).

From the above summary, it was concluded that among the entire treatments on boron fertilization of wheat under inorganic and integrated fertility management, the best result was achieved from T_2 (120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 1.5 kg B ha^{-1}) in terms of highest number of tillers plant^{-1}, total dry matter plant^{-1}, spike length, number of grains spike^{-1}, weight of 1000 grains, grain yield, straw yield and harvest index .

Further study can be conducted with different nutrient levels along with different boron doses at different locations of Bangladesh to evaluate the exact boron dose for wheat for different soils.

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APPENDICES

Appendix l: Experimental site showing in the map under the present study

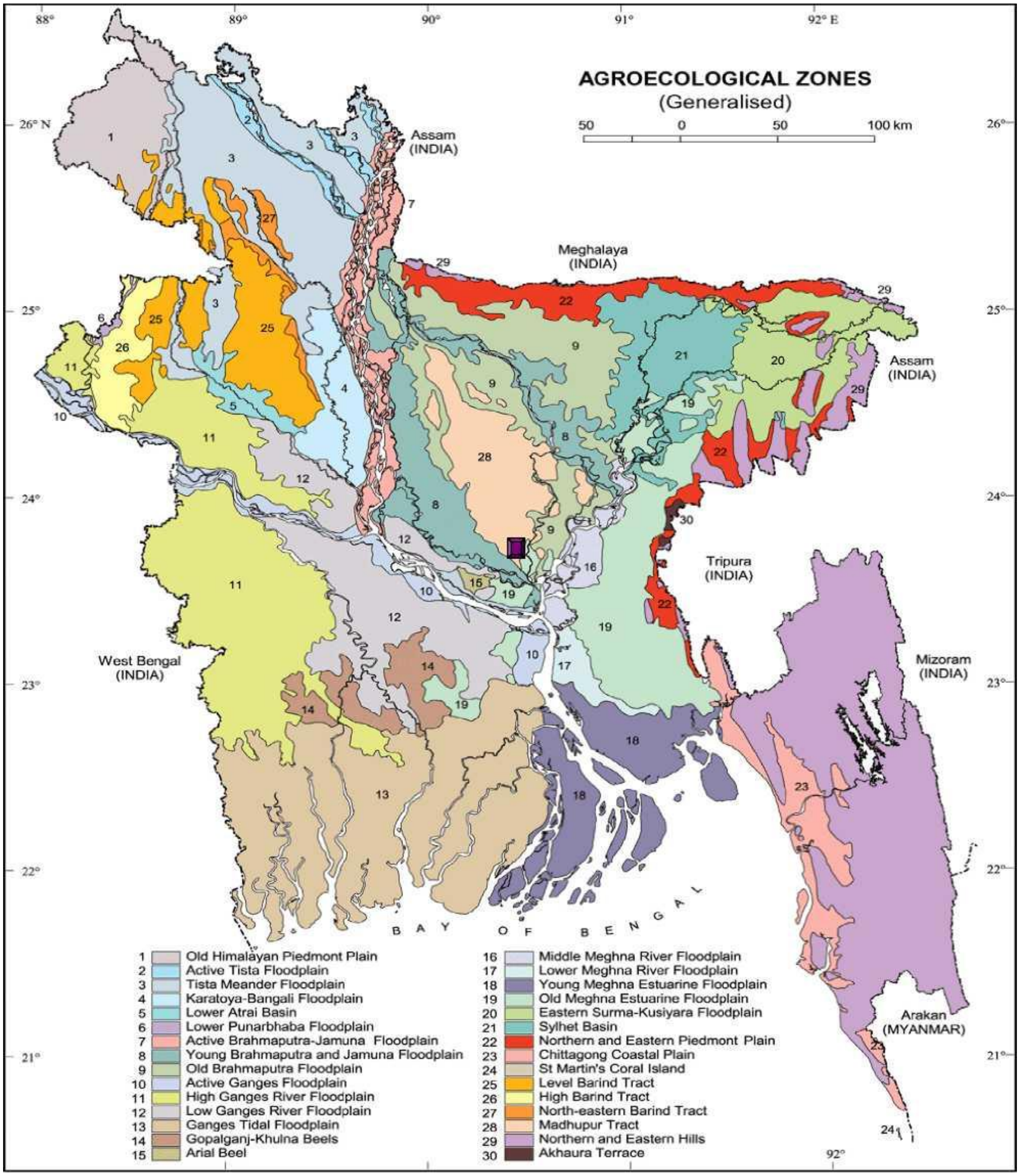


Fig. 1. Map of Bangladesh remarked with study area

Appendix II. Monthly records of air temperature, relative humidity, rainfall and sunshine during the period from November 2015 to March 2016

Year	Month	Air temperature (°C)			Relative humidity (%)	Rainfall (mm)	Sunshine (Hours)
2015	November	32.0	15.0	23.5	67	14	7.8
2015	December	28.2	13.5	20.9	79	8	3.8
2016	January	24.5	11.5	18.0	72	6	5.7
2016	February	33.1	12.9	23.0	55	10	8.1
2016	March	33.6	15.3	24.5	63	43	7.5

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

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

Particle size constitution:

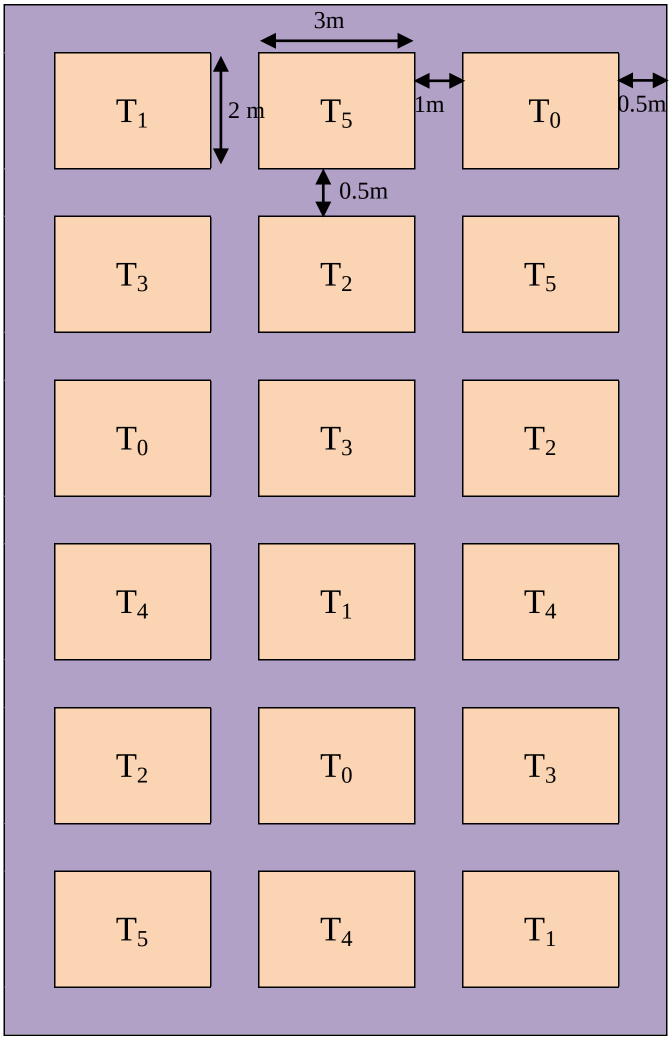
Sand	:	40 %
Silt	:	40 %
Clay	:	20 %
Texture	:	Loamy

Chemical composition:

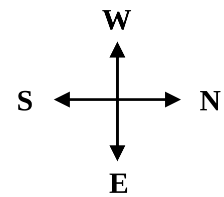
Constituents	:	0-15 cm depth
P^H	:	5.45-5.61
Total N (%)	:	0.07
Available P (μ gm/gm)	:	18.49
Exchangeable K (μ gm/gm)	:	0.07
Available S (μ gm/gm)	:	20.82
Available Fe (μ gm/gm)	:	229
Available Zn (μ gm/gm)	:	4.48
Available Mg (μ gm/gm)	:	0.825
Available Na (μ gm/gm)	:	0.32
Available B (μ gm/gm)	:	0.94
Organic matter (%)	:	0.83

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

Appendix IV. Layout of the experiment field



LEGEND



Layout:

Plot size: 3 m × 2 m

Plot spacing: 0.5 m

Between block: 0.1 m

Treatments:

1. T_0 = Control (No fertilizer was used)
2. T_1 = 120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1}
3. T_2 = 120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 1.5 kg B ha^{-1}
4. T_3 = 120 kg N, 30 kg P, 90 kg K, 20 kg S, 1.5 kg Zn ha^{-1} + 3.0 kg B ha^{-1}
5. T_4 = 70% NPKSZn from Inorganic fertilizer + 5 ton Compost ha^{-1} + 1.5 kg B ha^{-1}

Fig. 2. Layout of the experimental plot

Appendix V. Significant effect on plant height of wheat under inorganic and integrated fertility management influenced by boron fertilization

Source of variation	Degrees of freedom	Mean square of plant height			
		30 DAS	50 DAS	70 DAS	At harvest
Replication	2	1.730	1.361	2.012	2.047
Factor A	5	37.243	24.246	18.559	27.356
Error	10	0.808	1.114	2.312	2.526

Appendix VI. Significant effect on number of tillers plant^{-1} of wheat under inorganic and integrated fertility management influenced by boron fertilization

Source of variation	Degrees of freedom	Mean square of number of tillers plant^{-1}			
		30 DAS	50 DAS	70 DAS	At harvest
Replication	2	0.214	0.315	0.426	1.114
Factor A	5	12.328	16.327	16.578	20.347
Error	10	0.127	0.539	1.286	1.758

Appendix VII. Significant effect on dry weight plant^{-1} of wheat under inorganic and integrated fertility management influenced by boron fertilization

Source of variation	Degrees of freedom	Mean square of dry weight plant^{-1}			
		30 DAS	50 DAS	70 DAS	At harvest
Replication	2	0.044	0.217	0.387	0.529
Factor A	5	14.527	17.539	12.667	18.389
Error	10	0.384	0.488	0.412	1.314

Appendix VII. Significant effect on yield contributing characters of wheat under inorganic and integrated fertility management influenced by boron fertilization

Source of variation	Degrees of freedom	Mean square of yield contributing parameters		
		Spike length (cm)	Number of grain spike^{-1}	1000 see weight (g)
Replication	2	0.142	0.377	0.473
Factor A	5	22.569	18.539	24.557
Error	10	1.344	1.218	2.419

Appendix VIII. Significant effect on yield parameters of wheat under inorganic and integrated fertility management influenced by boron fertilization

Source of variation	Degrees of freedom	Mean square of yield parameters		
		Grain yield (t ha^{-1})	Stover yield (t ha^{-1})	Harvest index (%)
Replication	2	0.075	0.079	0.129
Factor A	5	10.529	12.728	14.722
Error	10	0.551	0.637	1.244

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Introduction

Chapter 2
Review of literature

Chapter 3

Materials and Methods

Chapter 4

Results and Discussion

Chapter 5
Summary and Conclusion

References

Appendices